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VOL. III—[WHOLE NUMBER, CCIII].

WITH THREE PLATES

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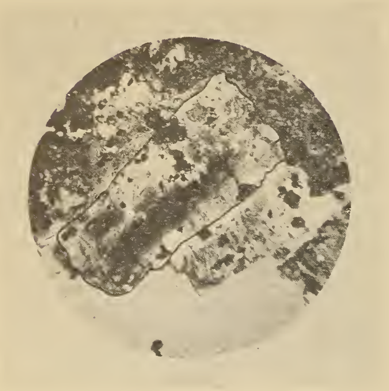

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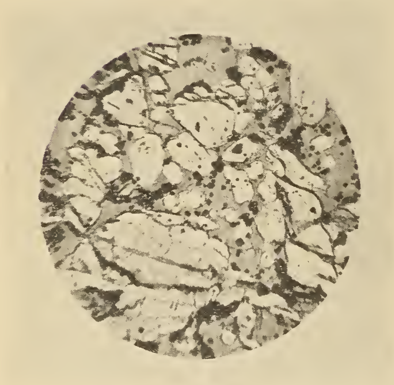

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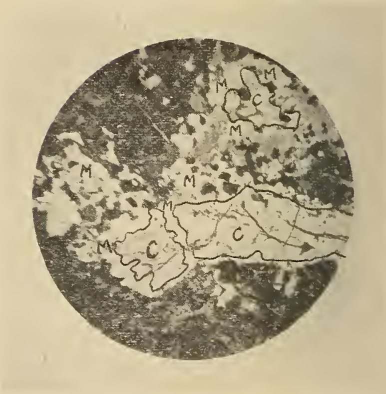

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AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. I.—*Genetic Features of Alnoitic Rocks at Isle Cadieux, Quebec;* by N. L. Bowen. With Plate I.

Introduction.

In the vicinity of Montreal, Canada, several intrusive masses of alnoitic character have been found that are genetically related to the main Mount Royal intrusion. It was, indeed, from this area that Dr. F. D. Adams described the first alnoite found on this continent.[1] These alnoites have a remarkable tendency to form breccias with the invaded pre-Cambrian and Paleozoic rocks and an excellent description of them, with particular reference to the breccia, has been given by Dr. Robert Harvie.[2]

During the past summer my attention was called by Dr. Harvie to the fact that a new occurrence had been found at Isle Cadieux in the course of a road-materials survey,[3] but that no detailed work had been done on it. Accordingly the locality was visited and the material collected has been found to be of such interest as to warrant special description. I am greatly indebted to Dr. Harvie and to the Director of the Geological Survey of Canada for the opportunity of making this study.

Location.

Isle Cadieux is a flag station at mileage 26.8 from Montreal on the Canadian Pacific short line between Ottawa and Montreal. The outcrop of alnoitic rocks is

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[1] F. D. Adams, this Journal, (3) 43, 269-279, 1892.

[2] On the origin and relations of the Palaeozoic breccia of the vicinity of Montreal, Trans. Roy. Soc. Can., 3d Ser., vol. 3, sec. IV, pp. 249-299, 1910.

[3] Geol. Surv. Can., Summary Report for 1916, pp. 198-206.

a rather inconspicuous knoll upwards of 200 yards in diameter lying immediately adjacent to and south of the railway track about half a mile west of the station. The rocks are well exposed in the knoll itself, but their relations to surrounding rocks are not visible. The similarity to the alnoites of the Paleozoic intrusives makes it impossible to doubt that it belongs, with them, to the alkalic rocks of the petrographic province to which Dr. Adams has given the name, Monteregian Hills.[4]

Rock Types.

The principal rock of the outcrop is dark gray, mostly fine-grained but mottled by large poikilitic biotites about 1 cm. in diameter which are the only crystals determinable in the hand specimen. This type constitutes practically the whole mass but there are streaks and indefinite patches of a coarser-grained type in which biotite and a light-colored constituent are readily distinguishable, and also, in one place, a fine-grained minette-like type as an irregular dike.

Mineral Constituents.

Under the microscope the principal type, constituting the main mass, is found to consist of *biotite*, *olivine*, *augite*, *melilite*, *perovskite*, an opaque *ore mineral*, *apatite*, *marialite*, and alteration products of the above minerals, principally *carbonates*. The rock therefore has the typical composition of an alnoite, that is, a mica peridotite with melilite. In one important particular this rock is different from all other alnoites as described. It contains two olivines, the ordinary olivine, *chrysolite*,[5] and *monticellite*, the lime-magnesia olivine, a mineral hitherto unrecognized except as a product of contact metamorphism.

Biotite is decidedly the most abundant constituent of the rock. It occurs in large grains up to 1 cm. in diameter that are full of corroded inclusions of chrysolite and augite, visible even in the hand specimen. The biotite

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[4] F. D. Adams, Jour. Geol., **11**, 239, 1903.

[5] Throughout this paper it will be necessary to refer to the ordinary, magnesia-iron olivine specifically as chrysolite in order to avoid the confusion that would be involved in the use of the group name, olivine.

is not highly colored, its strongest absorption being a rather pale greenish brown. In this respect it is, however, markedly variable in a single crystal and in particular tends to be less strongly colored where it abuts against enclosed augite and more strongly colored where it is against chrysolite. Its refractive indices are approximately $\gamma = 1.61$, $\alpha = 1.56$ and it is nearly uniaxial.

Monticellite is, on the whole, the second constituent in point of abundance. It occurs in fairly large grains up to 1.5 mm. in diameter. These likewise include corroded remnants of chrysolite and augite crystals, but since the monticellite is not in such large grains as the biotite, the poikilitic nature is not so obvious. Occasionally the monticellite is in optical continuity with an enclosed chrysolite grain. The optical properties of the lime-magnesia olivine, monticellite, agree with those of the same mineral as described by Penfield and Forbes from Magnet Cove.[6] The birefringence is moderate, the colors in thin section rising only to an orange-red of the first order and usually falling far short of that color. The optic axial angle $2V = 70° \pm 5°$ and the sign is negative.[7] In a section normal to the optic axis there is a marked bending of the bar and the sign is readily determined. In these respects the mineral is distinct from the other olivine, chrysolite, which frequently shows the brilliant colors of higher orders and for which the axial bar remains so nearly straight that one cannot be sure of the direction of its curvature or of the optical sign. The difference of birefringence is apparent in this interference figure also, for the chrysolite shows the inner colored lemniscates, whereas these are beyond the aperture of the objective in monticellite.

It is, however, particularly in their quite different relations to the other minerals that one is led in the first instance to suspect the existence of two distinct olivines in the rock, the monticellite occurring as oikocrysts, the chrysolite as chadacrysts.[8] These relations will be described in detail later, but advantage was taken of the

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[6] This Journal, (4) **1**, 135, 1896.

[7] The value of 2V for monticellite from Magnet Cove has been incorrectly transcribed into the texts of Iddings, Winchell and Rosenbusch, where it is given as 37°31′. This is really the value of V as determined by Penfield and Forbes.

[8] Iddings, Igneous Rocks, I, p. 202, 1909.

difference between the two olivines in this particular to permit the determination of the refractive indices. If the rock is powdered and the measurement of indices by the immersion method is undertaken, one usually cannot be sure to which olivine an individual grain belongs. In thin section, however, there is no confusing them, on account of the structural difference mentioned, so a slide was uncovered, washed free from balsam and the rock slice itself used in immersion liquids. Thus the indices of the monticellite were found to be $\gamma = 1.668$; $\alpha = 1.653 \pm .002$. Direct measurement of the maximum birefringence gave 0.015, so that while measurements so made are not of the highest accuracy, it appears that the birefringence is slightly less than that in the Magnet Cove mineral. The Magnet Cove mineral contains nearly 5 per cent FeO, and in view of the close approach in indices the present mineral must have nearly the same composition. Pure artificial monticellite has distinctly lower indices.[9]

The *chrysolite* has already been described in part, while contrasting it with monticellite. Its refractive indices, measured as above, are $\gamma = 1.700$; $\alpha = 1.665 \pm .003$ and 2V close to 90°. It probably contains in the neighborhood of 10 per cent FeO, though the effect of a possible TiO_2 content is not known.

The *augite* needs but brief mention. Its extinction angle mounts to about 45° and the refractive index $\gamma = 1.715$. This combination of properties rather excludes any significant alkali content and fixes it as ordinary augite. It is slightly brownish to greenish in thin section and the typical cleavage is well developed.

The *melilite* is in comparatively small grains that show the typical tabular development parallel to the base, though they are not idiomorphic. The basal cleavage is sometimes marked only by the development of minute seams of an alteration product of high birefringence. Occasionally it may be well developed and accompanied by prismatic cleavage of nearly equal strength. The melilite itself always has very low birefringence but is distinctly variable in optical properties. This variation appears to be connected with the amount of melilite in the rock. Where present in small amount it is optically

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[9] Ferguson and Merwin, this Journal, (4) 48, 92, 1919.

positive; in somewhat greater amount it is about isotropic, and where present in considerable amount it is zoned, with the inner zones nearly isotropic and the outer zones distinctly negative.

The *perovskite* is quite abundant for a constituent that usually occurs in such minor amounts. It is in sharp octahedra of a wine yellow color in thin section and is apparently isotropic, the twinning phenomena not being visible in these grains.

The *opaque ore mineral* has a bluish reflection and is presumably titaniferous magnetite; at any rate it is strongly magnetic. It occurs rather abundantly as disseminated grains and is particularly strongly developed as a rim about corroded chrysolite grains where they abut against biotite, monticellite or melilite.

The *apatite* is present in unusually large amount and in relatively large grains. It is distinguished from melilite by its higher birefringence and by the hexagonal shape of its basal sections.

The *marialite* occurs as a few small grains that were detected in only some of the slides where they were closely associated with monticellite. Its refringence is comparable with that of quartz, that is, only slightly higher than that of balsam, and in this particular it is in marked contrast with all the other constituents of the rock which are uniformly minerals of high relief. The birefringence is likewise comparable with that of quartz, but is appreciably higher. It is uniaxial and negative. These properties agree with those of a scapolite close to the sodic end of the series, that is, marialite. This mineral has been observed in trachytes of the Phlegrean Fields, near Naples.

The *alteration products* were not given very careful study. They are mainly carbonates formed by the alteration of monticellite and melilite. The carbonate patches are frequently crowded with minute needles of apatite which suggest that the alteration of the minerals is not to be assigned entirely to weathering but is in part a post-magmatic phenomenon intimately connected with the consolidation of the rock. It is noteworthy that neither olivine shows the serpentine type of alteration.

While the rock as a whole is considerably altered, the alteration is unevenly distributed, and in many parts of a section the minerals monticellite and melilite may be found without even incipient change. The monticellite is apparently considerably more susceptible than melilite.

Variation in the Principal Type.

The greater part of the mass appears to be essentially uniform in hand specimens and in order to gain an idea of such variability as might exist it was necessary to resort to collection of specimens regularly distributed over the outcrop. Some thirty specimens were collected and they show considerable variation in the proportions of the minerals. Usually biotite is the most abundant mineral and is always an important mineral, but it is not infrequently exceeded in amount by monticellite and sometimes by melilite or chrysolite. Melilite may be present to the extent of about 30 per cent and again may occur in vanishingly small quantity. Augite may amount to about 20 per cent but is usually less and there is a general tendency for monticellite to occur in greater quantity where augite is more abundant. Chrysolite may rise to 35 per cent or again sink to 10 per cent. Pyroxene, monticellite and melilite were practically absent in only one specimen, giving essentially an ordinary mica peridotite (see Plate I (c)).

Chemical Composition of the Principal Type.

In view of the variability of the rock it was desirable to choose for analysis a specimen which appeared under the microscope to represent the general average. At the same time it was desirable to choose material which was as unaltered as possible, and this latter restriction made it necessary to take material differing somewhat from the average. The actual specimen chosen contains the constituent minerals in approximately the following proportions in weight per cent: chrysolite 30, melilite 25, biotite 20, monticellite 10, augite 6, all others 9. No great accuracy is claimed for these figures because the rock as a whole is rather unfavorable for the estimation of proportions of the minerals. The general average of the rock would be decidedly higher in monticellite, considerably lower in melilite and chrysolite and somewhat higher in biotite and augite.

For the analysis (I, Table I) and for the other analyses in this paper I am indebted to Dr. Washington and take this opportunity of expressing my thanks.

TABLE I.

	I	II	Norm of I*	
SiO_2	33.26	30.85	An	8.06
Al_2O_3	5.90	8.21	Kp	1.93
Fe_2O_3	5.30	3.33	Ne	5.68
FeO	6.54	6.52	Ol	49.56
MgO	26.41	23.16	Cs	15.82
CaO	14.47	16.46	Mt	7.66
Na_2O	1.23	1.01	Il	4.10
K_2O	0.82	1.43	Ap	2.02
H_2O +	1.91	1.22	Symbol	
H_2O —	0.09	0.05	IV″ (1)2.5.2.1	
CO_2	1.10	3.04		
TiO_2	2.15	2.87		
ZrO_2	none	n.d.		
P_2O_5	0.76	1.90		
MnO	0.15	0.21		
Cr_2O_3	0.05	n.d.		
BaO	0.08	n.d.		
SO_3	0.22	n.d.		
	100.44	100.26		

I. Monticellite alnoite (melilite-rich) Isle Cadieux, Quebec. H. S. Washington analyst.

II. Monticellite alnoite (melilite-poor) Isle Cadieux, Quebec. H. S. Washington analyst.

Under II in Table I is given an analysis of a variety rather rich in monticellite and very poor in melilite. This specimen was chosen for analysis partly in order to have a chemical check upon the optical identification of the monticellite. The microscope shows the minerals to be present in roughly the following proportions in weight per cent: biotite 30, monticellite 25, chrysolite 15, augite 10, melilite 3, apatite 4, perovskite and ore 7, carbonates 6. Though there are lime minerals other than monticellite in considerable amount, they fail entirely to account for the 16.5 per cent of lime shown in the analysis. About one half the lime must be assigned to the monticellite which checks approximately with the amount of monti-

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* Calculated by Dr. Washington. The CO_2 indicates 2.50 per cent calcite.

cellite present. Except in its unusually low melilite, specimen II is fairly typical of the average.

Comparison of the two analyses shows no very marked differences in spite of the considerable contrast in proportions of the constituents. Lime is even higher in the variety poor in melilite because it is correspondingly richer in monticellite (and in minor lime-bearing minerals) and the lime content of monticellites and melilites is about the same. Magnesia is higher in I on account of the greater amount of chrysolite. The lower biotite content of I shows up in the lower potash and alumina. The biotite must contain much soda. The lower silica of II can not be assigned any special significance on account of its greater alteration (note CO_2).

Comparison of the analyses with those of other alnoites shows the present types to be higher in magnesia. Soda in excess of potash as in I is exceptional in alnoites which are usually like II in this respect in spite of their common association with sodic rocks. This is connected with the low biotite content of I; in fact, this type, in virtue of decreased biotite, leans toward melilite basalt.

Specimen I is apparently the freshest alnoite yet analyzed and even II compares favorably with others in this respect.

No new names are proposed for these rocks nor for any of the types described in this paper. It is believed that the descriptive terms employed have a distinct advantage over the meaningless names based on locality that are being coined daily and with which the literature is already overburdened.

Melilite-Biotite Rock.

Before going on to discuss the relations of one mineral to another in the principal type whose mineralogy was given above, the streaks and patches that have been mentioned as occurring in it will be described. The streaks are from 1 inch to 2 feet wide and traverse the main type after the manner of dikes or veins with indefinite boundaries. They consist almost entirely of *biotite* and *melilite* with subordinate amounts of *apatite*, *chrysolite*, *monticellite*, *perovskite*, and an opaque ore mineral.

The *biotite* is often in idiomorphic hexagonal-shaped plates and is not obviously poikilitic, but under the microscope occasional corroded inclusions of chrysolite, augite (?) and monticellite are to be found. It is much more strongly colored than the biotite of the main rock.

The *melilite* shows the typical tabular development and the plates may be as much as 5 mm. across. The crystals are conspicuously zoned, the zones being marked by a difference in birefringence. The center of the crystal is usually isotropic, though occasionally it is barely over the border and in the positive series. The outer zones are plainly negative and increasingly so as one passes toward the rim. (See Plate I (a).) Even here, however, the birefringence is still very weak, much less, for example, than that of apatite. The measured index of the ordinary ray is somewhat variable, but is close to 1.636. The melilite, like the biotite, contains corroded inclusions of chrysolite and monticellite.

The *apatite* is present in such amount and in such large prisms as to raise it somewhat above the class of minor constituents. It is characterized by its freshness, lack of cleavage and high birefringence as compared with melilite.

The presence of relatively small amounts of chrysolite, augite, and monticellite as corroded inclusions in biotite and melilite has already been mentioned. An analysis of the melilite-biotite rock is given in Table II under I.

Fine-grained Alnoite.

The fine-grained type that has been called minette-like in the hand specimen occurs at the southern side of the knoll as a dikelike intrusive in the main mass. It consists essentially of chrysolite crystals, partly resorbed, lying in a matrix of biotite and melilite with the usual minor constituents of the principal type of which it is merely a textural variant. Augite and monticellite are practically if not entirely absent, a condition which was noted in one specimen of the main mass. This fine-grained type is considerably fresher than the coarser facies usually is.

TABLE II.

	I	II	Norm of II.	
SiO_2	31.10	83.31	Q	61.08
Al_2O_3	10.08	4.46	Or	23.91
Fe_2O_3	3.64	1.10	Ab	0.52
FeO	3.35	0.45	Ac	3.23
MgO	12.25	0.28	Ns	1.83
CaO	22.77	2.87	Di	1.51
Na_2O	1.95	1.42	Wo	5.80
K_2O	3.56	4.02	Il	1.06
H_2O+	0.76	1.02		
H_2O-	0.46	0.18		
CO_2	4.94	n.d.		
TiO_2	2.73	0.64	Symbol	
P_2O_5	2.01	n.d.	(I) II. 2. 1. 1.	
MnO	0.09	ft. tr.		
	99.69	99.75		

I. Melilite-biotite rock, Isle Cadieux, Quebec. H. S. Washington analyst.

II. Aplitic inclusion in monticellite alnoite, Isle Cadieux, Quebec. H. S. Washington analyst.

Distribution of Similar Rock Types.

About a mile northwestward from the outcrop to which particular attention is here given, there is a cut on the railway track and the material taken from this cut is almost entirely of rock types similar to those in the outcrop studied. Here are found various facies of monticellite alnoite and biotite-melilite rock exactly like the types already described. From the present condition of the cut it is not possible to determine definitely whether this material had been in place, though its uniform nature strongly suggests that such was the case. Even if it was of the nature of drift it could not have been derived from the outcrop described, for it has not the appropriate position relative to the direction of motion of the glacier. The existence of this material proves definitely, then, that the types described are not confined to the outcrop studied and may be rather widespread in this area.

Inclusions.

Inclusions in the igneous mass are decidedly rare; not even locally was any facies observed that remotely approached a breccia.[10] A few inclusions were seen, however, and it was possible to obtain some of these for sectioning. They were found to be of three kinds: (*a*) large augite crystals, (*b*) an aplitic rock, (*c*) a sodic syenite.

The augite crystals are fairly numerous at the northern margin of the mass as exposed, and stand out as knobs about an inch in diameter on the weathered surface. Peripheral alteration of the crystals by the magma is often to be seen even in the hand specimens, the core being of black glassy appearance and the border dull. The optical properties of the crystals show them to be identical with the augite of the rock itself. This fact suggests that they may be phenocrysts rather than inclusions but their general appearance is rather that of cognate xenocrysts.

The inclusion of an aplitic rock that was broken out for study was found to be of a highly siliceous type, probably a fragment of a fine-grained dike. It is very rich in quartz; the feldspar, evidently an alkaline one, is much kaolinized, and these make up practically the whole rock. There is, however, a little ægiritic pyroxene "in minute prisms, frequently forming matted masses,"[11] with green to yellow pleochroic colors, small extinction angle, and negative elongation. A few grains of zircon were observed also. The quartz of this rock shows under the microscope a marked development of an imperfect cleavage that breaks it up into roughly rectangular pieces. The presence of this cleavage or cracking is probably to be taken as evidence that the inclusion has been heated above 575° by immersion in the alnoite material, the quartz therefore passing through the α-β quartz inversion point.[12] Presumably it was not heated to 870°, for there is no suggestion of a change to tridymite. In the course

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[10] The interior portions of some of the masses described by Harvie (op. cit. p. 256) are often nearly free from inclusions.

[11] The ægirite of the tinguaite of this province is so described by O'Neill, Geol. Surv. Can. Mem., 43, p. 60, 1914.

[12] Wright and Larsen, Quartz as a geologic thermometer, this Journal, 27, 437, 1909.

of the analysis of this rock Dr. Washington noted a resistance of its powder to wetting unusual in his experience. This resistance is characteristic of very fine powders and may be connected with the ease of reduction of the cracked quartz of this rock to such a fine state.

The analysis is given in Table II under II and the calculation of the norm, also by Dr. Washington, is given with it. It proves to be that of a very unusual rock, highly siliceous and showing high potash with rather high lime, in which respects it resembles moldavites that are believed to be of meteoric origin.[13] In its content of ægiritic pyroxene it would appear to be related to the alkalic rocks of the Monteregian province and thus to be a cognate inclusion. The high potash would seem to contradict this and the amount of silica is quite unmatched in any described rocks of this petrographic province.

The other type of inclusion examined consists almost exclusively of oligoclase with a little microcline. These are cut by veinlets of hydronephelite. A little mica and a greenish pyroxene are the only other constituents.

This is apparently a rock of the alkalic series also, and possibly all of the inclusions examined are to be regarded as cognate or belonging genetically with the containing rock.

Relations of the Minerals.

We shall now return to a discussion of the relations of one mineral to another in the principal type or, better perhaps, in the mass as a whole.

In order that the details may be more intelligently followed, the conclusion arrived at from them will be anticipated and may be stated as follows. The mass originally consisted of chrysolite and augite, nearly completely consolidated as such. It was then acted upon with falling temperature by an alkalic liquid (magma) which was, in part at least, its own interstitial liquid, and as a result of this action the other minerals, biotite, monticellite, melilite, perovskite, apatite and marialite were formed. The minerals may therefore be divided into two classes, the original minerals augite and chrysolite and

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[13] U. S. Geol. Survey, Prof. Paper 99, p. 53.

the replacing minerals principally biotite, monticellite and melilite.

There is no very obvious tendency for any one replacing mineral to be substituted for any particular original mineral. The replacement is rather of the mass as a whole. Occasionally, however, a more or less definite pseudomorph of monticellite after augite may be noted and frequently a monticellite band is interposed between mica and augite. Moreover, in facies of the rock where augite was absent monticellite is not developed. The evidence is good that augite is the principal if not the sole source of the monticellite. (See Plate I(d).)

The original augites were large crystals approaching 1 cm. in diameter but the corroded remnants are seldom one-tenth as large. Several adjacent individual remnants embedded in the replacing minerals are frequently seen to be similarly oriented, with their cleavages and extinctions coincident, and it is not difficult to picture the original augites now largely replaced. (See Plate I(b).) Where the replacing mineral is biotite it is practically always paler in color adjacent to augite.

The original chrysolites were rather less than one-half as large as the augites. Three or four adjacent remnants can frequently be connected up to construct the original crystals, though this is not so conspicuous as in the case of the augites. Whether biotite, monticellite or melilite is the replacing mineral the chrysolites nearly always show a rim about them of particularly strong concentration of ore minerals. (See Plate I(c).) The augites occasionally show such a rim but it is usually within the border rather than at the border. There is a development of very fine crystals of perovskite in these rims and as one passes outward coarser and coarser crystals are encountered. They are plentiful in the monticellite, melilite and biotite, but the central portions of chrysolite and augite crystals are free from them. There is a strong suggestion, then, that the perovskites were formed as a result of reaction upon the original minerals. As has been noted before, where monticellite resorbs and replaces chrysolite the two are frequently in optical continuity, their boundary being marked by the dark band of ore minerals.

When one thus separates the minerals into the two classes of original and replacing minerals and pictures the original minerals as they were before replacement began, it becomes apparent that there could have been no great amount of any material in much of the rock other than augite and chrysolite. It is probable that there was a moderate amount of interstitial liquid which gave opportunity for such uniform action at all points in the mass and upon each individual mineral grain. It is probable, too, that this interstitial liquid was itself of such a nature as to enter into reaction, as the temperature changed, with the crystals that had already separated from it, in such a manner as to produce the new minerals actually found. It is not probable, however, that the interstitial liquid was of sufficient quantity to produce so much change. Rather is it to be supposed that there was a movement of liquid of the same kind through the interstices of the mass, that the liquid reacted with the solid phases and passed on (or was crowded out), carrying with it some of the products of the reaction until finally the interstices were filled up.

However these details may fit the fact, it is certain that a liquid permeated the rock and partly replaced augite and chrysolite by monticellite, biotite and melilite. Now it is believed that the seams of melilite-biotite rock represent simply streaks along which the freedom of passage of liquid has been greater and where the replacement is more advanced. In these monticellite is corroded by biotite and melilite in much the same manner as are the original minerals in the main mass. The monticellite is, then, to be regarded as an intermediate step in the replacement of augite and chrysolite by melilite and biotite.

Nature of the Reacting Liquid.

The question naturally arises as to the nature of the liquid (magma) which could produce results of the kind noted. The formation of such minerals as monticellite and melilite might on first thought be considered to require a lime-rich liquid. On the other hand the formation of biotite points definitely to an alkalic liquid and it will be found that there are good reasons for believing that an alkalic liquid is capable of producing the lime-rich minerals as well. The alkalic liquid is, moreover, a decidedly appropriate one in this particular province; indeed nephelite is frequently an important groundmass constituent in some of the alnoites of Harvie.

Petrologists will have no difficulty in accepting the formation of biotite from other femic minerals (in this case principally chrysolite) because it is an action with which they are already acquainted. The formation of monticellite from other femic materials (in this case principally augite) has not been noted elsewhere. Assuming that it is desirable to describe the action in a few words, this may be done roughly by stating that the monticellite is formed as a result of desilication of augite by the alkalic liquid. We thus find an explanation of the fact that where no augite was present in the original material no monticellite was formed.

The liquid that accomplished this action was in all probability a nephelite-rich liquid closely related to that which formed the nephelite aplites of this province, and in order to throw some light on equilibrium in such liquids the results of experimental study of related liquids will now be presented.

Experimental Studies of Related Mixtures.

The system CaO-MgO-SiO_2 has been investigated by Ferguson and Merwin and their results are expressed in the equilibrum diagram, fig. 1. A liquid made up of 50 per cent forsterite and 50 per cent akermanite begins to crystallize with deposition of the olivine, forsterite, an end member of the chrysolites; when the temperature falls to 1450° monticellite begins to crystallize; and at 1436° akermanite, an end member of the melilites, begins to crystallize and monticellite redissolves until finally monticellite is entirely replaced by akermanite and the whole mass has completely solidified. In this case, then, we have the succession, forsterite (chrysolite)-monticellite-akermanite (melilite), the akermanite having a replacing relation to monticellite. This liquid and the adjacent liquids which show the same effects are, of course, themselves very rich in lime and magnesia, but when other components are added the same relations must persist at first though they will be modified and may finally disappear as more and more of other components are added. The writer has investigated the effects of the addition of nephelite to some of these mixtures. The complete quantitative solution of the problem can not be expressed in terms of less than five components, and this is, of course, not possible without a vast amount of preliminary work on the simpler systems. However, an approximate statement is possible; in other words, a statement of the kinds of mineral phases present at various temperatures may be made without giving the precise composition of the phases of variable composition or the exact relative proportions of the phases.

Fig. 1.

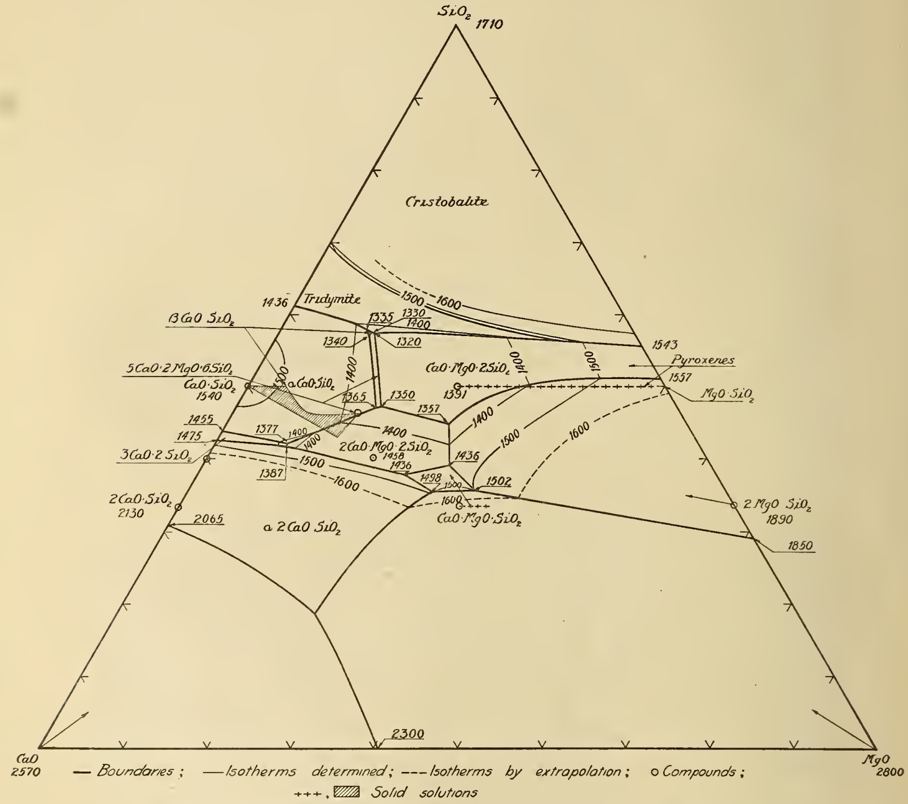

Fig. 1.—Equilibrium diagram of the system: CaO-MgO-SiO_2 (after Ferguson and Merwin).

course, not possible without a vast amount of preliminary work on the simpler systems.

The results of the investigation of equilibrium in mixtures of diopside, $CaMgSi_2O_6$, and nephelite, $NaAlSiO_4$ are given in Table III and in fig. 2, which, it must be realized, is not a two-component diagram, though having the same general form. It gives the names of the phases present at various temperatures in mixtures whose total composition can be expressed in varying proportions of

TABLE III.

Composition			
Nephelite	Diopside	Temp.	Phases present
10	90	1350	Glass and diopside
10	90	1355	Glass only
20	80	1100	Glass, diopside and melilite
20	80	1160	Glass, diopside and melilite
20	80	1200	Glass and diopside
20	80	1285	Glass and diopside
20	80	1290	Glass and forsterite
20	80	1295	Glass only
35	65	1100	Glass, diopside and melilite
35	65	1175	Glass, diopside and melilite
35	65	1180	Glass, diopside and olivine
35	65	1220	Glass, diopside and olivine
35	65	1230	Glass and olivine
35	65	1255	Glass and olivine
35	65	1260	Glass only
50	50	1050	Glass, melilite and olivine
50	50	1175	Glass, melilite and olivine
50	50	1180	Glass and olivine
50	50	1215	Glass and olivine
50	50	1220	Glass only
60	40	1050	Glass, melilite and olivine
60	40	1140	Glass, melilite and olivine
60	40	1150	Glass, nephelite, melilite and olivine
60	40	1175	Glass, nephelite, melilite and olivine
60	40	1180	Glass and olivine
60	40	1190	Glass only
70	30	1150	Glass, nephelite, melilite and olivine
70	30	1175	Glass, nephelite, melilite and olivine
70	30	1180	Glass and nephelite
70	30	1230	Glass and nephelite
70	30	1235	Glass only
80	20	1150	Glass(?)nephelite, melilite and olivine
80	20	1180	Glass and nephelite
80	20	1245	Glass and nephelite
80	20	1255	Glass and carnegieite

diopside and nephelite, but the composition of some of the individual phases can not be so expressed.[14]

FIG. 2.

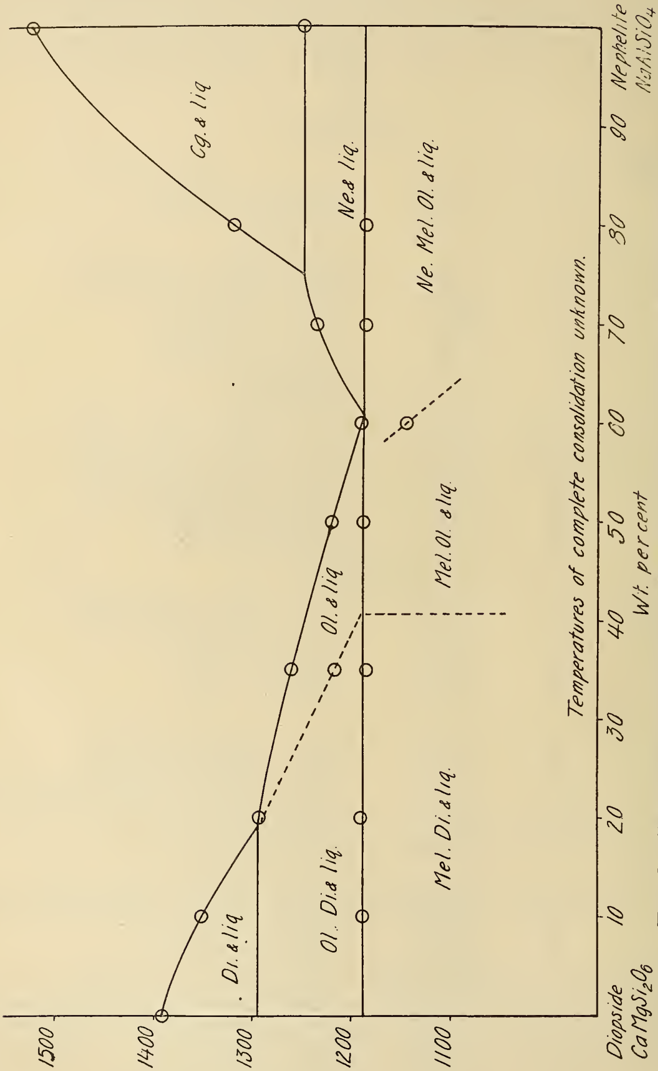

FIG. 2.—Pseudo-binary diagram of equilibrium in mixtures of nephelite and diopside.

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[14] In Table III and fig. 2 the group name, olivine, is used because the olivine formed at lower temperatures may be monticellite, though it is certainly forsterite at higher temperatures.

Since both components melt congruently there is, at either end, a portion which behaves at higher temperatures as an ordinary two-component mix but towards the middle the relations are much more complicated. In particular it is to be noted that the early crystals are olivine and melilite, that is, nephelite reacts with diopside in such a way as to produce these very basic molecules which are then precipitated. The separation of these necessarily renders the liquid with which they are in equilibrium correspondingly more siliceous. Another important general feature is the very low temperature at which there is still some liquid in the intermediate mixtures. Thus at temperatures in the neighborhood of 1000° some liquid remains and in many mixtures it is impossible to tell at what temperature complete solidification occurs, on account of the slowness with which crystallization proceeds at such temperatures.

The behavior of any particular mixture is given by the diagram, but will be put in words for certain of these that are of special significance. A mixture of 30 per cent nephelite, 70 per cent diopside begins to crystallize at 1270° with separation of forsterite. This continues to separate until a temperature of 1240° is reached, when diopside begins to separate and forsterite to redissolve. The re-solution of forsterite continues until the temperature has fallen to about 1180° and at about the same temperature melilite begins to separate. At temperatures below this and as far as 1100° the mass consists of diopside, melilite and liquid. Below 1100° the crystals formed are so small and the attainment of equilibrium so slow that further changes can not be definitely described, the temperature of final consolidation being also unknown. No nephelite is formed at any temperature where the identification of phases is certain; indeed the reaction which forms melilite presumably destroys the nephelite and part of the diopside.

A mixture of 50 per cent nephelite and 50 per cent diopside begins to crystallize at 1220° with separation of forsterite which continues down to about 1180°. At this temperature melilite begins to crystallize, and below this temperature the mass consists of melilite, forsterite and liquid down to temperatures where the crystals formed are no longer identifiable. Here again the temperature of final consolidation is unknown. Neither nephelite nor diopside appears, at least not at any temperature where the identification of phases is possible. They mutually destroy each other in the reaction which produces melilite.

A mixture of 70 per cent nephelite and 30 per cent diopside begins to crystallize at 1235° with separation of nephelite. At about 1180° the nephelite is joined by olivine and melilite, and down to temperatures where the crystals formed are no longer identifiable the mass consists of nephelite, melilite, forsterite and liquid. No diopside appears, it being used up by reaction with nephelite to form melilite.

Nature of the Melilites.

The melilites formed from the mixtures studied do not correspond with the end member, akermanite, whose equilibrium relations are given in fig. 1, but are strictly analogous to natural igneous melilites. Some of the crystals, particularly those formed at higher temperatures, are positive like akermanite but of much weaker birefringence. With increasing richness in nephelite in the total mixture the melilites separated become isotropic and finally pass over into negative melilites. The decrease of birefringence is accompanied by a slight decrease of refringence which is about 1.630 in the sensibly isotropic member. The series is quite different, therefore, from the akermanite-gehlenite series of Ferguson and Buddington in which the refringence increases as the birefringence decreases on passing away from akermanite. The present artificial melilites are, however, readily explained and correlated with natural melilites in the light of the recent work of Buddington.[15] The relation to Buddington's mixtures is brought out clearly by adding nephelite directly to akermanite and crystallizing the fused mixture at a low temperature. When 10 per cent nephelite is added to akermanite the product is nearly homogenous melilite of somewhat lower refringence and distinctly lower birefringence than akermanite. There is, however, a very little forsterite in excess and

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[15] These melilites fall under the subdivision humboldtilite as used by Buddington. Following paper, this number, p. 75.

also minute stringers of glass. As more nephelite is added the forsterite and glass increase somewhat and the birefringence of the melilite further decreases. When 25 per cent nephelite is added the melilite is sensibly isotropic and its index about 1.630, and further addition of nephelite produces negative melilite. The series of melilites is evidently strictly analogous to the akermanite: sarcolite: soda-sarcolite series of Buddington (p. 56). An equation can be written showing the formation of these molecules by reaction of akermanite and nephelite (the akermanite being in excess) with the formation of some forsterite and a more siliceous alkalic liquid that remains as glass. The equation is as follows:

$$\overset{\text{nephelite}}{15(NaAlSiO_4)} + \overset{\text{akermanite}}{6(2CaO.MgO.2SiO_2)} = \overset{\text{sarcolite}}{4(3CaO.Al_2O_3.3SiO_2)} + \overset{\text{soda-sarcolite}}{2(3Na_2O.Al_2O_3.3SiO_2)} + \overset{\text{olivine}}{3Mg_2SiO_4} + 3NaAlSi_2O_6$$

The melilites formed in the nephelite-diopside mixtures are exactly like those formed in the nephelite-akermanite mixtures except that they do not show as great range of composition. As noted, they may be either positive or negative but are never far removed from the isotropic member; in other words they never approach the pure akermanite end member but appear to center around the low melting mixture which Buddington has decided is the case in natural melilite (p. 87). The reactions taking place when nephelite is added to diopside may be pictured by imagining that the first step is the production of forsterite and akermanite from diopside by desilication as follows:

$$4CaMgSi_2O_6 + 3NaAlSiO_4 = 2(2CaO.MgO.2SiO_2) + Mg_2SiO_4 + 3NaAlSi_2O_6$$

The akermanite then further reacts with nephelite after the manner indicated in the first equation to produce the other molecules of the typical melilites. The forsterite and the melilites resulting are the first crystals precipitated from the intermediate mixtures.

The correspondence with the melilites of the rocks described is quite marked for it will be recalled that in the portion of the rock where reaction with the alkalic liquid has not proceded far the melilite is positive (akermanite-rich) whereas in the biotite-melilite seams where reaction has gone farther the melilites have isotropic cores and negative outer portions. A zoning of this particular nature has been noted in melilite from San Venanzo.[16] In the natural rock ordinary olivine was not one of the products of the reaction for the reason that the reacting liquid differed from the experimental liquid, notably in the potash content, with the result that mica was formed instead.

Space Relations of the Equilibrium Fields.

The separation of melilite and olivine from liquids whose total composition can be expressed as a mixture of nephelite and diopside has already been discussed in some detail and pictured in fig. 2. As an aid to the understanding of equilibrium relations in the rock we have described, it is perhaps desirable to present the results in a somewhat different manner, that is, in terms of a composition tetrahedron having as its base the CaO-MgO-SiO_2 triangle and nephelite at the other corner. The compounds and their equilibria with liquids for all compositions lying on the base have been studied by Ferguson and Merwin, and our present purpose is to describe how their fields are affected as we pass out into the tetrahedron, that is, as nephelite is added. It is apparent from the equations that have been given above that even four components are not sufficient to express accurately the composition of all the phases present but we could, as in the pseudo-binary diagram (fig. 2), mark the tetrahedron out into fields showing the nature of the solid phase in equilibrium with liquid, the *total composition of the mixture* being given by a point in the tetrahedron.

No attempt has been made to map out the fields throughout the whole tetrahedron, which would be a labor of many years. Attention has been concentrated upon the position of the melilite, olivine and pyroxene fields as having particular interest in the present connection.

The fields that have been delimited for the MgO-CaO-SiO_2 mixtures constituting the base will pass upward into the tetrahedron, the boundary curves becoming boundary surfaces. The position of these surfaces as

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[16] Rosenbusch, Mikroskopische Physiographie, I. 2, p. 71, 1905.

they are encountered by the lines indicating the changing composition of any crystallizing liquid mixture may be shown approximately by projecting upon the base the surfaces where thus encountered. The position of the point on the nephelite-diopside join (A) serves as a reference or indicating point.

In the CaO-MgO-SiO_2 system itself as shown in fig. 1 all of the liquids in equilibrium with monticellite are more siliceous than monticellite itself. On the other hand diopside lies in the pyroxene field, that is, the liquids with which it is in equilibrium surround it and are both more siliceous and less siliceous. When nephelite is added the pyroxene field is pulled over toward the silica corner and with about 19 per cent nephelite the boundary surface pyroxene-forsterite passes through the indicating point (A) which thereafter lies in the forsterite field. At 20 per cent nephelite the section through the tetrahedron shows the projected fields in the relative positions of fig. 3, the arrows indicating falling temperature. This shows that forsterite crystallizes first, pyroxene second, and then melilite from a mixture given by the indicating point.

With 40 per cent nephelite the relative positions of the projected fields are as shown in fig. 4. Thus forsterite crystallizes first and is joined simultaneously by both pyroxene and melilite from a mixture of diopside and nephelite as given by the indicating point. With 55 per cent nephelite the fields as projected are shown in fig. 5.

The manner in which the fields of forsterite and melilite are drawn farther over toward the silica corner as more and more nephelite is added is well shown by this series of figures (1, 3, 4 and 5).[17] A simple, if only qualitative explanation of this is that equilibrium in the liquid is such that the nephelite in the liquid takes silica to itself and leaves relatively little for the lime and magnesia, thereby increasing the concentration in the liquid of the low-silica, lime and magnesia compounds and causing their precipitation at an early stage. Indeed the series of figures is but a graphical and qualitative expression of the equations given on page 21. This affords an example of the manner in which both affinity and solubility combine

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[17] In fig. 1 the point corresponding to (A) is the diopside point itself.

FIG. 3.

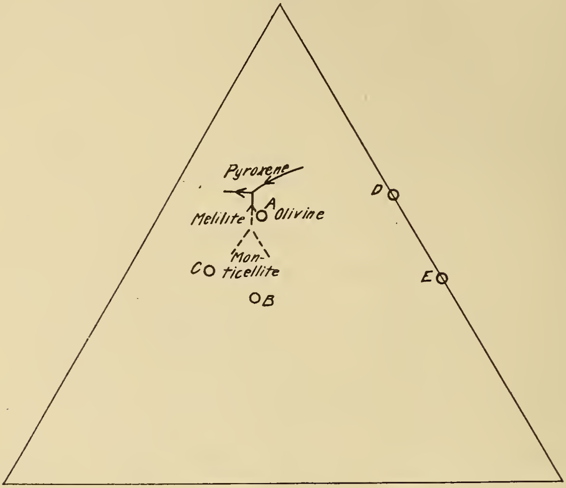
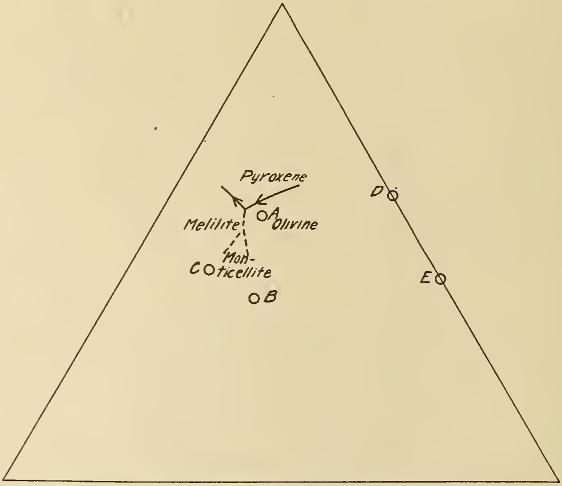


FIG. 4.



FIGS. 3, 4, 5 and 6.—Projections of fields of stability in nephelite-diopside mixtures upon the CaO-MgO-SiO_2 plane. Same orientation as fig. 1. Projected point for mixtures of nephelite with diopside, A; with monticellite, B; with akermanite, C; with enstatite, D; with forsterite, E.

FIG. 3, 20 per cent nephelite; Fig. 4, 40 per cent; Fig. 5, 55 per cent; Fig. 6, deduced relations in magma.

FIG. 5.

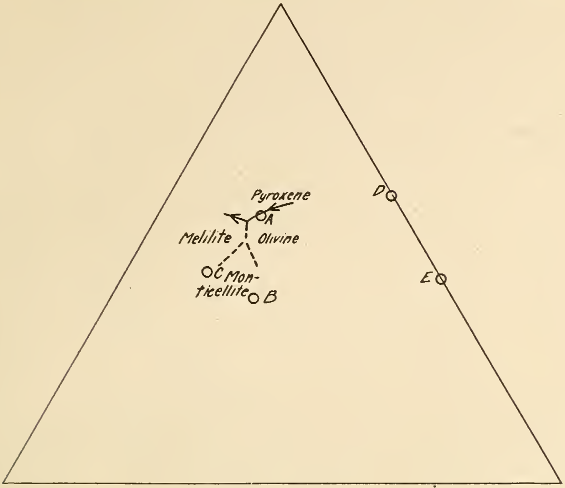
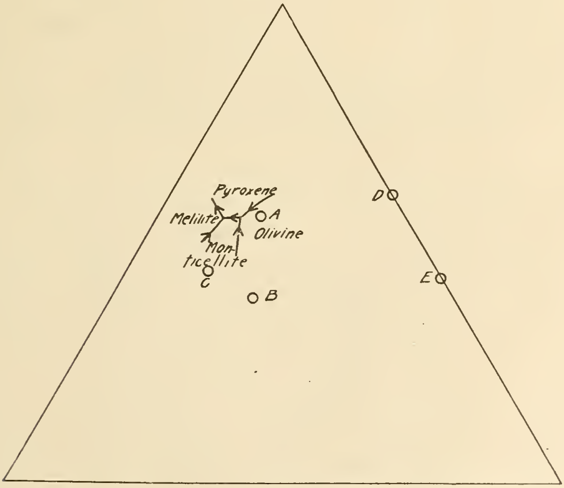

Pyroxene
A
Melilite
Olivine
C
Mon-
ticellite
B
D
E

FIG. 6.


Pyroxene
Melilite
A
Olivine
Mon-
ticellite
C
B
D
E

to determine the solid phases that shall separate from a liquid, the affinity of nephelite for silica being unquestionably an important factor in the present instance.

On account of the impossibility of distinguishing between forsterite and monticellite in the small crystals obtained at the relatively low temperatures, I am unable to speak with certainty regarding the behavior of the monticellite field. It is apparently pulled over in the same manner as the other fields, indeed even in the ternary system itself (fig. 1) it is displaced in that direction, so the addition of nephelite presumably emphasizes this natural tendency. Monticellite may therefore separate from liquids not particularly rich in lime and magnesia, providing they are alkalic. The manner in which the monticellite field separates a part of the forsterite field from part of the akermanite field, with a consequent reaction relation, has already been pointed out. This separation is apparently more marked in the alkalic liquids and in the case of the natural rock described it appears that, for the system it represents, the fields must be considered to have the relative positions shown in fig. 6, which gives their projection upon the CaO-MgO-SiO_2 plane in a manner analogous to that of figs. 3, 4, and 5. Such a figure will, at any rate, afford an explanation of the paragenesis of minerals in the rock and is but a further modification of figs. 3, 4, and 5 in the direction in which modification has been demonstrated in the presence of alkali-rich liquid. The figure (6) shows that the crystallization of a liquid given by the indicating point may begin with the formation of olivine, which is followed by pyroxene, then monticellite, then melilite, the monticellite and melilite having a reaction relation to pyroxene and olivine; that is, the latter are resorbed and replaced by monticellite and this in turn by melilite. This is the relation that the actual minerals of the rock show, with biotite as an additional replacing mineral, the investigation of which would require the addition of several other components. The occurrence of melilite as reaction rims about augite or olivine has been noted in other rocks of this area[18] and indeed a great many of the occurrences of melilite suggest its origin by reaction of pyroxene with alkalic liquid.

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[18] Robert Harvie, op. cit., p. 261.

Replacing or Reaction Relation of the Minerals of the Rock.

The use of the word *replacing* in the foregoing discussion and the division of the minerals of the rock into the two classes, original and replacing, should not mislead the reader into believing that the two sets of minerals are considered to have formed under markedly different conditions separated by an abrupt change. The chrysolite and augite may very well have formed from a somewhat alkalic liquid, but their separation, with decreasing temperature, rendered the liquid so much more alkalic that finally they became unstable in contact with such liquid and were replaced by melilite and biotite with monticellite as an intermediate step. It seems necessary to suppose, however, that the crystals of chrysolite and augite had accumulated locally and that there was only a relatively small amount of alkalic liquid, so that the composition of the mass as a whole was dominated by the richness in chrysolite and augite and the new minerals formed were determined mainly by this factor. In facies of the rock where chrysolite and augite had not accumulated in such large amounts the composition of the whole mass was characterized by the greater richness in the alkalic liquid and the new minerals formed from the augite and chrysolite are alkalic pyroxenes, amphiboles and mica, changes which have been described by those who have studied the essexites and other rocks of this particular province.[19]

The essexites, alkalic pyroxenites and other ultrabasic rocks of this province, that have received a host of locality names, have considerable interest in the present connection. The experimental results show that the fields of the basic silicates, olivine, melilite, etc., extend over beyond the join nephelite-diopside (metasilicate). The fields of the metasilicates themselves are, of course, crowded over in front of them to still more siliceous mixtures. The reaction relations of the alnoite minerals indicate similar conditions in the natural magmas. The suggestion is strong, therefore, that some of the basic rocks of this province, in so far as they consist of augitic pyroxene with some nephelite, could not have formed from liquids of their own composition but must have

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[19] In particular see G. A. Young, The Geology and Petrography of Mt. Yamaska, Geol. Surv. Can. 16, p. 25H, 1906.

formed by accumulation of their crystals from much more salic liquids (nephelite syenites, etc.). The remarkable development of flow structure in these rocks, which is summarized for the whole province by O'Neill,[20] might therefore be regarded as a natural result of their mode of origin. If, as is suggested, they do not come into existence except as a result of a considerable degree of crystal accumulation of the appropriate kind, the development of flow structure, when such a mass is moved is inevitable.

Formation of Lime-rich Minerals in Alkalic Rocks.

The series of figures (1, 3, 4, and 5) serves to emphasize the fact that in the presence of considerable nephelite the very basic silicates forsterite, melilite and possibly monticellite separate from liquids well over on the silica side of the nephelite-diopside join. The presence in a rock of the lime-rich mineral melilite need not, therefore, be considered as indicating the existence of a magma particularly rich in lime but rather of an alkali-rich magma from which melilite-bearing facies might be formed by differentiation (crystal accumulation). Moreover, the intimate association of melilite and nephelite rocks in nature is to be regarded as further evidence of the importance of crystallization-differentiation, melilite being a normal cafemic constituent of nephelite-bearing rocks.

Even such minerals as garnet and vesuvianite, closely related as they are to melilite,[21] may, perhaps, be capable of formation as normal constituents from alkalic magmas and are not necessarily an indication of contamination of the magma by lime-rich rocks such as limestone. These very basic silicates may conveniently be regarded as the normal basic minerals of rocks (mainly metasilicates) desilicated in the presence of alkalic molecules such as nephelite. It will be noted that this action, which has been demonstrated for the artificial mixtures, is exactly the opposite of that which Daly supposes to take place in magmas, viz., the desilication of feldspathic molecules by lime with formation of feldspathoids. This fact should not, however, in itself, be urged as necessarily disproving

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[20] Geol. Surv. Can. Memoir, 43, p. 22, 1914.

[21] The sarcolite molecule of melilite is also a garnet molecule.

Daly's assumption, for it is conceivable that we are dealing with a condition of equilibrium whose position may be varied under different conditions.

The occurrence of monticellite in alnoite is another example of the same sort of thing. It is a mineral which, like vesuvianite and garnet, is found in metamorphosed limestones, but it is commonly believed to be confined to such a mode of occurrence. However, there is in the collections of Dr. H. S. Washington a series of slides from the original Alnö locality,[22] only one of which is of alnoite (labeled fine-grained alnoite, Aldersnäset, Alnö) and in this slide I find that many of the chrysolite grains are surrounded by rims of monticellite, always in optical continuity with the chrysolite. Monticellite embays chrysolite and occasionally fingers through it. (See Plate I(f).) The reaction relation is very plain. In fact, while one cannot speak with confidence from the evidence of a single slide, there is much in this alnoite of the type locality suggestive of the same reactions (replacements) that have been detailed here for the Quebec occurrence. It seems not improbable that monticellite may occur in other examples but has been overlooked. It would be rather easy to do so in the presence of ordinary olivine (chrysolite), particularly in cases where their manner of occurrence was not so distinctive as in the present case. Indeed, O'Neill describes "an unknown colorless mineral," occurring in a much more salic type of rock in this same Monteregian province, whose properties as given agree excellently with those of monticellite. It occurs in a nephelite-sodalite syenite close to its contact only.[23] If it is monticellite its occurrence in the quickly chilled contact variety of the rock and its absence elsewhere is as one might expect, for in the more slowly cooled part its place is taken by other minerals just as ordinary olivine may occur in the contact facies of, say, a diabase which is elsewhere free from olivine.

On the whole, then, it seems not unlikely that monticellite may be of reasonably frequent occurrence in alkalic rocks. Indeed this is the more probable since the

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[22] The specimens were obtained from Dr. Högbom. A duplicate of this collection is in U. S. Geological Survey Petrographic Reference Collection, where this rock is No. 1044.

[23] St. Hilaire and Rougemont Mountains, Quebec, Geol. Survey. Can., Memoir 43, p. 42, 1914.

pure lime olivine itself (βCa_2SiO_4) is known to occur in such rocks, though it has frequently been stated that this compound is unknown as a rock mineral. F. P. Paul describes an unknown mineral in a nephelite-eudialite basalt from Shannon Tier, Tasmania.[24] His chemical determinations are sufficient to prove that the mineral is a lime-silica compound high in lime and free from magnesia, and he himself decides that it is probably Ca_2SiO_4. That he is certainly correct is demonstrated by the correspondence of properties with those of artificial βCa_2SiO_4,[25] which is shown below.

	Cleavage	γ	α	2V	Sign
βCa_2SiO_4	poor	1.735	1.717	large	+
Tasmanian mineral	2.olivine-like	1.746	1.718	64°	+

Petrographers appear to have entirely overlooked this occurrence of lime olivine.[26] Its nearest relative among recognized minerals is hillebrandite, $Ca_2SiO_4.H_2O$.[27] The occurrence of Ca_2SiO_4 as a mineral in an igneous rock may be regarded as further justification for the use of this molecule in calculating the norm.[28]

The compound Ca_2SiO_4 occurs in three forms. The β-form with which the natural mineral corresponds is stable only between 1420° and 675°, and when pure it changes at room temperature (or higher) to the γ-form, the change being accompanied by such increase of volume that the whole mass is reduced to powder. When embedded in a mass of glass or other minerals this change is prevented and in such a case it will persist and its properties can be studied at room temperature. Its occurrence as grains in the natural rock is, therefore, not contrary to laboratory experience. It may be noted that the artificial mineral is strongly attacked by water with solution of lime and it would be of interest to test the Tasmanian rock in this particular. According to Paul the natural mineral is readily attacked by very dilute HCl.

The rock in which this mineral occurs is a local variation of melilite-nephelite basalt. A reference to fig. 1 shows that the field of Ca_2SiO_4 borders against the aker-

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[24] T. M. P. M., 25, 309, 1906.

[25] Day, Shepherd and Wright, this Journal, 22, 295, 1906; also Rankin and Wright, ibid., 39, 75, 1915.

[26] For example, in Rosenbusch, Mikroskopische Physiographie (1908), p. 1449, it is still described as an unknown mineral.

[27] F. E. Wright, this Journal, (4) 26, 551, 1908.

[28] H. S. Washington, J. Wash. Acad. Sci., 5, 345, 1915.

manite (melilite) field and the composition of akermanite is quite close to the border. In view of the demonstrated effect of nephelite in pulling the fields over towards the silica corner the occurrence of Ca_2SiO_4 in such a rock is perhaps not surprising.

Analcite Dikes.

The formation of very basic minerals by a process which may be briefly, if somewhat inadequately, described as desilication has been demonstrated for the case of melilite in the artificial mixtures. The equations that have been written to show the formation of the characteristic melilite molecules from diopside show also, of necessity, a molecule that is formed by silication of the nephelite molecule; and the actual experimental results show the formation of a liquid which refuses to crystallize under dry melt conditions and has, as a glass, the very low refractive index appropriate to a more siliceous sodium aluminum silicate. This has been written $NaAlSi_2O_6$. Now alnoite is a monchiquite, and as such often contains analcite as a base or a glassy base of the composition of analcite, viz., $NaAlSi_2O_6.H_2O$. The Isle Cadieux alnoite shows none of this, but Harvie has found it, or alteration products that may be referred to it, in alnoites of this vicinity.[29] In this analcitic material we may, then, have the other product of the reaction of nephelite-rich liquid on augite to produce melilite. It appears here as a hydrous mineral, for the whole system was evidently quite rich in water, as witness, the abundance of biotite.

In discussing the replacement of the original minerals of the alnoite, it has been stated as probable that this was accomplished by a nephelite-rich liquid that passed through the partly consolidated rock filling the interstices with reaction minerals and carrying on some of the reaction products.[30] These latter were presumably largely analcite and it may be to such liquids that the analcite dikes of this vicinity are to be referred.[31]

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[29] Op. cit., p. 274.

[30] In this connection the arrangement of the small melilites about the older crystals is significant. They have a ''stream-like disposition,'' as Rogers and Du Toit describe a similar structure in African melilite basalts. Geol. Com., Cape of Good Hope, Ann. Rep., 1903, p. 47.

[31] F. D. Adams, Twelfth International Geologic Congress, Canada, Guide Book No. 3, p. 45.

Such straining or filtering of liquid from crystals I have elsewhere suggested as a dominant factor in the formation of those unusual types that occur only as complementary or diaschistic dike rocks.[32] A change in the nature of a dike along its strike is a feature that might be expected on this supposition, and Shannon has recently found such changes in lamprophyres of Idaho.[33]

For a discussion of certain reaction effects in analcitic rocks the reader is referred to papers by Tyrrell[34] and by Scott.[35]

Summary.

Alnoitic rocks at Isle Cadieux near Montreal, Canada, are found to consist principally of monticellite alnoite, a newly recognized (not a new) rock type. Besides this type there is a variety consisting almost exclusively of melilite and biotite, which is apparently new.

A study of the relations of the minerals indicates that the rock originally consisted of augite and chrysolite and was nearly completely consolidated as such. These minerals were then attacked, with lowering temperature, probably by their own interstitial liquid as it changed in composition, and were replaced by monticellite, melilite and biotite with marialite, perovskite and titaniferous magnetite as minor products of the reaction. The monticellite is itself replaced by melilite and biotite and the melilite-biotite rock is the end product of the replacement.

The replacement was accomplished by an alkalic liquid (magma) which formed monticellite from augite by desilicating it and later gave rise to melilite and the more definitely alkalic mineral biotite.

The melilites are both positive and negative and are sometimes conspicuously zoned, with a positive core, an isotropic intermediate zone, and a negative rim.

In an experimental part of the paper equilibrium in mixtures of nephelite and diopside is determined. It is found that from intermediate mixtures forsterite and melilite are the first products to crystallize and the

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[32] Proc. Nat. Acad. Sci., **6**, 161, 1920.

[33] Proc. U. S. Nat. Museum, 57, 1920, p. 480.

[34] G. W. Tyrrell, Quart. Jour. Geol. Soc., **72**, pt. 2, 84-131, 1917.

[35] Alex. Scott, Trans. Geol. Soc. Glasgow, **16**, pt. 1, 34-45, 1915-16.

melilites so formed are analogous to natural melilites in composition and optical properties.

It is thus proved experimentally that nephelite reacts with diopside to form melilite, a reaction analogous to that which is considered to have taken place between augite and alkalic liquid in the natural rocks.

This reaction is of the nature of a desilication of the diopside, and while the formation of monticellite in this manner has not been demonstrated in the relatively simple experimental mixtures, the demonstration of desilication of diopside in these mixtures is believed to give support to the idea that monticellite is so formed from augite in the more complex natural mixture.

An outstanding difference between the natural, replacing (reacting) liquid and the artificial mixtures is the presence of potash and water in the former. As a result of this difference the reaction products instead of being forsterite and melilite were, in the natural rock, biotite and melilite with monticellite as an intermediate step. In fact chrysolite, originally present, was itself a principal source of biotite. The liquid, as modified, by the reaction, passed on and possibly gave rise to analcite dikes.

It is probable that monticellite occurs fairly frequently as an igneous rock mineral in rocks related to those described. Re-examination of the original alnoite shows its presence there with, apparently, a similar relationship. Even the pure lime olivine itself (βCa_2SiO_4) has been found in a related rock from Tasmania, a fact to which attention is here directed because it appears to have been overlooked in general petrologic literature.

Such lime-rich minerals, including also melilite and the related minerals garnet, vesuvianite and others, may be considered to have formed in alkalic magmas as the result of desilication of the more normal cafemic molecules (metasilicates). Their presence in alkalic rocks may therefore be the result of normal equilibrium processes in the magma and not of addition to the magma of lime-rich rocks (limestone, etc.).

Geophysical Laboratory,
Carnegie Institution of Washington,
May, 1921.

EXPLANATION OF PLATE I.

a. Zoned melilite with isotropic core and birefracting (negative) rim; x 20. Melilite-biotite rock, Isle Cadieux.

b. Remnants of a single pyroxene crystal (P, P) in matrix principally of biotite; x 67. Monticellite alnoite, Isle Cadieux.

c. Resorbed chrysolite crystals (chadacrysts) in matrix (a single oikokryst) of biotite showing rims of ore at borders of chrysolites; x 33. Alnoite (approaching mica peridotite), Isle Cadieux.

d. Resorbed pyroxene crystal (P) in matrix principally of monticellite; x 20. Monticellite alnoite, Isle Cadieux.

e. Blocky replacement of a pyroxene crystal by biotite; x 20. Monticellite alnoite, Isle Cadieux.

f. Resorbed chrysolites (*c*) surrounded by similarly oriented monticellite (M); x 33. Alnoite from Aldersnäset, Alnö.

ART. II.—*On Some Natural and Synthetic Melilites;* by A. F. BUDDINGTON.

INTRODUCTION.

The melilite group is usually considered to include the minerals akermanite, gehlenite, humboldtilite, sarcolite, fuggerite, and the ferric iron-rich melilite originally called melilite. Many different theories have been proposed to explain their composition. One of the most recent is suggested by Schaller,[1] who has reconsidered previous theories and all the available analyses of the natural minerals and has arrived at a new theory of their composition. His statement, in brief, is that all the suitably described members of the melilite and gehlenite group can be satisfactorily explained as isomorphous mixtures of the primary compounds, sarcolite ($3CaO.Al_2O_3.3SiO_2$), a hypothetical soda-sarcolite ($3Na_2O.Al_2O_3.3SiO_2$), velardeñite ($2CaO.Al_2O_3.SiO_2$), and akermanite ($4MgO.8CaO.9SiO_2$). He further suggests the possibility that a ferric sarcolite ($3CaO.Fe_2O_3.3SiO_2$) may be another component of the melilites.

The present work was undertaken to test this hypothesis, and it is a pleasure to state that the results of the laboratory study on pure mixtures confirm the more essential features of Schaller's theory. The present work, however, indicates that the melilites are too complex to be wholly explained in this way and that several modifications are necessary. These concern, in part, the composition of the mineral akermanite, and the polymorphic character of the $3RO.R_2O_3.3SiO_2$ compounds and certain solid solutions into which they enter.

Schaller states that the composition of akermanite is $4MgO.8CaO.9SiO_2$. Ferguson and Merwin[2] in their study of the ternary system $CaO\text{-}MgO\text{-}SiO_2$ were unable to prepare a compound or solid solution having this formula. On the other hand, they prepared a compound $2CaO.MgO.2SiO_2$ whose crystal system and essential optical properties corresponded to those of the mineral

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[1] W. T. Schaller, U. S. Geol. Surv., Bull. 610, pp. 106-128, 1916. Whenever the work of Schaller is referred to in this paper, the reference is that given here.

[2] J. B. Ferguson and H. E. Merwin, this Journal, 48, 118-122, 1919.

akermanite. They therefore suggested that the compound $2CaO.MgO.2SiO_2$ found by them is the synthetic equivalent of akermanite. Later, Ferguson and Buddington[3] found that the compounds $2CaO.MgO.2SiO_2$ and $2CaO.Al_2O_3.SiO_2$ form a complete isomorphous series of solid solutions. This confirmed the suggestion of Vogt[4] that akermanite and gehlenite form a complete series of solid solutions, and also serves to indicate the correctness of the formula assigned to akermanite by Ferguson and Merwin. The same series of analyses of natural minerals used by Schaller in his study has been recalculated on the assumption that $2CaO.MgO.2SiO_2$ is the correct formula for akermanite, and the results have been found to check equally well with those of Schaller for the humboldtilite and gehlenite varieties, but not for the ferric iron rich melilites or for akermanite itself. In this paper the term akermanite will be applied to the compound $2CaO.MgO.2SiO_2$, since the balance of the evidence seems to favor this interpretation.

Schaller has proposed that the compound $2CaO.Al_2O_3.SiO_2$ be called velardeñite, since the natural gehlenites are not definite compounds but variable solid solutions, and since the gehlenite of Velardeña, Mexico, approaches more nearly than any so far analyzed to the pure compound, $2CaO.Al_2O_3.SiO_2$. The term gehlenite, however, has been used by Vogt[5] to designate one of the independent primary members of the melilite group, and this usage is common in the literature. The pure compound $2CaO.Al_2O_3.SiO_2$ was first prepared by Shepherd and Rankin[6] and was called gehlenite.

The term albite is used both for the pure end member and also for any plagioclase between Ab and Ab_6An_1. Similarly, the term gehlenite may be used for the pure end member and for solid solutions within certain limits. The compound $2CaO.Al_2O_3.SiO_2$ is therefore called gehlenite in this paper, and is the equivalent of the velardeñite of Schaller.

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[3] J. B. Ferguson and A. F. Buddington, this Journal, 50, 131-140, 1920.

[4] J. H. L. Vogt, Mineralbildung in Schmelzmassen, p. 96, 1892. Vogt gives the formula $(Ca,R_3)_3.(Al_2,Fe_2)Si_2O_{10}$ for gehlenite and $(Ca,R)_4Si_3O_{10}$ for akermanite.

[5] J. H. L. Vogt, loc. cit.

[6] E. S. Shepherd and G. A. Rankin, Preliminary report on the ternary system $CaO-Al_2O_3-SiO_2$; a study of the constitution of portland cement clinker, with optical study by F. E. Wright, J. Ind. Eng. Chem., 3, 224, 1911.

A statement showing the names of the minerals equivalent in composition to the compounds used in this investigation is given in Table I.

TABLE I.

Formulæ of compounds and names of the mineral or synthetic equivalent.

Compound	Mineral equivalent
$2CaO.MgO.2SiO_2$	Akermanite
$2CaO.Al_2O_3.SiO_2$	Gehlenite
$3CaO.Al_2O_3.3SiO_2$	Grossularite
$3CaO.Fe_2O_3.3SiO_2$	Andradite
$3Na_2O.Al_2O_3.3SiO_2$	Lagoriolite*
$\left\{\begin{matrix} 90\ (3CaO.Al_2O_3.3SiO_2) \\ 10\ (3Na_2O.Al_2O_3.3SiO_2) \end{matrix}\right\}$	Sarcolite

*Prepared and named by Morozewicz. Known only in synthetic preparations.

CHOICE OF SOLID SOLUTIONS FOR INVESTIGATION.

Akermanite and gehlenite had previously been found to form a true binary system, but each of the three compounds $3Na_2O.Al_2O_3.3SiO_2$; $3CaO.Al_2O_3.3SiO_2$; and $3CaO.Fe_2O_3.3SiO_2$ is unstable at or below its melting point, and most of the solid solutions of these compounds with akermanite and gehlenite which were investigated are likewise unstable at their melting point; so that these solutions as a whole, from the standpoint of the phase rule, must be treated as a part of a six-component system embracing their constituent oxides. No attempt has been made in this work to study the solid solutions of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and the $3RO.R_2O_3.3SiO_2$ compounds as a problem in itself. This can be done only after the many simpler systems embraced within the six-component system of which these solid solutions form a portion shall have been worked out. Only a few of the possible solid solutions of the compounds under consideration have been studied. These, numbering in all about 100, were chosen with the object of obtaining data to explain the melilite group of minerals as now known from recorded analyses. No effort has been made to determine the nature of the dissociation products of the unstable solid solutions, nor of the other phases present in those mixtures exhibiting inhomogeneity.

Schaller, from a study of the natural gehlenites, showed that the major components are gehlenite, akermanite, and $3CaO.Al_2O_3.3SiO_2$. Accordingly, these three compounds were chosen as end members and their relations were studied. They were found to have a limited field of solid solution. The composition 90% $3CaO.Al_2O_3.3SiO + 10\% \; 3Na_2O.Al_2O_3.3SiO_2$, corresponding to the composition of sarcolite, was then taken as another end member, and its relations in mixtures of $2CaO.MgO.2SiO_2$ and $2CaO.Al_2O_3.SiO_2$ were studied. A field of complete solid solution was found for these mixtures, with the exception of a doubtful zone close to the $2CaO.MgO.2SiO_2$ end.

Schaller, from a study of the humboldtilites and the original melilites of Capo di Bove, had shown that the major components of these minerals were the compounds $3CaO.Al_2O_3.3SiO_2$, $2CaO.MgO.2SiO_2$, and $3CaO.Fe_2O_3.3SiO_2$, with minor amounts of $3Na_2O.Al_2O_3.3SiO_2$ and $2CaO.Al_2O_3.SiO_2$. The soda compound varies from 8 to 12 percent, averaging about 9 percent. Accordingly, a system was studied in which the percentage of $3Na_2O.Al_2O_3.3SiO_2$ was maintained constant at 10 percent, and the percentages of the compounds $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Fe_2O_3.3SiO_2$ were varied.

Another system was studied in which all five compounds were introduced, the percentage of the soda compound being maintained constant at 10 percent and $2CaO.Al_2O_3.SiO_2$ at 20 percent, while the percentages of the other three compounds were varied.

The compositions of all the analyzed natural minerals of the melilite group, except one, approximate to compositions embraced within or between the systems thus studied. A synthetic preparation corresponding in composition to the mineral fuggerite, which is classed with the melilites but falls outside these compositions, was studied separately.

Three analyses of natural humboldtilites made for the writer by Dr. H. S. Washington showed that a ferrous iron compound was an accessory component constituting up to 15 percent or more of this mineral. Apparatus for dealing with ferrous iron compounds must be developed before this component can be studied; it is therefore not considered in this work.

METHODS.

Six constituents, CaO, Na_2O, MgO, Al_2O_3, Fe_2O_3, and SiO_2, enter into the composition of the solutions dealt with. Chemically pure calcium carbonate, anhydrous sodium carbonate, silica, and ferric oxide were used in making up charges. Pure magnesium oxide was obtained by heating basic magnesium carbonate in a Fletcher gas furnace, leaching to separate alkalic impurities, and reheating. The aluminum oxide was purified by boiling with a solution of ammonium chloride followed by heating in the Fletcher furnace.

Charges of a definite composition were made up by mixing together the constituent oxides or their equivalents in proper weights to give a ten gram portion. These were then ground for one hour in a mechanical grinder.

All charges containing ferric oxide were melted in a platinum crucible suspended in a platinum resistance furnace at temperatures of from 1400° to 1450° and were then quenched to form glasses. Charges were melted three times with intervening grindings to a fineness sufficient to pass a sixty-five mesh sieve.

Charges free from ferric oxide were made up by using the Fletcher blast furnace in place of the electric furnace. This treatment gave homogeneous glasses that were used in subsequent experiments.

In their work on the system lime-ferric oxide, Sosman and Merwin[7] found that a certain amount of ferrous iron is formed in all melted mixtures of CaO and Fe_2O_3. When the molecular percentage of Fe_2O_3 was less than 50 percent in mixtures heated to 1400°-1500°, they found the percentage of ferrous oxide was small. In order to ascertain the possible extent of dissociation in the ferric oxide mixtures used in the course of this work, two charges of prepared glasses were analyzed for ferrous iron by Dr. H. S. Washington. One preparation contained 3.14 percent of Fe_2O_3 and showed 0.36 percent of FeO; the other contained 14.1 percent of Fe_2O_3 and 1.19 percent of FeO. The optical and thermal data for mixtures rich in ferric iron, therefore, need a slight correction for dissociation.

[7] R. B. Sosman and H. E. Merwin, J. Wash. Acad. Sci., 6, 532-7, 1916.

The quenching method was employed throughout the research. Details of this method may be found in many of the previous publications of this laboratory. A diagram of the type of furnace used in this work may be found in the paper by Ferguson and Merwin[8] on the ternary system CaO-MgO-SiO_2. The melting points used in the calibration of the thermoelements were those of: gold 1062.4°, diopside 1391.5°, akermanite 1458°, anorthite 1550°, and gehlenite 1590°.

In most cases, crystals used for the determination of their optical properties were prepared by holding the proper glass over night at a temperature just below the dissociation point, or the beginning of melting. A very great difference was found in the character of the crystallization. Mixtures with 50 percent or more of the $3CaO.Al_2O_3.3SiO_2$ compound crystallized in fibrous aggregates which did not grow appreciably with continued heating. If these charges are heated above the dissociation point, so that a little liquid is obtained to facilitate recrystallization, the resulting aggregates are mottled throughout with the dissociation products and are unsatisfactory, unless the material is crystallized so far above the solidus that a change in their composition results and the optical properties of the crystals obtained are materially changed. The best crystallized preparations of such compositions were obtained by heating the glasses 20 hours or longer somewhat above the lowest temperature at which the glass will recrystallize. The optical determinations of the indices of refraction made on mixtures rich in the $3CaO.Al_2O_3.3SiO_2$ compound may be in error as much as $\pm$ 0.005. Glasses with less than 50 percent of the $3CaO.Al_2O_3.3SiO_2$ compound and as little as 20 percent of the $3CaO.Fe_2O_3.3SiO_2$ compound give very good crystalline material if held for fifteen minutes to an hour at a temperature a little below the solidus. The glass of composition containing 90 molecular percent of $3CaO.Al_2O_3.3SiO_2$ and 10 percent of $3Na_2O.Al_2O_3.3SiO_2$ was held for one week at a point just above the solidus to obtain crystals free from air for the determination of the specific gravity. Some glass and dissociation products were present in this material.

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[8] J. B. Ferguson and H. E. Merwin, op. cit., p. 88.

The succeeding tables present only selected data which are considered significant for the problem. The indices of refraction are all for sodium light. Where indices of refraction are given for mixtures which are slightly dissociated, the observations apply to the dominant crystal phase.

MIXTURES OF $3CaO.Al_2O_3.3SiO_2$; $2CaO.MgO.2SiO_2$, AND $2CaO.Al_2O_3.SiO_2$.

A preliminary series of experiments made on mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Al_2O_3.3SiO_2$ gave unsatisfactory inhomogeneous crystalline aggregates at the temperatures of the experiments. Work on these mixtures, accordingly, was temporarily abandoned. The constant presence of a sodium compound in the natural melilites and the existence of the natural mineral sarcolite, containing about 10 percent of the compound $3Na_2O.Al_2O_3.3SiO_2$, suggested that material of the composition of sarcolite be tried in place of the calcium compound $3CaO.Al_2O_3.3SiO_2$. In the progress of this later work it was discovered that certain mixtures which were heterogeneous at temperatures just below the solidus were homogeneous at lower temperatures. With this information as a guide, work on mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Al_2O_3.3SiO_2$, was resumed and significant results were obtained.

Mixtures of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$, which contained 70 percent or more of the former component, are homogeneous below the dissociation point except for a few grains with a much higher index of refraction. Whether these grains actually mean an incomplete solid solution or are the result of slight impurities in the melt, or whether they are compounds formed at lower temperatures and existing in unstable equilibrium at higher temperatures, was not ascertained.

It has been previously shown[9] that the compounds $2CaO.Al_2O_3.SiO_2$ and $2CaO.MgO.2SiO_2$ are isomorphous and form a complete series of solid solutions with a minimum melting point. In table II the optical characters and thermal data for mixtures of these two components are given, and in fig. 1 the indices of refraction are plotted against the composition in weight percent. The

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[9] J. B. Ferguson and A. F. Buddington, loc. cit.

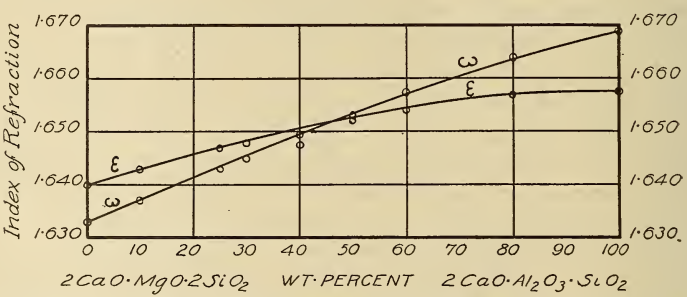
TABLE II.

Optical and thermal data for mixtures of $2CaO.Al_2O_3.SiO_2$; and $2CaO.MgO.2SiO_2$. Compositions expressed in weight percent, temperatures in degrees Centigrade.

$2CaO.Al_2O_3.SiO_2$.	$2CaO.MgO.2 SiO_2$	$n\omega$	$n\epsilon$	All crystal	Crystal + trace Glass	Glass + trace crystal	All glass
100	0	1.669	1.658				1590°
80	20	1.664	1.657	1498°	1502°	1553°	1557°
60	40	1.657	1.654	1441°	1445°	1506°	1512°
50	50	1.653	1.652			1475°	1478°
40	60	1.648	1.649	1400°	1404°	1430°	1432°
30	70	1.645	1.648	1390°	1392°	1394°	1397°
25	75	1.643	1.647	1385°	1388°		1390°
10	90	1.637	1.643	1416°	1420°	1424°	1427°
0	100	1.632	1.639				1458°

optical properties are a continuous function of the composition, and crystals of a certain intermediate mixture are isotropic for sodium light, constituting a transition phase from the positive akermanite to the negative gehlenite.

FIG. 1.



1.—Curves for refractive indices plotted against composition in weight percent for mixtures crystallized just below the solidus.

From the data given by Rankin and Wright[10] in their study of the ternary system $CaO-Al_2O_3-SiO_2$, it is found that the point of beginning of melting for all mixtures of $2CaO.Al_2O_3.SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ is the eutectic melting at 1265° and that no solid solution exists above this point. Mixtures of these two compounds are the only ones investigated in the present work which failed to show evidence of some solid solution above the beginning of melting, either accompanied or unaccompanied by

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[10] G. A. Rankin and F. E. Wright, this Journal, 39, 1-79, 1915.

dissociation. Below the solidus for mixtures of these two components, however, solid solution does exist for limited ranges of temperature and of composition.

TABLE III.

Optical and thermal data for mixtures of $2CaO.Al_2O_3.SiO_2$ and $3CaO.Al_2O_3.3SiO_2$. Compositions expressed in weight percent and temperature in degrees Centigrade.

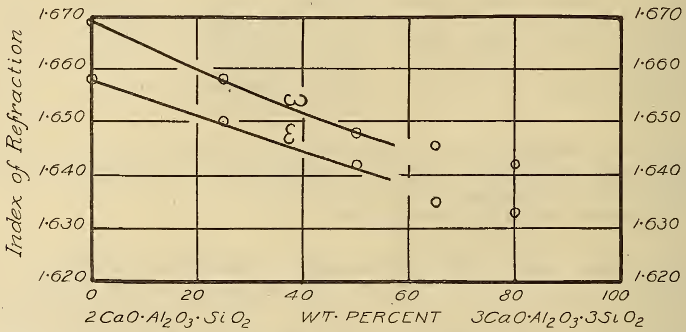
$2CaO.$ Al_2O_3 SiO_2	$3CaO.$ $Al_2O_3.$ $3SiO_2$	$n\omega$	$n\epsilon$	One phase	Trace of ciation	Glass crystals	All glass
100	0	1.669	1.658				1590°
75	25	1.658	1.650	1145° (1 hr.)	*1170° (1 hr.)	1566°	1574°
50	50	1.648	1.642	1110° (1 hr.)	1150° (1 hr.)	1524°	1530°
35	65	†1.643	†1.635	Trace dissoc. (16 hrs. at 980°)		1484°	1490°
20	80	†1.642	†1.633	Inhomogeneous (16 hrs. at 980°)		1428°	1433°
0	100			Inhomogeneous (16 hrs. at 980°)		1340°	1347°

*The dots thought to represent dissociated products are so small in amount, and so minute, that this determination is doubtful, and this mixture may be homogeneous up to the eutectic.

† Determined on major crystal phase.

In Table III are given the optical characters and thermal data for the mixtures of these two compounds which were investigated. Owing to the very finely fibrous character of the preparations crystallized some distance below the eutectic, it is very difficult in many cases to determine the homogeneity or inhomogeneity of the material under examination. For this reason no importance is attached to the temperatures given as marking the beginning of dissociation, and the limits of solid solution are likewise only approximations. The end component, $3CaO.Al_2O_33SiO_2$ when held for 16 hours at 980° gave a fibrous aggregate which was conspicuously inhomogeneous. Filaments of a mineral, presumed to be wollastonite, are prominent. A mixture containing 20 percent of $2CaO.Al_2O_3.SiO_2$, heated for 16 hours at 980°, likewise gave a conspicuously inhomogeneous fibrous aggregate, but not to such an extent as the end member alone. With an increasing percentage of $2CaO.Al_2O_3.SiO_2$ the evidence of inhomogeneity decreases and in a mixture of the composition 35 percent $2CaO.Al_2O_3.SiO_2$-65 percent $3CaO.Al_2O_3.3SiO_2$ these is a mere trace of inhomogeneity in material held for 16 hours at 980°; and a mixture of equal parts of the two components, treated at the same temperature for the same length of time, appears perfectly homogeneous. The upper range of homogeneity for this latter mixture, however, is limited, and dissociation products appear in preparations heated for one hour at 1150°, or over 100° below the eutectic. In a mixture of 75 percent $2CaO.Al_2O_3.SiO_2$ and 25 percent $3CaO.Al_2O_3.3SiO_2$ the beginning of dissociation is not well marked, and the material may be homogeneous up to the eutectic. In summary, then, mixtures of $2CaO.Al_2O_3.SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ exhibit a limited range for complete homogeneity extending from the $2CaO.Al_2O_3.SiO_2$ component to a little beyond a 50-50 mixture, and within a temperature range that is limited upwards by dissociation or the eutectic point, and of unknown lower limits. Partial solid solution is found in mixtures containing so much as 80 per cent $3CaO.Al_2O_3.3SiO_2$, as is indicated by the indices of refraction determined on the major constituent of preparations crystallized at 980°, and may extend further. But a break in the series of completely homogeneous mixtures towards the $3CaO.Al_2O_3.3SiO_2$ component beyond a 50-50 mixture is indicated by a break in the curves for indices of refraction. In fig. 2 the indices of refraction are plotted against com-

FIG. 2.



2.—Curves for refractive indices plotted against composition in weight percent for mixtures which show complete homogeneity when crystallized at about 1000°. Indices of refraction for dominant phase of inhomogeneous mixture are indicated where determined.

position in weight percent, and the curves connect those mixtures which show complete homogeneity for a temperature range above 980° (the lower working limit under the conditions of the experiment). The indices of refraction for the major constituent of inhomogeneous mixtures crystallized for 16 hours at 980° are also plotted.

Since dissociation takes place at or before the eutectic, thermal data for the liquidus and solidus cannot be used as evidence of solid solution.

None of the crystallized mixtures of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ was found to be absolutely homogeneous within the temperature range explored. Mixtures containing 70, 80, and 90 percent of the $2CaO.MgO.2SiO_2$ compound, however, showed only a trace of some included, minute, more highly refracting, low-birefringent grains, and are essentially homogeneous for a range below the dissociation point, or the point of beginning of melting, as the case may be. The lowest temperature at which experiments were made was 980°, so that nothing is known of the relations below this point. A mixture containing only 10 percent of the $3CaO.Al_2O_3.3SiO_2$ compound appears homogeneous up to the point of beginning of melting (1417°±6°) except for the qualification noted above. Dissociation (in addition to the trace of grains noted above) in mixtures richer in this compound, however, takes place much below this, and those containing 55 percent $3CaO.Al_2O_3.3SiO_2$ show a trace of interstitial inhomogeneity at 980°; those containing a greater percentage of this compound show still greater inhomogeneity at the same temperature. In Table IV the optical characters and the thermal data for mixtures of these two compounds are given. Owing to the lack of positive evidence of the complete homogeneity of any of the preparations examined, no curves have been drawn to show the relation of the optical characters to the composition. It is believed, however, that the optical characters given are those of material essentially the same in chemical composition as would be indicated by the mixture designated.

Mixtures of the three components $2CaO.Al_2O_3.SiO_2$, $3CaO.Al_2O_3.3SiO_2$ and $2CaO.MgO.2SiO_2$ form an incomplete series of solid solutions, completely homogeneous in the field along the $2CaO.Al_2O_3.SiO_2$-$2CaO.MgO.2SiO_2$

TABLE IV.

Optical and thermal data for mixtures of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$. Compositions expressed in weight percent and temperatures in degrees Centigrade.

$3CaO.Al_2O_3.3SiO_2$	$2CaO.MgO.2SiO_2$	n_ω	n_ϵ	*Essentially one crystal phase	*Trace of dissociation	Glass + crystals	All glass
0	100	1.632	1.639				1458°
10	90			1408°		1420°	1525°
20	80	1.634	1.639	1215° (1 hr.)	1240° (½ hr.)	1403°	1409°
30	70	1.629	1.632	1200° (1 hr.)	1240° (½ hr.)	1380°	1386°
45	55	1.629†	1.630†		980° (16 hrs.)		
65	35			Inhomogeneous (980° 16 hrs.)		1317°	1324°
80	20			Inhomogeneous (980° 16 hrs.)		1317°	1323°
100	0			Inhomogeneous (980° 16 hrs.)		1340°	1347°

* Trace of higher refracting birefringent dots present, and preparations are therefore not completely homogeneous.

† Determined on major crystal phase.

side, and incomplete towards the $3CaO.Al_2O_3.3SiO_2$ component, at temperatures above 980° (the lower limit at which experiments were performed) and below the temperature of dissociation.

The intermediate mixtures of the three end members containing 40 percent $3CaO.Al_2O_3.3SiO_2$ proved extremely unsatisfactory. Held for 16 hours at 980°, they appeared as homogeneous fibrous aggregates, whereas at 1100°, for the same length of time, they are so very cloudy, with areas of brownish dots, as to make it impossible to judge whether they are simply full of included air or, as seems more probable, are mineralogically inhomogeneous. At 1170° the preparations are relatively clear again and show distinct interstitial birefringent material. It is possible but not probable that even in the preparations at 980° the material is actually inhomogeneous but appears to be homogeneous because of the finely fibrous character. The general rule is that the preparations rich in the $3CaO.Al_2O_3.3SiO_2$ component, both in this system and in those containing the $3Na_2O.Al_2O_3.3SiO_2$ compound, with slow nucleation and crystallization (about 1000°), are clear and quite free of air; whereas with more rapid nucleation and crystallization at higher temperatures (about 1100°±50°), much more air is included and the crystalline material is very cloudy. As soon as dissociation begins, the air is expelled and the preparations are clear but minutely heterogeneous with the dissociated products.

The optical characters and thermal data for mixtures of the three components are given in Table V. In fig. 3

TABLE V.

Optical and thermal data for mixtures of $2CaO.Al_2O_3.SiO_2$;$2CaO.MgO.2SiO_2$:$3CaO.Al_2O_3.3SiO_2$. Compositions expressed in weight percent and temperatures in degrees Centigrade.

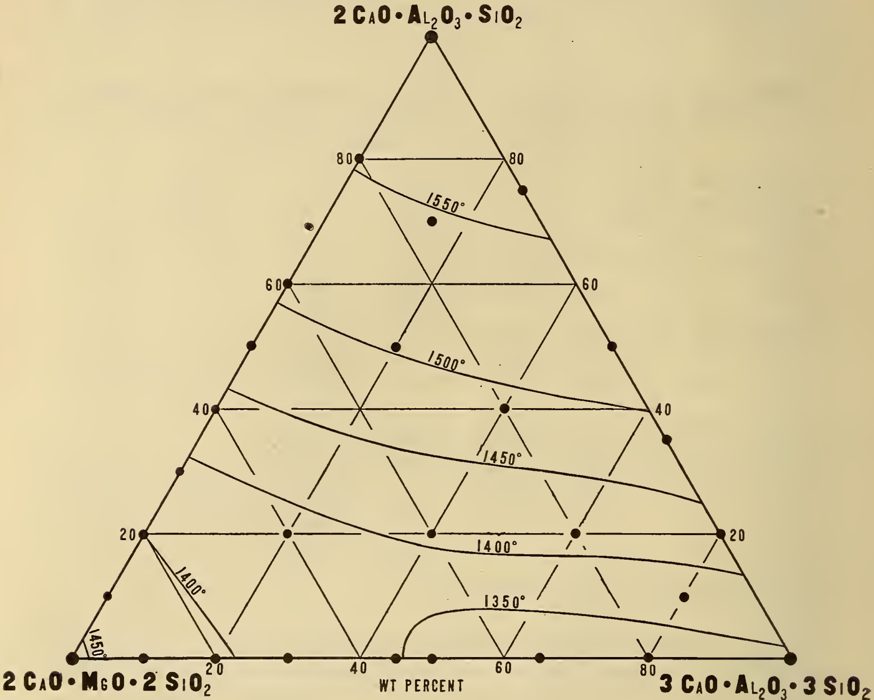
$3CaO.Al_2O_3.3SiO_2$	$2CaO.MgO.2SiO_2$	$2CaO.Al_2O_3.SiO_2$	$n\omega$	$n\epsilon$	One crystal phase	Trace of dissociation	Glass + trace of crystals	All glass.
20	30	50	1.652	1.648	1170° (16 hrs.)	1190° (16 hrs.)	1494°	1501°
20	60	20	1.637	1.639	1100° (16 hrs.)	1140° (16 hrs.)	1378°	1383°
40	20	40	1.647 (980° 16 hrs.)	1.642		1170° (16 hrs.)	1480°	1486°
60	20	20	*1.641	*1.634		980° (16 hrs.)	1408°	1415°
80	10	10	*1.638	*1.633	Inhomogeneous (16 hrs. at 980°)			
40	40	20	1.640 (980° 20 hrs.)	1.637		1180° (20 hrs.)	1410°	1414°
15	15	70	1.657	1.652	1180° (16 hrs.)	1200° (16 hrs.)	1541°	1547°

* Determined on major crystal phase.

the compositions in weight percent of the mixtures investigated are plotted in triangular coordinates with isotherms for the temperatures of complete melting. A point of possible significance bearing on the origin of the natural melilites is that the mixtures which are closest in composition to the natural minerals lie in the zone with lowest temperatures of complete melting. In fig. 4, lines connecting similar indices of refraction of the ordinary ray and the extraordinary ray have been plotted against the composition in weight percent for those mixtures which show complete solid solution within a definite temperature range above 980° (the approximate lower working limit under the conditions of the experiment). Lines connecting those mixtures which show the same birefringence have also been plotted. Both $2CaO.Al_2O_3$.

SiO_2 and the $3CaO.Al_2O_3.3SiO_2$ compound have negative optical characters, whereas $2CaO.MgO.2SiO_2$ is positive, so that the combination of the three end members gives a certain definite series of mixtures which are isotropic to a definite wave length of light. The lines connecting compositions whose birefringence is 0.000 and 0.005 are more or less concentric to the $2CaO:MgO.2SiO_2$ component.

Fig. 3.



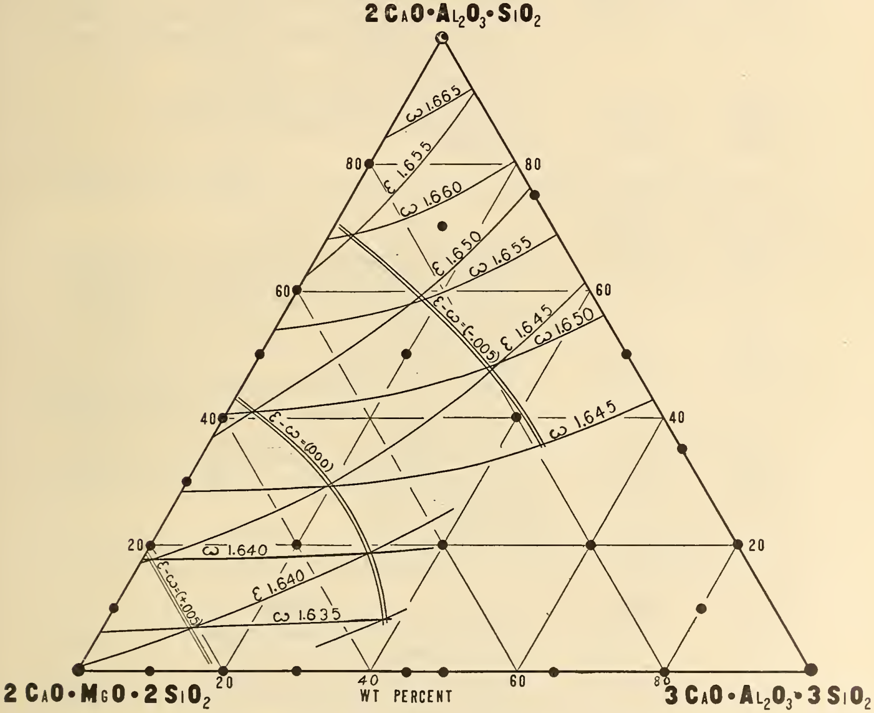
3.—Triangular concentration diagram showing compositions of preparations investigated and the isotherms for the temperatures of complete melting.

Mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $[(90\ 3CaO.Al_2O_3.3SiO_2)\ (10\ 3Na_2O.Al_2O_3.3SiO_2)]$

Mixtures of $2CaO.MgO.2SiO_2$ and the solid solution, equivalent in composition to the natural mineral sarcolite, which contain 80 percent or more of the $2CaO.MgO.2SiO_2$

molecule, show a trace of grains with a much higher index of refraction at temperatures below the dissociation point. The same phenomenon has already been referred to in the case of the mixtures of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$, and its meaning is not known. With this possible exception, the mixtures of the compounds $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and the solid solution with the composition of sarcolite [(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)] form a complete series of solid solutions within a temperature range above 980°—the approximate lower working limit under the conditions of the experiments—and below the solidus or the dissociation point, as the case may be.

FIG. 4.



4.—Triangular concentration diagram showing compositions of preparations investigated. Lines connecting similar indices of refraction have been plotted for those mixtures which show complete homogeneity within a definite temperature range above 980° (the lowest temperature of experiments). Lines for equal birefringence also plotted.

TABLE VI.

Optical and thermal data for mixtures of $2CaO.MgO.2SiO_2$; and [(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3$ $3SiO_2$)] Compositions expressed in weight percent, and temperatures in degrees Centigrade.

$$90\ \ 2CaO.MgO.2SiO_2 - 10 \left\{ \begin{array}{l} 90\ \ 3CaO.Al_2O_3.3SiO_2 \\ 10\ \ 3Na_2O.Al_2O_33SiO_2 \end{array} \right.$$

Temperature	*Time*	*Phases*
1180°	16 hrs.	Essentially homogeneous very fine grained fibrous aggregate, with sutured texture. Trace of minute grains of much higher index of refraction. $n_\omega = 1.634$ $n_\epsilon = 1.639$
1200°	1 hr.	Trace of dissociation in some grains.
1428°	½ hr.	Glass plus trace of crystals.
1430°	1/3 hr.	All glass.

80 $2CaO.MgO.2SiO_2$ — 20[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
900°	16 hrs.	Essentially homogeneous, fibrous granular aggregate. Trace of minute grains of much higher index of refraction and low birefringence.
1100°	1 hr.	Same as above.
1150°	1 hr.	Same as above. $n_\omega = 1.632$ $n_\epsilon = 1.637$
1175°	2 hrs.	Trace of dissociation.
1300°	45 hrs.	Conspicuous poikilitic texture. Second phase occurring as minute inclusions in the major crystal phase.
1320°	½ hr.	Single crystal phase plus trace of glass.
1409°	1/3 hr.	Glass plus trace crystals; crystal habit tabular parallel to base.
1414°	1/3 hr.	All glass.

60 $2CaO.MgO.2SiO_2$ — 40[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1100°	2 hrs.	Homogeneous bladed aggregate, full of minute air bubbles.
1130°	3 hrs.	Minute trace dissociation. Fine grained, ribbed and bladed aggregate. Anomalous interference colors. $n_\omega = 1.632$ $n_\epsilon = 1.632$
1361°	1/3 hr.	Glass plus trace crystals.
1366°	1/3 hr.	All glass.

50 $2CaO.MgO.2SiO_2$ — 50[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1100°	16 hrs.	Homogeneous bladed aggregate full of minute air bubbles. $n_\omega = 1.631$ $n_\epsilon = 1.630$
1130°	3 hrs.	Trace of dissociation; interstitial strongly birefringent material.
1170°	40 hrs.	Distinct dissociation; 2d phase interstitial.
1200°	40 hrs.	2d phase in well-formed rods.
1341°	1/3 hr.	Glass plus trace crystals; crystal habit thick tabular to pseudo-cubic with and without modification by 2d order prism.
1346°	1/3 hr.	All glass.

40 $2CaO.MgO.2SiO_2$ — 60[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1075°	40 hrs.	Homogeneous fibrous aggregate.
1100°	2 hrs.	Essentially homogeneous; trace of interstitial second crystal phase in some grains. Much air; fibrous aggregate. $n\omega = 1.630$ $n\epsilon = 1.628$
1130°	3 hrs.	More distinct trace of interstitial higher birefringent material. Clear of air.
1210°	16 hrs.	Two crystal phases; approximately half and half.
1328°	1/3 hr.	Glass plus trace crystals.
1331°	1/3 hr.	All glass.

20 $2CaO.MgO.2SiO_2$ — 80[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
980°	16 hrs.	Fibrous and bladed aggregate. Homogeneous. $n\omega = 1.632$ $n\epsilon = 1.622$.
1100°	1 hr.	Essentially homogeneous; trace of dissociation in some aggregates.
1130°	3 hrs.	Trace of interstitial second crystal phase.
1320°	1/3 hr.	Glass plus trace crystals.
1325°	1/3 hr.	All glass.

10 $2CaO.MgO.2SiO_2$ — 90[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1000°	16 hrs.	Homogeneous, fibrous, and bladed aggregate. $n\omega = 1.633$ $n\epsilon = 1.619$
1125°	40 hrs.	Practically all homogeneous; trace of dissociation in some grains.
1150°	1 hr.	Trace of dissociation and interstitial second crystal phase.

[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
700°	144 hrs.	Still all glass. No trace of crystallization.
980°	16 hrs.	Very fine grained fibrous aggregate. Trace of wollastonite fibers believed to be due to impurity of melt or to exceptionally strong crystallizing power of wollastonite. Otherwise homogeneous.
1000°	16 hrs.	Very well crystallized material. Ribbed and bladed aggregates and coarse laths. Trace of feather-like crystals, probably wollastonite. $n\omega = 1.631$ $n\epsilon = 1.615$
1100°	2 hrs.	Trace of dissociation in some grains, mostly homogeneous fine-grained fibrous aggregate.
1125°	1 hr.	Very fine grained fibrous granular aggregate with interstitial strong birefringent material forming second crystal phase.
1140°	2 hrs.	Trace of dissociation very distinct.
1165°	168 hrs.	Coarse blades and laths, with interstitial dissociated material and a trace of glass. $n\omega = 1.640$ $n\epsilon = 1.616$

Temperature	*Time*	*Phases*
1260°	24 hrs.	Euhedral tetragonal crystal plus glass. Crystal habit is thick tabular, pseudo-cubic, and short prismatic; combination of 1st order prism and base alone, or 1st and 2d order prism and base. $n_\omega = 1.651$ $n_\epsilon = 1.636$
1320°	72 hrs.	Glass plus euhedral crystals, similar to preceding. $n_\omega = 1.656$ $n_\epsilon = 1.645$
1327°	1 hr.	Glass plus trace of crystals.
1334°	1 hr.	All glass.

TABLE VII.

Optical and thermal data for mixtures of $2CaO.Al_2O_3.SiO_2$ and [(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)] Compositions expressed in weight percent, and temperatures in degrees Centigrade.

90 $2CaO.Al_2O_3.SiO_2$ — 10[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1200°	18 hrs.	Fibrous granular aggregate with sutured texture. Clear and homogeneous single crystal phase.
1415°	1 hr.	Coarse crystalline aggregate with faintest trace of glass. $n_\omega = 1.664$ $n_\epsilon = 1.654$
1490°	1 hr.	Essentially all crystal. Barest trace of glass. No evidence of dissociation.
1500°	1 hr.	Crystals plus distinct trace of glass.

80 $2CaO.Al_2O_3.SiO_2$ — 20[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1100°	2 hrs.	Very good, clear crystalline material with large coarse laths and bladed spherulites. $n_\omega = 1.660$ $n_\epsilon = 1.650$
1220°	1 hr.	Little dissociation shown by interstitial strong birefringent material. Fine-grained aggregate.
1270°	1 hr.	Crystals plus included minute drops of glass.
1435°	1 hr.	Coarse grained crystalline aggregate plus a little interstitial glass. $n_\omega = 1.661$ $n_\epsilon = 1.653$
1562°	½ hr.	Glass plus trace of crystals.
1568°	½ hr.	All glass.

60 $2CaO.Al_2O_3.SiO_2$ — 40[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1200°	1 hr.	Spherulitic fibers and blades, and fibrous and ribbed structured grains. Homogeneous single crystal phase. $n_\omega = 1.653$ $n_\epsilon = 1.642$
1225°	1 hr.	Most grains with a trace of glass, some grains apparently homogeneous.

Temperature	*Time*	*Phases*
1250°	1 hr.	Crystals plus trace of glass, the glass occurring as minute droplets in the crystals.
1524°	½ hr.	Glass plus trace of crystals. Crystal habit is medium tabular parallel to base; combination of 1st order prism and base, usually modified by the 2d order prism. 2d order pyramid rare.
1533°	½ hr.	All glass.

40 $2CaO.Al_2O_3.SiO_2$ — 60[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1085°	2 hrs.	Perfectly homogeneous radiating fibrous aggregate with some plates and ribbed structure.
1110°	1 hr.	Perfectly homogeneous. $n_\omega = 1.645$ $n_\epsilon = 1.633$
1125°	1 hr.	Beginning of trace of dissociation.
1150°	1 hr	Trace of dissociation.
1415°	16 hrs.	Glass plus few crystals. Crystal habit predominantly tabular parallel to base; combination of base and 1st order prism modified by 2d order prism. 2d order pyramid and ditetragonal noted on a few crystals. A few equidimensional crystals present.
1485°	1/3 hr.	Glass plus trace crystals.
1490°	1/3 hr.	All glass.

20 $2CaO.Al_2O_3.SiO_2$ — 80[(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_3.3SiO_2$)]

Temperature	*Time*	*Phases*
1000°	16 hrs.	Homogeneous ribbed and bladed aggregate. Much coarser grain than 16 hrs. at 1175°. $n_\omega = 1.637$ $n_\epsilon = 1.625$
1150°	16 hrs.	Minute trace of dissociation. Some aggregates seem homogeneous.
1418°	½ hr.	Glass plus trace crystals.
1422°	½ hr.	All glass.

TABLE VIII.

Optical and thermal data for mixtures of $2CaO.MgO.2SiO_2$; $2CaO.Al_2O_3.SiO_2$; and [(90 $3CaO.Al_2O_3.3SiO_2$) (10 $3Na_2O.Al_2O_33SiO_2$)] Composition in weight percent and temperatures in degrees Centigrade.

$$70\ 2CaO.Al_2O_3.SiO_2 — 15\ 2CaO.MgO.2SiO_2 — 15 \left\{\begin{array}{ll} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{array}\right.$$

Temperature	*Time*	*Phases*
1200°	1 hr.	Homogeeous single crystal phase. $n_\omega = 1.658$ $n_\epsilon = 1.652$
1205°	16 hrs.	Trace of beginning of dissociation. Poikilitic texture.
1537°	1/3 hr.	Glass plus trace of crystals.
1542°	1/3 hr.	All glass.

$$50\ \mathrm{2CaO.Al_2O_3.SiO_2} - 30\ \mathrm{2CaO.MgO.2SiO_2} - 20\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
1100°	16 hrs.	Homogeneous fibrous granular and radiating sperulitic aggregate. $n\omega = 1.650$ $n\epsilon = 1.645$
1200°	1 hr.	Homogeneous fine fibrous aggregate.
1210°	1 hr.	Coarse laths and trace of glass.
1280°	16 hrs.	Crystals plus little glass.
1478	1/3 hr.	Glass plus trace crystals.
1484°	1/3 hr.	All glass.

$$50\ \mathrm{2CaO.Al_2O_3.SiO_2} - 10\ \mathrm{2CaO.MgO.2SiO_2} - 40\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
1150°	1 hr.	Very fine fibrous homogeneous aggregate.
1175°	1 hr.	Trace of beginning of dissociation. $n\omega = 1.650$ $n\epsilon = 1.644$
1290°	40 hrs.	Crystals plus little glass. $n\omega = 1.655$ $n\epsilon = 1.649$

$$40\ \mathrm{2CaO.Al_2O_3.SiO_2} - 40\ \mathrm{2CaO.MgO.2SiO_2} - 20\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
1175°	1 hr.	Homogeneous single crystal phase. $n\omega = 1.648$ $n\epsilon = 1.645$
1185°	1 hr.	Trace of beginning of dissociation.
1446°	1/3 hr.	Glass plus trace of crystals.
1450°	1/3 hr.	All glass.

$$40\ \mathrm{2CaO.Al_2O_3.SiO_2} - 20\ \mathrm{2CaO.MgO.2SiO_2} - 40\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
1110°	1 hr.	Homogeneous single crystal phase. $n\omega = 1.645$ $n\epsilon = 1.640$
1140°	1 hr.	Distinct trace of dissociation.

$$30\ \mathrm{2CaO.Al_2O_3.SiO_2} - 40\ \mathrm{2CaO.MgO.2SiO_2} - 30\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
900°	18 hrs.	Homogeneous single crystal phase.
1175°	1 hr.	Homogeneous aggregate of coarse plates and laths. $n\omega = 1.644$ $n\epsilon = 1.641$
1220°	1 hr.	Trace of dissociation.
1250°	1 hr.	Little dissociation. Minor phase as strong birefringent rods and interstitial.
1419°	1/3 hr.	Glass plus trace of crystals.
1423°	1/3 hr.	All glass.

$$20\ \mathrm{2CaO.Al_2O_3.SiO_2} - 60\ \mathrm{2CaO.MgO.2SiO_2} - 20\left\{\begin{array}{ll}90 & \mathrm{3CaO.Al_2O_3.3SiO_2}\\ 10 & \mathrm{3Na_2O.Al_2O_3.3SiO_2}\end{array}\right.$$

Temperature	*Time*	*Phases*
1200°	2 hrs.	Homogeneous. $n\omega = 1.641$ $n\epsilon = 1.641$
1205°	40 hrs.	Trace of dissociation.

Temperature	*Time*	*Phases*
1360°	16 hrs.	Glass plus few crystals. Crystal habit, thin to thick tabular parallel base, combination of 1st order prism and base modified by 2d order prism.
1375°	½ hr.	Glass plus trace of crystals.
1378°	½ hr.	All glass.

$$20\ 2CaO.Al_2O_3.SiO_2 — 40\ 2CaO.MgO.2SiO_2 — 40 \left\{ \begin{matrix} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{matrix} \right.$$

Temperature	*Time*	*Phases*
900°	16 hrs.	Very fine grained fibrous granular aggregate.
1130°	1 hr.	Homogeneous single crystal phase. $n_\omega = 1.640$ $n_\epsilon = 1.638$
1150°	1 hr.	Trace of dissociation. 2d crystal phase occurs as interstitial material.
1388°	½ hr.	Glass plus trace of crystals.
1395°	½ hr.	All glass.

$$20\ 2CaO.Al_2O_3.SiO_2 — 30\ 2CaO.MgO.2SiO_2 — 50 \left\{ \begin{matrix} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{matrix} \right.$$

Temperature	*Time*	*Phases*
1100°	1 hr.	Homogeneous single crystal phase. $n_\omega = 1.639$ $n_\epsilon = 1.635$
1150°	1 hr.	Bare trace of dissociation.
1390°	1/3 hr.	Glass plus trace of crystals.
1400°	1/3 hr.	All glass.

$$20\ 2CaO.Al_2O_3.SiO_2 — 20\ 2CaO.MgO.2SiO_2 — 60 \left\{ \begin{matrix} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{matrix} \right.$$

Temperature	*Time*	*Phases*
1125°	1 hr.	Homogeneous crystal aggregate with ribbed structure and coarse laths. $n_\omega = 1.639$ $n_\epsilon = 1.632$
1150°	1 hr.	Trace of beginning of dissociation.
1360°	16 hrs.	Glass plus few crystals. Crystal habit; tabular to pseudo-cubic; combination of base and 1st order prism usually modified by 2d order prism. 2d order pyramid present on an occasional crystal.
1389°	½ hr.	Glass plus trace of crystals.
1395°	½ hr.	All glass.

$$10\ 2CaO.Al_2O_3.SiO_2 — 80\ 2CaO.MgO.2SiO_2 — 10 \left\{ \begin{matrix} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{matrix} \right.$$

Temperature	*Time*	*Phases*
1160°	16 hrs.	Large clear crystal plates obtained by first melting material and undercooling rapidly. $n_\omega = 1.636$ $n_\epsilon = 1.641$
1200°	1 hr.	Homogeneous fibrous granular aggregate.
1225°	1 hr.	Trace of dissociation; poikilitic texture.
1397°	½ hr.	Glass plus trace of crystals.
1405°	½ hr.	All glass.

10 $2CaO.Al_2O_3.SiO_2$ — 50 $2CaO.MgO.2SiO_2$ — 40 $\left\{\begin{array}{ll} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{array}\right.$

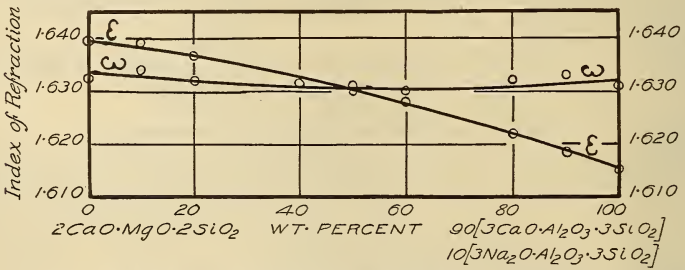
Temperature	*Time*	*Phases*
1110°	1 hr.	Homogeneous crystal aggregate.
1125°	1 hr.	Trace of beginning of dissociation. $n_\omega = 1.634$ $n_\epsilon = 1.635$
1358°	1/3 hr.	Glass plus trace of crystal.
1363°	1/3 hr.	All glass.

10 $2CaO.Al_2O_3.SiO_2$ — 10 $2CaO.MgO.2SiO_2$ — 80 $\left\{\begin{array}{ll} 90 & 3CaO.Al_2O_3.3SiO_2 \\ 10 & 3Na_2O.Al_2O_3.3SiO_2 \end{array}\right.$

Temperature	*Time*	*Phases*
980°	10 hrs.	Homogeneous medium grained fibrous aggregate and lath shaped crystals in a finer ground mass. $n_\omega = 1.634$ $n_\epsilon = 1.623$
1050°	4 hrs.	Homogeneous fine grained fibrous granular aggregate.
1100°	40 hrs.	Homogeneous crystal phase.
1150°	1 hr.	A little dissociation.

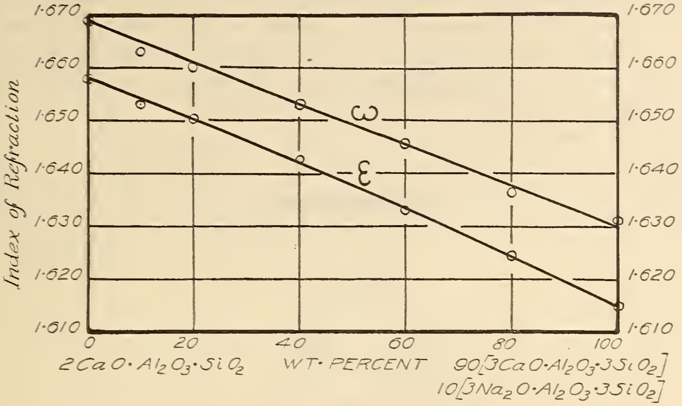
Tables II, VI, VII, VIII give the optical characters and thermal data for the preparations examined. Figures 1, 5, and 6 show the indices of refraction plotted against composition in weight percent. In fig. 7 the compositions of the mixtures investigated are plotted in triangular coordinates together with the isotherms for the temperatures of complete melting. As in the case of fig. 4, a significant point is that those compositions which approximate most closely to the natural minerals lie in the zone of mixtures with the lowest temperatures of complete melting. In fig. 8 the indices of refraction are

Fig. 5:



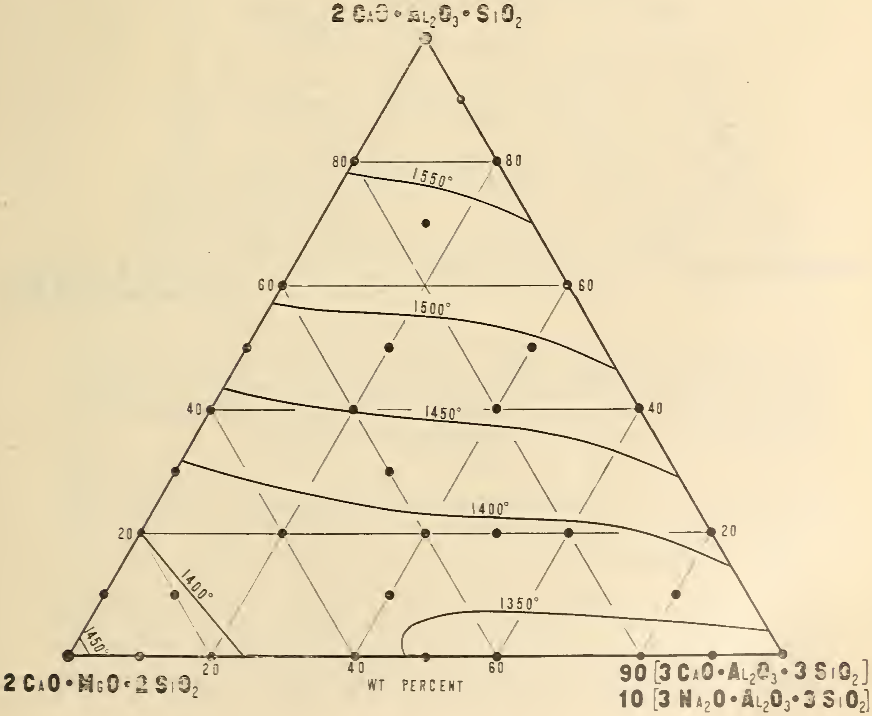
5.—Curves for refractive indices plotted against composition in weight percent for mixtures crystallized above 1000° and below the point of dissociation.

FIG. 6.



6.—Curves for refractive indices plotted against composition in weight percent for mixtures crystallized above 1000° and below the point of dissociation or the beginning of melting.

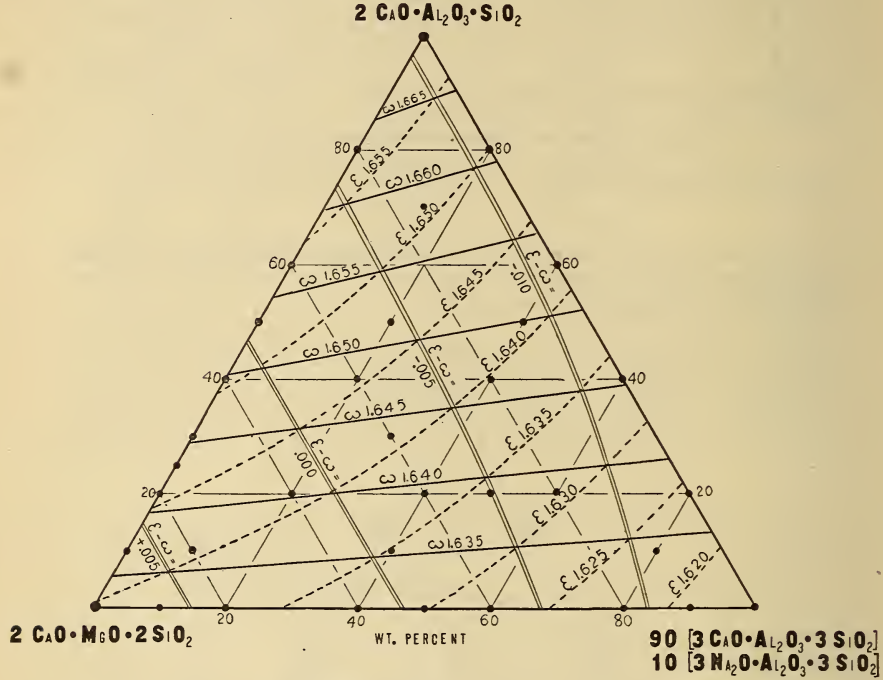
FIG. 7.



7.—Triangular concentration diagram showing compositions of preparations investigated and the isotherms for the temperatures of complete melting.

plotted against the compositions, and curves are drawn connecting mixtures which show equal birefringence. The results are similar to those obtained in the case of mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Al_2O_3.3SiO_2$.

Fig. 8.

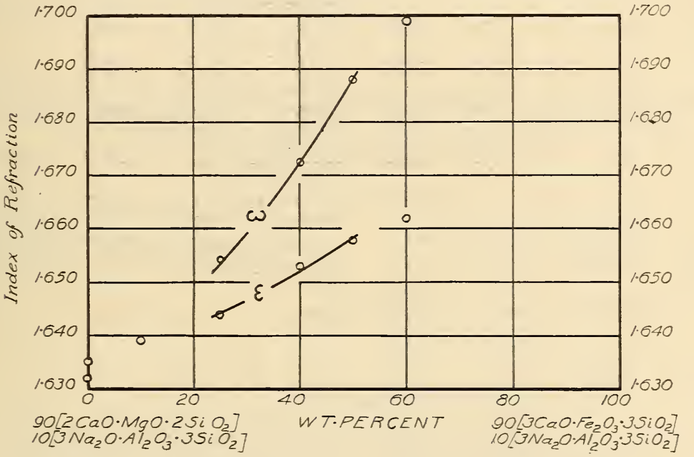


8.—Triangular concentration diagram showing the compositions of preparations investigated. Lines connecting similar indices of refraction have been plotted for those mixtures which show complete homogeneity within a definite temperature range above 980° (the lowest temperature of experiments). Lines of equal birefringence also plotted.

Mixtures of 10 Percent $3Na_2O.Al_2O_3.3SiO_2$ with Varying Amounts of $3CaO.Fe_2O_3.3SiO_2$, $3CaO.Al_2O_3.3SiO_2$, and $2CaO.MgO.2SiO_2$.

Mixtures made up by maintaining the compound $3Na_2O.Al_2O_3.3SiO_2$ at a constant ratio of 10 percent and varying the percentages of $3CaO.Fe_2O_3.3SiO_2$, $3CaO.Al_2O_3.3SiO_2$, and $2CaO.MgO.2SiO_2$ gave a very limited field of solid solution lying along the line between $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ and restricted to the $3CaO.Al_2O_3.3SiO_2$ end. However, if the compositions are plotted upon a triangular diagram, there is a zone extending from the component $3CaO.Al_2O_3.3SiO_2$ to about the center of the line connecting the components $2CaO.MgO.2SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$ in which the preparations lack but a trifle of being completely homogeneous. Tables IX-XII give the optical and thermal data for the mixtures investigated.

Fig. 9.



9.—Curves for refractive indices plotted against composition in weight percent for mixtures crystallized just below the solidus which show complete homogeneity. Indices of refraction for dominant phase of inhomogeneous mixtures are indicated when determined.

Fig. 9 shows the refractive indices plotted against the composition in weight percent for those compositions that lie along the line connecting the components $2CaO.MgO.2SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$, the amount of $3Na_2O.Al_2O_3.3SiO_2$ being kept constant at 10 percent. The curves connect only those compositions which were found to form completely homogeneous mixtures within a temperature range lying above 1000°, the lowest temperature at which observations of these mixtures were made. In the case of those mixtures which showed inhomogeneity, the indices of refraction for the dominant phase are

TABLE IX.

Optical and thermal data for mixtures of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$. Compositions in weight percent.

$3Na_2O.$ $Al_2O_3.$ $3SiO_2$	$2CaO.$ $MgO.$ $2SiO_2$	$3CaO.$ $Fe_2O_3.$ $3SiO_2$	nω	nε	One crystal phase	Crystals + trace of glass	Glass + trace of crystals	All glass
10	90	00	*1.632	*1.635	Inhomogeneous (40 hrs. at 1000°)		1391°	1358°
10	82	8	*1.639	*1.639	Inhomogeneous (40 hrs. at 1000°)			
10	75	75			Inhomogeneous (40 hrs. at 1000°)			
10	67.5	22.5	1.654	1.644	1164° (½ hr.)	1170° (½ hr.)	1352°	1357°
10	54	36	1.675	1.653	1145° (40 hrs.)	1160° (½ hr.)	1325°	1330°
10	45	45	1.688	1.658	1145° (15 hrs.)	1162° (½ hr.)	1305°	1309°
10	36	54	*1.699	*1.662	Inhomogeneous (40 hrs. at 1000°)		1284°	1290°
10	18	72			Inhomogeneous (2 hrs. at 1070°)		1235°	1240°
10	00	90			Inhomogeneous (2 hrs. at 1070°)		1235°	1244°

* Determined on dominant crystal phase.

TABLE X.

Optical and thermal data for mixtures of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$. Compositions in weight percent.

$3Na_2O.$ $Al_2O_3.$ $3SiO_2$	$2CaO.$ $MgO.$ $2SiO_2.$	$3CaO.$ $Al_2O_3.$ $3SiO_2.$	nω	nε	One crystal phase	Trace of dissociation.	Glass + trace crystals	All glass.
10	90	00	*1.632	*1.635	Inhomogeneous		1391°	1398°
10	63	27	*1.632	*1.630	Inhomogeneous		1360°	1367°
10	50	40	1.630	1.628	1130° (1 hr.)	1150° (1 hr.)		
10	45	45	1.630	1.628	1140° (1 hr.)	1160° (1 hr.)	1334°	1340°
10	27	63	1.631	1.625	1165° (1 hr.)	1185° (1 hr.)	1317°	1324°
10	9	81	1.633	1.621		1125° (16 hrs.)	1327°	1334°

* Determined on dominant crystal phase.

TABLE XI.

Optical and thermal data for mixtures of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ with varying percentages of $3CaO.Al_2O_3.3SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$. Compositions in weight percent.

$3Na_2O.Al_2O_3.3SiO_2$	$3CaO.Al_2O_3.3SiO_2$	$3CaO.Fe_2O_3.3SiO_2$	n_ω	n_ϵ	Glass + trace of crystals	All glass	
10	90	00	1.631	1.615	1327°	1334°	
10	81	9	*1.642	*1.632			Inhomogeneous (40 hrs. at 1000°)
10	67.5	22.5	*1.655	*1.637	1270°	1275°	Inhomogeneous (16 hrs. at 1125°)
10	54	36					Inhomogeneous (16 hrs. at 1160°)

* Determined on dominant crystal phase.

TABLE XII.

Optical and thermal data for mixtures of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$; $3CaO.Al_2O_3.3SiO_2$; and $3CaO.Fe_2O_3.3SiO_2$. Compositions expressed in weight percent.

$3Na_2O.Al_2O_3.3SiO_2$	$2CaO.MgO.2SiO_2$	$3CaO Fe_2O_3 3SiO_2$	$3CaO.Al_2O_3.3SiO_2$	n_ω	n_ϵ	*Essentially one crystal phase.	Trace of dissociation.	Glass + Trace of crystals.	All glass.
10	54	27	9	1.663	1.648	1140° (20 hrs.)	1170°	..	..
10	45	27	18	1.663	1.648	1160° (1 hr.)	1170° (16 hrs.)	..	..
10	54	18	18	1.651	1.641	1150° (1 hr.)	1170° (16 hrs.)	1329°	1335°
10	40	18	32	1.650	1.640	1150° (16 hrs.)	1170° (1 hr.)	..	..
10	38	14	38	1.645	1.638	1140° (20 hrs.)	1170° (16 hrs.)	..	..
10	40	10	40	1.639	1.635	1140° (16 hrs.)	1165° (1 hr.)	1311°	1316°
10	27	9	54	1.640	1.632	1140° (1 hr.)	1160° (1 hr.)	1308°	1315°
10	18	9	63	1.642	1.633	†1000° (40 hrs.)	1125° (16 hrs.)	..	..
10	47	33	10	^{a}1.671	^{a}1.653	Inhomogeneous (16 hrs. at 1110°)		1316°	1320°
10	63	13.5	13.5	^{a}1.643	^{a}1.640	Inhomogeneous (16 hrs. at 1000°)		..	..
10	36	36	18			Inhomogeneous (16 hrs. at 1170°)		..	..
10	30	30	30			Inhomogeneous (16 hrs. at 1150°)		1285°	1291°
10	34	22	34	^{a}1.655	^{a}1.645	Inhomogeneous (4 hrs. at 1040°)		..	..

* These preparations are not completely homogeneous as they contain a trace of minute grains of much higher indices of refraction. It is believed, however, that the inhomogeneity is so slight that the crystals are of essentially the same composition as the melt, except in the case of those mixtures marked inhomogeneous.

† Completely homogeneous. [a] Determined on dominant crystal phase.

TABLE XIII.

Optical characters and thermal data of mixtures containing 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 20 percent $2CaO.Al_2O_3.SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$. Compositions expressed in weight percent.

$3Na_2O.$ $Al_2O_3.$ $3SiO_2$	$2CaO.$ $Al_2O_3.$ SiO_2	$2CaO.$ $MgO.$ $2SiO_2$	$3CaO.$ $Fe_2O_3.$ $3SiO_2$	$n\omega$	$n\epsilon$	One crystal phase.	Crystals + Trace of glass.	Glass + Trace crystals.	All glass.
10	20	70	00	Inhomogeneous (2 hrs at 1050°)					
10	20	56	14	Inhomogeneous (1 hr. at 1176*)					
10	20	46	24	Inhomogeneous (1 hr. at 1151°)					
10	20	35	35	*1.679	*1.666 (16 hrs. at 1150°)	Trace of Inhomogeneity		1298°	1305°
10	20	28	42	1.689	1.669	1177° (2 hrs.)	1191° (2 hrs.)	1278°	1284°
10	20	17.5	52.5	1.694	*1.673	Inhomogeneous (40 hrs. at 1160°)			
10	20	10.5	59.5	*1.711	*1.684	Inhomogeneous (16 hrs. at 1125°)			

* Determined on dominant crystal phase.

TABLE XIV.

Optical characters and thermal data of mixtures containing 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 20 percent $2CaO.Al_2O_3.SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$.

$3Na_2O.$ $Al_2O_3.$ $3SiO_2$	$2CaO.$ $Al_2O_3.$ SiO_2	$2CaO.$ $MgO.$ $2SiO_2$	$3CaO.$ $Al_2O_3.$ $3SiO_2$	$n\omega$	$n\epsilon$	One crystal phase.	Trace of dissociation.	Glass + Trace of crystals	All glass.
10	20	70	00	Inhomogeneous (2 hrs. at 1050°)		..	..	..	..
10	20	35	35	Inhomogeneous (2 hrs. at 1050°)		..	..	..	..
10	20	28	42	1.638	1.633	1200° (1 hr.)	1220° (½ hr.)	1380°	1386°
10	20	17.5	52.5	1.641	1.634	1130° (16 hrs.)	1145° (1 hr.)		
10	20	00.0	70	1.638	1.624	1140° (2 hrs.)	1165° (1 hr.)		

TABLE XV.

Optical characters and thermal data of mixtures containing 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 20 percent $2CaO.Al_2O_3.SiO_2$ with varying percentages of $3CaO.Al_2O_3.3SiO_2$ and $3CaO.Fe_2O_33SiO_2$. Compositions expressed in weight percent.

$3Na_2O.Al_2O_3.3SiO_2$	$2CaO.Al_2O_3.SiO_2$	$3CaO.Al_2O_3.3SiO_2$	$3CaO.Fe_2O_3.3SiO_2$	n_ω	n_ϵ	One crystal phase.	Trace of dissociation.	Glass + Trace crystals	All glass.
10	20	70	00	1.638	1.624	1140° (2 hrs.)	1160° (16 hrs.)	1412°	1417°
10	20	56	14	1.653	1.640	1142° (20 hrs.)	1160° (40 hrs.)	1380°	1386°
10	20	49	21	1.657	1.645	1145° (2 hrs.)	1160° (1 hr.)	1360°	1366°
10	20	42	28	Inhomogeneous (16 hrs. at 1125°)				1344°	1350°

TABLE XVI.

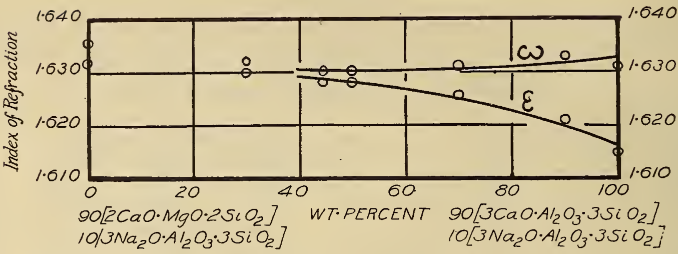
Optical characters and thermal data of mixtures containing 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 20 percent $2CaO.Al_2O_3.SiO_2$ with varying percentages of $2CaO.MgO.2SiO_2$; $3CaO.Al_2O_3.3SiO_2$; and $3CaO.Fe_2O_3.3SiO_2$ Compositions in weight percent.

$3Na_2O.Al_2O_3.3SiO_2$	$2CaO.Al_2O_3.SiO_2$	$2CaO.MgO.2SiO_2$	$3CaO.Fe_2O_3.3SiO_2$	$3CaO.Al_2O_8.3SiO_2$	n_ω	n_ϵ	One crystal phase.	Trace dissociation.	Crystals plus trace glass.	Glass plus trace crystals.	All glass.
10	20	10	10	50	1.648	1.638	1155° (1 hr.)	1175° (1 hr.)	....	1376°	1382°
10	20	30	10	30	1.648	1.642	1225° (1 hr.)	....	1240° (1 hr.)	1358°	1364°
10	20	21	21	28	1.660	1.649	1200° (1 hr.)	1220° (½ hr.)	....	1328°	1335°
10	20	28	28	14	1.671	1.657	1220° (1 hr.)	....	1235° (1 hr.)	1310°	1316°
10	20	7	28	35	*1.671	*1.656	Bare trace inhomog. (1 hr. at 1147°)			1334°	1342°
10	20	21	35	14	*1.680	*1.663	Bare trace inhomogeneity (16 hrs. at 1150°)				
10	20	35	21	14	*1.661	*1.653	Trace of inhomogeneity				

*Determined on major crystal phase, which lacks but little of complete homogeneity.

plotted. Fig. 10 similarly shows the indices of refraction plotted against composition in weight percent for the solid solutions consisting of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and variable amounts of $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$, within a temperature range above 1000°. Mixtures of $3CaO.Al_2O_3.3SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$ with as little as 10 percent of the latter constituent, showed some inhomogeneity, as they did also at all higher percentages investigated.

FIG. 10.



10.—Curves for refractive indices plotted against composition in weight percent for mixtures crystallized between 980° and the dissociation point.

MIXTURES OF 10 PERCENT $3Na_2O.Al_2O_3.3SiO_2$ AND 20 PERCENT $2CaO.Al_2O_3.SiO_2$ WITH VARYING PERCENTAGES OF $3CaO.Fe_2O_3.3SiO_2$, $3CaO.Al_2O_3.3SiO_2$, AND $2CaO.MgO.2SiO_2$.

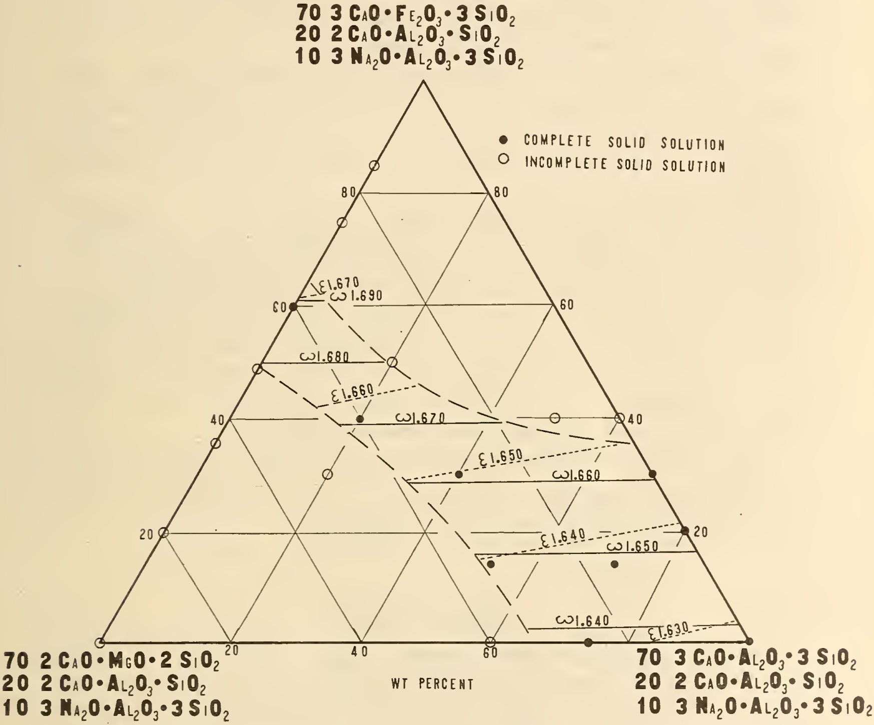
Mixtures of 10 percent $3Na_2O.Al_2O_3.3SiO_2$ with varying percentages of $3CaO.Al_2O_3.3SiO_2$, $3CaO.Fe_2O_3.3SiO_2$ and $2CaO.MgO.2SiO_2$ were found to form inhomogeneous mixtures under the conditions of experiment, except for a very small range of compositions near the $3CaO.Al_2O_3.3SiO_2$-$2CaO.MgO.2SiO_2$ line at the $3CaO.Al_2O_3.3SiO_2$ end. Natural melilites have a wider range of composition, and some have a considerable percentage of the gehlenite molecule. A series of mixtures was therefore prepared, each of which contained 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 20 percent $2CaO.Al_2O_3.SiO_2$, but with varying amounts of $3CaO.Fe_2O_3.3SiO_2$, $2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$. The results (fig. 11) show that the presence of 20 percent $2CaO.Al_2O_3.SiO_2$ has greatly extended the area of solid solution (for a temperature range above 980°), and includes mixtures which are similar in composition to the natural melilites. Tables XIII-XVI.

The compositions of the mixtures experimented with are relatively far apart, and the plotted limits of solid solution are therefore only approximate.

COMPARISON OF MINERALS WITH SYNTHETIC PREPARATIONS.

Introduction.—The data obtained from a study of some synthetic mixtures of compounds, believed to be the more common components of the natural melilites, have been set forth in the preceding pages. It now remains to attempt to correlate these data with those derived from studies of the minerals. The optical data suggest themselves as being the best for this purpose, but unfortunately, with respect to this group of minerals, such data are meager and in only a few cases have both the optical data and the chemical analysis been given for the same specimen. This is strikingly true of the best known melilites, those of Italy.

Fig. 11.



11.—Triangular concentration diagram showing compositions of preparations investigated. Lines connecting similar indices of refraction have been plotted for those mixtures which show complete homogeneity just below the beginning of melting, or the point of dissociation, and above 1100° (the lowest temperature at which experiments were made).

Partially to remedy this defect, specimens of Italian ferric iron-rich melilites, and of gehlenites, humboldtilites, sarcolite, and fuggerite were obtained for purposes of study from the U. S. National Museum and from various dealers in the United States. Dr. H. S. Washington of this laboratory also obtained for the writer several specimens of the Capo di Bove melilites from Professor F. Millosevich of the University of Rome. These specimens proved of exceptional interest and afforded a melilite of composition different from any hitherto reported from this locality. The writer is greatly indebted to Professor Millosevich for his courtesy and generosity in sending these specimens.

Four samples of the minerals of this group were obtained in sufficient purity for analytical purposes, and Dr. H. S. Washington very generously made the chemical analyses. The writer wishes to express his appreciation of this service.

Separation of material.—The samples of humboldtilite studied were obtained by crushing the rock containing them as an accessory constituent to a sufficient fineness to pass a 35 mesh sieve. The lighter components, mainly nephelite and leucite, were separated with bromoform, and the pyroxene by means of an electro-magnet. After this treatment the samples were examined under the microscope and found to be sufficiently pure.

The densities given for the minerals represent the density at 25° of the solutions in which the heavier portion of the purified materials sank.

AKERMANITE.

Akermanite was first named and described by Vogt from its occurrence in artificial slags long before its discovery in nature. The mineral akermanite was identified by Zambonini[11] at Vesuvius and its properties are given by him as follows: tetragonal, cleavages 001 and 110; density 3.12; uniaxial, positive; for sodium light, $n_\omega = 1.6332$, $n_\varepsilon - n_\omega = 0.006$. The compound $2CaO.MgO.2SiO_2$ was obtained by Ferguson and Merwin[12] and correlated by them with the mineral akermanite as a result of a study of its optical characters, which are given by them as tetragonal, uniaxial positive, for sodium light $n_\omega = 1.631$ and $n_\varepsilon = 1.638$. The density was determined

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[11] F. Zambonini, Mineralogia Vesuviana, p. 255, 1910.

[12] Op. cit., pp. 118 and 122.

by Ferguson and Buddington[13] as 2.944. The explanation for the much lower density of the artificial akermanite is not apparent, but the natural mineral is not pure and the synthetic material may be a trifle light owing to the presence of included air. Material crystallized from akermanite glass at 700° has the same indices of refraction as that crystallized at 1450° so that there is no evidence of polymorphism between these temperatures. The compound $2CaO.MgO.2SiO_2$ enters into complete solid solution with $2CaO.Al_2O_3.SiO_2$ and into limited solid solution with $3RO.R_2O_3.3SiO_2$ compounds. In this property it is analogous to the mineral akermanite. The two analyses of natural akermanites, however, show silica in excess of that called for by the formula for the synthetic compound $2CaO.MgO.2SiO_2$. This discrepancy remains to be explained but the balance of evidence favors the essential identity of the synthetic preparation and the mineral.

TABLE XVII.

Akermanite from Vesuvius.

Calculation from Freda's analysis.

	Original analysis	Analysis reduced	Mol.	$2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ molecules	Difference
SiO_2	46.70	46.47	7764	6902	—862
Al_2O_3	1.09	.96	94	94	
CaO	39.62	39.23	7054	6902	—152
MgO	13.38	13.34	3310	3310	
	100.79	100.00			

Table XVII gives the analysis by Freda of akermanite from Vesuvius, stated in terms of its constituent molecules and compared with the total number of molecules which can be recomputed to form $2CaO.MgO.2SiO_2$ (90.4 percent) and $3CaO.Al_2O_3.3SiO_2$ (4.2 percent).

Table XVIII gives the analysis by Zambonini of akermanite from Vesuvius, stated in terms of its constituent molecules and compared with the total number of molecules which can be recomputed to form $2CaO.MgO.2SiO_2$ (90 percent) and $3CaO.Al_2O_3.3SiO_2$ (4.8 percent).

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[13] Op. cit., p. 132.

TABLE XVIII.

Akermanite from Vesuvius.
Calculation from Zambonini's analysis.

	Original analysis	Analysis reduced	Mol.	$2CaO.MgO.2SiO_2$ and $3CaO.Al_2O_3.3SiO_2$ molecules	Difference
SiO_2	46.55	46.33	7683	6908	—775
Al_2O_3	.96	1.08	106	106	
CaO	39.30	39.31	7020	6908	—112
MgO	13.30	13.28	3295	3295	
FeO	.12				
	100.23	100.00			

GEHLENITE.

Gehlenite of Velardeña.—The gehlenite described by Wright[14] from Velardeña, Mexico, approximates more closely in composition the compound $2CaO.Al_2O_3.SiO_2$ than any of the other gehlenites described. According to Wright it is associated with colorless pyroxene, yellow garnet, magnetite, rutile, and spurrite, and is formed at the contact of a basic intrusive diorite and limestone.

TABLE XIX.

Gehlenite from Velardeña, Mexico.

	Original analysis	Analysis reduced	Mol.	Calculated molecules	Difference
SiO_2	26.33	26.76	4438	4438	
Al_2O_3	27.82	28.27	2771	2779	+ 8
CaO	39.55	40.19	7177	7158	—19
MgO	2.44	2.48	615	623	+ 8
TiO_2	.03	.03	4		— 4
Fe_2O_3	1.43	1.45	81	80	— 1
FeO	.50	.50	70	72	— 1
MnO	.01	.01	1		
Na_2O	.21	.21	34	44	
K_2O	.10	.10	10		
H_2O	1.85				
	100.27	100.00			

In Table XIX is given the analysis by Allen of this gehlenite from Velardeña, Mexico, reduced, with elimina-

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[14] F. E. Wright, this Journal, 26, 545-7, 1908.

tion of water, stated in terms of its constituent molecules, and compared with the calculated molecules in a mixture composed of 76 percent $2CaO.Al_2O_3.SiO_2$, 17 percent $2CaO.MgO.2SiO_2$, 4 percent $3CaO.Fe_2O_3.3SiO_2$, 2.3 percent $2CaO.FeO.2SiO_2$ and 0.7 percent $3(Na,K)_2O.Al_2O_3.3SiO_2$.

When recalculated in terms of the components already described it is found to consist roughly of 76 percent gehlenite, 17 percent akermanite, and 7 percent ferric and ferrous compounds. A comparison of its properties with those of artificial gehlenite having the same ratio of akermanite to gehlenite, but free of iron compounds, is given in Table XX. It will be seen that the agreement is very close, and would be even closer if the values of the mineral were corrected for the presence of iron compounds which tend to raise the indices of refraction, raise the density, and lower the solidus and liquidus. In order to ascertain whether the mineral gehlenite would invert to some different form at higher temperatures, a charge was heated for 16 hours at 1450° without showing any change in indices of refraction. A second charge was

TABLE XX.

Comparison of propertics of natural Gehlenites with those of similar artificial preparations.

	Natural	Artificial	Natural	Artificial	Natural	Artificial
Locality	Valardeña, Mexico.		Monzoni, Italy.		Tulare Co., Calif.	
Analyst	E. T. Allen.		Rammelsberg.		E. V. Shannon.	
Gehlenite	76	82	58	67	66	70
Åkermanite	17	18	28	33	28	30
Iron Compounds	7		14		6	
n_ω	1.639	1.639	1.662	1.659	1.660	1.660
n_ϵ	1.633	1.632+	1.657	1.655	1.657	1.656
Birefringence	.006	.007	.005	.004	.003	.004
Density	3.039	3.024		3.008	3.02	3.01
Solidus.	1475°±20°	1504°±5°	1375°±25°	1462°±5°		
Liquidus	1555°±20°	1556°±5°	1500°±20°	1530°±5°		

Remarks: The data on the Velardeña gehlenite were determined by F. E. Wright on the same sample as that analyzed. The optical data and thermal data for the Monzoni gehlenite were determined by the writer on a sample different from that analyzed by Rammelsberg. The optical data for the California gehlenite were determined by the writer on the same sample as that analyzed by Shannon.

completely melted and quenched to form glass. This glass was then recrystallized at 1450° and the resulting crystals had the same indices as the original material.

California Gehlenites.—A gehlenite from Crestmore, near Riverside, California, has been described by W. F. Foshag.[15] It occurs associated with spurrite and other minerals. It is rather striking that such a rare mineral as spurrite should occur associated with the relatively rare mineral gehlenite at two such widely separated localities. A specimen of the gehlenite loaned by the U. S. National Museum (No. 87275) had the following indices: $n_\omega = 1.662 \pm 0.003$, $n_\varepsilon = 1.658 \pm 0.003$.

A specimen of gehlenite from Tulare County, California, also loaned by the U. S. National Museum, had the following indices: $n_\omega = 1.660 \pm 0.003$, $n_\varepsilon = 1.657 \pm 0.003$. This material was associated with garnet (index 1.813 ± 0.006), magnetite, and pyroxene, and had a density of about 3.02. It has been analyzed by E. V. Shannon, and the recalculated analysis shows roughly about 66 percent gehlenite, 28 percent akermanite, and 6 percent ferric and ferrous compounds. A comparison of its properties with those of artificial gehlenite having the same ratio of gehlenite to akermanite, but free of iron compounds, is given in Table XX. The agreement is very close.

The analysis by Shannon, reduced to 100, stated in terms of its constituent molecules and compared with the calculated molecules in a mixture of assumed components most closely approximating the natural mineral in composition is given in Table XXI.

TABLE XXI.

Gehlenite from Tulare County, California.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2 ……	27.88	27.75	4602	4814	+212	66 $2CaO.Al_2O_3.SiO_2$
Al_2O_3 …..	25.52	25.40	2490	2400	— 90	28 $2CaO.MgO.2SiO_2$
Fe_2O_3 …..	1.59	1.58	99	88	— 11	4.5 $3CaO.Fe_2O_3.3SiO_2$
FeO ……	.43	.43	60	49	— 11	1.5 $2CaO.FeO.2SiO_2$
MgO …..	4.18	4.17	1042	1026	— 16	
CaO ……	40.86	40.67	7250	7214	— 36	
H_2O+ ….	.30					
H_2O- ….	.04					
	100.80	100.00				

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[15] Am. Mineralogist, 5, 80-81, 1920.

Monzoni gehlenite.—A specimen of limestone, labeled Monzoni (Fassathal), with minute disseminated crystals of gehlenite, was obtained by Dr. Wright from the U. S. National Museum. The indices of refraction were determined on this mineral, and rough tests made for the location of the solidus and liquidus. If we assume this material to be essentially the same as that analyzed by Rammelsberg from this locality, and recalculate the analysis in terms of constituent compounds, we find that the mineral consists of about 58 percent gehlenite, 28 percent akermanite, and 14 percent ferric and ferrous iron compounds. The results of the study of the natural mineral and a comparison of its properties with those of an artificial preparation having the same ratio of gehlenite to akermanite, but free of iron compounds, are given in Table XX. If the relatively large percentage of iron compounds in the mineral is taken into account, the agreement is good.

Table XXII.

Gehlenite from Monzoni.

	Original analysis	Analysis reduced	Mol.	Calculated molecules	Difference
SiO_2	29.78	30.20	5008	5218	+210
Al_2O_3	22.02	22.33	2155	2109	— 46
CaO	37.90	38.43	6850	7508	+342
MgO	3.88	3.93	975	1025	+ 50
Fe_2O_3	3.22	3.27	205	181	— 24
FeO	1.63	1.65	230	262	+ 5
MnO	.19	.19	27		
Ign. by difference	1.38				
	100.00	100.00			

Table XXII gives the analysis by Rammelsberg of gehlenite from Monzoni, stated in terms of its constituent molecules and compared with the calculated molecules in a mixture composed of 58 percent $2CaO.Al_2O_3.SiO_2$, 28 percent $2CaO.MgO.2SiO_2$, 8 percent $2CaO.FeO.2SiO_2$, and 6 percent $2CaO.Fe_2O_3.SiO_2$.

The agreement between the properties of the artificial preparations and the corresponding minerals is so close that we feel warranted in concluding that the artificial series of $2CaO.MgO.2SiO_2$-$2CaO.Al_2O_3.SiO_2$ solid solutions are pure synthetic analogues of the akermanite-gehlenite mineral series. Reference is also made here to the fact that Vogt[16] studied the relations of akermanite, gehlenite, and their mixtures in artificial slags, and concluded that they form an isomorphous series. His materials necessarily contained iron, manganese, soda, and other impurities, and differed to that extent from the artificial preparations studied in this work.

GROSSULARITE.

The pure compound $3CaO.Al_2O_3.3SiO_2$ is known in nature only as the mineral grossularite, one of the garnet group, crystallizing in the isometric system. As a component of other minerals, however, it forms 90 percent of sarcolite, up to 50 percent of some humboldtilites, and isomorphous mixtures with other members of the garnet group.

The mineral sarcolite is positive, uniaxial; crystallizing in the tetragonal system, with indices of refraction $n_\omega = 1.6035$ and $n_\varepsilon = 1.6147$. Since sarcolite contains 90 percent of $3CaO.Al_2O_3.3SiO_2$, this compound may have similar, though somewhat modified, optical characters in the form in which it exists there.

A series of solid solutions of $3CaO.Al_2O_3.3SiO_2$ with $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, $3Na_2O.Al_2O_3.3SiO_2$ and $3CaO.Fe_2O_3.3SiO_2$, formed within a temperature range above 1000°, have been described in this paper. These solid solutions crystallize in the tetragonal system and the $3CaO.Al_2O_3.3SiO_2$ compound has the effect of a negative uniaxial material with a moderate birefringence. If we project the curves of the indices of refraction for complete solid solutions of $3CaO.Al_2O_3.3SiO_2$ and $3Na_2O.Al_2O_3.3SiO_2$, we find that the former component will have the indices $n_\omega = 1.633 \pm 0.005$; $n_\varepsilon = 1.624 \pm 0.005$; and that it is uniaxial negative with a birefringence of 0.011 ± 0.005.

We therefore have evidence of at least three distinct forms in which the compound $3CaO.Al_2O_3.3SiO_2$ may exist in solid solutions.

Further evidence of the polymorphism of this compound is indicated by the birefringence observed in many

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[16] Loc. cit.

garnets. Many attempts have been made to synthesize grossularite, usually without success. Shepherd and Rankin,[17] however, describe the formation of grossularite by the action of aluminum chloride upon calcium orthosilicate heated with water under pressure in a steel bomb at a temperature of 400° ± 50°.

Artificial glass of the composition of grossularite was crystallized for 16 hours at 980° and gave an unidentified fibrous aggregate of moderate birefringence in which at least two different compounds are present. At the eutectic or melting point (1265°) it forms a mixture of gehlenite, anorthite, and pseudo-wollastonite.

Grossularite held for possible inversion or dissociation for 166 hours at 800° and for 16 hours at 1100° was unchanged.

SARCOLITE.

The composition of the mineral sarcolite is usually expressed as $3(9Ca.Na_2)O.Al_2O_3.3SiO_2$, and the crystal system is tetragonal. The indices of refraction given by Zambonini[18] are $n_\omega = 1.6035$ and $n_\varepsilon = 1.6147$, and the density 2.92. The mineral is optically positive.

Bladed crystals formed by crystallizing a synthetic mixture of the same composition for 16 hours at 1000° have the indices $n_\omega = 1.631 \pm 0.005$ and $n_\varepsilon = 1.615 \pm 0.005$; the optical character being negative and the crystal system tetragonal. Thus the indices of refraction of the artificial crystals do not agree with those of the natural sarcolite, and the optical character is different so that the artificial crystals must be a polymorphic form, though crystallizing in the same system.

To test for possible inversion phenomena, a specimen of sarcolite from Monte Somma, obtained from the U. S. National Museum, was subjected to a series of heat treatments. The mineral was held for 156 hours at 700°, 166 hours at 800°, 96 hours at 1000°, and 4 hours at 1100° without showing a trace of alteration except in an occasional grain. In a few grains the alteration observed might be interpreted as indicating inversion, but the natural mineral could not be obtained in absolute purity

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[17] E. S. Shepherd and G. A. Rankin, this Journal, 28, 305, 1909.

[18] F. Zambonini, op. cit., p. 247.

and reactions with impurities may explain the changes observed.

When the sarcolite is held for 40 hours at 1150°, however, it breaks down and all the grains are locally so full of minute, much higher refracting dots that they appear cloudy and brownish in color. Some of the grains invert to material of negative optical character, whereas others remain unaltered except for numerous minute dots. Some of the inverted grains show a trace of glass. A few grains of the sarcolite contain small pseudo-cubes as the result of recrystallization. Many of the clouded brownish grains have a clear border which has higher indices than the original sarcolite. Similarly, when held for 2 hours at 1170°, the sarcolite grains are partly changed to minute pseudo-cubes of higher indices of refraction with here and there traces of glass. Positive evidence of inversion without trace of melting is lacking and the experiments do not prove whether such may or may not take place, as the rate of reaction may be so slow that a longer time interval or the presence of a mineralizer would be necessary.

FUGGERITE.

Weinschenk[19] has described a mineral near Lake Selle in the Monzonithal which resembles in some of its properties some of the gehlenite-akermanite series. It occurs in limestone at the contact with monzonite and is in thick four-sided tabular crystals, probably tetragonal. The color is light apple green and the density is 3.18. Indices of refraction for yellow light are essentially the same: $n_\omega = n_\varepsilon = 1.691$, with anomalous interference colors. It is decomposed by dilute acids with separation of pulverulent silica.

A chemical analysis of the material was made by E. Mayr, and this on recalculation gives about 40 percent $2CaO.Al_2O_3.SiO_2$, 35 percent $2CaO.MgO.2SiO_2$, 10 percent $3CaO.Fe_2O_3.3SiO_2$, 10 percent $3CaO.Al_2O_3.3SiO_2$, and 5 percent $3Na_2O.Al_2O_3.3SiO_2$. An artificial mixture of this composition crystallized just below the solidus (1345° ± 10°) had the following indices for the crystals:

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[19] E. Weinschenk, Z. Kryst., 27, 577, 1896.

$n_\omega = 1.658$ and $n_\varepsilon = 1.654$, tetragonal system. Crystals formed at 1150° give the same results. It forms a complete solid solution with a melting interval extending from the solidus at 1345° ± 10° to the liquidus at 1423° ± 10°.

The optical properties of the mineral and of artificial crystals equivalent in composition but formed at about 1345°, therefore, do not agree by a wide margin. The difference is far greater than the limits of error involved. The synthetic preparation, therefore, is a polymorphic form involving the same compounds as the mineral fuggerite.

Many specimens labeled "fuggerite" were obtained by the writer from dealers and museums in the United States, but all were too completely replaced by grossularite or were too much altered to be satisfactory for experimentation. One specimen alone still showed a minute core of the original material, only partially replaced by garnet. Its indices were similar to those given by Weinschenk and it showed conspicuous anomalous interference colors. Such garnet pseudomorphs were described by Weinschenk in his original paper.

HUMBOLDTILITE.

The term melilite was originally (1796) applied to the reddish-brown to yellow crystals found in the leucitophyre at Capo di Bove, Italy, in allusion to the honey yellow color. The name humboldtilite was subsequently (1882) given to the white to greenish crystals of similar crystallographic habit found in the metamorphosed blocks of limestone at Vesuvius. As a result of a study of the chemical and crystallographic characters of these two minerals by Des Cloizeaux and Damour (1843) the mineral humboldtilite was classified as melilite. Mierisch,[20] however, has given sufficient data as to differences in manner of occurrence, crystallographic habit, color, mineral association, and cleavage between the original melilite of Capo di Bove and humboldtilite of Vesuvius to warrant the retention of the latter name to designate in general a series of minerals of the melilite group similar

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[20] Tscherm. Mitth., N. F., pp. 149-153, 1887.

in composition and character to that first described from Vesuvius. They differ essentially from the mineral originally called melilite in having relatively less ferric iron and in some cases a relatively greater percentage of ferrous iron, and a larger percentage of the $3CaO.Al_2O_3.3SiO_2$ molecule.

TABLE XXIII.

Chemical analyses of Humboldtilite from Monte Somma, Vesuvius.

	A	B	C	D	E
SiO_2	39.86	41.69	40.36	40.69	41.09
Al_2O_3	11.37	9.59	12.04	10.88	10.93
Fe_2O_3	.50	.76	.75	4.43	3.40
FeO	1.78	3.75	1.53		.
MgO	7.63	5.32	6.56	5.75	5.87
CaO	35.58	32.82	34.71	31.81	34.78
Na_2O	2.13	4.76	3.34	4.43	3.40
K_2O	.82	.68	.30	.36	.68
H_2O+	0.49	0.29	0.79		.
H_2O-	0.10	0.05	0.13		.24
Total	100.26	99.71	100.51	98.35	100.39
Density	2.975	2.925	2.92 to 2.95		

A. White crystals, thickly tabular parallel to base, occurring in vugs and as interstitial material in Vesbite, a lava composed of about 65% leucite, 18% humboldtilite, 20% pyroxene, 2% magnetite. See Jour. Wash. Ac. Sci., vol. 10, No. 9, 272, 1920. Washington, analyst.

B. Crystals and interstitial material in vesbite. Crystal habit is tabular parallel to base, combination of 1st order prism and base modified by 2d order prism. Washington, analyst.

C. Crystals occurring in pockets in limestone masses included in leucitite. Crystal habit thick tabular parallel to base; combination of 1st order prism modified by ditetragonal prism and base. Colorless to transparent. Washington, analyst.

D. Analysis by Damour, Dana's System of Mineralogy, 6th edit., p. 475.

E. Analysis by Bodlaender, Neues Jahrb., 1893, 1, p. 17.

Monte Somma Humboldtilite.—In Table XXIII are given the chemical analyses of three specimens of humboldtilite selected by the writer and analyzed by Dr. H. S. Washington. Two analyses made by other analysts are included for comparison. A noteworthy difference lies in the fact that the iron as found by Dr. Washington is for the most part in the ferrous state, whereas the condition of the iron as reported by most of the other analysts is the ferric oxide, the two oxides not having been separately determined.

TABLE XXIV.

Comparison of Humboldtilite analyses with calculated composition of isomorphous mixtures.

Humboldtilite A.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2	39.86	39.98	6630	6634	+ 4	50 $2CaO.MgO.2SiO_2$
Al_2O_3	11.37	11.41	1116	1041	— 75	24 $3CaO.Al_2O_3.3SiO_2$
Fe_2O_3	.50	.50	31	39	+ 8	10 $2CaO.Al_2O_3.SiO_2$
FeO	1.78	1.79	249	230	— 19	7 $2CaO.FeO.2SiO_2$
MgO	7.63	7.65	1898	1831	— 67	7 $3(Na,K)_2O.Al_2O_3.3SiO_2$
CaO	35.58	35.69	6362	6563	+201	2 $3CaO.Fe_2O_3.3SiO_2$
Na_2O	2.13	2.15	347	347		
K_2O	.82	.83	88	88		

Humboldtilite B.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2	41.69	41.94	6958	6844	—114	37 $2CaO.MgO.2SiO_2$
Al_2O_3	9.59	9.65	944	969	+ 25	31 $3CaO.Al_2O_3.3SiO_2$
Fe_2O_3	.76	.77	48	59	+ 11	16 $2CaO.FeO.2SiO_2$
FeO	3.75	3.78	527	525	— 2	13 $3(Na,K)_2O.Al_2O_3.3SiO_2$
MgO	5.32	5.36	1330	1355	+ 25	3 $3CaO.Fe_2O_3.3SiO_2$
CaO	32.82	33.02	5886	5998	+112	
Na_2O	4.76	4.79	773	773		
K_2O	.68	.69	73	73		

Humboldtilite C.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2	40.36	40.52	6719	6653	— 66	43 $2CaO.MgO.2SiO_2$
Al_2O_3	12.04	12.09	1185	1191	+ 6	32 $3CaO.Al_2O_3.3SiO_2$
Fe_2O_3	.75	.75	47	40	— 7	9 $3(Na,K)_2.Al_2O_3.3SiO_2$
FeO	1.53	1.54	214	197	— 17	6 $2CaO.FeO.2SiO_2$
MgO	6.56	6.60	1638	1575	+ 63	2 $3CaO.Fe_2O_3.3SiO_2$
CaO	34.71	34.85	6223	6373	+150	
Na_2O	3.34	3.35	540	540		
K_2O	.30	.30	32	32		

In Table XXIV are given the original chemical analyses of the humboldtilites, the analyses reduced to 100 per cent, the constituent molecules, and for comparison the calculated molecules of the mixture of assumed components most closely approximating the natural mineral in composition.

In Table XXV are given the results of recalculating the first three analyses of Table XXIII in terms of their assumed components, together with the optical characters of the minerals analyzed.

TABLE XXV.

Comparison of properties of natural Humboldtilites with those of similar synthetic preparations.

	A		B		C	
Components	Natural	Artif.	Natural	Artif.	Natural	Artif.
Gehlenite	10	10	..	..	8	10
Akermanite	50	54	37	48	43	45
$3CaO.Al_2O_3.3SiO_2$	24	26	31	39	32	33
$3Na_2O.Al_2O_3.3SiO_2$ $3K_2O.Al_2O_3.3SiO_2$ ..	7	10	13	10	9	10
$3CaO.Ge_2O_3.3SiO_2$	2		3	3	2	2
Ferrous minerals	7		16		6	
$n\omega$	1.639	1.635	1.637	1.633	1.637	1.635
$n\epsilon$	1.633	1.633	1.631	1.630	1.631	1.632
Birefringence	.003	.002	.006	.003	.006	.003

The nature of the ferrous iron compound is unknown, but for purposes of recalculation the writer follows Schaller in assuming it to exist as a ferrous iron akermanite ($2CaO.FeO.2SiO_2$).

For purposes of comparison, the optical data for artificial mixtures of similar composition, but lacking the ferrous iron compound, have been computed and are included in Table XXV.

From an inspection of this table, it is evident that the effect of the ferrous iron compound is to increase both the indices of refraction and the birefringence.

The comparison of the natural minerals and the artificial mixtures shows an agreement of the optical characters well within the limits of the possible errors involved. As a further check on this matter, several experiments (Table XXVI) were made on the natural minerals, and the results obtained are all confirmatory of the essential identity of the natural minerals and the synthetic preparations.

This interpretation, however, is conditioned by the facts that the nature and properties of the ferrous iron compound are unknown, and that accurate analyses and indices of refraction of humboldtilites showing a wider range of composition than those now available are very much needed. The amount and effect of ferric iron in the humboldtilites also needs to be studied.

Table XXVI shows that all three humboldtilites when held for 16 hours at 1150° showed no noticeable change. All three, when completely melted and quenched to form

TABLE XXVI.

Thermal data for Humboldtilites from Monte Somma.

		Humboldtilite A.
1150°	16 hrs.	Clear and unaltered.
1170°	40 hrs.	Trace of dissociation. Poikilitic rods in some grains, but most grains unchanged. Altered grains are mottled in appearance, unaltered grains are fresh and clear.
1200°	16 hrs.	Part of material is dissociated, and traces of glass are present; part is unaltered and without traces of glass. Indices of refraction of altered material are higher.
1225°	16 hrs.	Crystals plus a small amount of interstitial glass.
1320°	1 hr.	Glass plus few crystals. The crystals exhibit anomalous bluish and brownish yellow interference colors.
1343°	1 hr.	All glass.
		Humboldtilite B.
1150°	16 hrs.	Clear and unaltered.
1170°	20 hrs.	Dissociated. For the major crystalline material $n_\omega = 1.642$ and $n_\epsilon = 1.635$.
		Humboldtilite C.
1150°	16 hrs.	Glass formed by melting at higher temperature and quenching was recrystallized and the crystals had the following indices $n_\omega = 1.639$ $n_\epsilon = 1.633$.
1170°	20 hrs.	Unaltered; clear and fresh.
1200°	16 hrs.	Most grains are clear without a trace of glass. A few grains with impurities show traces of glass.
1235°	16 hrs.	Interstitial glass noticeable.
1313°	1 hr.	Crystals with gray interference colors and glass.
1335°	1 hr.	All glass.

glass, and when subsequently recrystallized at 1150° for 16 hours, exhibited indices of refraction which are within the limits of error for those of the original material.

A and B are also similar to the synthetic preparations inasmuch as they dissociate at similar temperatures, most of the material having higher indices of refraction after dissociation. No trace of dissociation was noted in experiments with C.

The indices of refraction alone were determined on two other Italian specimens with the following results. The first specimen is a limestone fragment, with humboldtilite crystals occurring in pockets with biotite and pyroxene. The crystals are short prismatic, a combination of the base and first order prism modified by the ditetragonal prism. $n_\omega = 1.636$ $n_\varepsilon = 1.629$. The other specimen is from Monte Albano, Latium, Italy, and is a leucite lava with medium sized tabular crystals of humboldtilite partly enclosing leucite. $n_\omega = 1.639$ $n_\varepsilon = 1.637$.

Humboldtilite from Latium.—In a recent article on melilites F. Millosevich[21] describes melilite (humboldtilite) obtained from blocks in peperino associated with pyroxene, leucite, hauyne, and yellow garnet. In Table XXVII are given the original chemical analysis, the analysis reduced to 100, the constituent molecules, and for comparison the calculated molecules for a mixture of assumed components most closely approximating the natural mineral in composition.

TABLE XXVII.

Humboldtilite from Latium.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2	41.07	41.24	6839	6802	—37	40 $2CaO.MgO.2SiO_2$
Al_2O_3	10.47	10.51	1030	1055	+25	38 $3CaO.Al_2O_3.3SiO_2$
Fe_2O_3	3.80	3.82	239	236	— 3	12 $3CaO.Fe_2O_3.3SiO_2$
FeO	None					10 $(Na,K)_2O.Al_2O_3.3SiO_2$
CaO	33.92	34.06	6071	6157	+96	
MgO	6.02	6.05	1501	1465	—36	
Na_2O	3.25	3.27	527	527		
K_2O	1.04	1.05	111	111		
	99.57	100.00				

The indices of refraction for the natural mineral are given by Millosevich as $n_\omega = 1.633$ and $n_\varepsilon = 1.629$ with a birefringence of 0.004. The indices of refraction for a synthetic preparation of similar composition are $n_\omega = 1.639$ and $n_\varepsilon = 1.635$ with a birefringence of 0.004. The difference is greater than might be expected, but the agreement may still be considered good.

Colorado humboldtilite. A humboldtilite from Gunnison County, Colorado, has been analyzed by Schaller and described by Larsen and Hunter.[22] It forms two-thirds of a rock called uncompahgrite, and is associated

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[21] Rend. Accad. Lincei, vol. 30, pp. 80-84, 1921.

[22] E. S. Larsen and J. F. Hunter, J. Wash. Acad. Sci, vol. 4, p. 473, 1914.

Table XXVIII.

Humboldtilite from Colorado.

	Original analysis	Analysis reduced.	Mol.	Calculated molecules	Difference	Mixture weight percent.
SiO_2	42.07	43.80	7263	6830	—433	45 $3CaO.Al_2O_3.3SiO_2$
TiO_2	.20	.20	25		— 25	34 $2CaO.MgO.2SiO_2$
Al_2O_3	10.30	10.52	1052	1189	+137	10 $2CaO.FeO.2SiO_2$
CaO	35.41	34.64	6174	6254	+ 80	9 $3(Na,K)_2O.Al_2O_3.3SiO_2$
MgO	4.15	4.32	1072	1245	+173	
Fe_2O_3	.50	.52	33	39	+ 6	2 $3CaO.Fe_2O_6.3SiO_2$
FeO	2.18	2.27	315	328	+ 1	
MnO	.16	.16	22			
Na_2O	3.24	3.37	543	576	+ 33	
K_2O	Trace					
P_2O_5	.82					
CO_2	.90					
H_2O	.47					
	100.40	100.00				

with pyroxene, perofskite, and apatite. Its density is 2.98. Table XXVIII gives a statement of the original analysis, the analysis reduced to 100 with elimination of water, apatite, and calcium carbonate, the analysis stated in terms of its constituent molecules, and for comparison the calculated molecules of a mixture of assumed components most closely approximating the natural mineral in composition. This analysis does not lend itself readily to recalculation in terms of the components considered.

A comparison of its optical properties with those of a similar synthetic preparation is given in Table XXIX. The agreement here, again, is as close as could be expected.

Table XXIX.

Comparison of properties of Colorado Humboldtilites with those of similar synthetic preparations.

Components.	Natural.	Artificial.
Åkermanite	34	40
$3CaO.Al_2O_3.3SiO_2$	45	50
$3Na_2O.Al_2O_3.3SiO_2$ $3K_2O.Al_2O_3.3SiO_2$	9	10
$3CaO.Fe_2O_3.3SiO_2$	2	
Ferrous minerals	10	
$n\omega$	1.632+	1.630
$n\epsilon$	1.626—	1.627
Birefringence	.007	.003

A specimen of the mineral supplied by Dr. Larsen was heated for 20 hours at 1150°C. and exhibited no alteration; heated for 20 hours at 1175°C., it dissociated. The synthetic material dissociates at about the same temperature. The mineral, called simply melilite by Larsen, is here more specifically regarded as the humboldtilite variety.

The agreement between the optical properties of the humboldtilite minerals and homogeneous preparations of similar composition formed above 1000°C. is very close and within the limits of error involved. Assuming that the pure solid solutions are essentially true equivalents of the corresponding humboldtilites, it follows by analogy that the compound $3CaO.Al_2O_3.3SiO_2$ enters into the humboldtilites with the effect of a negative, moderately birefringent, uniaxial compound, for which a mineral equivalent as a separate entity is unknown.

The present explanation obviates the difficulty of conceiving the formation of a negative uniaxial mineral from an isomorphous mixture of two positive uniaxial end members, as suggested by Schaller.

The humboldtilites, according to the interpretation offered here, are essentially isomorphous mixtures of positive uniaxial akermanite ($2CaO.MgO.2SiO_2$) and a negative uniaxial, moderately birefringent form of $3CaO.Al_2O_3.3SiO_2$ with minor amounts of gehlenite, a ferrous iron compound, and $3RO.R_2O_3.3SiO_2$ compounds.

FERRIC IRON-RICH MELILITE.

Among the specimens of melilite from Capo di Bove, obtained by Dr. H. S. Washington from Professor F. Millosevich, was one which proved to be a new member of the group. It occurs in pockets, about 1½ inch in diameter, of massive crystalline granular material associated with nephelite and pyroxene, and as minute crystals coating druses in a melilite-leucitite lava. The crystals are yellowish-brown and coated with a needle-like unidentified mineral. Their habit is tabular to pseudo-cubic, or a combination of the first order prism and base modified by the second order prism.

Under the microscope they are found to show a marked zonal growth. The cores are isotropic for Na light and give an anomalous berlin-blue interference color for daylight. Surrounding the cores are zones showing yellowish-brown interference colors grading outward into material with normal yellow interference colors. The index of refraction of the isotropic cores is about 1.654 and the indices of the material exhibiting the maximum interference colors are $n_\omega = 1.666$ and $n_\varepsilon = 1.661$ with a birefringence of about 0.005-0.006. Peg structure is conspicuous.

The material is so intimately associated with nephelite and pyroxene that it was necessary to grind it to a fineness sufficient to pass a 150 mesh screen. Bromoform was then used to separate the lighter constituents, Klein's solution to effect a first separation of the melilite from the pyroxene, and an electro-magnet to complete the purification. The melilite after this treatment was found, when examined under the microscope, to contain about 4 percent pyroxene and 2 percent nephelite.

Table XXX.

Capo di Bove Melilite.

	I	II
SiO_2	40.56	40.03
Al_2O_3	6.18	5.66
Fe_2O_3	7.44	7.76
FeO	.51	.40
MnO	none	none
MgO	9.53	9.43
CaO	31.07	32.17
Na_2O	2.96	2.83
K_2O	1.76	1.72
TiO_2	none	none
	100.01	100.00

I. Analysis of Capo di Bove melilite with 2 percent nephelite and 4 percent pyroxene. Washington, analyst.
II. Analysis recalculated for pure melilite.

Only a small amount of material was obtained from a large amount of the granular nodule. A chemical analysis was made of this by Dr. Washington. Owing to the small quantity of material available, only 0.2936 gram in all, water was not determined. In Table XXX are given the original analysis and the analysis recalculated to eliminate the effect of the impurity of 2 percent of nephelite and 4 percent of pyroxene. The analysis, recalculated in terms of the assumed components, shows considerable discrepancy.

The analysis differs from the others in that ferric oxide is high and alumina low, the former evidently replacing the latter. The indices of refraction also differ from those of other specimens obtained by the writer from Capo di Bove. To test for possible inversion phenomena, a sample was heated for 5 days at 1100° ± 25°. A few grains are completely inverted but most are cloudy with clear material working in from the edges. Held for 16 hours at 1140° ± 20° the material is completely inverted to an aggregate of clear bladed grains with lower indices of refraction $n_\omega = 1.647$ and $n_\varepsilon = 1.639$. Held for 2 hours at 1165° there is a little glass present.

The composition of this material is such that it does not fall within the limits of the compositions of the synthetic mixtures studied, and no comparison can be made.

Another specimen from the same locality, among those received from Professor Millosevich, has the following indices: $n_\omega = 1.645$ and $n_\varepsilon = 1.638$. This material was held for one week at 1050° and was then found to consist of an unidentifiable cloudy brown aggregate.

Another specimen of melilite from Capo di Bove obtained from the U. S. National Museum had the following indices of refraction: $n_\omega = 1.644$ and $n_\varepsilon = 1.637$. The mineral occurs as reddish-brown pseudo-cubic to tabular crystals in a crevice in leucitophyre. Thermal data determined on this specimen are given in Table XXXI.

The ferric iron rich melilites cannot be recalculated in terms of the components used in the synthetic mixtures

TABLE XXXI.

Thermal data for Capo di Bove Melilite. $n_\omega = 1.644$ and $n_\epsilon = 1.637$.

700°	170 hrs.	Clear and altered.
850°	140 hrs.	Completely changed to a fibrous aggregate of mottled grains with irregular extinction. Indices of refraction 1.648-1.656.
1050°	20 hrs.	Dense aggregate of birefringent fibers with minute dots of high refracting material. Av. $n = 1.661$.
1135°	15 hrs.	Similar to preceding, but more highly refracting grains more conspicuous.

without discrepancies of some magnitude. The chemical analyses by Zambonini of two ferric iron rich melilites from Capo di Bove are given in Table XXXII. The composition of a synthetic mixture composed of 45 percent akermanite, 35 percent andradite, 10 percent $3Na_2O.Al_2O_3.3SiO_2$, and 10 percent gehlenite is given for comparison. The crystallized synthetic mixture of this composition has the following indices of refraction: $n_\omega = 1.676$ and $n_\varepsilon = 1.658$. These indices are conspicuously higher than those of the natural melilites of similar composition, if we may assume that our mineral was similar to those analyzed by Zambonini. The natural mineral, when heated at 850°, changes to a fibrous aggregate of higher indices of refraction and the actual inversion or dissociation point may be much lower. The synthetic preparation and the natural mineral therefore do not correspond.

TABLE XXXII.

Comparison of analyses of ferric iron rich melilites by Zambonini with calculated composition of synthetic mixture.

	I.	II.	III.
SiO_2	40.14	39.20	38.38
Al_2O_3	6.47	7.56	5.90
CaO	32.98	43.18	34.13
MgO	6.33	6.41	6.64
Fe_2O_3	9.95	11.34	10.98
FeO	.53		
Na_2O	2.18	2.21	3.97
K_2O	1.49	1.45	
H_2O	.27	.21	
TiO_2,MnO	Trace	Trace	
	100.34	100.56	100.00

I. Yellow melilite from Capo di Bove.
II. Brown melilite from Capo di Bove.
III. Calculated composition of mixture of 45 percent $2CaO.MgO.2SiO_2$, 35 percent $3CaO.Fe_2O_3.3SiO_2$, 10 percent $3Na_2O.Al_2O_3.3SiO_2$ and 10 percent $2CaO.Al_2O_3.SiO_2$.

The following results show that the synthetic preparations may have different phases. A glass consisting of 10 percent $3Na_2O.Al_2O_3.3SiO_2$, 67.5 percent $2CaO.MgO.2SiO_2$, and 22.5 percent $3CaO.Fe_2O_3.3SiO_2$ was held for 1 month at 700° ± 25°. The result was an aggregate of minute spherulites with blue gray fibers with an average index of refraction of about 1.695 and more strongly birefringent fibers with index about 1.680. The indices for the same preparation crystallized at the solidus are $n_\omega = 1.654$ and $n_\varepsilon = 1.644$. A mixture composed of 10 percent $3Na_2O.Al_2O_3.3SiO_2$, 45 percent $2CaO.MgO.2SiO_2$, and 45 percent of $3CaO.Fe_2O_3.3SiO_2$, heated for 1 month at about 700°, gave an aggregate of low birefringent spherulites with an average index of about 1.730 ± 0.010 and more strongly birefringent fibres. This is contrasted with the indices $n_\omega = 1.688$ and $n_\varepsilon = 1.658$ for the same preparation crystallized at the solidus. Several experiments with other mixtures at the same temperature for the same length of time gave similar results, with varying high indices of refraction.

SUMMARY

The character of the work upon which this paper is based and the conclusions reached are briefly summarized here.

Over 100 synthetic crystalline mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3\ddot{R}O.R_2O_3.3SiO_2$ compounds were prepared from appropriate glasses at temperatures above 1000° (the approximate lower limit of experiments); and their homogeneity, the optical characters of those forming homogeneous mixtures and of the dominant phase of some of those forming inhomogeneous mixtures, and the temperatures of complete melting, were determined.

The compounds $2CaO.MgO.2SiO_2$ and $2CaO.Al_2O_3.SiO_2$ have previously been shown to form a complete series of solid solutions at the solidus, and are here shown to agree very closely in their properties with the akermanite-gehlenite series of minerals.

In certain homogeneous solid solutions with the other compounds at certain temperatures $3CaO.Al_2O_3.3SiO_2$ is shown to have the properties of a negative, uniaxial, moderately birefringent crystalline compound.

Mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and a mixture of 90 percent $3CaO.Al_2O_3.3SiO_2$ + 10 percent $3Na_2O.Al_2O_3.3SiO_2$ form a complete series of solid solutions, except for a trace of inhomogeneity in some preparations high in $2CaO.MgO.2SiO_2$. Mixtures of these compounds yield crystallized products essentially similar in composition and properties to the minerals of the humboldtilite series, varietal members of the melilite group relatively poor in ferric iron.

The humboldtilites are interpreted as essentially isomorphous mixtures of positive uniaxial akermanite ($2CaO.MgO.2SiO_2$) and a negative, tetragonal, uniaxial, moderately birefringent form of $3CaO.Al_2O_3.3SiO_2$ with minor amounts of gehlenite, a ferrous iron compound, and $3RO.R_2O_3.3SiO_2$ compounds. The compositions of the humboldtilites lie in a zone which exhibits the lowest temperatures of complete melting for the components involved.

Mixtures of $3CaO.Fe_2O_3.3SiO_2$, $2CaO.MgO.2SiO_2$, $3Na_2O.Al_2O_3.3SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Al_2O_3.3SiO_2$, similar in composition to some of the ferric iron rich melilites, were studied, and the properties of the synthetic crystalline material were found to be quite different from those of natural minerals of similar composition.

The natural ferric iron rich melilites probably form at temperatures lower than those of the present experiments since some of such melilites investigated decompose or invert at temperatures at least as low as 850° C.

Three new analyses of humboldtilites and one of ferric iron rich melilite by Dr. H. S. Washington are given. The ferric iron rich melilite differs from any hitherto analyzed.

This study serves to emphasize the great complexity of this group of minerals and the necessity for further data on their composition and properties, and for further experiment in synthesis. The extent to which such known and hypothetical compounds as $3MgO.Al_2O_3.3SiO_3$; $3FeO.Al_2O_3.3SiO_2$; $3K_2O.Al_2O_3.3SiO_2$; $2CaO.FeO.2SiO_2$; $2CaO.Fe_2O_3.SiO_2$, etc., may enter into the melilite minerals, and their corresponding effect, is yet to be studied.

In conclusion, the writer desires to express his thanks to Doctors N. L. Bowen, H. E. Merwin, and H. S. Washington for their friendly criticism and assistance in this work.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., June 20, 1921.

Art. III.—Carex Notes; by Ira W. Clokey. *Carex apoda sp. nov.* With Plate II.

Culms 7-8 dm. tall, erect, sharply angled, smooth, phyllopodic, dark brown at base. Leaves shorter than the culm, 3.5-5 mm. wide, flat, rough on the margins, situated on the lowest third of the culm. Sheaths overlapping, loose; ventral band hyaline, white or tawny, easily ruptured. Spikes 4-6, contiguous but distinct or the lowest somewhat separated, erect, upper sessile or subsessile, lower one or two short peduncled. Terminal spike gynaecandrous, lateral spikes pistillate, *all many flowered;* 10-20 mm. long, 5-7 mm. wide. Lowest bract or bracts leaf-like, shorter to about the length of the inflorescence, upper bracts scale-like. Scales lanceolate, acute to short cuspidate, about as wide as but shorter than the perigynia, brown, somewhat shining; midrib obsolete or narrow and a little lighter than the balance of the scale. Perigynia *nerveless, compressed, narrowly oblong or narrowly elliptic, sessile,* white or tinged with light brown, *darkest over the achene,* 4-4.2 mm. long, 1.2 mm. wide, membranous, smooth, with short, cylindric, dark brown, emarginate beak. Achene triangular, elliptic, light brown, dull, 1.3-1.4 mm. long, .7-.75 mm. wide, *on a slender stipe 1 mm. long raising the achene to the center of the perigynia.* Stigmas three.

Rhizoma verisimiliter cæspitosum. Culmus 70-80 cm. altus, strictus, ad basin vaginis aphyllis purpureis obtectus. Folia culmo breviora plana angusta fere glabra. Spiculae 4-6 oblongae 1-2 cm. longae densiflorae obtusae contiguæ sessiles, ima remotiuscula brevissime pedunculata, terminalis gynaecandra clavata, laterales ♀ longiones. Bracteae superiores setaceæ ima foliacea evaginans spicam terminalem attingens. Squamæ ♀ oblongo-ovatae acutae vel brevissime cuspidatae atro-purpureae nervo medio obscuro. Utriculi squamas subaequantes sed lationes erecti ellipticæ 4-4.2 mm. longi glagri albidi leviter pupreo maculati plurinervosi haud stipitati, rostro brevi bidentulo apiculati. Nux elliptica stipitata trigona. Stigmata 3.

The above description is based on specimens collected by Prof. Aven Nelson and J. F. Macbride in ponds at an elevation of 1794 meters, at Mackay, Custer Co., Idaho, Aug. 1, 1911. Their number 1533, deposited in my herbarium, is designated as the type. Their number 1535,


x5
6
x1/3
1
x1/3
7
x5
5
x5
11
x5
12
x5
2
x5
3
x5
4
x5
10
x5
8
x5
9

collected at the same locality, belongs here. Both numbers were distributed as *Carex atrata* L. from the Rocky Mountain Herbarium.

Carex apoda belongs to the *Atraræ* Kunth. or *Melonanthæ* Drej. and is probably most closely related to *Carex atrata* L. and *Carex epapillosa* Mackenzie. It can be distinguished from these two species as well as from *Carex atratiformis* Britton (Carex atrata L. var. ovata (Rudge) Boott) with which it might be confused, as follows:

The margins of the perigynia much narrower than the achene

Perigynia 4 mm. long, 1.2 mm. wide. Upper lateral spikes sessile or subsessile, lower spikes short peduncled
Carex apoda

Perigynia 2.5-3 mm. long, 1.5 mm. wide. Lateral spikes on slender peduncles
Carex atratiformis Britton

The margins of the perigynia as wide as the achene

Perigynia smooth, achene long stipitate
Carex epapillosa Mackenzie

Perigynia granular-roughened, achene short stipitate
Carex atrata L.

In addition to the above, *Carex apoda* differs from Carex *atrata* L. and *Carex epapillosa* Mackenzie, in having the leaves scattered over the lowest third of the culm, not clustered at the base; the scales are about as broad and noticeably shorter, not narrower and as long or longer than the perigynia. Further *Carex apoda* differs from *Carex atrata* L. in having the perigynia smooth and the achene long stipitate. Finally the perigynia of *Carex apoda,* having the length more than three times the width, differs from that of any other species in the group.

Carex Paysonis sp. nov.

Grows in clumps; rootstock slender, light brown, covered with dull, light brown scales which are not fibrolous. Culms light green, slender, rough below the head, 3-5 dm. high, about twice the length of the leaves, *phyllopodic,* with base surrounded by the non fibrolous remains of the leaves of the previous year, dull brown not purplish tinged at base. Leaves 3-6 to the fertile culm, situated close to the bottom of the culm, light green, attenuated

1.5-3 mm. wide, flat, slightly rough on the edges. Culm otherwise naked except for a slender green leaf or bract 4-12 cm. below and not reaching the top of the inflorescence, with or without a pistillate spike. Sheaths overlapping, ventral band hyaline, white or tawny, easily ruptured. Terminal spike staminate, sessile or subsessile, narrowly elliptic, 11-18 mm. long, 3-5 mm. wide. Frequently one or two very small staminate or androgynous, sessile spikes at the base of the terminal spike. Lateral pistillate spikes 2-3, separated, upper sessile, the other one or two short peduncled, ascending, elliptic, acute or acutish, 8-20 mm. long, 4-8 mm. wide. All spikes dark brown or black. Upper bracts scale-like, brown; lower bracts slender, brownish, shorter than the subtended spike. Scales acute or acutish, dull, dark brown, uniform, midrib obsolete; staminate scales broadly lanceolate; pistillate scales lanceolate, much narrower than and one half to almost as long as the perigynia, hidden or almost hidden by the perigynia. Perigynia strongly compressed, sessile, glabrous, dull, broadly elliptic, 4-5 mm. long, 2-3 mm. wide, texture thin, lower half white, upper half and beak dark brown or black, lateral nerves usually well defined; beak cylindric, one third millimeter long, emarginate. Achene situated low in the perigynia, short stipitate, oblanceolate, pointed at both ends, smooth, triangular, tan colored, 2 mm. long, 8.-9. mm. wide. Stigmas three.

Rhizoma laxe cæspitosum et stoloniferum. Culmus 30-40 cm. altus versus apicem leviter curvatus. Folia culmo breviora carinata angusta fere glabra. Spiculae 3-5 remotae ± pedunculatae, ima longe-pedunculata, terminalis ♂, altera ♂ brevis adjecta, laterales ♀ ellipticae fere turgidi. Bractea infirma brevis evaginans spicam terminalem haud attigens. Squamae ♀ lanceolatae acutae nigricantes. Utriculi squamas subaequantes sed multo lationes patentes papyracei late ovales compressi 4-5 mm. longi stramineo-virides grosse purpereo maculati glabri tenuiter plurinervii, haud stipitati in rostrum breve ore integro vel bidentulo contracti. Nux elliptica subsessilis trigona. Stigmata 3.

The above description is based upon plants collected by Dr. and Mrs. E. B. Payson, No. 2224, on dry rock slides on the eastern slope of Grand Teton, Jackson's Hole, Wyoming. All the material of this number has been examined. Named for Mrs. Lois B. Payson. The type is deposited in my herbarium.

Carex Paysonis belongs to the *Atratæ* Kunth or *Melonanthæ* Drej. Though *phyllopodic* it is most closely related to the *aphyllopodic Carex spectabilis* Dewey. Mr. Theodore Holm, who has done so much to differentiate the species in this part of the troublesome *Atratæ* Kunth. or *Melonanthæ* Drej., has kindly examined some of this material and places it "not far from *Carex spectabilis* Dewey, but very distinct from this." *Carex Paysonis* can be separated from the most closely related species by the following key:

Culms aphyllopodic
Carex spectabilis Dewey
Carex montanensis Bailey
Carex venustula Holm
Carex macrochaeta C. A. Mey
Carex Tolmiei Boott
(As defined by Mr. Theodore Holm)
Culms phyllopodic
Pistillate spikes 3-6, perigynia 3 mm. long
Carex Tolmiei Boott
(As described in Rydberg's Rocky Mountain Flora)
Pistillate spikes 2-3
Pistillate spikes filiform stalked, drooping
Carex atrofusca Schk.
(*Carex ustulata* Wahl.)
Pistillate spikes erect, upper sessile, lower short peduncled
Scales with pale midvein extended into a short awn, longer than the stipitate perigynia
Carex microchœta Holm
Scales at most acute, uniform dark brown, midrib obsolete, shorter than the perigynia which is not stipitate
Carex Paysonis

EXPLANATION OF PLATE II.

Fig. 1—*Carex apoda.*
Fig. 2—Idem pistillate scale.
Fig. 3—Id. pistillate scale.
Fig. 4—Id. perigynia.
Fig. 5—Id. achene.
Fig. 6—Id. perigynia, longitudinal section.
Fig. 7—*Carex Paysonis.*
Fig. 8—Idem staminate scale.
Fig. 9—Id. pistillate scale.
Fig. 10—Id. perigynia.
Fig. 11—Id. achene.
Fig. 12—Id. perigynia, longitudinal section.

Drawings by Miss Rena Duthie.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *A New Process for Determining Fluorine.*—Since the methods that have been employed for this determination are difficult and often inaccurate, the new process devised by M. Travers appears to be very important. He precipitates the fluorine in cold solution in the form of K_2SiF_6 and titrates the washed precipitate by means of 1/5 normal K O H in the presence of boiling water, using penolphthalein as an indicator. The whole process can be carried out in glass vessels.

The fluorine is brought into solution in the form of an alkaline fluoride, then a solution of potassium silicate of known strength is added in sufficient amount to furnish about double the theoretically required quantity of silica. The solution is then neutralized with ordinary hydrochloric acid, with the use of helianthine as an indicator, and a slight excess, about 2 cc, of the acid is added. Then solid potassium chloride is added to the extent of about 20% of the liquid. The precipitate is filtered upon a dense filter, washed with 20% KCl solution or with 50% alcohol until the washings are neutral to helianthine, and then the precipitate with the filter paper is boiled with water and titrated as mentioned above. Of course, the volumetric KOH solution should be free from carbonate. Test analyses showed excellent results with HKF_2, and the author states that the presence of boron does not interfere. It is expected that the method will be useful, not only in the ordinary determination of fluorine, but also in the study of compounds in which a part or the whole of this element is disguised in the form of complex radicals.

It should be stated that the author has used this method successfully, with a reversed precipitation, for the determination of silica. This process was carried out in silver vessels, and, while this process is designed for general use in the determination of silica, it is evident that it would be particularly useful for silica in the presence of fluorides.—*Comptes Rendus,* **173**, 714, 836.

H. L. W.

2. *The Separation of the Element Chlorine into Isotopes.*—William D. Harkins and Anson Hayes, by the fractional diffusion of hydrogen chloride gas through clay pipe-stems in a very elaborate apparatus, have obtained heavier fractions of the acid which gave for the atomic weight of chlorine values of about 35.49 in place of 35.46, the constant of ordinary chlorine. The atomic weights were compared by getting the purified acids in solution to practically the same density by dilution and careful employment of the pycnometer, and then titrating the solutions by the use of sodium hydroxide in weight burettes.

The increase in the atomic weight seems very small when it is considered that Harkins supposes the heavier isotope to have the atomic weight 37.00, but it appears that the small increase is a definite one, and the authors say that this seems to be the first separation of isotopes reported from which there is any definite evidence.

The work on the diffusion of chlorine and hydrogen chloride was begun in 1915, and Harkins has been aided by several co-workers in the investigation. Several previous announcements of successful results have also been made previously.—*Jour. Amer. Chem. Soc.*, **43**, 1803. H. L. W.

3. *Qualitative Chemical Analysis;* by OLIN FREEMAN TOWER. 8vo, pp. 89. Philadelphia, 1921 (P. Blakiston's Son & Co. Price, $1.50 net).—This is the fourth edition, revised, of a laboratory manual for use in inorganic qualitative analysis. It gives unusually clear and full directions, together with numerous explanatory notes, in connection with the analytical processes. While many teachers of qualitative analysis use the course as an opportunity to give a thorough drill in the writing of chemical equations, the author of this book does not appear to favor such a plan, for, besides a few equations given in the theoretical introduction, scarcely any others are given, although the chemical formulas of products formed in the operations are mentioned. In connection with descriptive matter the student is frequently given references to text-books of general chemistry.

In conclusion it may be said that the book gives a very good course of analysis, with well-selected methods very satisfactorily presented. H. L. W.

4. *A Course of Instruction in Quantitative Chemical Analysis;* by GEORGE MCPHAIL SMITH. 8vo, pp. 218. New York, 1921 (The Macmillan Company).—This is a revised edition of a work which first appeared about two years ago. It presents a course of laboratory work for beginners in the subject, with very full and clear directions, copious explanatory notes, and an excellent list of questions. There are also 100 analytical problems without answers, equally divided between gravimetric and volumetric analysis.

The book in general gives a very good impression, but it is unfortunate that it teaches a slow and difficult method of weighing, including the finding of the ''rest-point'' of the balance by the use of long swings. This is likely to discourage the beginner and to handicap him greatly in his subsequent analytical work. It is far easier and quicker, as well as decidedly more accurate to employ the shortest swings that can be seen readily, and to use the center of the graduated scale as the basis, since any deviation from equilibrium in the balance is eliminated in the practically invariable practice of weighing by difference. H. L. W.

5. *American Chemistry;* by HARRISON HALE. 8vo, pp. 215. New York, 1921 (D. Van Nostrand Company).—We find in this book a series of essays in popular style giving very interesting accounts of various achievements in applied chemistry and their importance in some of the large industries. There are 63 good illustrations, many of them of full-page size; there are many striking statistical statements and comparisons; there are numerous references to the literature, and the topics discussed are of great general interest. The book is, therefore, a useful one for the general reader with scientific inclinations, and it appears to be well suited for arousing the interest of students. H. L. W.

6. *Report on Atomic Structure.*—The report of a committee on Atomic Structure appointed by the National Research Council and consisting of Professors David L. Webster of Stanford University, and Leigh Page of Yale University, has been published by the above named body. In the first part, entitled The Present Conception of Atomic Structure, Professor Webster has discussed the evidence as to the existence of electrons and nuclei; the number of electrons in the atom; the speculations of Lewis and Langmuir as to the position of the electrons as deduced from chemical statics; Bohr's theory of energy levels, and Parson's hypothesis as to the forces holding electrons in their places. Various questions as to the structure and dynamics of the nucleus raised by radioactive data, and the significance of the data of radiation and chemical dynamics as bearing on the structure and dynamics of the electron, are also reviewed. The author inclines to the radical view that in this field the law of the conservation of energy is only statistical.

The second and longer part of the report, by Professor Page, is devoted to The Dynamical Theory of Atomic Structure. The author shows how far the postulate of electrons revolving about a central nucleus, and the quantum theory, are able to account quantitatively for the spectroscopic data. The various topics treated are the spectra of hydrogen and similar elements, X-ray spectra, the Kossel relations, the Stark effect, the Zeeman effect and the Ritz formula.—*Bull. Nat. Research Council* **2**, 336, 1921. F. E. B.

7. *Velocity of Sound at High Temperatures.*—A research published under the above title by Messrs. H. B. Dixon, C. Campbell, and A. Parker, was undertaken with the object of arriving at formulæ for the variation of the specific heat of gases with the temperature, which might be applicable to the extremely high temperatures reached in explosions. The result forms an important contribution to the knowledge of the gradients of these curves. The sound method was chosen chiefly for the reason that the velocity of sound in a heated gas gives the ratio of the specific heats at the temperature of the experiment, and not

as in the method of mixtures at a mean temperature between that of the heated and of the cooled gas.

In the experiments as carried out, direct measurements were made of the time taken by a sound wave to travel a known distance through the gas which was contained in a coiled tube so that it could be raised to the desired temperature. Each end of the tube was closed by a steel diaphragm which might be struck by a hammer controlled by an electromagnet. As the compression travelled along the tube it successively raised two disks placed about 18 meters apart, breaking a circuit, and recording the interval of time elapsed upon a pendulum chronograph. As certain small portions of the tube at either end projected beyond the bath, or furnace, and were cooled by a water jacket, it was necessary to introduce a proper correction for these ends.

The different gases studied were air, nitrogen, carbon dioxide, nitrous oxide, methane, ethane and argon. Tubes of lead, steel and silica were employed. The lead tube was conveniently used for temperatures up to 100° C. and the steel tube for the higher temperatures up to 1000° C. Exception had to be made however in the case of air and carbon dioxide as they attacked the metal. For these gases a tube of silica heated electrically by a wire coiled around it was employed. The relation between the velocity of sound in a tube and that in a free gas is discussed and a satisfactory correction formula adopted.

The means of the velocities as found from the different tubes were then plotted and tabulated for the different temperatures and the various gases. The formulas both for the ratio of the specific heats and their difference are introduced and the values calculated. The final result sought, namely, the value of the specific heat expressed as a function of the temperature is now calculated, and discussed with reference to the determinations of other investigators. For the detailed results the reader will desire to consult the original memoir.—*Proc. Roy. Soc.* **100**, 1, 1921.
F. E. B.

8. *Traité de Dynamique;* by JEAN D'ALEMBERT. Vol. I, pp. XL, 102. Vol. II, Pp. 187. Paris, 1921 (Gauthier-Villars et Cie). This is a reprint in the collection, *Les Maitres de la Pensée Scientifique,* of the work of D'Alembert edited by Maurice Solorine. As these memoirs are most complete they may, in the words of the editor's notice, be regarded as indispensable documents to historians of science and civilization. They also offer to the student an easy and inexpensive means of meeting at the source the experimental methods and ingenious processes of the great investigators. To many these concrete methods will be far more fertile and suggestive than the schematic rules of the manuals.
F. E. B.

9. *Heat and Light;* by S. E. BROWN. Pp. numbered 170-

428, Cambridge, 1921 (Cambridge University Press). This volume contains sections IV and V of the author's *Experimental Physics* and may be described as a laboratory manual of high-school, or first year college grade. It contains directions for a large number of experiments, together with numerous problems to test the student's understanding of the principles involved. It is self-contained in that it does not require the study of any other text. The press work is inferior. F. E. B.

10. *Physik und Erkenntnisstheorie;* by E. Gehrcke, Pp. II, 119. Leipzig, 1921 (B. G. Teubner).—This brochure is an examination of the fundamental postulates and principles of physics considered as a system of philosophy. Its scope is about that of the order of a doctor's dissertation. The author does not appear to be particularly sympathetic toward the Einstein hypothesis. F. E. B.

11. *Séries Trigonométrique;* by Maurice Lecat. Pp. VIII, 168. Louvain, 1921 (Chez l'Auteur). This is a very complete bibliography of the subject indicated. The author index occupies 133 pages, and a list of the journal and collections cited fills 16 pages more. Supplementary tables show the distribution of the articles according to geographical location, language, and university. The appendix contains a list of papers on the *Calculus of Variations* which have appeared during the period 1915 to 1920. F. E. B.

12. *Die Grundlagen der Geometric;* by Lothar Heffter, Pp. II, 27. Leipzig, 1921 (B. G. Teubner).—A discussion of the fundamental postulates of geometry. The treatment possesses such rigor as has been deemed necessary that they may serve for the foundation of analytical and projective geometry as developed in the two volume *Lehrbuch der Analytische Geometrie* of the author. F. E. B.

II. Geology.

1. *A prehistoric Human Skull from Rhodesia—Nature* of November 24 states that the new skull from Rhodesia was exhibited by Dr. A. Smith Woodward at a meeting of the Zoological Society on November 22. The skull, which was found in the Broken Hill Mine at a depth of 60 ft. below the water-level and 90 ft. below ground level, is in a remarkably fresh state of preservation. It is much broken on the right side and the lower jaw is missing. The brain-case is of modern human type, and the bone not thicker than that of the ordinary European; the capacity, though not yet accurately determined, is clearly above the lower human limit. The orbits are large and square, with pronounced overhanging ridges much extended laterally. The forward position of the foramen magnum indicates that the skull

was poised on an upright trunk. The palate is large, but typically human, and adapted to perfect speech. It is remarkable that the teeth are much affected by caries. The lower jaw must have been massive and larger than the Heidelberg jaw. The appearance of flatness of the frontal area suggests a comparison with *Pithecanthropus erectus.* Dr. Smith Woodward was inclined to find the nearest approach to the Rhodesian skull in the Neanderthal type from La Chapelle aux Saints in France. Though markedly modern in regard to the brain-case, in its facial characters, while it is essentially human, it appears to hold a position between the gorilla and the Neanderthal man. Fragments of the long bones, both femur and tibia, which have been found indicate that, unlike Neanderthal man, Rhodesian man walked in a perfectly upright posture. Dr. Smith Woodward regarded Rhodesian man as possibly a later development than Neanderthal man, but Prof. Elliot Smith suggested that he might represent a primitive type of which Neanderthal man might be a highly specialised form.

2. *A new Generic Name for Pliocyon Marshi;* by M. R. Thorpe (Communicated).—At the time of the publication of my paper on "Two new Carnivora" (this Journal (5), **1**, June, 1921), I was not aware of the fact that the generic name *Pliocyon* was preoccupied. Since such was the case, I now propose the name *Arœocyon* (ἀραιός, slender) to supplant my *Pliocyon,* and the type of the genus will therefore be *Arœocyon marshi.*

In April, 1918, W. D. Matthew described a new genus of dogs under the name of *Pliocyon.* The type of this genus was collected in the Snake Creek beds (Lower Pliocene) of western Nebraska, and represents a genus totally distinct from *Arœocyon,* which is from the Rattlesnake beds (Middle Pliocene) of Oregon.

3. *Publications of the United States Geological Survey,* George Otis Smith, director.—The well-understood difficulties connected with the printing industry the past year have made it impracticable to present promptly and in full the publications of the U. S. Geological Survey as has been the custom in this Journal (see earlier, **50**, 469–70). The most important issues received are the following:

Topographic Atlas: Fifty-one sheets.

Geologic Folios: No. 211, Elkton-Wilmington Folio; by F. Bascom and B. L. Miller. No. 212, Syracuse-Lakin Folio; by N. H. Darton.

Professional Papers: No. 121, Helium-bearing natural gas; by G. S. Rogers. No. 128, Part E. No. 129. Parts A, B.

Forty-first Annual Report of the Director for the year ending June 30, 1920.

Bulletins:—No. 679, Microscopic determination of nonopaque minerals; by E. S. Larsen. No. 682, Marble resources of southeastern Alaska; by E. F. Burchard and T. Chapin. No.

702, Oil possiblities, Baxter Basin, Wyoming; by A. R. SHULTZ. No. 703, Iron and other Industries of the Sarre district; by A. H. BROOKS and M. F. LACROIX. No. 704, Igneous rocks, Essex Co., Mass.; by C. H. CLAPP. No. 706, Iron Resources of Europe; by M. ROESLER. No. 713, Resources of Fort Hall Reservation, Idaho; by G. R. MANSFIELD. No. 714, Mineral Resources of Alaska; by A. H. BROOKS et al. No. 719, Petroleum in Alaska; G. C. MARTIN. No. 721, Petroleum Resources of Kern Co., Calif.; by W. A. ENGLISH. Also parts of Nos. 715, 716, 725, 726.

MINERAL RESOURCES OF THE UNITED STATES; 1918, 1919, 1920, separate chapters and Summaries.

WATER SUPPLY PAPERS: Nos. 447, 449, 453, 456, 459, 460, 462, 466, 467, 468, 470, 471, 475, 476, 481, 491. Also parts of 490, 500.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Bibliotheca Zoologica II. Verzeichnis der Schriften ueber Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861–1800 selbständig erschienen sind;* bearbeitet von DR. O. TASCHENBERG. Lieferung 24. Leipzig (Wilhelm Engelmann.)—Parts 21 to 23 of this important work were noticed in the number for June, 1921 (vol. **1**, p. 519) and part 20 in the following number (vol. **2**, p. 60.) Part 24 has since been issued, embracing pages 6313-6392 and signatures 785-794 of the Supplements. It is put out at the cost of 36 marks.

It is interesting to note that the earlier issue of the Bibliotheca Zoologica, edited by Professor V. Carus, contained a catalogue of zoological papers published from 1846 to 1860. The present work, begun in 1886, was planned to cover the period from 1861 to 1880 (see the full notice in this Journal (3), **33**, p. 246, 1887). Twelve parts of some 320 pages each were contemplated and the year 1888 set for the completion of the work. Now, however, thirty-five years after the first part was published such has been the thoroughness and care with which the undertaking has been conducted that the whole up to the present time covers very nearly 6,400 pages. This is a monumental work, indispensable to all zoologists who can hardly fail to appreciate the magnitude of the debt they owe to the self-sacrificing labors of the author.

2. *Publications from the Ronald Press Company* (20 Vesey St., New York City).—The following volumes from the Ronald Press have been noticed in this Journal: *Practical Bank Operation,* by L. H. Langston (**1**, 378; *New York State Income Tax Procedure,* by R. H. Montgomery (**1**, 468); *Personal Relations in Industry,* by A. M. Simons (**2**, 238); *Elements of Bond Investment,* by A. M. Sakolski (**2**, 308). Volumes recently received are:

Wall Street Accounting; by F. S. TODMAN. Pp. xv, 352, 1921 (Price six dollars).—This book gives a thorough, detailed description of the accounting methods developed by leading brokerage houses in handling their highly specialized business. It gives, in addition, in the course of the discussion of the special problems involved, a full and illuminating analysis of the technique of trading in the stock and commodity markets. It represents an enlargement and fundamental revision of "Brokerage Accounts" by the same author (1916).

Time Study and Job Analysis; by W. O. LICHTNER. Pp. xvii, 397; 81 figures. 1921 (Price six dollars).—The standardization of working methods is the subject here discussed in detail. After presenting the methods followed in accomplishing the result aimed at, explicit directions are given for training the engineering staff. These are followed by charts and illustrations giving the accepted engineering procedure for installing and maintaining standardized methods, followed by a discussion of standardization in its relation to production, stability of labor, etc.

The Ronald Press also conducts a monthly periodical entitled *Administration* ($5 per year); this is described as a Journal of Business Analysis and Control. The editors are R. B. KESTER, J. M. LEE and E. H. GARDNER. The scope of the periodical is broad, the subjects treated are of vital interest to the community as well as to the capital invested in individual enterprises, and the writers are men of experience in practical business.

3. *The "Electrician" Diamond Jubilee Number.*—The Electrician, which appeared on November 9, 1861, celebrated its Diamond Jubilee on November 11. A great change has taken place in electrical engineering in these sixty years. Many inventions and designs have been perfected making electric lighting possible from 1880 on; later a network of supply mains has spread through all large cities. In 1890 came the genesis of electrical traction as on the City and South London Railway. This period too has seen the invention of the telephone and the widespread adoption of the electric motor for industrial purposes. The pioneer work of Marconi, Hertz, Lodge and Fleming has culminated in the invention of commercial wireless telegraphy. Thus the pages of the Electrician are a chronicle of the transformation of electricity from a little understood science not only into a great industry but into a means of improving our present civilization.

The Jubilee issue gives congratulatory messages from many eminent engineers and scientists; it also has historical and technical accounts of the development of telegraphic and other electrical applications since 1861.

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[FIFTH SERIES.]

Art. IV.—*Gastropod Trails in Pennsylvanian Sandstones in Texas;* by Sidney Powers.

During a brief examination of the Pennsylvanian section near Shafter, western Texas, in 1919, the tracks here described were observed on the eastern side of Cibolo Creek. Dr. J. A. Udden reported on the geology of the region in 1904 and described the tracks as those of trilobites (?).[1] In the same report he described conglomerates which he believed to be of glacial origin. The drawings of the tracks (figs. 1–3) have been made with great care by Mr. G. S. Barkentin, of Albany, N. Y. The following analysis of their origin has been made possible through the careful study of Professor P. E. Raymond who is contributing an accompanying paper on trails. The specimens were given to the Museum of Comparative Geology.

Shafter, a silver mining camp situated in the canyon of Cibolo Creek, 19 miles north of Presidio on the Mexican border, is shown on the Shafter topographic sheet of the U. S. Geological Survey. It is in the midst of the Trans-Pecos volcanic plateau and the exposures of Cretaceous and Pennsylvanian sedimentary rocks are due to block-faulting followed by deep dissection. The silver is largely chloride and occurs as fissure and contact deposits in the Cibolo limestone of Pennsylvanian age. The country rock runs 1 to 3 ounces to the ton, average ore 10 oz., good ore 80 to 90 oz.

The geologic column is as follows:

Pleistocene	Bolson deposits.
Tertiary	Volcanics.
Upper Cretaceous	Volcanics, granitic intrusions (?)
Lower Cretaceous	Limestones.

---

[1] The geology of the Shafter silver mines district, Presidio County, Texas, University of Texas Mineral Survey, Bull. 8, p. 60, 1904.

Permian	Cibolo limestone.
Lower Pennsylvanian	Transition beds. Alta sandstone. Alta shale. Cieneguita beds.
(Intrusive contact)	

The correlation of the Pennsylvanian section is with the Tesnus, Dimple, Haymond, and Gaptank formations of the Marathon uplift, with the Strawn formation (?) of Northern-central Texas, and with part of the Hueco limestone of western Texas. The Cibolo limestone is correlated with the Capitan limestone on the New Mexico line.[2]

Exposures of Pennsylvanian rocks are limited to six localities, but further investigation will doubtless reveal others. Two of these have not been verified. The principal exposures are north of Shafter, one "east and southeast of the Ojo Bonito and the Cieneguita ranches," and one along Sierra Alta creek east of Cibolo ranch. An exposure only a few hundred feet long is found on the southernmost Morita creek one mile southwest of the Morita road, and a short distance northeast of a mine tunnel. Two exposures are reported below the box canyon south of the junction of Cibolo and Morita creeks, one above the site of the Spunk ranch, and above the site of the Dutchover ranch. Another exposure is mapped by B. F. Hill on the western side of the Chinati Mountains. Pennsylvanian rocks also outcrop southeast of Shafter in the Solitario dome and in Mexico where they have been found by Dr. Udden.

Northeast of the present Cieneguita ranch and east of the volcanics there is an area of black shales and quartz-pebble conglomerates striking north-south and cut off on the northeast by fine-grained, porphyritic, gray granite, the femic constituents of which are pyroxene and biotite. There is little metamorphism at the contact, but the igneous rock has invaded the shales in the form of tongues and fragments of the shale are included in the granite. The granite at the contact is of moderate grain with pink feldspar and colorless quartz crystals of equal

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[2] J. A. Udden et al., Review of the geology of Texas, Univ. of Texas, Bull. 44, p. 43, 1916.

size. Some distance east of this outcrop Dr. Udden found exposures of the same Cieneguita series with pebbles of limestone and quartz ranging "in sizes up to three inches in diameter. . . . faceted in a manner similar to the faceting of small boulders and pebbles in glacial deposits" (*loc. cit.* p. 14). Where observed by the writer in another locality the conglomerate showed well rounded quartz pebbles ¼ to ½ inch in diameter which indicated long transportation by running water. Numerous fossils are reported from this formation by Dr. Udden.

In Sierra Alta creek the upper beds of the series are well exposed. An additional outcrop was recently noted by Dr. Udden where the new road to Cieneguita ranch climbs out of Cibolo creek. East of the creek along this road there is an excellent exposure of Alta shales with interbedded sandstone strata one inch to four inches thick. The upper surfaces of the sandstones are covered with trails like those here illustrated and described.

Trails were found by Dr. Udden in a small limestone ledge on the northern side of Sierra Alta hill (a conspicuous volcanic butte unnamed on topographic sheet) associated with a *Productus* (near *cora*), a *Chonetes*, and a *Pleurotomaria*. They were found by the writer at the Morita creek exposure not far east of an old prospect tunnel. No shells are associated with the tracks, but fine limestone conglomerates about 20 feet lower in the section at the last locality contain numerous bryozoa and small tabulate corals.

Description of the Trails.

There are two distinct kinds of trails: a simple type about ¼ inch wide consisting of crescentic indentations 6 to 10 in a linear inch, and 1/20 inch deep (fig. 2); a compound type ¾ inch to 1¼ inches wide consisting of a central groove from ¼ to 5/16 inch wide with elevated looped concentric ridges 1/20 inch high and ¼ to ½ inch wide on either side (figs. 1 and 3). The central groove in the second type appears to be similar to the simple tracks where it is clearly shown. These two types never appear on the same surface and only the first type was observed at Morita creek. The compound type is confined to sandstones whose surface is covered by minute

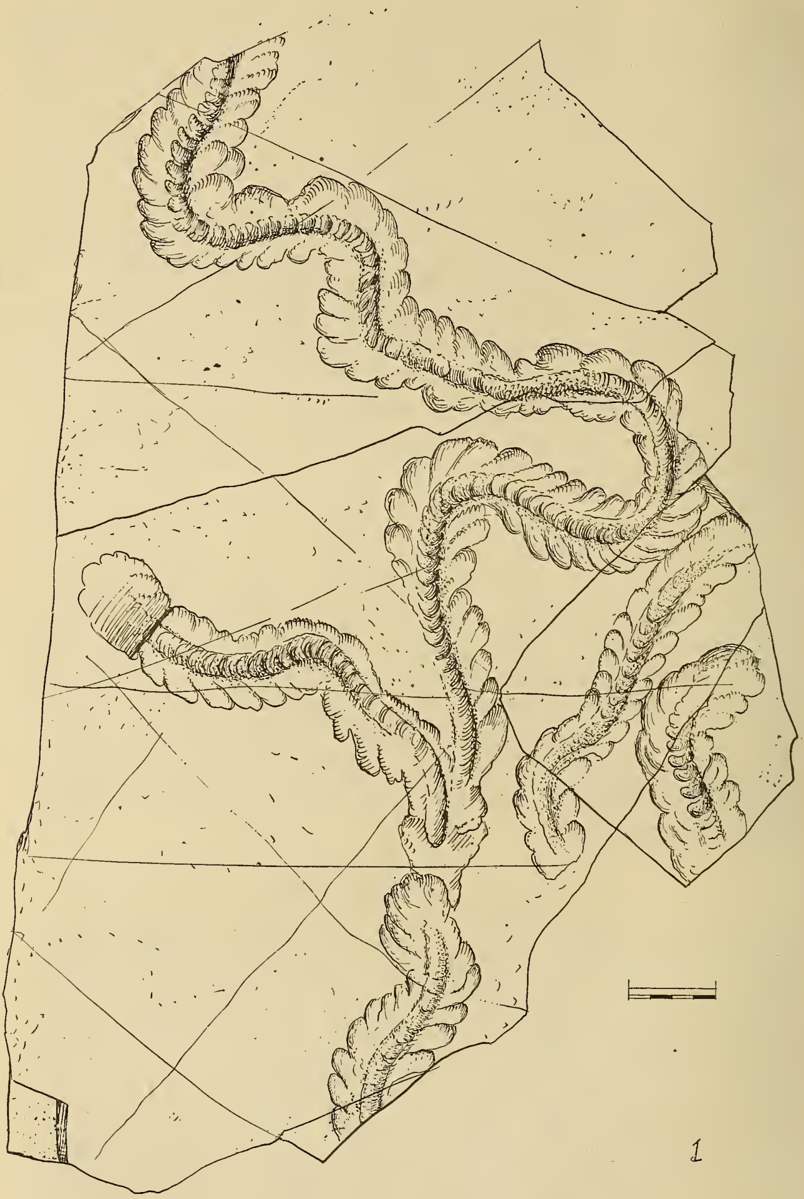

FIG. 1.—A slab of sandstone about 14 inches long and 8.5 inches wide, showing the characteristics of the wide trails, and their frequency. A little less than one half natural size. The total length of the scale is one inch.

flakes of mica. Therefore, it is believed that both types of trails were made by the same animal and that the preservation of the complete markings is dependent upon the character of the surface over which the animal travelled. The essential means of locomotion was a single foot which pressed deeply into soft mud and lightly into hard, mica-covered sand. The concentric ridges on either side of the central groove in the compound trails are evidently the impression of the shell or body of the animal on either side of the foot and the preservation of these delicate markings was dependent upon a relatively firm surface. In the case of mud these markings were elevated above the central groove and the slightest amount of erosion would remove them while burying the groove. If this is not the correct explanation for the two kinds of trails the fact that certain micaceous surfaces show only the com-

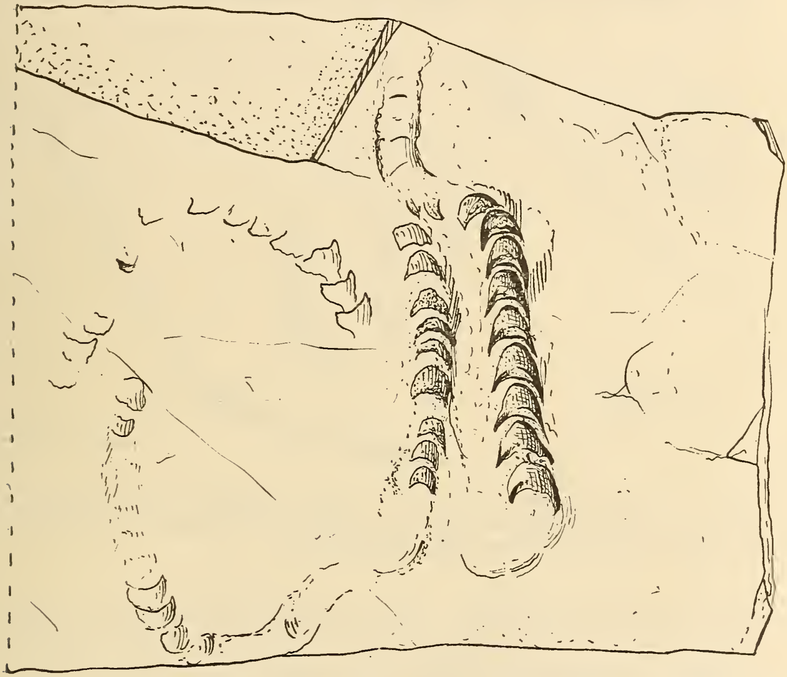

Fig. 2.—Some trails of the narrow type. The depressions between the septa-like ridges are very deep. Compare with the central part of the trail shown in fig. 1. Natural size.

pound type while all other surfaces within a few inches both above and below in the section show simple trails is difficult to account for.

The frequency and curvature of the trails are best understood by referring to the illustration. One slab shows 26 distinct trails in 56 sq. inches or one trail to 2 sq. inches. The trails bend sharply, cross, and occasionally combine, but there is no indication that the animals had any common trail or that they crawled over a former trail except by accident. The frequent turns in the trails indicate that the animals were not in the habit of progressing in a straight line and therefore it is inferred that their power of vision was extremely limited. Because there is no indication of common centers from which tracks lead and because the tracks end suddenly it is evident that the animals burrowed into the sand or mud and that the wet mud concealed the places where they disappeared and reappeared.

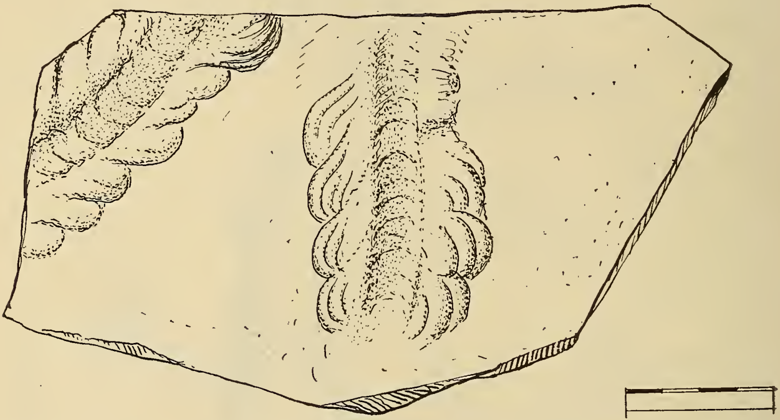

Fig. 3.—Short portions of two very well preserved trails showing the lobate character of the sand which was pushed aside during the advance of the animal. One-fourth less than natural size.

Professor Raymond has examined trails on beaches near Boston with reference to the origin of these tracks and he finds that the common gastropod *Littorina* practically duplicates them except that the convex ridges along center are not so steep as in some of the fossil trails. The ridges in the modern trails point forward and may be present or absent according to the firmness of the sand. Professor Raymond finds that both the direction and the preservation of the modern trails is dependent upon the condition of moisture on the beach as well as upon the composition of the beach surface. The gastropods make the trails when the beach is out of water and early drying is necessary for preservation. In addition to the positive evidence of the gastropodous origin Professor Raymond notes that the eccentric winding course is very different from the straight trails made by annelids. It is therefore concluded that both types of the Shafter trails were made by gastropods and that the difference between these trails was dependent upon physical conditions rather than upon different species of gastropods.

Art. V.—*Seaside Notes;* by Percy E. Raymond.

The logical place for the student of invertebrate fossils during the summer is at the seashore, but unfortunately most of us find ourselves occupied in the interior of the country when we leave our laboratories. Many things which have a geological or paleontological bearing are happening at the present moment, and it is the purpose of this note to record two observations which seem to have a certain significance.

Preservation of Jelly-fishes.

I happened in the early summer of 1919 to be on the sandy outer beach at Duxbury, Mass., on a windy day shortly after a storm. A large number of the common jelly-fish, Staurophora, had been driven inshore and when I arrived had been left stranded for some hours by the retreating tide. A stiff land breeze was drifting sand down the beach in considerable quantities, and much of it found lodgment in the jelly-fishes. The sand so caught adhered to the jelly-fish, which had lost so much water by evaporation that its thickness was less than one millimeter. Although the specimens had shrunk considerably, their diameters averaging from 90 to 100 mm., most of them retained a nearly circular outline. The sand varied from fine to coarse, and one specimen which I preserved has in it a flat pebble 14 mm. across.

I expected to find these specimens very fragile but had no difficulty in lifting them off the sand by taking hold of one edge and peeling them off slowly. I spread four of them flat in a newspaper and placed them under the back seat of the car. Three weeks later, on removing them, they had not changed in any respect. They were then laid on a laboratory table, still in the newspaper, and a book placed on them. At the end of three months they were in the same condition as when collected. They were still limp and flexible and could be lifted by the edge without pulling apart.

At this time I treated them lightly with shellac, which caused a certain amount of wrinkling and contraction, and has made them brittle. The specimens with the finest sand are of course the best preserved, but all still show more or less prominently the characteristic cross and the outline of the velum.

These observations suggest a method by which jelly-fish and other soft-bodied animals may at times have been preserved as fossils. The gelatinous material of the body appears to cement the grains of sand together, and at the same time, the mass of the latter checks the shrinkage. If particles of clay instead of sand covered the animal, the preservation would be much more perfect, and the extreme slowness of decomposition shown by the present specimens would indicate ample time for burial. Agassiz[1] long ago made this same observation in regard to the possible preservation of jelly-fish in sand. It is not, however, probable that permanent fossils could be formed in this way under the conditions which prevail on modern sandy beaches. In early Paleozoic times there were, however, extensive flats with aluminous or calcareous muds which seem to have been inundated periodically, perhaps in periods of persistent onshore winds, and then subjected to long periods of desiccation. These muds became thoroughly dried out and cemented between inundations, and conditions were optimum for preservation in the manner indicated above.

Trails.

Among the more common fossils are the little understood trails which are so frequently seen on the surfaces of layers of sandstone and shale. It has long been the custom to refer to them as ''worm trails,'' the idea having originated apparently from the fact that the early investigators (see particularly MacLeay in Murchison's Silurian System, 1839, p. 699 *et seq.*) considered them to be the actual impressions of Annelida. Nathorst long ago pointed out that many of them must have been made inorganically, or by Crustacea and Mollusca (K. Svensk. Vetensk. Akad. Handl., vol. 18, p. 66, 1881) and a visit to the seashore should be sufficient to convince any palæontologist that he was correct.

Winding, irregular trails are ascribed to worms, because they look like elongate chætopods, or masses of their castings. A little reflection, however, will show that it is just these trails, with their sharp turnings,

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[1] Contributions to Natural History of U. S. of America, 1862, vol. 4, p. 63.

which must have been made by short and not elongated animals. Investigations on the sandy beaches during the last few years have shown that whenever a trail-making animal can be identified, it invariably turns out to be something other than a worm. One of the most tortuous of the worm-like trails, seen usually in the troughs of ripple marks, is made by a small amphipod which travels about just beneath the surface of the sand.

One frequently sees on the mud by the roadside trails of the common earthworms. These are usually nearly straight, or in curves of long radius. Doubtless marine chætopods may come to the surface and crawl along, but I have not seen such trails on the beaches near Boston.

The most common trail seen in this vicinity is that made by the omnipresent gastropod, *Littorina litorea.* These animals live on those parts of the beach where there are rocks or other substances to which to cling, and during the time of ebbing of the tide, many of them crawl across the wet sand. The trail which they leave is generally a little wider than the transverse diameter of the aperture of the shell, is bounded by a pair of lateral ridges, and marked transversely by ridges which are bowed forward in the direction in which the animal travels. In creeping along, the outer lower part of the lip is directed forward and the spire points backward to the right. When moving forward the sand is pushed up in a little ridge ahead of the animal, then the shell is raised somewhat and pushed over the mound in front, so that the ridge is preserved even after the Littorina has crawled over it.

The trails vary a great deal according to the firmness of the sand. When the animal travels through water the lateral ridges are usually high and broad and the transverse ones are not seen at all. On very firm sand neither set of ridges is made, so that there is much change in the character of the trail from one point to another as it leads over the various inequalities of the rocky and rippled beach.

The course in the case of Littorina is usually quite straight except for deviations due to the various obstacles encountered, but the animals do sometimes wander rather aimlessly and make a considerably curved trail. One marking made by a Littorina was 13 feet long, and, to the outside of the lateral ridges, averaged from 11 to 12 mm. in width, except on firm sand, where it was 10 mm. The shell of the animal which made it measured 10 mm. across the aperture. There were six transverse bars in 33 mm. Another trail was 14 mm. wide, 2.50 mm. deep, and had 14 transverse ridges in 80 mm. A good photograph by Miss Dickerson of *Littorina litorea* and its trails may be seen in the American Museum Journal, vol. 16, p. 374, 1916.

Lunatia heros is another gastropod which makes conspicuous trails on the sandy beaches. Being a large shell it makes a broad track very similar to that of Littorina, but with much more obscure transverse ridges. The latter characteristic is probably due to the enormous size of the foot. This animal is in the habit of burying itself in the sand, and plowing along just beneath the surface. A trail can often be seen ending abruptly, with a little heap of sand at the end. Digging away the sand will reveal the Lunatia just beneath the surface. Such markings remind one very much of Climacticnites, and support Woodworth's contention that the famous Cambrian trail was made by a large Mollusk.[2] Climacticnites is essentially the same sort of trail as that made by Littorina, and since the transverse ridges point forward in the latter, Woodworth and Walcott were probably right in their interpretations of the direction of motion of the animal which made the former. The oval depressions at the end of the trail of Climacticnites seem to me not merely the place where it rested for a time. The specimen from the Potsdam at Moers, N. Y., now in the Museum of Comparative Zoology shows that the terminal impression was not a simple one, but there are two or three depressions at the end of each trail, all more or less irregular, and in one case the sand is piled up at one end, in another it has slumped at one side just as the sand appears after a Lunatia has buried itself.

The specimens of *Climacticnites youngi* figured by Walcott[3] also support the interpretation as the trail of a gastropod. These beautifully preserved specimens not only show the forward-directed transverse ridges produced by the foot, but also a series of very regular, closely

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[2] N. Y. State Mus., Bull. 69, 1903, p. 959.

[3] Smithson. Miscl. Colls., 1912, vol. 57, p. 259, pl. 38, fig. 1, pl. 39, fig. 2.

spaced curved lines such as might have been made by the frontal margin of the anterior part of the foot (propodium) which is most strongly developed in those gastropods which crawl on wet sand, and is apparently pushed ahead to smooth out the path of the animal.

Nicholson and Etheridge[4] figured the trail made by a recent Purpura, and called attention to the fact that it greatly resembled some of the markings ascribed to annelids. In spite of the evident similarity of this trail to those generally called Nereites, and which are so common in the early Paleozoic rocks of Europe and North America, Nicholson still referred the latter to the Annelida. Nereites is a trail with exceedingly numerous and abrupt turnings, and how an elongate animal like a chætopod could drag itself along and leave so sharp and clean cut an impression is difficult to understand. A short gastropod, hitching itself along, and wandering back and forth in search of food, would make just such a trail.

Hancock[5] was among the first to doubt the vermiceous origin of markings of this nature, and was led by observations on the beaches of Durham, Eng., to ascribe them to the activities of Amphipoda. Trails like that shown on pl. 14, fig. 1 of Hancock's paper are very common in the hollows between ripples on the beaches about Boston, and are made by small Amphipods. On plate 17 of the same article is represented a trail very like the smaller form described by Dr. Powers in the article accompanying this one. This nodular type of trail was explained by Hancock as due to the work of an amphipod or other crustacean burrowing its way, with frequent periods of rest, through a rather tenacious mud which was strong enough to prevent collapse of the tunnel after the animal had passed through. The nodular character he conceived of as being produced by a deviation of the animal from the horizontal plane, rising and sinking a little at each advance. The specimens which he described seem quite perfect, and do not show any trace of lateral ridges, and hence differ from the trails of gastropods.

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[4] Mon. Silurian Foss. Girvan Dist., fasc. III; reproduced in Nicholson & Lydekker, Manual of Palaeontology, ed. 3, 1889, vol. 1, p. 489, fig. 351.

[5] Am. Mag. Nat. Hist., ser. 3, vol. 2, p. 443, 1858.

Trails in the Pre-Cambrian.

The proper recognition of the origin of trails is of particular importance in the case of Pre-Cambrian strata. The following have been described as trails of worms by Walcott.[6] All were obtained from the Beltian of Montana.

Helminthoidichnites? neihartensis Walcott was described as the trail of a slender worm, a minute mollusk, or a crustacean. Walcott grouped this specimen with the worms, but evidently rather favored its interpretation as a mollusk, for he stated: "From the convolutions shown on the upper portions of figures 2 and 4 (pl. 24) the impression is given that the animal moved very much as a small mollusk does when wandering about on the mud at low tide." This view is the one shared by the present writer, and since mollusca other than gastropoda do not appear till very late in the Cambrian, it seems probable that this trail was made by some kind of a snail.

Helminthoidichnites? spiralis Walcott has the spiral form of a watch-spring and while it reveals no very conclusive evidence of its origin, is very likely organic, and if so, was probably formed by a small gastropod, since it lies entirely upon the surface of the layer, and is too smoothly coiled to have been made by an annelid in motion.

Helminthoidichnites meeki Walcott is from 1.50 to 2.00 mm. in width, and is notable for its remarkably symmetrical curves. It is not a furrow or ridge, but a plane marking such as might have been made by a gastropod crawling along and leaving a path of mucous behind it.

Planolites corrugatus Walcott was described as the cast of a burrowing worm, but is more likely a burrow. It appears to be 4 or 5 mm. in diameter, and along a part of it the cast is annulated, suggesting the former occupancy of a segmented worm. Such annulations are not, however, due directly to the segmentation of the animal which made them, but as an annelid eats its way through the mud, the material passes through the body and fills the tunnel behind, so that each segment of the fossil corresponds to a hitch forward, rather than to a portion of the body.

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[6] Bull. Geol. Soc. Am., vol. 10, pp. 236, 237, pl. 24, 1899.

Planolites superbus Walcott may or may not be organic. It has somewhat the appearance of the cast of a tunnel parallel to the bedding and if so, may have been made by a gastropod, a crustacean, or possibly, an annelid.

Only one of these Pre-Cambrian trails presents any appearance which would seem to entitle it to be called the burrow of a worm. The others are more probably either of a gastropodean origin, or are entirely inorganic.

The Preservation of Trails.

After studying the trails on the beaches it becomes evident that to allow their preservation somewhat unusual conditions must prevail. Trails made during the ebbing of the tide are completely obliterated in the flow, and those made in shallow water are destroyed by the motions of currents and waves. To insure preservation, it appears to be necessary that the mud shall contain sufficient cement, in the way of calcium carbonate, oxides of iron, hydrous silica, or finely divided clay, to consolidate the surface quickly. An example of the latter process was noted recently. A fresh bird-track was noted in mud which was not yet dry at noon on Monday. Tuesday noon it was dry and firm. Tuesday night there was a hard rain, and Wednesday noon the track was still visible, covered with about two inches of water and partially filled with fine mud. It had not lost its clear outlines and enough cementation had taken place during the drying process to allow preservation.

Although it is possible that such action may take place between tides, as indicated by Agassiz's oft-quoted observations on the calcareous mud of Florida, it does not occur in ordinary sediments. The flood plains of deltas, and the playa deposits of arid regions present ideal conditions, but such localities are not inhabited by marine animals. To preserve the trails of the latter requires the postulation of some such processes as are outlined above in connection with the jelly-fishes, and the abundance of trails in formations of all ages would seem to indicate the presence of marine playas throughout geologic time.

Geological Museum,
Cambridge, Mass.

ART. VI.—*The "Varve Shales" of Australia**; by T. W. EDGEWORTH DAVID, Professor of Geology and Physical Geography, University of Sydney.

1. *Varve Shales of Lower Carboniferous Age.*

Varve shales interstratified with beds containing the Carboniferous fossil ferns *Cardiopteris* and *Rhacopteris* have recently been described by Mr. Sussmilch and the author.[1] They occur chiefly at two horizons separated by 100 feet to over 600 feet of strata.

The specimen here exhibited is a laminated shale—laminæ of deep brick-red alternating with thinner laminæ of pink to light grey tint. It exhibits beautiful examples of minute contemporaneous contortions, affecting intermediate laminæ, but leaving those above and below the contorted zone quite undisturbed. The shales are interstratified with tillites, and glacial conglomerates and glaciated pebbles occur in turn. It is considered, therefore, that they are genuine Paleozoic "varves" as defined by Professor Gerard de Geer,[2] and described by Robert W. Sayles.[3]

The paired laminæ are very conspicuous and on the assumption that each pair of laminæ has an average thickness of two-tenths of an inch and that each pair represents one year's deposition of sediment, the authors have roughly counted the number of pairs in such sections as are available and estimated that the aggregate of 220 feet of varve shale required a period for deposition of at least 4,000 years. This is a minimum estimate. For example, in the specimen exhibited, which is 84 millimeters thick, there are twelve pairs of laminæ. If this were the average thickness of the paired laminæ the time needed for their formation would be nearer 10,000 years.

The authors ascribe the contemporaneous contortions in these "varves" to the movement of ice in some form tending to develop horizontal gliding planes.

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* Read at the First Pan-Pacific Scientific Conference at Honolulu, August, 1920.

[1] Sussmilch, C. A. and David, T. W. Edgeworth, Carboniferous and Permo-Carboniferous rocks, New South Wales, Journ. Roy. Soc., New South Wales, vol. 53, pp. 270-273, 1919.

[2] de Geer, Gerard, A geochronology of the last 12,000 years, Compt. Rend. Cong. Geol. Intern. Sess. II, pp. 241-253, 2 plates, 1910, 1912.

[3] Sayles, Robert W., The Squantum tillite member of the Roxbury conglomerate series. Memoirs, Mus. Comp. Zool. Harvard, vol. 47, No 1, 1919.

A fragment of the middle Carboniferous plant *Cardiopteris* is preserved at the top of the specimen exhibited and it is hoped that when these varves are examined in detail they will throw some light on middle Carboniferous chronology.

2. *Varve shales of late Proterozoic or Lower Cambrian Age.*

The specimens of laminated rock exhibited were obtained by Mr. E. C. Andrews and Mr. W. H. Browne at Campbell's Creek near Poolamacca, north of the Barrier mines at Broken Hill, New South Wales. They belong to the horizon of 'Tapley's Hill Shale,'' so named from the type locality near Adelaide, South Australia.[4] These shales immediately overlie the masses of tillite described by Professor Howchin as aggregating some 1,000 feet in thickness. There can be little doubt that they are "varve" shales, and that the laminæ indicate seasonal deposition. One specimen shows marked contemporaneous contortion. The paired bands have a maximum thickness of about one inch and their total thickness is about 1,000 feet. This gives a minimum of 12,000 years as the time needed for the accumulation of the Tapley Hill Shales.

[4] Howchin, Walter, The geology of South Australia, pp. 344, 362.

Art. VII.—*Mineralogy. Augite of Haleakala, Maui, Hawaiian Islands;*[1] by Henry S. Washington and H. E. Merwin, Geophysical Laboratory, Carnegie Institution of Washington.

The Hawaiian lavas are, on the whole, of very simple mineral composition,[2] but we know little of the chemical characters of the minerals that compose them. Augite and olivine constitute almost the only mafic minerals; the orthorhombic pyroxenes, amphiboles, and micas being seldom present in the lavas. Of the olivines we have one analysis,[3] that of one from a flow of Mauna Loa, Hawaii; and M. Aurousseau, of this Laboratory, is now studying others. But no analysis has been published of any augite from the islands, although this mineral is more constant and abundant in the lavas than is olivine, which frequently occurs as large phenocrysts and is therefore more prominent. Some knowledge of the general composition of the Hawaiian augite is consequently of considerable importance for the study of the petrology of the Hawaiian Islands, so it is a pleasure to have the opportunity to determine the optical and chemical data for a Hawaiian augite. The augite crystals described here were collected in September, 1920, by Dr. J. Allan Thomson, of Wellington, New Zealand, who very kindly placed them at our disposal for study, a courtesy for which we extend our hearty thanks.

The augite crystals were found "along the trail from the Rest House to Red Hill," a small parasitic cone at the southwest corner of the rim of the great crater of Haleakala, on the island of Maui. The crystals are unquestionably some of those that are mentioned by Cross[4] and other writers as abundant in this locality, and are probably derived from a lava that is perhaps identical with one which is called picritic basalt by Cross, who gives an analysis by Steiger.

The crystals vary from about one half to one centimeter in length, are of a shining jet-black color, and of

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[1] Received November, 1921.

[2] Cf. W. Cross, U. S. Geol. Survey, Prof. Paper 88, 1915.

[3] Analysis by G. Steiger, in Daly, Jour. Geol., 19, 295, 1911.

[4] W. Cross, U. S. Geol. Survey, Prof. Paper 88, p. 28, 1915.

the simple habit which is usually shown by such loose crystals of augite from basaltic rocks. The planes present are: *a*(100), *b*(010), *m*(110), and *s*($\bar{1}$11). Some of the crystals are twinned on the front pinacoid (100). The crystals were measured goniometrically, but subsequent sectioning showed the presence of a surface film, about 0.05 mm. thick, having a much higher refractive index, stronger pleochroism, and other properties, indicating a higher ferric iron content than the rest of the crystal, so that the goniometric measurements cannot be of definite value, and they are therefore not given.

In thin section the color is a very pale gray, almost colorless, but with a faint tinge of green; the pleochroism is so slight as to be scarcely noticeable. Extinction angles were measured on two sections parallel to the side pinacoid (010), cut centrally through two crystals that were twinned on *a*(100). The angle $\gamma \wedge c = 47°–48°$ for red (630 $\mu\mu$), and 49° for blue (480 $\mu\mu$). For the same wave lengths $2V_r$ measured 61°–62° and $2V_b = 58°–60°$. The birefringence $\gamma – \alpha$ on these sections was .024; $\beta – \alpha$ (calculated) is .006.

Measurements of refractive indices were made on a sample of the powder prepared for analysis. The lowest value found was 1.695, the highest was 1.727; β was 1.704–1.709. Thus, the following indices represent the material used for the chemical analysis; $\alpha = 1.700$, $\beta = 1.706$, $\gamma = 1.724$.

The density was kindly determined by Dr. L. H. Adams, using a pycnometer and thermostat, on the material used for the analysis. The value obtained was 3.358.

A chemical analysis was made of material carefully separated by heavy solutions and the electromagnet, that was practically free from the outer film and from glass and other inclusions. The powder was dried at 110°. The results are shown in the table of analyses, with analyses of other augites from basalts for comparison. The analysis does not differ materially from those of other augites from basaltic lavas, but the presence of about one-quarter of one per cent of chromic oxide is of interest. Steiger found 0.18 per cent of Cr_2O_3 in the olivine of Mauna Loa, and several analyses of various Hawaiian lavas show that this constituent is present in many of them in readily determinable amounts.

Analyses of augites from basalts.

	1	2	3	4
SiO_2	47.70	47.06	50.09	50.94
Al_2O_3	6.82	7.77	3.71	3.37
Fe_2O_3	3.36	1.30	1.47	2.05
FeO	4.43	8.15	4.96	7.41
MgO	13.34	13.52	14.01	14.59
CaO	21.35	19.33	22.48	20.34
Na_2O	0.65	0.33	0.73	0.61
K_2O	0.03	0.11	0.01	0.18
H_2O+	0.15	0.20	0.22	0.08
TiO_2	1.89	1.82	2.11	0.96
Cr_2O_3	0.23	trace	n. d.	n. d.
MnO	0.16	0.20	0.21	0.10
	100.11	99.85	100.00	100.71
Density	3.358		3.366	3.236

1. Augite, near Red Hill, Haleakala, Maui, Hawaiian Islands, Washington analyst.
2. Augite, near Grant's, Mount Taylor Region, New Mexico, Chatard analyst. J. S. Diller, U. S. Geol. Survey, Bull. 591, p. 149, 1915.
3. Augite, Monti Rossi, Eruption of 1669, Etna, Sicily, Washington analyst. Washington and Merwin, this Journal, **1**, 29, 1921. Corrected for 4 per cent of magnetite.
4. Augite, Il Liscione, Stromboli. Washington analyst, Kozu and Washington, this Journal, **45**, 467, 1918. Contains 0.08 SrO.

When we attempt the interpretation of the analysis in terms of mineral molecules we are confronted with the question of the disposition of the sesquioxides, that is, the alumina and ferric oxide above the amounts needed to form acmite or possibly jadeite molecules. This is the crux in the interpretation of all aluminous augites, and it is usually met, it is scarcely necessary to say, by the assumption of the existence of the so-called Tschermak molecule $(Mg, Fe)O.(Al, Fe)_2O_3.SiO_2$. This is not the place for a proper discussion of this vexed matter, which must be postponed to a later occasion when the general subject of the composition of the pyroxenes is taken up. It may, however, be said here that our studies so far have led us to disbelief in the existence of the Tschermak molecule, a conclusion in which we are at one with Boeke[5] and Zambonini.[6] We cannot, however, agree with Boeke's conclusion that "the aluminous monoclinic augite is

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[5] H. E. Boeke, Zs. Kryst., 53, 445, 1914.

[6] F. Zambonini, Atti Acc. Sci. Napoli, 16, No. 2, p. 9, 1914.

essentially a mix-crystal of the components SiO_2, CaO, (Mg, Fe)O, and $(Al, Fe)_2O_3$'' whose saturation boundaries are defined according to his tetrahedral projection. According to this view the aluminous augites would differ from the other pyroxenes in the lack of stoichiometric relations or the presence of definite molecules, and would be regarded as indefinite mixtures. Zambonini assumes the presence in the aluminous augites of three general molecules, diopside-hedenbergite (with their components), acmite-jadeite, and spinel. While we agree with him that the augites are best regarded as made up for the most part or almost wholly of the first two mineral molecule groups, yet there are serious difficulties in the way of assuming the presence of a spinel molecule to account for the presence of the sesquioxides. The most important of these, and the only one to be mentioned here, is that combination of the basic RO needed for the spinel would subtract just that amount from the bases needed to satisfy the silica in order to conform to the metasilicate ratio and would leave unsatisfied the equivalent amount of silica. This is especially true of the best analyses of the augites,[7] and would seem to be an insuperable objection to Zambonini's view of the composition of the aluminous augites.

For various reasons, which it is not necessary to discuss fully here, we assume that, in general, the alumina and ferric oxide (above that needed for acmite-jadeite molecules) are present as such in solid solution with diopside-hedenbergite (with or without clinoenstatite) and acmite-jadeite. As was pointed out many years ago by Piccini,[8] the Tschermak molecule is equivalent to one of $(Mg, Fe)O.SiO_2$ plus one of alumina or ferric oxide, that is, $RSiO_3 + R_2O_3$. It should furthermore be noted that the assumption of the Tschermak molecule binds an amount of (Mg, Fe)O, equal to that of the $(Al, Fe)_2O_3$, which would otherwise enter into the diopside molecule; this tends to the formation of molecules of wollastonite,

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[7] It may be pointed out that a very considerable number of the analyses of augite used by Boeke (and also by Zambonini), are of very poor quality, either because of imcompleteness (as regards titanium and soda especially), or because of inaccuracy in the execution (such as Doelter's analyses of Cape Verde augites). A much more critical and exacting selection of analyses is necessary for study of the problem.

[8] A. Piccini, Trans. Acad. Lincei, (3), 4, 224, 1880. Cf. Zambonini, op. cit., p. 10.

a mineral which must be regarded as but doubtfully pyroxenic, and which does not appear in the recasting of the best analyses of the non-aluminous pyroxenes.

The molecular composition of the Haleakala augite, on the basis assumed by us, and with titanium dioxide reckoned with silica, is as follows:

$CaMgSi_2O_6$	69.12
$CaFeSi_2O_6$	15.13
$NaFeSi_2O_6$	5.08
$MgSiO_3$	1.90
$FeSiO_3$	0.40
$(Al, Fe)_2O_3$	8.65
	100.28

The $SiO_2 + TiO_2$ demanded by the bases on this interpretation is (molecularly) 0.828 or 49.68 per cent (reckoned as silica), while there was actually found 0.819 or 47.70 SiO_2 + 1.89 TiO_2, that is 49.59 per cent, a fairly satisfactory agreement. The augite is thus essentially a hedenbergite-diopside, with small amounts of acmite, clinoenstatite, and alumina in solid solution.

It may be instructive to give the molecular composition as calculated on the basis of Zambonini's assumption, that the Al_2O_3 is present as a spinel ($RO.R_2O_3$) in solid solution. The composition on this basis is as follows:

$CaMgSi_2O_6$	58.97
$CaFeSi_2O_6$	12.65
$NaFeSi_2O_6$	5.08
$CaSiO_3$	6.61
$(Mg, Fe)O.(Al, Fe)_2O_3$	12.23
SiO_2 (excess)	4.20

This interpretation is clearly not as satisfactory as the preceding one, chiefly because of the presence of excess silica, and partly because of the presence of the doubtfully pyroxenic wollastonite molecule instead of the purely pyroxenic clinoenstatite molecule. The presence of both of these somewhat exotic molecules is directly brought about by the assumption of a spinel molecule rather than free alumina and ferric oxide in solid solution.

In calculating the mode from the norm in rock classification, it has been found to be very convenient to calculate the norms of the mafic minerals present in the rock (augite, hornblende, or biotite), the process being the same as that for the calculation of the norm of a rock, and to use the standard mineral molecules thus obtained for making the necessary readjustments.[9] The recalculation of norm into mode, or mode into norm, is thus much simpler than if the ratios of the various constituents of the mineral are used, as was advocated in the original publication of the quantitative classification.[10] The norm of the Haleakala augite is given here, as it will be of use in calculating the modes of many Hawaiian, and probably other, lavas.

Norm of Haleakala Augite.

Anorthite	15.57
Nephelite	3.12
Diopside	70.68
Olivine	2.23
Magnetite	4.87
Ilmenite	3.65
Chromite	0.37

Attention may be called to the presence of the outer film of more highly ferric material, which was noted on a previous page. This points to a state of more highly oxidizing conditions in the magma during the last stages of crystal growth. Possibly a similar relation might be detected in other zonally built augite phenocrysts by observation of the differences in extinction angle between the border and the interior, if a definite relation between the extinction angle and the ferric oxide content could be established. The case of our augite seems to be analogous with that of the acmite-aegirite group, in which it has been often noted that mixed crystals of acmite and aegirite generally show a border of acmite with an interior of aegirite. This is readily observable because of the very pale yellow color of acmite and the bright green, pleochroic color of aegirite. This subject of the higher state of oxidation of the iron in the outer parts of pyroxene crystals suggests some interesting lines of thought, but discussion of them must await another occasion.

Geophysical Laboratory,
Washington, D. C.

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[9] Cf. H. S. Washington, The Roman Comagmatic Region, Carnegie Publication No. 57, p. 134, 1906.

[10] Cross, Iddings, Pirsson, and Washington, A Quantitative Classification of Igneous Rocks. Chicago, 1903, p. 211.

ART. VIII—*Oligocene Rodents of the Genus Ischyromys*; by EDWARD L. TROXELL.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

A great diversity of form is shown in the rodents of the Early Tertiary period; some of these have lived even to the present time, others became extinct long ago and are only remotely connected with existing genera.

Leidy in 1856[1] first described the squirrel-like rodent which he called *Ischyromys typus*, and in 1889[2] published a detailed morphology of the skull and teeth, having not only a full appreciation of the relationship to the modern *Sciurus* but also a realization that the one was not ancestral to the other.

Cope in 1873[3] and 1881[4] added new points of interest concerning the skeleton, and further emphasized the relationship of this genus to the squirrels in the nature of the teeth, but to other genera, *Arctomys, Castor*, etc., in skull and skeletal features, and he agreed with Alston that there should be a separate family, the Ischyromyidæ. Several new genera and species were made by Cope, which he afterward concluded were synonyms of *Ischyromys typus* Leidy or belonged to entirely different groups.[5] *Colotaxis cristatus* and *Gymnoptychus chrysodon* are equivalent to Leidy's genus and species; they are based on what one finds to be moderate-sized specimens with or without the variable tubercles between the lobes of the lower molars.

Matthew[6] has worked out the interrelation of the early rodents and discusses in full the family Ischyromyidæ. His new species and subgenus *Ischyromys* (*Titanotheriomys*) *veterior* was based on the narrow heel of M_3, the narrow incisors, and the earlier geological age, i. e. Titanotherium beds. He places the following genera under Ischyromyidæ Alston: *Ischyromys, Paramys, Sciuravus,*

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[1] Joseph Leidy, Proc. Acad. Nat. Sci. Phila., **8**, 89.

[2] Joseph Leidy, Jour. Acad. Nat. Sci. Phila. (2), **7**, 335, pl. 26, figs. 1-6.

[3] E. D. Cope, Pal. Bull. No. **15**, p. 1; ibid., No. **16**, p. 5.

[4] E. D. Cope, Bull. U. S. Geol. and Geog. Survey Terr., vol. 6, 366-368.

[5] See O. P. Hay, Science (2), **10**, p. 253, 1899.

[6] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, 43-72.

Mysops, and *Prosciurus,* and comes to the conclusion that the genus *Ischyromys* reached extinction in Oligocene time. In the present paper, however, the suggestion is offered that they may have developed into the modern prairie-dog of the genus *Cynomys.*

Description of New Species.

Ischyromys pliacus, sp. nov.

(Fig. 1.)

Holotype, Cat. No. 12511, Y. P. M. Middle Oligocene, Cherry Creek, Colorado.

Fig. 1.—*Ischyromys pliacus,* sp. nov. Lower right dentition of the largest species of the genus. Note the many small cusps on teeth. Holotype. Cat. No. 12511, Y. P. M. × 2.

This specimen, consisting of the right lower jaw, is notable for its large size and for the great number of tubercles and deep pits on both premolar and molars. The posterior cross crests do not arise directly from the external tubercle but from its union with the central longitudinal ridge, thus forming a "Y". This cross crest is made up of two distinct minute cusps, but only on P_4 and M_2 are they still unworn. Small additional tubercles are to be seen on the posterior side of the anterior cross crests on all the teeth and conspicuous cusps occupy the wide openings of the external grooves.

Measurements are given in a table further on.

Ischyromys typus nanus, subsp. nov.

(Figs. 2, 3.)

Holotype, Cat. No. 12519, Y. P. M. Oligocene (lower Oreodon beds), Warbonnet ranch, 12 miles north of Harrison, Nebraska. Paratype, Cat. No. 12555. Gerry's Ranch, Weld Co., Colo.

The specimens here described consist of the small lower jaws with the molar teeth. The holotype was a part of a young animal in which the last molar was just being cut. Besides the fact that this is the smallest subspecies of ischyromyds, it is further distinguished by the very narrow M_2 and by the general absence of secondary tubercles, external basal cusps, etc. In the ratios given in the table beyond, it is seen that *I. pliacus* is over 50 per cent larger in certain dimensions and averages about 30 per cent greater.

Fig. 2

Fig. 3

Fig. 2.—*Ischyromys typus nanus,* subsp. nov. Holotype. Cat. No. 12519, Y. P. M. Three molars from right lower jaw. $M^{1.2}$ very narrow. × 2.

Fig. 3.—*Ischyromys typus nanus,* subsp. nov. Paratype. Cat. No. 12555, Y. P. M. Left lower molars, to show results of wear. × 2.

Ischyromys typus lloydi, subsp. nov.

(Figs. 4, 5, 7.)

Holotype, Cat. No. 12521, Y. P. M. Oligocene (lower Oreodon beds), from the ranch of Mr. Paul Zerbst, 10 miles north of Harrison, Nebraska.

This new subspecies is based upon an unusually complete skull and jaws, together with certain portions of the skeleton. These were found in 1915 by the writer who takes pleasure in adding them to the collections of Peabody Museum. The new name is given in honor of Dean Lloyd of the University of Michigan, in appreciation of a delightful friendship.

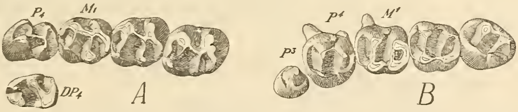

Fig. 4.—*Ischyromys typus lloydi,* subsp. nov. Holotype. Cat. No. 12521, Y. P. M. × 2. *A,* molars and premolar of lower right side, and single deciduous premolar, Dp_4, from opposite side. *B,* left upper molars and premolars; the latter were drawn from a vertical position, and the skull was then rotated inward in order to get the crown view of the molars.

The specimen is moderate in size and corresponds in general to the dimensions of *I. typus* Leidy. The upper molars, unlike those in most specimens, do not decrease in size toward the rear, for the last molar is actually greater than the premolar or M^1. The third permanent premolar, the first of the cheek series, is just coming into view; it was actually hidden beneath the conical deciduous predecessor when first worked out of the matrix. A single tubercle with a crescentic ridge on the postero-internal corner forms the crown of this tooth, which in shape and size resembles the lead of a pencil, an elongated cylinder.

P^4 is distinctly molariform, but small and nearly round. Unlike the molars, it has no internal groove and the cross crests extend more than halfway across the crown. This tooth now stands vertical in the maxillary, but had it grown to its normal position, it would have turned outward, following the curve of the large interior root, to face more nearly like the molars.

M^1 and M^2 are alike in general form. In each, the posterior groove, after slight wear, becomes a pit near the center of the posterior side. M^3 seems to be slightly rotated backward and inward, giving the cross crests an oblique direction; it is elongated fore and aft. The triangular area about the posterior pit is small.

The lower molars have the two simple outer cusps with the two main, parallel cross crests leading from them. The crowns are higher and the teeth are larger and wider than in *I. typus nanus* just described. The last molar is the widest; the first is narrowest and the total length of the three molars is 10 per cent greater than that of *I. nanus*. In all the subspecies of *I. typus* there is a notable absence of small secondary cusps.

The first premolar was just appearing in the lower jaw to take the place of the single deciduous tooth which had been serving the young animal. Dp_4 is elongated but narrow and has a low crown. The anterior cusps are not paired transversely, for the inner one is placed far anterior. (See fig. 4 *A*.)

The lower jaws are short and relatively deep; the ventral border forms a broad curve backward to a point beneath M_3; here there begins a reverse curve and the thin edge is folded inward to lend support to the pointed angle. The coronoid extends as far above the condyle as the angle does below; the two together give a vertical measurement of about 26 mm. to the posterior part of the ramus. On the upper side of the ridge leading to the condyle opens the mandibular foramen; this passage then leads down and forward, following along the upper surface of the incisor root within the ramus, and finally emerges in the mental foramen just in front of P_4. Except for the greater height of the ascending ramus, the extended angle, and the lack of a distinct muscle scar on the outer surface, this mandible resembles that of *Sciurus*, cf. *S. carolinensis.*

Additional distinctive features in the present subspecies may be noted in the vascular impressions on the supra-occipital and the slight overhanging of this bone, the large otic bullæ, slightly crushed down, the flat triangle formed by the sagittal crest where it joins the inion, and the absence of a deep groove on the zygomatic pedicle near the maxillary.

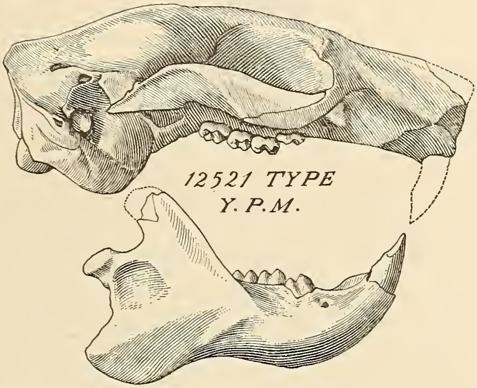

Fig. 5.—*Ischyromys typus lloydi,* subsp. nov. Holotype. Cat. No. 12521, Y. P. M. Side view of skull and jaws. Premolars just coming into view. Skull slightly bent downward by crushing. Nat. size.

Measurements of Holotypes.

	I. nanus mm.	Ratio	*I. pliacus* mm.	Ratio	*I. lloydi* mm.
Length of three lower molars....	9.8	124	12.2	113	11.1
Length of M_1	3.2	116	3.7	113	3.6
Width of M_1	2.7	137	3.7	119	3.2
Length of M_2	3.2	125	4.0	116	3.7
Width of M_2	2.7	152	4.1	126	3.4
Length of M_3	3.2	131	4.2	119	3.8
Width of M_3	3.0	123	3.7	110	3.3

INTERPRETATION OF ISCHYROMYS.

Wear of the teeth.—The long transverse ridges or crests and the corresponding grooves led Leidy to observe that the upper teeth were like the lower ones reversed; this is true, however, only in a general sense. In addition to the transverse crests of enamel, the teeth show series of ridges clearly the result of lateral wear; furthermore, the upper teeth are often worn to the roots on the inner side while the outer borders still stand high. This gives evidence that the movement of the jaws was transverse rather than longitudinal as in the case of many rodents where the grinding surface as a unit is worn to one smooth plane (cf. the water hog, *Hydrochœrus capybara*).

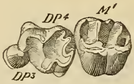

Fig. 6.—Upper milk teeth of *Ischyromys typus* Leidy, Cat. No. 12508, Y. P. M. Dp^3 is very much like the premolar which succeeds it. Dp^4 is short-crowned, but elongated fore and aft. Note that the first molar faces outward. × 2.

The third superior molar is set in the maxillary facing downward and outward at an angle of more than 40°, but the deviation from the vertical is progressively less toward the anterior teeth; the lower teeth correspondingly face upward and inward. In the action of chewing, therefore, the first contact is formed by the vertically placed premolars, then, as the lower teeth move inward, the molars from front to rear successively come into use.

Taking each tooth separately, its action may be analyzed into a chopping process with the first contact of the sharp grooves and crests; this becomes secondarily a tearing or grinding where two teeth are fully opposed; at that phase the inner tubercles of the upper tooth and the outer cusps of the lower tooth resist further lateral movement, thus causing additional grinding of the food particles.

The milk teeth, like the premolars in their early stages, stand vertical both above and below, but the wear of these teeth indicates that the immature individual has already learned the transverse movement of the jaws. There are two milk teeth above and one below in the young animal.

Relationship and adaptations.—A most interesting comparison may be made between *Ischyromys*, the fossil, and *Cynomys*, the prairie dog, and although certain features stand out sharply separating the two genera, yet they show a fundamental similarity which tells of close relationship. The skull of *Cynomys* (Cat. No. 01228,

Y. P. M.) is about the same length but broader, especially across the temporal portion of the zygomatic arch; there are strong postorbital processes which are entirely absent in the fossil. Further distinctions of *Cynomys* are the narrower antero-posterior dimension of the teeth, the large P^3 and $M\frac{3}{3}$, the anterior position of the infraorbital foramen resulting from the large groove anterior to and beneath the zygomatic projection of the maxillary, the large angle of the lower jaw with numerous additional projections for muscle insertions, the decrease in the size of the coronoid, the longer segments of the hind limbs with the cnemial crest of the tibia and the third trochanter of the femur far up on the shaft, the single groove (instead of double as in the fossil) on the distal end of the tibia for the tendon of the deep digital flexor running to the sole of the foot, and the large, longer claws.

Important similarities, on the other hand, may be noted in the structure of the teeth with the cross crests of enamel, the shape of the occipital region of the skull and the sagittal crest, the form of the nasals and premaxillaries, the peculiar supra-auditory foramen, and the same dental formula. There is a remarkable agreement in the size and form of the humerus and of the distal end of the femur in each genus, both being distinct from those of the squirrel, *Sciurus*. In the humerus there is a strong deltoid crest, a wide condyloid crest on the outer side, and a supracondylar foramen on the inner side distally. This foramen, according to Flower, is a departure from the general rodent humerus, but is seen in the wombat and in certain carnivores. It is thought probable that the spiral condylar grooves on the humerus permit a freer movement of the ulna and allow its rotation for swimming or burrowing as in the beaver, while the large deltoid prominence and the lateral condyloid crest, again like those of the beaver, tell of the strong muscles which manipulated the front limb.

An objection which may be offered to any theory attempting to derive *Cynomys* from *Ischyromys* is the presence of the very small third premolar in the latter. This resolves itself into the question whether P^3 of the fossil is reduced to a vestigial state and therefore much advanced in evolution, or whether it is small and yet undeveloped but has within it the potential molariform tooth of *Cynomys*.

The prairie dog now occupies the same Great Plains region where once scurried the small ischyromyds, but the conditions are greatly changed: the former is a burrowing animal in a semi-arid climate; the latter lived where the Oligocene streams from the young Rocky Mountains spread widely their flood waters, just as the rivers from the east slope of the Andes do to-day. This probably necessitated burrowing in the dry seasons and at other times called for the ability to cope with the rising flood.

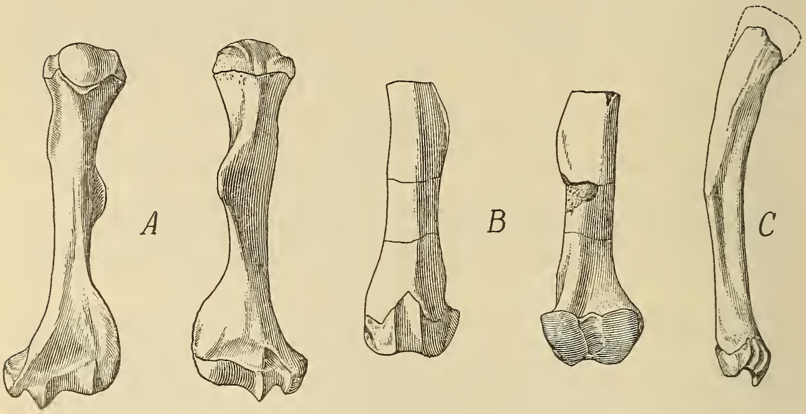

Fig. 7.—*Ischyromys typus lloydi,* subsp. nov. Holotype. Cat. No. 12521, Y. P. M. Nat. size. *A,* front and back views of humerus; note broad distal end, supracondylar foramen on posterior side, spiral condylar grooves, and large deltoid crest on one side. *B,* front and rear of distal end of the heavy femur. *C,* right tibia viewed from inner side, showing deep double groove for tendons to the foot. (See also figs. 4 and 5.)

Art. IX.—*Glaciation of the Mountains of Japan**; by N. Yamasaki.

Glaciation, which played so important a role in the development of the topography of parts of Europe and America, is as yet known only in a few places in eastern Asia. In China proper there are only a few evidences of glaciation. Loczy notes its existence on the great snowy mountains on the western boundary of the Province of Szechuan. He also observed moraines on an eroded plateau in the same mountains, but at an elevation below the extremities of the present glaciers. We have no further information as to the existence of glaciers in any of the other high mountains of that mighty country, save the discovery of tillite of great geologic age near the Yangtze Gorge by Willis and Blackwelder. There is scarcely a report of the existence of glaciation farther north, in the Amur Region, the Littoral Province, Kamtschatka or in Siberia.

It is only recently that the question of glaciation in Japan has attracted the attention of scientists and been discussed by them. Forty years ago the Hida Mountains, a lofty chain in Middle Japan, had already been visited by a score of foreign alpinists. Among them, Atkinson reports that the snow of the snowfield on Mount Hakusan and Mount Tateyama near the coast of the Japan Sea is hard enough to be called ice. Kinch, who crossed the famous Harinoki Pass, described three or four snowbeds and miniature glaciers. Divers also observed in the same region some snowfields with the characteristic appearance of glaciers. John Milne, then professor at Tokyo, compiled their observations and came to the conclusion that at an elevation of about 5,000 feet in middle Japan and at 4,000 feet a little farther north, near the coast of the Japan Sea, there are fields of permanent snow, which are sometimes so firmly consolidated as to form small glaciers. He further proved the possibility of Pleistocene glaciation in Japan on the ground of climatological and biological data. He also reported the presence of "roches moutonnées" on Gassan, a high, dormant volcano

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* Read at the First Pan-Pacific Scientific Conference at Honolulu, August, 1920.

in North Japan, but later observers are doubtful of their character.

Since that time no further investigations were reported, not even from Milne, until recently some of our geographers took up the subject again. I have always been of the opinion that there may be some traces of glaciers in our mountains, especially the lofty ones of Middle Japan, for there are several peaks 3,000 meters or more in height, which have snow during nearly all of the year in consequence of the heavy precipitation that results from the oceanic climate. The winter snowfall is greater than that of the European Alps. Moreover the temperature does not differ greatly from that of the Alps. So believing the possibility of the existence of glacial features in our lofty mountains, I have visited them several times to investigate the question more thoroughly. Fortunately I made the discovery of topographic forms characteristic of glaciated mountains with the supporting evidence of moraines and striæ which show the former existence of an ice covering in these mountains.

Now let us consider the topography of Middle Japan. In the center of the main island of Japan, where the two principal mountain arcs of North Japan and South Japan meet, the terrestrial configuration attains its greatest complexity. Several mountains, both tectonic and volcanic, stand side by side and upon one another. Indeed the renowned volcanic chain of Fuji, with its numerous gigantic cones, traverses the island and occupies the depression zone between the precipitous scarps of the two principal arcs. Especially esteemed for their prominent features are the mountains that lie on the western side of the Fuji chain and form the northern extremity of the southern arc of the cordillera of our archipelago. Their culminating peaks are 3,000 meters in elevation, or even more. The ridges are sharp and ragged, forming sometimes pointed needles, pinnacles, or steep rocky walls facing gorges a thousand meters deep. These scenes are of truly Alpine character, and some years ago these mountains were given the popular name of "The Japanese Alps." There are three principal mountains, namely Akaishi, Kiso and Hida, which run parallel to each other and trend southwest to north-northeast. Of these, Hida is the highest and most characteristic. It forms the eastern margin of Hida Plateau and falls abruptly to the rift valleys of Matsumotodairai and Himekawa with precipitous fault scarps. The most gigantic and imposing view that it presents attracts many alpinists every summer from all parts of the country. Yarigataka or Spear Peak, often called the Japanese Matterhorn, Shiroumadake, Hodakayama, Kurodake, Yakushidake, and Tateyama are the best known peaks. Besides them, Ontake, Norikuradake and Yuodake are eminent volcanic cones and lie in the southern part of this mountain. Hari-nokitoge is noted as the highest mountain pass in Japan.

Climatologically treated, there is at present no mountain in Japan from the central chain of the Island of Sakhalin on the north to the backbone of Formosa in the south (nearly 4,000 meters high) which rises above the snowline. Even the beautiful snow-clad cone of Fuji, 3,778 meters high, loses its white cap in midsummer, leaving only small patches or streaks of snow on the shaded side of the crater or in the radial valleys. The same is true of the northern part of the Japanese Alps. The annual precipitation in this region is as high as 2,500 millimeters, owing to the great winter snowfall. Not on the mountain itself, but on the plains or hills at the foot of its northern slopes, the snow is so deep that small village houses are entirely buried in it. On the ridges and flanks of the mountains there are many patches of snow even in midsummer. These, however, gradually melt away before the next snowfall—by the end of October at the latest. But it is not infrequently observed that rather large snowfields, often a few meters deep, last through the year in shaded valleys or below cliffs. Most of these snowfields consist merely of snow, but in some cases, as I have observed in Shiroumadake, for example, the snow is consolidated partly to translucent ice near its base. One might give the names "puny glaciers" or "miniature glaciers" to such ice masses.

The climatic conditions in these mountains are not far different from those of certain other regions where glaciers are found at present. We have no meteorological stations on any peak of the Japanese Alps, but if we compare the temperatures of three meteorological stations in the towns of Takayama, Matsumoto, and Nagano near the mountains, with that of Vienna at the foot of the European Alps, we can prepare the following table in which temperatures are reduced to sea-level.

Station	Elevation, above sea-level, meters	Temperature, Annual, C.	January Temperature	July Temperature
Takayama	561.4	10.0°	—2.3°	21.8°
Matsumoto ...	582.1	10.1°	—2.1°	22.0°
Nagano	420.4	10.9°	—1.5°	22.9°
Average ...	521.3	10.3°	—2.0°	22.2°
Vienna	170.0	10.0°	—1.6°	22.5°

The temperatures at the four stations are nearly equal to each other, while the elevations of the Japanese stations are greater than the elevation of the Vienna station. Dachstein, near Vienna, in the northern Limestone Alps, has its snow-line below 3,000 meters elevation, and Hohe Tauern in the Central Alps is covered with permanent snow at an elevation of 2,860 meters. Of course, snowfall and glaciation are influenced by not only temperature but also by other controlling conditions such as the amount of precipitation, the humidity, the direction of the prevailing winds, and topographic features. If we consider only temperature, we find that the snow-line for the Japanese Alps would be only a few hundred meters above their summits, so that with a fall of only a few degrees in temperature the snow-line would be depressed to these peaks. The precipitation would be sufficient to make snowfields and glaciers.

In the course of a close examination of the topography of the mountains we found various characteristic forms of ridges and valleys due to glacial processes. The most distinctive feature is the occurrence of cirques or kar at the valley heads near the crests. Along the crest of the central range of the Japanese Alps proper or the Hida Mountain, from the gigantic needle of Yarigatake to the renowned peak of Shiroumadake, we find this particular type of topography. Again, nearly a dozen cirques lie side by side on the ridges of Yakushidake and Tateyama, to the west of the former, and between them is the deep gorge of Kurobe. If we stand on a prominent peak, such as Tateyama, it is not difficult to find a score of cirques on the surrounding mountains. Some of them, and the valleys below them as well, are often covered with snow patches in midsummer days. Weathering and erosion have not as yet altered the forms greatly, and they are still fresh and well preserved. Where many cirques lie close together, as in Kurotake and Yakushidake, characteristic comb-ridges are formed between them.

The most important and peculiar feature of these cirques is that their floors are all of about the same height above sea-level, as shown in the following table:

	Meters.
Goro	2550
Mitsu	2600
Harinoki	2500
Nakanomata	2550
Kurotake	2500-2600
Yakushi	2600
Renge	2500
Tateyama	2500-2600

In short, the cirque floors range from 2,500 to 2,600 meters in elevation, and average 2,550 meters. What is the significance of this regularity? Perhaps there is no better explanation than a former lower altitude of the snow-line. Above this level the lofty ridges of the Japanese Alps were once covered with permanent snow, and just below there were hanging glaciers here and there along the flanks of the ranges. Of course these glaciers were not so large or extensive as those which existed in the European Alps during the last ice age. We have not yet found any morainal landscape at the foot of the mountains. There are neither terminal moraines nor glacial lakes at the lower extremities of the mountain valleys. The glaciers must have terminated at a little higher elevation. Perhaps certain exceedingly deep incisions in the upper parts of the valleys are due to glacial erosion. Other indications of glaciation that have been noted are the striations on the rock blocks of Shirouma and the moraines in several places, especially the peculiar moraine mounds in a high valley basin of Kamikochi near the famous peaks of Yarigatake and Hodakayama, which were recently discovered by the late Professor Ozeki.

There is no question at present as to the glacial origin of the peculiar features of our lofty mountains, and it remains only to discuss when this glaciation took place. We have not come to any satisfactory conclusions on this question as yet. The correlation of that period with the ice age of Europe and America is too difficult with our present knowledge. We have not yet found any glacial or glacio-fluviatile strata of diluvial age of undoubted extension. Most of the Tertiary and post-Tertiary strata that have been studied to date consist of marine or brackish water formations, and our paleontologists are eagerly endeavoring to determine the climatic conditions of that epoch with especial reference to their fossil faunas. Their opinions are as yet in disagreement. According to Prof. Yokoyama of Tokyo University, who has studied especially the formations of Tertiary and later ages in the approaches of the Bay of Tokyo, the climate of Middle Japan in the Pliocene was colder and then became warmer in the diluvium than at present. So he denied the evidence of an ice age in our diluvium. On the other hand Professor Yabe, of the University of Sendai, holds that at the end of the Tertiary the climate of Japan became gradually colder and reached the minimum temperature in the ice age, after which it became somewhat warmer but again colder until it attained the temperature of the present.

Summing up briefly what I have mentioned here, the lofty mountains in Middle Japan in 36° north latitude were once covered by permanent snow and bore glaciers. Their existence is clearly proved only by the characteristic cirque topography with the corroborating evidence of moraines and striae. The floor of many cirques are nearly at a uniform elevation, 2,550 meters, which marks the former snow line. The glaciers were hanging glaciers and not of great extent and were located near the summits of the ridges. No glacial or glacio-fluviatile deposits have been discovered as yet that would allow of exact determination of the date of the glaciation. In short, the glaciated area of Japan is limited to a small district of high elevation, in great contrast to the vast extent of the glaciated areas of America and Europe. The lack of traces of glaciation in eastern Asia, even in high latitudes, will also deserve further research. How and when did the ice age occur in our country? How is it related to that of other regions? Other equally important subjects for investigation are the direct cause of the change of climate, and its influences on topography and the distribution of fauna and flora. Of course it is not our aim to attack the problem of glaciation and subordinate questions from only the geographical point of view. Help from geology, paleontology, astronomy, climatology, biology and all allied sciences must be cordially accepted. Especially necessary are actual observations and comparative study of the data. To such research, I am sure, this Conference will give the best opportunities, and I beg you, gentlemen, to kindly help me with your valuable suggestions as to the present subject.

Art. X.—*Studies in the Cyperaceæ;* by Theo. Holm.

XXXIII. *Carices aeorastachyæ: Macrochætæ* nob. and *Nesophilæ* nob. (With 12 figures drawn from nature by the author.)

Among the tristigmatic sections of the *Aeorastachyæ* the *Macrochætæ* comprise only a few species, viz. *C. macrochæta* C. A. Mey., *C. flavocuspis* Franch. et Sav., *C. gansuensis* Franch., and *C. scita* Maxim.

C. macrochæta:

For many years this species has passed for *C. podocarpa* R. Br., as stated in a previously published paper.[1] C. A. Meyer described the species,[2] and has given an excellent figure of it; some parts of the diagnosis may be reprinted here inasmuch as, after all, the original diagnosis is the most important:

> "Carex spica mascula solitaria, femineis binis distantibus pedunculatis fructiferis subnutantibus, stigmatibus tribus, perigyniis laevibus compressis oblongo-lanceolatis acutis ore integerrimis, gluma aristata brevioribus, bracteis foliaceis amplectentibus. . . . Folia floralia basi auriculato-amplectentia (nec vaginata); infimum culmi partem superiorem excedens, superius setaceo-filiforme spica duplo triplove longius. . . . Glumae masculae et femineae oblongae, acutae, carina setaque longissima scabra flava instructae; caeterum piceae et margine omnino concolores. . . . Perigynium obsolete nervosum, basi flavescens, apice piceum, glumarum seta multo brevius. . . . Stigmata tria, rarissime duo."

The species is aphyllopodic, and remarkably constant in its habit, inflorescence and flowers. The terminal spike is usually staminate, but in a few specimens from Unalaska this was either androgynous, gynæcandrous or even entirely pistillate. The number of lateral spikes varies from one to four; our material, representing sixty one specimens, showed:

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[1] This Journal, vol. 48, p. 17, 1919.

[2] Cyperaceæ novæ descriptionibus et iconibus illustratæ. (Mém. Savants Etrangers, St. Petersbourg; vol. 1, p. 30, 1831.)

1 staminate spike in 50 specimens.
2 “ “ “ 11 “
3 pistillate “ “ 33 “
2 “ “ “ 26 “
1 “ “ “ 2 “

The relative length of the staminate and pistillate scale, and the perigynium varies considerably even in the same spike, when examined from base to apex. For instance, in the typical plant we measured these organs, and the length of the staminate scale was 10 mm., including the arista, 3 mm.; in the same specimens the length of the pistillate scale was 8.5 mm. including the arista, 3.5 mm.; the length of the mature perigynium was 5 mm., and the width 2.5 mm. But in some specimens from Unalaska of which the spikes were exceptionally thick and heavy, the following measures were observed: The staminate scale was 19 mm. in length, including the arista, 8 mm.; the length of the pistillate scale, from near the base of the spike, was 23 mm., including the arista, 10 mm.; at the middle of the same spike the pistillate scale measured 20 mm., including the arista, 10 mm.

We have described two varieties: *emarginata* (figs. 4-6) from Alaska: Kukak Bay, and *macrochlæna* (fig. 7-9) from St. Paul Island, Bering Sea.[3] Of these the latter possesses remarkably large perigynia, measuring 7 mm. in length, and 3 mm. in width, while the subtending squama measured only 6 mm. in length, including the arista, 1.5 mm.

Typical *C. macrochæta* is widely distributed on the coast of Alaska, extending to Yukon, Washington and Oregon; it occurs on the Asiatic coast: St. Lawrence Bay, Kamtschatka and Sachalin. A near ally of *C. macrochæta* is:

C. flavocuspis.

Franchet has redescribed the species[4] and the diagnosis reads as follows:

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[3] This Journal, vol. 17, p. 314, 1904.

[4] Les Carex de l'Asie orientale (Nouv Arch. Mus. d'hist. naturelle, ser. III, vol. 9, p. 143, Paris, 1897).

"Rhizoma stoloniferum, stolonibus gracilibus, horizontalibus; culmi debiles 20-30 cm. alti, acute trianguli, etiam superne leves, inferne tantum foliati; vaginae infimae fulvae; folia culmos aequantia vel superantia, mollia, 4 mm. lati; bracteae, evaginatae, inferior foliacea inflorescentiam superans; spiculae 3-4 inferiores pedunculatae, pedunculis ochrea fusca 5 mm. longa, cinctis; spicula mascula unica, late oblonga vel oblonga, circiter 2 cm. longa, squamis obovatis, fuscis, dorso lutescentibus, nervo in mucronem levem excurrente; spiculae femineae 2-5 cm. longae, superior sessilis, squamis intense fuscis oblongis, masculis homomorphis sed longius acuminatis; utriculus 4 mm. longus squamas subaequans, laete virescens, apice fuscescens, compressus, ellipticus, margine et faciebus levis, in rostrum breve paulo emarginatum sensim desinens; stylus trifidus, achaenium sessile. Hab. Le Japon: île de Nippon, etc."

C. gansuensis.[5]

"Repens; culmi 40-70 cent., acutanguli, etiam apice leves; folia 4-6 mm. lata, culmis breviora; bractea inferior foliacea, inflorescentia brevior; spiculae 3-4, omnes pedunculatae, suprema tota mascula, rarius feminea superior subsessilis; spicula mascula linearis, squamis rubro-fuscis, oblongis, mucronatis; spiculae femineae cylindraceae, inferne et superne attenuatae acutae, inferior paulo remota, pendens 3-4 cent. longa; squamæ fuscae, ovato-lanceolatæ, mucronatæ vel breviter cuspidatae utriculos vix superantes, utriculi ovati, nervosi, leves, apice attenuati, in rostrum tubulosum ore truncatum 1 mm. longum desinens; stylus trifidus.

Hab. Le Japon.

Rappelle assez bien le *C. Gmelini,* mais les feuilles sont plus larges, les écailles au moins aussi longues que les utricules et terminées par une pointe lisse; le bec des utricules est aussi sensiblement plus long."

These two species are so well defined by Franchet that there seems no doubt of their validity as distinct species. The fact that Kükenthal (1. c. p. 414) has disposed of them as mere synonyms is of no importance, and especially not, when we examine his compilation of the so-called "*Scitæ*"; in this section, which is characterized as being composed of "*Aphyllopodæ,*" we meet with several species, which nevertheless are true "*Phyllopodæ,*" namely *C. rariflora* Sm. (*C. podocarpa* R. Br.), *C. microchæta* nob., *C. nesophila* nob., and *C. littoralis* Schw.

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[5] Nouv, Archives l. c., p. 152.

C. scita.[6]

''Rhizomate brevi obliquo squamis castaneis tecto stolonifero, culmo fertili 3-pedali gracili trigquetro laevi ac fasciculo sterili per bina appositis basi squamis castaneis superioribus laminigeris vestitis, foliis linearibus acuminatis carinatis margine reflexo remote scaberulis culmo breviaribus, inflorescentia brevi e spiculis 4-6 pedunculatis multifloris: terminali ♂ oblongo-lineari utrinque attenuata erecta, reliquis apice masculis, superioribus 2 approximatis breve pedunculatis erectiusculis, inferioribus distantibus pedunculos teretiusculos laeves superantibus nutantibus, fructiferis oblongo-ellipticis v. oblongo-lanceolatis pollicaribus v. brevioribus, bracteis foliaceis non vaginantibus, infima culmum superante, sequente subaequante, tertia spiculam quartaque pedunculum subsuperante fere setaceis, squamis (infimis vacuis) lanceolato-linearibus atris utriculo brevioribus et angustioribus costa viridi sensim in aristam scabram utriculo et in inferioribus squama longiorem abeunte, utriculis erectis triquetris membranaceis viridibus secus angulos superne atrodenticulatis quavis facie tenue 2-3-nerviis oblongo-linearibus ore parvo quasi immerso brevissime bidentatis, stigmatibus 3 (2) late villosis stylum inclusum parum excedentibus, caryopsi in medio utriculo laxe nidulante in stipitem stylumque sesquibreviores sensim attenuata lanceolato-elliptica acute triquetra laevi straminea faciebus convexiusculis.

Nippon media, ad rivulos, verosimiliter in montibus Hakone.

In serie mere artificiali androgynarum prope *C. scitulam* Boott. (Ill. IV. 177. t. 600) ponenda, sed ab omnibus hisce jam culmis basi squamatis abhorrens. Quo ultimo signo et gracilitate appropinquat speciebus distigmaticis *C. cryptocarpae* C. A. Mey. et *C. Middendorffii* F. Schmidt., signis numerosis tamen adhuc diversis.''

In the work of Franchet, cited above, some species are described which evidently are close allies of *C. scita,* viz. *C. riishirensis, C. scabrinervia, C. xanthathera* and *C. urolepis,* all from Japan, but of which we have no material for comparison. Moreover Meinshausen[7] has described a species *C. koraginensis* from Koraginsk, Kamtschatka, which evidently also belongs to this section.

The *Macrochaetæ* represent a very natural section; the species show the same general habit, and are aphyllopodic. The distribution of the sexes varies but slightly; we

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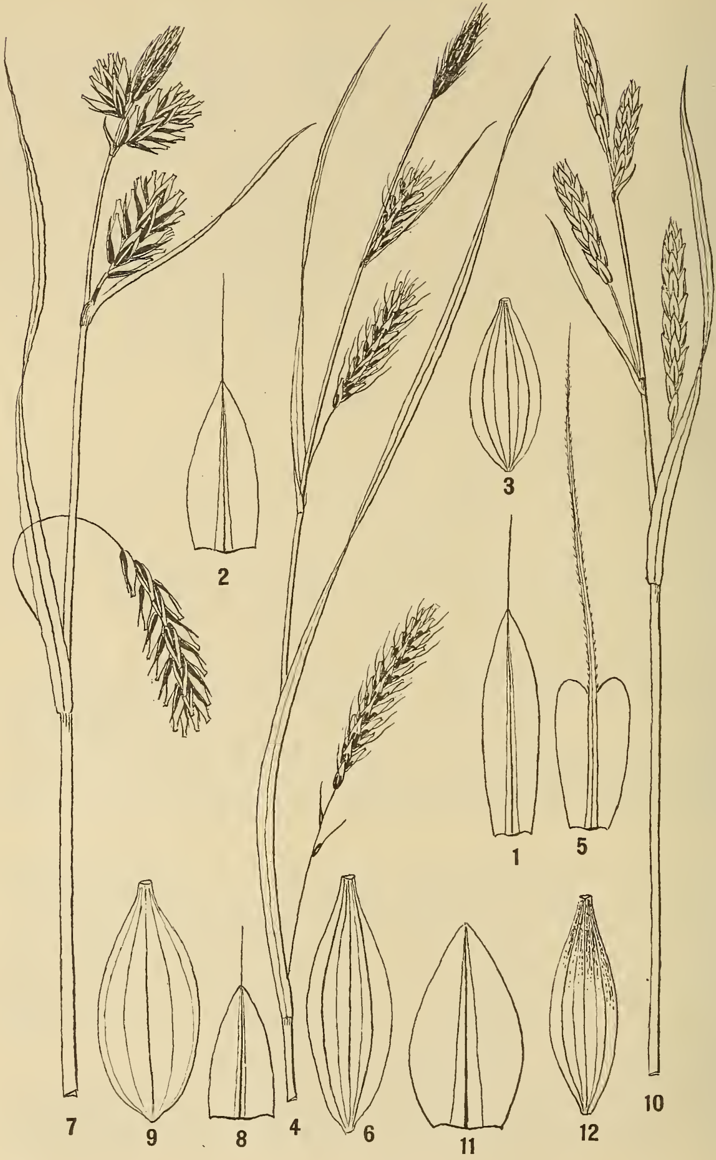
[6] Maximovicz, C. I. Diagnoses plantarun navarum asiaticarum VI. (Bull. de l'Acad. Imp. d. sc. de St. Petersbourg, vol. 31, p. 115), 1887.

[7] Die Cyperaceen der Flora Russlands St. Petersburg, 1901, p. 351.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have seen that in *C. macrochæta* the terminal spike may sometimes be androgynous, gynæcandrous or even purely pistillate, but such structures are merely exceptions; in *C. koraginensis* the terminal spike is often androgynous. Very characteristic are the mucronate to aristate squamae, and the membranaceous, more or less elliptic perigynia with a short beak, though tubular in *C. gansuensis;* the perigynium varies from glabrous to densely spinulose (*C. scita,* etc.) The species are confined to the northwestern corner of this continent, and to the Asiatic coast from St. Lawrence Bay to Japan.

Nesophilæ.

Carex nesophila nob. (figs. 10-12) is a species of such peculiar habit and structure, that we feel unable to place it in any other way than in a section of its own. The culm is phyllopodic; the bracts are not sheathing; the pistillate spikes are most often pedunculate, and sometimes even drooping; the squamae are acute, amplectent, and the midrib is thick, consisting of three veins; the perigynium varies from oval to elliptical oblong; it is distinctly several-nerved, and the short beak is mostly entire; the number of stigmata is three, or sometimes two.[8] In other words the habit reminds of that of *C. salina* Wahlenb. or *C. hyperborea* Drej., while the perigynium corresponds well with that of *C. macrochæta.* The species was found abundant on uplands (St. Paul Island and Popoff Island, Bering Sea) associated with *Sieversia, Potentilla* and *Artemisia,* but not with any other species of *Carex;* it seems to be a type characteristic of these islands.

It is thus somewhat related to *C. macrochæta,* but cannot be regarded as a variety of this, since it is phyllopodic; moreover as stated above, the structure of the squama is different. When *C. macrochæta* ascends the mountains it does resemble *C. nesophila* to some extent by the coarser structure of culm, leaves and spikes. Such specimens we have received from Dr. Walter H. Evans, who collected them "on mountain top, 1,200 ft. (Kodiak, Alaska)"; but in these specimens the culms are

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[8] This Journal, vol. 17, p. 315, 1904.

aphyllopodic, the staminate and pistillate scales are mucronate to aristate.

It is also interesting to notice that the *Macrochætæ*-alliance in the Japanese islands, so excellently described by Franchet, contains no type comparable to *C. nesophila;* the members of this alliance are aphyllopodic and of the same graceful habit as the typical *C. macrochæta.*

Clinton, Md., August, 1921.

EXPLANATION OF FIGURES.

Fig. 1. *Carex macrochaeta* C. A. Mey., the typical plant; scale of the staminate flower; enlarged.

Fig. 2. Same species; scale of the pistillate flower; enlarged.

Fig. 3. Same species; utriculus; enlarged.

Fig. 4. *C. macrochaeta* var. *emarginata* nob.; the inflorescence; natural size.

Fig. 5. Scale of pistillate flower of same; enlarged.

Fig. 6. Utriculus of same; enlarged.

Fig. 7. *C..macrochaeta* var. *macrochlaena* nob.; the inflorescence; natural size.

Fig. 8. Scale of pistillate flower of same; enlarged.

Fig. 9. Utriculus of same; enlarged.

Fig. 10. *C. nesophila* nob.; the inflorescence; natural size.

Fig. 11. Scale of pistillate flower of same; enlarged.

Fig. 12. Utriculus of same; enlarged.

SCIENTIFIC INTELLIGENCE

I. CHEMISTRY AND PHYSICS.

1. *A New Cyanide.*—W. S. LANDIS has given an interesting account of the recent development of the commercial preparation of cyanide from calcium cyanamide at Niagara Falls.

After the successful fixation of atmospheric nitrogen by bringing this gas into contact with hot calcum carbide, CaC_2, with the formation of the cyanamide, CaNCN, and free carbon, work was carried on in Germany for about 15 years in the effort to manufacture cyanide from the cyanamide. The most promising method appeared to be fusion with sodium chloride, but the process was not a commercial success on account of difficulties in carrying it out and the low yields of cyanide obtained.

In 1916 the supply of sodium cyanide in this country became very small and its price very high, so that an attempt was made at Niagara Falls, where a cyanamide plant was in successful operation, to manufacture cyanide from this material by fusing it with sodium chloride. By means of improvement in the process, such as the addition of a little calcium carbide to prevent frothing, and rapid heating to a higher temperature for a shorter time, cyanide was produced on a larger scale of a much higher grade than the Germans had ever hoped for. Within a year the process was further improved and the product made still better. Since that time cyanide has been manufactured on a very large scale, equivalent to the production of 4,000,000 lbs. of sodium cyanide per year, and of a grade corresponding to about 35% of sodium cyanide. Even richer products than this have been obtained, and it is expected that the quality will be considerably improved in the future.

The product has proved itself very satisfactory for use in gold extraction, for the preparation of sodium ferro-cyanide, and for other purposes, so this development may be regarded as a remarkable triumph of the American electrochemist.—*Trans. Amer. Electro-chem. Soc.* **38** (1920). H. L. W.

2. *A Very Sensitive Reaction for Copper.*—PIERRE THOMAS and GEORGES CARPENTIER have found that the alkaline solution phenolphthalin (the colorless reduction-product of the well-known indicator phenolphthalein) which was used by Kastle for the detection of vegetable oxydases and afterwards recommended by Meyer as a test for blood, is, under proper conditions, an exceedingly delicate reagent for copper. The reagent was prepared by dissolving 2g of phenolphthalein and 20 of pure potash in 100 cc of water and boiling the solution with 10g of zinc-dust until colorless. To 10 cc of very dilute solutions of copper four drops of the reagent were added and then a drop of hydrogen peroxide solution of a strength corresponding to 5 or 6 volumes

of oxygen. A solution containing 10^{-6}, that is, one millionth of copper, gave immediately a rose tint changing to bright red in a few seconds. At a dilution of 10^{-7} the color did not appear until after 10 or 20 seconds, while at 10^{-8}, the limit, a very pale color appeared after a few minutes which could be easily seen by comparison with a blank containing no copper.

The authors have compared this test with others, including the one with hematoxylin described in this journal in 1906 by Bradley, and they conclude that it is the most delicate of all. They give warning that certain supplies of distilled water and many so-called chemically pure reagents contain appreciable amounts of copper when subjected to this test.—*Comptes Rendus,* **173,** 1082. H. L. W.

3. *Lehrbuch der Eisenhüttenkunde;* von BERNHARD OSANN. Zweiter Band: Erzugung und Eigenschaften des schmiedbaren Eisens. 8vo, pp. 794. Leipsic, 1921 (Verlag von Wilhelm Engelmann).—This text-book on the production and properties of wrought iron and steel appears to be a most excellent treatise that can be highly recommended to those who read German and are interested in the subject. It presents many tables of statistics, explains the historical development of the important processes, and give a very complete and satisfactory account of the present condition of the art from both the theoretical and practical points of view.

The book is copiously supplied with no less than 651 illustrations "in the text" and 10 larger tables or plates. A large proportion of the figures are admirable sectional drawings of apparatus, showing the details of construction.

It should be noticed that the operations which give the final form to the metal, such as rolling, drawing, hammering and casting, are not treated in the book on account of the necessity for limiting its size. Theoretical metallography is only very briefly discussed, although the practical subjects of hardening, cementing, ignition, etc., are thoroughly treated. H. L. W.

4. *Mining Physics and Chemistry;* by Z. W. WHITAKER. 12mo, pp. XII and 268. New York, 1921 (Longmans, Green & Co. Price, $3.00).—The author of this text-book is a Certified Colliery Manager, and Lecturer in the Mining Department, University College, Nottingham, England. The book presents the simpler fundamental principles and facts of physics and chemistry, with particular attention to topics of special interest in connection with coal-mining. For instance, considerable attention is paid to pumps, and the subject of mine gases is rather elaborately treated in connection with the detection of explosive mixtures and the physiological effects of CO_2 and CO_4. As another example the discussion of explosives and their employment in the mining of coal is quite elaborate.

The book gives an excellent impression in regard to its clear presentation of the subject in an elementary way. Without doubt it might be used to advantage by many of those engaged in coal mining in the United States, for the differences in technical terms, mining regulations, and weights and measures in England and this country world be of little importance in a book devoted chiefly to scientific instruction. H. L. W.

5. *The Adsorption of Gas by Charcoal and Silica.*—The extensive application of the phenomenon of adsorption of gases by charcoal in the construction of masks for protection from noxious gases, and for the reduction of pressure at liquid air temperatures in evacuated vessels has greatly stimulated research upon the nature of the process. An investigation by Professor Henry Briggs recently published had for its main object the discovery of a non-inflammable substitute for activated charcoal but the results are also important from his consideration of the theoretical aspects of the phenomenon.

The gases used were nitrogen and hydrogen and out of a large number of non-inflammable substances tried a dried and granular silica gel prepared from water glass was found to be the best. Its capacity for nitrogen at 190° C. and at atmospheric pressure was found, on the volumetric basis, to be greater than that of the best charcoal by 66 per cent. Both of these substances showed preferential adsorption for nitrogen and hydrogen and exemplify the influence of chemical composition upon the phenomenon.

In any sample of granulated charcoal or silica the author regards the gross volume to be made up of: (a) the volume of the solid matter, (b) the interstitial volume i. e. of the open spaces or voids between the grains, (c) the internal gaseous volume which is made up of the volume of the capillaries or polymeral interstices within the granules themselves. A rough estimate indicates that these volumes constitute 27, 31, and 42 per cent of the whole in activated charcoal or silica but have the relation 51, 6, 43 per cent in de-activated silica. The author is of the opinion that in considering the intrinsic nature of adsorption we have not to do with the ultimate molecule of the solid but with elaborate polymers. The degree of canalization of the substance both on the microscopic and the molar scale is important but these passages are of use only when they traverse a medium which is in proper physical condition. For a high capacity silica when de-activated has no adsorbing power although it still retains one-fifth of its original internal gaseous volume, and on the other hand powdered graphite which has no capillary passages shows considerable adsorbing power. It is to be inferred that the connecting passages serve to distribute the gas but that it is held chiefly on the surfaces of polymers in the openings of molar dimensions. On this view any treatment which would disrupt the elaborate polymers of a substance would render the material more active and this is apparently confirmed. A high capacity silica may be de-activated by a heating which does not destroy the capillaries since 20 per cent of the original porosity remained. Here a granule which was originally an aggregate of small polymers riddled with openings has been converted into a completely polymerized unit by partial vitrification.

The behavior of carbon may also be explained on the above assumption. It is known that a dense charcoal subjected to a prolonged heating in the presence of a small amount of oxygen or when treated for a shorter time with superheated steam has its adsorptive power greatly increased. Many writers have thought that this activation resulted mainly from the expulsion of the residual hydrocarbons of the raw charcoal, but this assumption is open to the objections, (1), that the small amount of volatile hydrocarbon which is left to be expelled is disproportionate to the result produced; (2), that the presence of oxygen though helping to break up the hydrocarbons would not be essential to their ejection, and, (3), the fact that a temperature exceeding 1000°C. is needed before they would be all expelled does not square with the theory, if as is usually stated, a temperature from 350° to 450° C. is the optimum for air activation. The more probable explanation is that a highly polymerized substance like carbon is likely to be simplified by heating. It is found, however, that heating to 1000° alone has no permanent effect; the simplification resulting from the raising of temperature is followed by a reunion on cooling. But if a little oxygen either from air or from steam is available when the polymers are split, a portion of the carbon is removed as CO_2, and their cleavage is perpetuated.

Obviously oxygen would not serve the same useful purpose in the case of silica, but here the preparation of the silica from the hydrogel by heating involves the driving off of water which is for the most part chemically combined with the silica and the process will tend to break up the polymers.—*Proc. Roy, Soc.* **100**, 88, 1921.
F. E. B.

6. *Tables Annuelles de Constantes et Données Numériques;* by the *Comité international de l'Union de Chimie pure et appliquée.* Vol. IV, Part I. Pp. XXII, 626. Paris, 1921 (Gauthier-Villars et Cie.).—The present volume contains the determinations of physical constants as abstracted from researches which appeared during the years 1913-1914-1915-1916, and is published with financial aid from a large number of scientific societies throughout the world.

Without sacrificing anything of their purpose to make the tables complete, the editors have wisely exercised their discretion in making useful condensations and omitting results which were obtained under uncertain or ill-defined conditions, but including reference to them in the list of memoirs. In certain cases the printing of innumerable figures has been avoided by drawing curves; in others, such as the study of fusion in binary and tenary systems, only the properly characteristic values have been retained.

The material is tabulated first under the twenty chapter heads, compressibility, elasticity, density, viscosity, surface tension, expansion, specific heats, thermal conductivity, thermodynamics, melting points, vapor pressures, gas laws, acoustics, photometry, radiation, infra-red spectrum, absorption, refraction and dispersion, spectroscopy, rotatory power. These are printed in each of the four languages, French, German, English, and Italian, arranged in parallel columns. Each chapter head is followed with a detailed list of topics and the pages upon which the tables are to be found. The text of the work, however, where any explanation is necessary is in French. The source from which the values were taken is indicated in every instance and a considerable bibliography is frequently appended.

This relatively large work will be found extremely valuable in every technical or university laboratory. The distribution in this country is to be made through the University of Chicago Press from whom it may be obtained at $13.25 net.

The second part which is promised for 1922 will treat of electrical constants, solubilities, colloids, and other matters pertaining more particularly to chemistry. F. E. B.

7. *Report of the National Physical Laboratory for 1920.* Pp. 132. London, 1921 (His Majesty's Stationery Office).—The activities of this (Teddington) laboratory will be of interest to anyone engaged in research in Physical Science, and attention may be called to the list of papers, pp. 37-42, published by the laboratory or communicated by members of its staff to scientific societies or to technical journals. F. E. B.

8. *Die Naturwissenschaften: Zweiter Band;* by FRIEDRICH DANNEMANN. Pp. X, 508. Leipzig, 1921 (Wilhelm Engelmann).—This is the second edition of the volume in which the author has traced with great care the progress of scientific thought from Galileo to the middle of the Eighteenth Century. It appears to be historically accurate and is entertainingly written. It was the author's aim to supply a book which should exhibit not only the development of the principles of physical science but also to show their relation to such other branches as philosophy, mathematics, therapeutics and technology. The volume is illustrated with 132 figures drawn from the original memoirs and gives their sources. The work is well indexed and contains extensive notes to the literature of the subject. It will be appreciated both by students and by teachers. F. E. B.

II. GEOLOGY AND MINERALOGY.

1. *Geological Survey of Canada.*—Bulletin 33 of the Canadian Geological Survey (109 pp., 12 pls., October, 1921) is made up of the following papers: Faunal and Sediment Variation in the Anticosti Sequence, by W. H. Twenhofel; New Species of Devonian Crinoidea from Northern Canada, by Frank Springer; The Range of certain Lower Ordovician Faunas of the Ottawa Valley, with Descriptions of some New Species, by Alice E. Wilson; The Fossil Molluscan Faunas of the Marl Deposits of the Ottawa District, by E. J. Whittaker; and Two New North American Cycadeoids, by G. R. Wieland.

Professor Twenhofel sets forth in his paper very important conclusions regarding the Anticosti Island Silurian and Ordovician sediments and faunas. He says that "lateral gradation of sediments and faunas may so develop that one type of sediment with its fauna may overlap another—the conditions responsible for one type of deposition migrating laterally with respect to the other. The common interpretation would be 'overlap' of the one by the other, a withdrawal of the sea, a land interval, and the development of an unconformity." Twenhofel does not accept this current interpretation of lateral changes, but states it to be "the purpose of this article to describe examples of sediment and faunal variation in the shallow Ordovician and Silurian seas in which were deposited the sediments which now constitute the rocks of the Anticosti sequence."

Doctor Springer's paper describes and figures two new crinoids belonging to the genus *Melocrinus*, from the Mackenzie basin.

The paper by Miss Wilson materially increases our knowledge of the geological range of the species comprising the Black River and Trenton faunas in the Ottawa valley, and adds some new forms to these faunas. The author shows the range of species by means of a series of tables. These indicate at just what point in the section each species makes its first appearance, and just where it disappears from the section. This paper is a good example of the sort of precise work in collecting and studying fossil faunas which is very much needed.

Mr. Whittaker's contribution deals with a fresh-water fossil fauna found in the marls of the Ottawa valley, which, in its time relations, lies between the latest marine Pleistocene interval and the living molluscan fauna. Students wishing to study the fresh-water fossils of the Ottawa valley Pleistocene will find the plates and keys of this paper most useful. The illustrations include an aeroplane photograph showing the relation of the fossil marl deposits to the present water-level at McKay Lake. So far as the reviewer is aware, this is the first aeroplane photograph to be used in illustrating a paleontological paper.

Doctor Wieland describes the first cycad ever recorded from Canadian rocks, found in the Belly River beds in Alberta, and a second new species from the Trinity of Texas. E. M. KINDLE.

2. *A Review of the Evidence for the Taconic Revolution;* by THOMAS H. CLARK; Proc. Boston Soc. Nat. Hist., **36**, 135-163, 1921.—The author finds but little orogenic evidence on which the hypothesis of the Taconic Revolution of Dana (1863) can be based. This evidence is restricted to the southwestern margin of the New England mass from Otisville, New Jersey, north to Becraft Mt., New York. "Beyond this region there is no evidence of the Taconic Revolution." He does not deny epeirogenic movement and high land areas toward the close of the Ordovician, resulting in thick formations of clastics of Richmondian and early Silurian times. C. S.

3. *Fossilium Catalogus, 1: Animalia. Pars 12, Aves,* by K. LAMBRECHT, *Pars 13, Cnidaria triadica,* by C. DIENER. *Pars 14, Ammonoidea permiana,* by C. DIENER. 1921.—Part 12 of this valuable work gives the more important literature on the known fossil birds of the world, nearly 700 in number; also the material on which the species are based, the geologic horizon, the geographic locality, and the museum in which the material is kept. The classification followed is in the main that of Fürbringer. Part 13 cites the literature of 185 forms (in 33 genera) of Hexacoralla, 7(3) of Tetracoralla, 11(5) of Tabulata, 13(6) of Monticulipora, 1 of Alcyonaria, and 15(12) of Hydrozoa. Part 14 gives a bibliography for 198 forms of Permian ammonites, in 41 genera or subgenera. Seven of these genera also occur in the Carboniferous and the same number pass into the Triassic. The author also gives valuable remarks on their geologic and geographic distribution. C. S.

4. *Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1919–1920,* 332 pp., 47 pls., 24 text figs., 1921.—This report consists of the following ten papers: Structural and metamorphic geology of the Hanover district, New Hampshire, by J. W. Merritt; A contribution to the geology of Essex County, by R. A. Schroeder; Notes on areal geology of the western flank of the Green Mountains, by N. C. Dale; Geology and mineralogy of Braintree, by C. H. Richardson and C. K. Cabeen; Detailed study of the Trenton beds of Grand Isle, by State Geologist G. H. Perkins; Report on Trenton fossils from Grand Isle, by R. Ruedemann; Progress in talc production, by E. C. Jacobs; Studies in the geology of western Vermont, by C. E. Gordon; The geology of Lake Willoughby, by E. C. Jacobs; and Mineral resources, by G. H. Perkins.

5. *Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History, Honolulu, Hawaii.*—Recent publications of this Museum include the following titles. From the Occasional

Papers, vol. 7, (1) Director's Report for 1918 (pp. 1-12); (2) The Languages of the Pacific, by J. M. Brown (15-29); (3) New Hawaiian Plants, VII, by C. N. Forbes (33-39); (4) A New *Cyanea* from Lanai, Hawaii, by C. N. Forbes and G. C. Munro (43); (5) Notes on *Marsilea villosa* Kaulf, by C. N. Forbes (47-49); (6) a New Variety of *Partulina horneri,* by J. J. and A. Gouveia (53); (7) New Species of *Sierola* with Explanatory Notes by D. T. Fullaway (57-158); (8) Director's Report for 1919 (163-176); (9) Edible Mollusca of the Oregon Coast, by C. H. Edmondson (179-201); (10) Fish Poisoning in the Hawaiian Islands, by J. F. G. Stokes (219-232); (11) An Archæological Survey of Haleakala, by K. P. Emory (237-259); vol. 8, (1) Report of the Director for 1920 (3-28). In the series of Memoirs: vol. I, (1) A Monographic Study of the Genus *Pritchardia,* by O. Beccari and J. F. Rock (77 pp., 23 pls.); (2) A Contribution to Samoan Somatology, by L. R. Sullivan (17 pp., 7 pls.).

6. *Mikroskopische Physiographie der Mineralien und Gesteine;* by H. ROSENBUSCH. Band 1, Erste Hälfte: *Die Petrographische wichtigen Mineralien und die Methoden ihrer Untersuchung.* Fifth edition, fully revised by E. A. WÜLFING. First installment, 252 pages, with 192 text figures and one colored plate (an interference chart). Stuttgart, 1921 (E. Schweizerbart'sche Verlagsbuchhandlung).—From the preface we learn that the new edition of the Physiographie, whose appearance has been delayed by the war, is practically a new work, so great has been the addition, selection, and reworking of the material. In order to make room for the large amount of matter available and to keep the new edition from growing unwieldy, some matter that appeared in the previous edition has been omitted, such as the treatment of stereographic projections, some of the graphical methods, and certain demonstrations in geometric optics.

Following the Introduction, which is shortened and much changed from that in the fourth edition, is a section on methods of preparing material for optical examination, the main portion of which is, of course, devoted to describing the methods of making of thin sections. Incidentally, Wülfing shows that he does not view with sympathy the substitution of kollolith for the time-honored Canada balsam! The new position of this section in the book is obviously an improvement over that in the old edition, where it was inserted in the midst of the theory of optics.

Much new material appears in the book. Some of this may be briefly mentioned. There is an interesting computation on the requisite size (or number) of thin sections necessary to obtain certain definitely oriented sections of a mineral, say a basal section of a uniaxial mineral or a section cut parallel to the *c*-axis. The treatment of the dispersion of birefringence is newly added material.

Becke's point that the thin sections generally used in microscopical work are so thin that most interference figures do not show isochromatic curves and that therefore the isogyres are the characteristic phenomena is given proper emphasis. The interference figures shown in most manuals are such as we never see in everyday work. On the whole, the treatment of interference figures is inadequate, as it is in all manuals. The only adequate presentation of this difficult subject is Becke's masterly exposition, which should be consulted in the original.[1] Probably the second installment, which will deal with practical applications, will remedy this inadequacy.

The treatment of dispersion has been improved and clarified and is illustrated by excellent figures. The new account of pleochroic halos shows more clearly than any other revision in the book one of the notable lines of progress since the fourth edition. The description of the various kinds of luminescence is new and has been introduced in the hope that it is anticipatory of future advances.

The descriptions of the various prisms for obtaining polarized light, occupying pages 222-239, seem unnecessarily detailed, in view of the professed purpose of the book; and they might well be condensed or omitted. The installment ends with the section on the preparation of monochromatic light.

In conclusion, we can say that the thoroughness of the revision and the care shown in the first installment of the new edition to bring the subject abreast of the times leads us to look forward with anticipation to the succeeding installments of the great source book in microscopic petrography. ADOLPH KNOPF.

7. *Morphogenese der Oetscherlandschaft.* Vienna, 1921, KARL DIWALD (published by the Author). Large 8vo, 404 pages with a large folded map, 1:25,000, and a 21-page supplement containing 70 block diagrams.—This volume is a serious but seemingly venturesome effort to interpret the complicated forms of the Oetscher district, near the northern margin of the Alps, about 80 kil. west-southwest of Vienna, in terms of successive episodes of erosion prompted by many partial uplifts of the region. Twelve systems of forms are thought to be identified. The book is difficult reading because the text is a veritable ticket of details, without summaries. W. M. D.

8. *New Meteorites;* by GEORGE P. MERRILL (communicated).—The National Museum reports the receipt of a fragment of a heretofore unknown meteorite (pallasite of the Rockiky type) from Cold Bay, western Alaska. The entire mass as found was in form of a badly oxidized mass of but a few pounds weight, which was at once broken up and in large part lost. The find is of interest, being the second from Alaska proper, the first being that of Chilkat (an iron). Two finds, Skookum Gulch and Gay

[1] Becke, F., Tschermak's Min. Petr. Mitt., vol. 24, pp. 1-34, 1905.

Gulch, have been reported, however, from the Yukon District, Canada.

Samples of the recently reported "2-ton" mass of meteoric iron found near Navajo, Arizona, which have reached the National Museum show it to belong to the dense, nearly structureless varieties carrying but 5.81 per cent nickel, and provisionally referred to the Nedagolla group. This puts to rest the early supposition that the same might be a straggler from the Canyon Diablo fall.

A 54-pound mass of meteoric iron belonging to the octahedrite group has been reported to the National Museum from Mount Tabby, 20 miles northwest of Hannah P. O., Utah. G. P. M.

9. *Feldspar Studies.*—From Science Reports of the Tohoku Imperial University, Series III, vol. **1**, No. 1, pp. 1-32. Sendai, Japan, 1921. *X-ray analysis of Adularia and Moonstone and the influence of temperature on the atomic arrangement of these minerals;* by SHUKUSUKE KOZU and YOSHITOSHI ENDO.—The two feldspars investigated had the following compositions:

	Orthoclase	Albite	Anorthite
Adularia, St. Gotthard	88.3	23.1	2.5
Moonstone, Ceylon	74.4	23.1	2.4

The adularia was shown to have a single space-lattice which showed no variation over a wide range of temperature. The moonstone showed a combination of two space-lattices which were stable at 700° C. and lower temperatures, but as the temperature was raised above this point the two lattices approached each other until they became identical. The eight plates contain many Laue-spot photographs.

Optical, Chemical and Thermal Properties of Moonstone from Korea; by SHUKUSUKE KOZU and MASATOSHI SUZUKI.—This material corresponded to the composition,

Orthoclase ..	61.0	Albite	33.7	Anorthite ..	5-3

The Laue-photograph showed also in this case double spots indicating two intergrown space-lattices, although here they appeared in the picture taken on the side pinacoid while with the Ceylon moonstone they appeared on the base. The two lattices merge into one on raising the temperature but at a lower point than was the case with the Ceylon mineral. At the same time the schillerization shown by the mineral disappeared, leading the authors to assume that this property is in some way due to the presence of two molecular lattices in the mineral.

10. *A Manual of Determinative Mineralogy with Tables;* by J. VOLNEY LEWIS. Third, Revised and Enlarged Edition. 298 pp. New York, 1921 (John Wiley and Sons).—The present edition of this very useful book is at least twice the original size.

Complete Determinative Tables based upon physical characters have been added which occupy nearly one-half of the book. These together with the older tables based upon blowpipe and chemical tests make a very complete series of determinative tables which should serve for all ordinary purposes. The whole book has been recast and revised. W. E. F.

Sanidine from the Eifel; by SHUKUSUKE KOZU and KUNIKATSU SETO.—The paper is a continuation of a previous thermal study made of this material by the senior author. W. E. F.

11. *A Text-Book of Mineralogy;* by EDWARD S. DANA. Third edition revised and enlarged by WILLIAM E. FORD. Pp. ix, 720. New York, 1922 (John Wiley & Sons).—A notice of the new edition of this well-known work, just issued, will be given later.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Dairy Bacteriology;* by ORLA-JENSEN. Pp. 180, Philadelphia, 1921 (P. Blakiston's Son & Co.)—This, the English translation by Paul S. Arup of the second Danish edition of 1916, brought up to date by recent corrections and additions by the author, is a text-book for use of students of dairying, and also others who have to deal with milk and dairy products. It is essentially a practical, understandable book on dairy bacteriology, and not a scientific treatise. The three chapters given to general microbiology are very elementary, concise and to the point. The remainder of the book is a study of the relation which various microorganisms have to the changes taking place in dairy products. The normal and abnormal microbial flora of milk, butter, and the cheeses are very ably discussed. Other defects in these products which are not caused by bacteria, yeasts, or molds are described and remedies for each suggested. The best methods for properly handling and preserving milk are outlined. There is a rather full discussion of the various sour milks, the methods of preparation, characteristics of the particular organisms used, etc. The chapter on cheese-making takes up in detail the methods of controlling the processes of ripening. One chapter is devoted to a consideration of the various tests used in the grading of market milk.

Considering the ability of the author in the field of systematic bacteriology, it is rather a disappointment not to find a detailed scheme of classification for at least the milk bacteria. However, since the book is intended for elementary students and dairymen, the brief classification of the lactic acid bacteria given will probably serve the purpose quite as well as a more elaborate one. The book is of exceptional value because it is built up on the experience of the author covering a period of twenty-five years.

GEORGE F. REDDISH.

2. *Report of the Secretary of the Smithsonian Institution,* Charles D. Walcott, *for the year ending June 30, 1921.*—The Smithsonian Institution ever since its foundation has made most commendable use of the income at its disposal, but it has suffered, with other institutions having an original considerable endowment, from the fact that additions to its funds have been slow to come by gift or bequest. The need arising from this is felt peculiarly by the Smithsonian since the scope of its work has been continually enlarged in directions not contemplated at the beginning. The situation is aggravated at present by the general increase in cost of materials and labor. In this connection it is gratifying to learn that most of the bequest ($50,000) of Mrs. Virginia P. Bacon has been paid during the past year. It is also announced that, by her will, the entire estate of Miss Caroline Henry, daughter of the first secretary, Joseph Henry, will finally come to the Institution; she has in addition made special gifts immediately available.

Among the numerous varied lines of scientific exploration being carried on, none is more important than the work of Dr. Walcott that has already yielded such valuable results. His recent field work in the Canadian Rockies had as its main objects: "(1) the determination of the character and extent of the great interval of nondeposition of sedimentary rock-forming material along the Front Range of the Rocky Mountains west of Calgary, Alberta; (2) the clearing up of the relations of the summit and base of the great Glacier Lake section of 1919 to the geological formation above and below."

Dr. Walcott describes the solution of the two problems as follows: "The Rocky Mountain front is formed of masses of evenly bedded limestone that have been pushed eastward over the softer rocks of the Cretaceous plains-forming rocks. This overthrust is many miles in extent and occurred long before the Devils Gap, Ghost River Gap, and other openings were cut through the cliffs by running water and rivers of ice. Great headlands and high buttes have been formed by the silent forces of water and frost, many of which stand out against the western sky as seen from the distant foothills and plains.

It was among these cliffs that we found that the first great cliff was of lower Middle Cambrian age, and that resting on its upper surface there were 285 feet of a yellowish weathering magnesian limestone, named the Ghost River formation, which represents the great interval between the Cambrian below and the Devonian above. Sixty miles to the west, over 4 miles in thickness of limestone, shales and sandstones occur in the break in sedimentation of Ghost River cliffs. Returning to Bow Valley, the party left the Canadian Pacific Railroad at Lake Louise and went north over Pipestone Pass to the Siffleur River, which is tributary to the Saskatchewan. In the northward-facing cliffs, 25 miles east of the Glacier Lake section of 1919, and 40 miles north of Lake Louise, a geological section was studied that tied in the base of the Glacier Lake section of 1919 with the Middle and Lower Cambrian formations. Returning up the canyon valley of the Siffleur River to the wide upper valley of the Clearwater River, a most perfectly exposed series of limestones, shales, and sandstones of Upper Cambrian and later formations was found, which cleared up the relations of the upper portion of the Glacier Lake section to the Ordovician above.''

The year's work of the National Museum, now in charge of W. DE C. RAVENEL, has been particularly important in that the National Gallery of Art has now been separated from the museum and made an independent unit. The Aircraft Building has also been opened to the public, and much work has been done in reorganization, so that the museum at present has a total of 49 recognized subdivisions. A total of nearly 340,000 specimens have been added to the museum during the year; many of these are mentioned in detail.

The International Exchange service has been much enlarged owing to the resumption of relations with Germany; an increase of more than 82,000 packages over the preceding year is noted.

The work of the Astrophysical Observatory is summarized by the director, Dr. C. G. ABBOT, as follows:

``The year has been marked by the transfer of the solar radiation measurements from Mount Wilson, California, to Mount Harqua Hala, Arizona, to secure more perfect weather conditions. It is intended to continue solar constant observations there daily when possible throughout the entire year for several years. Similar duplicate observations are to be carried on at Montezuma, Chile, at the private station of the Smithsonian. Thus it is hoped to provide an excellent basis of solar radiation measurments to compare with weather phenomena. This may lead to advance in methods of weather forecasting. Volume IV of the annals, covering the years 1912 to 1920, is practically ready for the press.''

3. *Publications of the Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are given in the following list (see earlier, vol. **1**, p. 376, 1921):

No. 185. Index to United States Documents relating to foreign affairs, 1828 to 1861; by ADELAIDE R. HASSE. In three parts: Part III, pp. 1333, 1980; quarto.

No. 273. Contributions to Embryology, Nos. 47 and 48. Vol. X, quarto, pp. iii, 103; 16 plates.

Nos. 275, 276. Contributions to Embryology, No. 56. Vol. XII. Studies on abortuses; by F. P. MALL and A. M. MEYER.

Quarto, pp. 364; 25 plates, 6 figs. Vol. XIII, Nos. 57-64. Pp. 146; 20 plates, 25 figs.

No. 284. Distribution of Vegetation in the United States as related to climatic conditions; by B. E. LIVINGSTON and FORREST SHREVE. Pp. xvi, 590; 73 plates, 74 figs., 152 tables.

No. 293. Leodicidæ of the West Indian Region; by A. L. TREADWELL. Quarto, pp. iv, 131; 9 plates, 467 figs.

No. 303. Tables, Factors and Formulas for computing respiratory exchange and biological transformation of energy; prepared by T. M. CARPENTER. Pp. 123; 33 tables with introduction explaining description and use.

No. 305. Selection in Cladocera on the basis of a physiological character; by ARTHUR M. BANTA. Pp. 170; 18 figs., 49 tables.

No. 307. Growth in Trees; by D. T. MACDOUGAL. Pp. 41; 16 figs.

No. 310. Displacement Interferometry applied to acoustics and to gravitation; by CARL BARUS. Pp. viii, 149; 183 figs.

No. 313. Rubber-Content of North American Plants; by HARVEY M. HALL and FRANCES E. LONG. Pp. 65; 3 plates.

No. 315. Aeration and Air-Content: The Role of Oxygen in Root Activity; by FREDERIC E. CLEMENTS. Pp. 183.

Also a Classified list (with prices) of publications of the Carnegie Institution, dated February 15, 1921.

4. *Report of the Librarian of Congress,* HERBERT PUTNAM, and *Report of the Superintendent of the Library Building and Grounds,* F. L. AVERILL, *for the year ending June 30, 1921.* Pp. 207, with 6 full page illustrations. Washington, D. C.—The striking point made by Mr. Putnam is one already urged, namely a thorough readjustment of the salary schedule. The lack of this is causing a serious loss in the staff through resignations. A small number of additional assistants and clerks is also needed to make the organization more perfect. The sum called for by these needs is $170,930; deducting present bonuses, the net increase is $83,330. The library continues to gain in numbers, the number of books added for the year being 86,923. Besides these, manuscripts, maps and charts, music and prints have been obtained by gift or purchase. Many of these are described in detail.

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SCIENTIFIC INTELLIGENCE.

VOL. III MARCH, 1922

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

FIFTH SERIES
VOL. III—[WHOLE NUMBER, CCIII].
No. 15—MARCH, 1922.

WITH PLATE III.

NEW HAVEN, CONNECTICUT.
1922.

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Plate III (Fig. 1).—Restoration of *Blastomeryx marshi* Lull. Skeletal aspect. × about 1/7.

THE

AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. XI.—*Restoration of Blastomeryx marshi;* by Richard S. Lull. With Plate III.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

In this Journal for August, 1920, I described the skull and jaws of a new species of *Blastomeryx* which was collected by Professor Marsh in 1873 along the Niobrara River not far from the mouth of Antelope Creek, Nebraska. Further material pertaining to this species has come to light in the skull and a considerable portion of the skeleton of a second individual collected at the same time and place and designated by Professor Marsh "Rum[inant](XX)," the holotype, Cat. No. 10937, Y.P.M., being "Rum.(X)."

The second skull, Cat. No. 10756, Y. P. M., differs from the type in its slightly smaller size, the teeth being in about the same degree of wear in the relatively smaller canine alveolus, and in the position of the horn, which is not only smaller, but is set back from the rim of the orbit as in the female prong-buck. One is therefore justified in the assumption that this second specimen represents the female of the species of which the holotype is the male.

The skeletal material was so much more complete that a mount of the animal was attempted, utilizing the male skull and jaws and the female skeleton. Thus the mount is composite, and embraces both Nos. 10937 and 10756, difference in size of the skeletal parts present in each animal being almost negligible.

Distally the limbs are beautifully preserved, including the entire manus with complete lateral metacarpals and digits. Whether the pes possessed lateral digits is not clear. Proximally the posterior limb bones are represented by articular portions only, although those of the

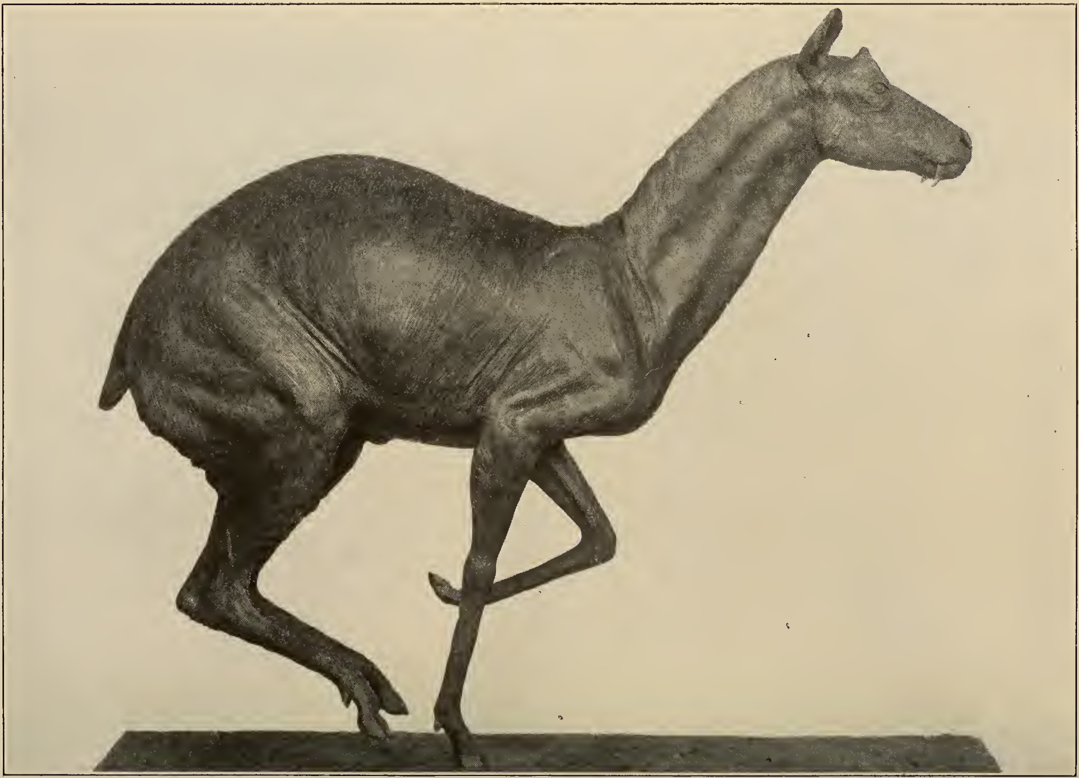

Fig. 2.—Restoration of *Blastomeryx marshi* Lull. Flesh aspect. Modeled by R. S. Lull. × about 1/7. Apparent change of posture of hind limbs as compared with Fig. 1 due to angle of vision.

fore limb were approximately complete. The humerus could have been no shorter than restored, as there is bone throughout; it may have been longer, but this is extremely doubtful. Of the femoral and tibial length I am not so sure. Doctor Matthew's restoration of *Blastomeryx*[1] was used, but in no two limb segments was there correspondence where the length was actually preserved. The two restorations differ in many details, some of which may well be due to interpretation of material. As usual with these small mounts, I have restored the flesh on the right side, with carefully wrought muscular interpretation and a minimum of conjectural surface detail. The mounting of the skeleton was very largely the work of Mr. Hugh Gibb.

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[1] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 24, fig. 6, 1908.

ART. XII.—*Oregon Tertiary Canidæ, with Descriptions of New Forms;* by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

CONTENTS.

INTRODUCTION.

During the course of a study of the canid and allied material in the Marsh Collection at Yale, it was found that *Amphicyon angustidens* Marsh and *Canis gregarius* Cope were specifically identical. Evidence of this will be presented in a forthcoming paper on the Great Plains Canidæ. Marsh's description antedates Cope's by two years, and since both species belong in the genus *Cynodictis,* the *C. angustidens* of Marsh (1871) has precedence over Cope's name proposed in 1873. The type, Cat. No. 11762, Y. P. M., consists of the anterior part of a right ramus with teeth.

The taxonomic position and affinities of the new genus, *Pericyon,* herein proposed, are not at present discussed, other than to say that it is probably a derivative of *Mesocyon.* It apparently stands closer to that genus than it does to *Temnocyon,* which it approaches in size.

DESCRIPTION OF SPECIES.

Cynodictis oregonensis Merriam.

This specific name was applied to the John Day forms of

C. angustidens (Marsh) (*Galecynus gregarius* (Cope)). The species is distinguished from the latter by the "constant presence of a posterior cusp in addition to the anterior and posterior basal tubercles on P_2, the larger M^2, larger brain case, less pronounced postorbital constriction, and other characters" (Merriam 1906, p. 11). The presence of the additional cusp on P_2 was not noted by Cope nor is it shown in the figures accompanying his description of the John Day specimens of *C. angustidens.* This character appears on some of the Yale specimens of the White River *C. angustidens* and *C. paterculus,* and is apparently an individual variation which can not be used for specific determination. The other characters, mainly dependent upon larger size, are what we should expect from the John Day beds. This increase in size over the White River forms is seemingly a very constant character in various genera, having representatives, in both that area and the Great Plains region, of approximately the same geologic age.

This species is represented in the Marsh Collection by several skulls, all from the middle John Day. The infraorbital foramen above the interval between P^3 and P^4, size and shape of the bullæ, posteriorly pointed nasals, flat palate, and moderate slope of basicranial axis are all similar to those in *C. angustidens.* Specimen No. 12733, Y. P. M., from the Fossil Horse beds on Cottonwood Creek, has three upper and lower premolars on the right side and four on the left. It is upper John Day in age.

A variant from the typical *C. oregonensis* is found in skull No. 12700, Y. P. M., collected near Logan Butte, Crook County, Oregon, in middle John Day beds. The face and jaws are unusually long; cranium high; diameter of postorbital constriction small; postorbital processes prominent; angle on ramus prominent; length of inferior molar-premolar series 48 mm.

Measurements.

(Chiefly from Cat. No. 12679, Y. P. M.)

	mm.
Total skull length	103
Diameter of brain-case, max.	37
Diameter of postorbital constriction	14

Length of superior tooth-row, with canine	45.5
Length of superior premolar series	25
Length of superior molar series	11.2
Ant.-post. diameter of M^2	5
Transverse diameter of M^2	8
Length of inferior premolar series (No. 12681, Y. P. M.)	20
Length of inferior molar series (No. 12681, Y. P. M.)	19

Cynodictis angustidens (Marsh).

Parts of rami with teeth, from the John Day formation, have been tentatively identified with this species. The majority of these were collected at Bridge Creek. They are very close to the type and much smaller than *C. oregonensis.*

Two specimens from the Fossil Horse beds on Cottonwood Creek, Cat. No. 12696, Y. P. M., are more slender than the type, and the teeth are more crowded. These may represent a new form, more closely allied to *C. angustidens* than is *C. oregonensis,* but with material so fragmentary it seems best to identify them with the former species for the present.

Nothocyon geismarianus (Cope).

Remains of this species were collected at Turtle Cove and Haystack Valley from middle John Day strata. The specimens consist of parts of skulls and associated jaws, with both superior and inferior dentition, but unfortunately are not well preserved.

Nothocyon latidens (Cope).

In the Marsh Collection, a pair of mandibles with teeth, Cat. No. 12794, Y. P. M., represent this species. Both carnassials exhibit "a narrow tubercle at the external base of the principal cusp" which Cope considered diagnostic of *latidens.* In addition there is also present a quite small tubercle just anterior to the base of the entoconid. The specimen was found at Turtle Cove in middle John Day strata.

Measurements.

	Cat. No. 12794 Y. P. M. mm.	Holotype of *N. latidens* mm.
P_4, ant.-post. diameter	6	5.5
M_1, ant.-post. diameter	8.4	8
M_1, ant.-post. diameter of heel	3.5	3.5
Depth of ramus at sectorial	10.5	10.5

Nothocyon lemur (Cope).

Parts of a right and of a left ramus with teeth are referred to this species. They bear the catalogue number 12797, Y. P. M. The ramus is considerably more slender than that of *N. latidens,* and the measurements of this specimen accord well with those of the type. However, the sectorial possesses the small tubercle on the external base of the protoconid, a characteristic of *latidens.* Merriam has described mandibles possessing this character, but otherwise agreeing with *N. lemur,* and he is inclined to think that this feature is common to both species. I am inclined to concur in this opinion.

Measurements.

	Cat. No. 12797 Y. P. M. mm.	Holotype of *N. lemur* mm.
P_4, ant.-post. diameter	5.5	
M_1, ant.-post. diameter	8	8
M_1, ant.-post. diameter of heel	2.9	3
Depth of ramus at sectorial	7	8

Philotrox condoni Merriam.

Several parts of rami with teeth represent this genus and species, but they furnish no additional data to Merriam's descriptions (1906) of the form. They were collected at both Bridge Creek and Turtle Cove, from middle John Day strata. Cat. No. 12725 is the left ramus of a submature individual, showing partly deciduous and partly permanent dentition, including the incisors.

Paradaphænus transversus (Wortman and Matthew).

This genus was defined by Wortman and Matthew in 1899 (p. 129) as follows: "Upper molars much extended and symmetrical transversely; M^3 aligned with outer cusps of anterior molars. Heels of lower molars wide and deep, basin-shaped; M_2 and M_3 with two anterior cusps and basin-heel." The type species of the genus is *P. cuspigerus* (Cope), which is based on specimen No. 6852, A. M. N. H.

The species *P. transversus* was defined at the same time (p. 130) as "Size one third larger (lineal). Upper premolars compressed." The type is No. 6851, A. M. N. H. (referred to *Amphicyon hartshornianus* by Cope). For amplification of this genus and species, Cat. No. 10064, Y. P. M., may be used. It is a skull which lacks the posterior part of the cranium, as well as the crowns of part of the dental series, leaving the roots distinct, except those of the incisors.

In addition to the characters mentioned by Wortman and Matthew, we are enabled to add the following: infraorbital foramen above posterior part of P^4; face short; diameter of postorbital constriction large; cranium low and full; sagittal crest barely marked; frontal ridges unite just posterior to coronal suture; palatonarial border opposite M^3; palate flat, descending abruptly at alveolar parapet; P^1 and P^2 spaced; deuterocone of P^4 prominent; M^3 very small; zygomata not widely expanded.

A pair of lower jaws, Cat. No. 12714, Y. P. M., collected near Camp Watson on the John Day River, are identified with this species. In many respects these jaws are similar to those of *Daphænus*. M_3 is a very small convex nub, considerably worn, and may be smaller than indicated by Wortman and Matthew. P_3 differs from that of *Daphænus* in having a very small incipient posterior cusp. The incisors are small and laterally compressed. Both Nos. 10064 and 12714 are middle John Day.

It is well to note the spelling of this generic name, *Paradaphænus,* while Leidy's generic name is *Daphænus.*

Measurements.

(Cat. No. 10064, Y. P. M.)

	mm.
Total skull length, partly estimated	157
Bizygomatic diameter, partly estimated	77
Diameter of postorbital constriction	30
Length of superior premolar series	44
Length of superior molar series	20

(Cat. No. 12714, Y. P. M.)

Length of inferior dental series, C-M_3 inc.	72
Length of inferior premolar series	34
Length of inferior molar series	27.5
Ant.-post. diameter of M_1	14.5
Ant.-post. diameter of M_2	8
Ant.-post. diameter of M_3	4

Temnocyon altigenis Cope.

This comparatively rare species is represented in the Marsh Collection by a fully adult skull, Cat. No. 10065, Y. P. M., and other material. This specimen corresponds with Cope's type, and possesses the zygomata and cranium which were lacking in his specimen and which have been heretofore undescribed. It varies somewhat from the individuals described by Merriam (1906, pp. 21-29), as will be seen from a comparison of measurements.

The condylar foramen is small, while the foramen lacerum posterius is large. The eustachian opening and the external carotid foramen are separate. The optic foramen is large. The infra-orbital foramen is larger than in any specimen of *Canis familiaris* of equivalent or even of somewhat larger size.

The palatonarial border lies 8 mm. posterior to M^2. The zygomata are slender in proportion to the size of the skull, absolutely weaker than in *C. familiaris* of equivalent size, and less expanded. The cranium is large and full, while the postorbital constriction is well marked. The sagittal crest is well defined. The very marked medial frontal depression, seen in *C. familiaris,* is totally lacking in this species.

The deuterocone of P^4 is very large and heavy and is separated by a deep valley from the protocone. Normally P^3 has no posterior tubercle, but this specimen shows an exceedingly small incipient one, while the posterior basal tubercle is much smaller than in *T. ferox,* but practically the same as in the type. Merriam 1906 (p. 23) says that *T. altigenis* is characterized by the absence of a posterior basal tubercle, but in the absence of other divergent characters, I do not consider that this tubercle on P^3 invalidates the identification with this species.

Measurements.

(Cat. No. 10065, Y. P. M.)

	mm.
Skull length, prosthion to occip. condyles, inc.	205*
Diameter of brain-case	62
Diameter of postorbital constriction	32.3
Bizygomatic diameter	120
Length of molar series	20
Length of P^4	19
Transverse diameter across deuterocone of P^4	14.5

*Approximate.

Mesocyon coryphæus (Cope).

This species was very abundant in the John Day Basin and is represented in the Marsh Collection by some excellently preserved skulls with jaws. Cat. No. 12702, Y.P.M., collected at Turtle Cove, differs in some respects from the type as described and figured by Cope. It is about 10 mm. shorter than the type, but the postorbital constriction is one-third greater than that of Cope's specimen, while the latter shows a little greater bizygomatic diameter. The muzzle is 24.5 mm. in minimum transverse diameter; in the type it is 30.2 mm. The superior canine of the Yale specimen is much more slender and recurved. The superior tooth measurements correspond more closely to those of No. 1383, Univ. Calif. Coll. Vert. Pal. (Merriam 1906, p. 19) than to the type. The junction of the temporal ridges lies 16 mm. posterior to the postorbital constriction and in the type it is nearly above the constriction.

Cat. No. 12703, Y. P. M., also found at Turtle Cove, is a skull and jaws, which, in the main, lack only the zygomata and some of the incisors. This is a typical example of the species. P_1 is very much reduced; the posterior tubercle of P_3 is fairly prominent, but the one on P_4 is very heavy and prominent; the masseteric fossa very large and deep.

Measurements.

(Cat. No. 12703, Y. P. M.)

	mm.
Length of ramus, angle to incisor border, inc.	122
Length of inferior dental series with canine	78
Length of inferior premolar series	37
Length of inferior molar series	27
Depth of ramus below middle of M_1	17.5

Specimen No. 12704, Y. P. M., from Turtle Cove, is the anterior part of a skull with some teeth. It is an old individual, with the teeth much worn. These teeth are more robust and heavier than in the type or in the other Yale specimens of this genus. M^2 is nearly a third wider antero-posteriorly and 1 mm. greater in transverse diameter than the type M^2. The individual tooth measurements are close to those of *M. brachyops* Merriam, but the total length from the posterior edge of M^2 to the posterior edge of the canine is 2 mm. greater than in the type of *M. coryphæus.* Merriam (1906, p. 17) found a considerable variation in size within this species and the Yale specimens apparently confirm this opinion. I suspect that this latter specimen, Cat. No. 12704, represents a male.

Mesocyon brachyops Merriam.

Cat. Nos. 12710 and 12719 of the Marsh Collection, from Bridge Creek and Turtle Cove, respectively, consist of maxillæ with parts of premolar and molar series. They are from upper John Day strata.

Mesocyon josephi josephi (Cope).

A nearly complete skull with mandibles attached, Cat. No. 12705, Y. P. M., is very close to the type. It was collected in middle John Day strata in the Fossil Horse beds on Cottonwood Creek. This species has been known heretofore only from an anterior part of a skull with teeth. The description may be amplified as follows:

Specific characters.—About 12 per cent shorter in total length than *M. coryphæus;* muzzle short; infra-orbital foramen above the interval between P^3 and P^4; postorbital constriction narrow; brain-case moderately large; junction of temporal ridges slightly beyond postorbital constriction; zygoma expanded; sagittal crest low; bullæ narrow and ovate; masseteric fossa large and deep, with long axis nearly horizontal; coronoid low and angle heavy. In the Yale specimen, P^1 is quite close to the canine, a condition analogous to that in *M. brachyops* Merriam. An individual variation of No. 12705 is the possession of five inferior premolars in the right ramus. The accessory premolar is of nearly equal size with P_1. The posterior basal heel of P_4 is robust, as well as the posterior tubercle of the same tooth. P_3 has a small posterior cusp and small basal tubercle.

Measurements.

(Cat. No. 12705, Y. P. M.)

	mm.
Length of skull, prosthion to occip. condyles, inc.	144
Bizygomatic diameter	98
Diameter of postorbital constriction	20
Diameter of brain-case, max.	47
Length of ramus, max.	105.5
Depth of ramus below middle of M_1	19.3
Length of inferior dental series, with canine	66
Length of inferior premolar series	29
Length of inferior premolar series, with accessory premolar	32
Length of inferior molar series	26

Mesocyon josephi secundus, subsp. nov.

(Figs. 1 and 2.)

Holotype, Cat. No. 10063 (skull), Y. P. M. Upper Oligocene (middle John Day), John Day Basin, Oregon.

Distinctive characters.—Premolars crowded and no diastemata between the molars and canine; P^2 obliquely placed, much the same as the corresponding tooth in *Cynodesmus thoöides* Scott; P^3 has a small posterior tubercle in addition to the posterior basal one; canine more ovate in cross-section; molars and P^4 increased in size and P^2 decreased.

In comparison with *M. josephi,* sensu stricto, the new subspecies differs in the characters noted above, and in the fact that the molars of the latter are about one third larger in both transverse and antero-posterior diameters; P^4 is one fourth larger, P^3 the same size, P^2 about one fourth smaller, and P^1 alike in both. The total length of dentition from M^2 to I^3 inclusive is the same in both, 67 mm.

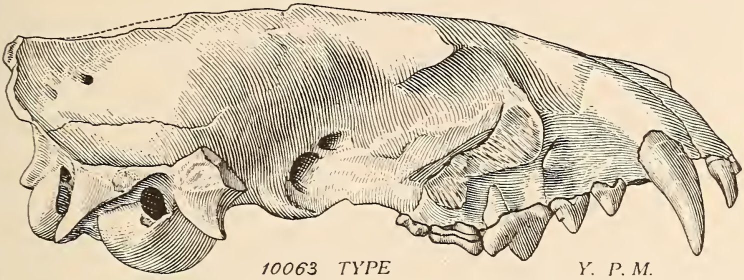

FIG. 1.—*Mesocyon josephi secundus,* subsp. nov. Holotype. × 2/3.

Cat. No. 10063 is approximately the same length and has the same bizygomatic diameter as *M. drummondanus* Douglass, but it differs from the latter in the following respects: (1) larger I^3; (2) premolars crowded; (3) P^4 longer but not wider; (4) P^2 obliquely placed, and P^1 smaller and ovate in cross-section; (5) transverse part of maxillo-palatine suture lies on a line back of the deuterocone of P^4, while in *M. drummondanus* it is on this line; (6) bullæ more ovate and their long diameter less oblique to the sagittal plane in *M. drummondanus;* (7) smaller brain-case diameter.

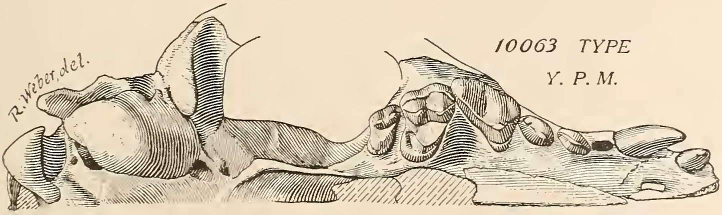

FIG. 2.—*Mesocyon josephi secundus,* subsp. nov. Holotype. × 2/3.

M. josephi secundus, M. josephi, and *M. drummondanus* are closely allied and yet show clearly recognizable differences. No. 10063 and *M. josephi josephi* are middle John Day and from the John Day Basin, while the type of the other species was collected a little east of Drummond, near the Hellgate River, Montana, and is probably likewise of Upper Oligocene age.

Measurements of Holotype.

	mm.
Length of skull, occip. condyles to prosthion	143.5
Diameter of postorbital constriction	21.9
Diameter of brain-case, max.	46
Length of superior molar series	15.5
Length of superior premolar series	37

Pericyon socialis, gen. et sp. nov.

(Fig. 3.)

Holotype, Cat. No. 12715, Y. P. M. Both rami, permanent dentition, unworn. Upper Oligocene (upper John Day), Haystack Valley, John Day Valley, Oregon. Paratype, Cat. No. 12737, Y. P. M., from Turtle Cove.

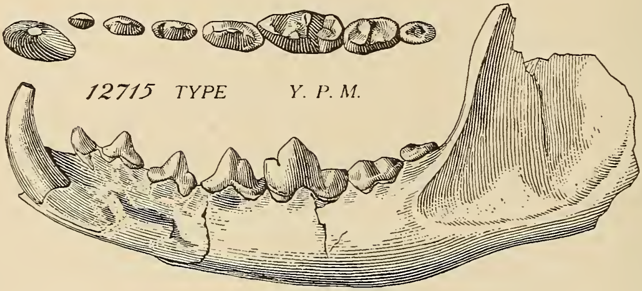

Fig. 3.—*Pericyon socialis*, gen. et sp. nov. Holotype. × 2/3.

Distinctive characters.—Slightly smaller than *Daphœnus vetus* Leidy; dental formula (lower jaw) I3, C1, P4, M3; inferior premolars compressed; P$_3$ has posterior tubercle but very small posterior cingulum; very prominent posterior tubercle and large basal heel on P$_4$; M$_1$ has large and well developed metaconid and prominent hypoconid; M$_2$ with two anterior cusps, a low hypoconid and a basin-shaped entoconid; M$_3$ nearly three quarters as long as M$_2$, with a small paraconid from which extends inward, backward, and finally outward a faint semi-lunar ridge; masseteric fossa deep; inferior border of ramus more curved antero-posteriorly than that of *D. vetus*, but about the same depth below the toothrow in each.

The major distinctions between this form and *Paradaphœnus* are: (1) much larger size than any species of the latter genus; (2) M_3 absolutely very much larger, for in *Paradaphœnus* and *Daphœnus* this tooth is a small convex nub; and (3) presence of posterior cusp on P_3. From *Temnocyon* it differs in being smaller, with the heels of M_1 and M_2 very much less trenchant; with both protoconid and metaconid of M_2 on anterior half, and with posterior cusp on P_3. M_1 is not medially constricted as in *T. altigenis,* nor is the posterior cusp of P_4 so externally situated in this new form. *Mesocyon* has anterior basal tubercles on P_3 and P_4, which are lacking in *Pericyon.* The heels of P_4 and of M_1 are much larger than in *Mesocyon,* and the posterior cusp of P_4 is higher and much more prominent. *Mesocyon* is smaller, with the premolars less compressed.

From *Tephrocyon, Pericyon* is differentiated by the much larger M_3; the different arrangement of the conids and heel of M_2; the much more marked lateral compression of the premolars, their greater degree of hypsodonty, and the smaller posterior cusp on P_3, as well as the larger size; the greater area occupied by the masseteric fossa and the much less steeply inclined postero-inferior border of the ramus below the coronoid process, the anterior border of which rises more nearly vertically in *Tephrocyon* than in the new genus. *Tephrocyon* is Middle Miocene; *Pericyon,* Upper Oligocene.

Measurements of Holotype.

	mm.
Length of dental series with canine	85.5
Length of molar series	35
Length of premolar series	40
Depth of ramus below middle of M_2	22
Ant.-post. diameter of M_1	17
Ant.-post. diameter of M_2	11
Ant.-post. diameter of M_3	8

Enhydrocyon oregonensis, sp. nov.

(Figs. 4 and 5.)

Holotype, Cat. No. 12730, Y. P. M. Skull lacking posterior and basicranial areas of cranium. Upper Oligocene (middle John Day), Turtle Cove, John Day Valley, Oregon.

This species is much smaller than *E. basilatus* and *E.*

sectorius. I am inclined to view the latter two as practically the same or at most as being one a subspecies of the other. In comparison with *E. stenocephalus* Cope, the new form differs in having less expanded zygomata; nasal bones differently shaped and pointed posteriorly, terminating just anterior to the postfrontal processes; frontal ridges uniting just beyond the postorbital constriction; muzzle 20 per cent longer; less interorbital width; shorter length of superior dental series; longer sectorial; considerably smaller M^2; longer and wider M^1; less axial length.

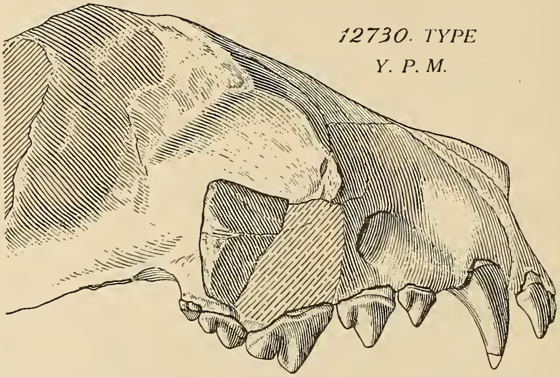

FIG. 4.—*Enhydrocyon oregonensis,* sp. nov. Holotype. × 2/3.

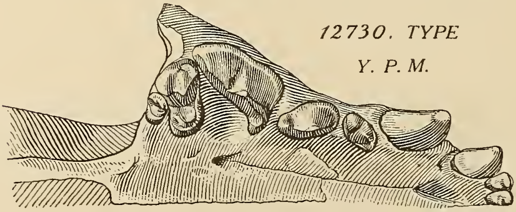

FIG. 5.—*Enhydrocyon oregonensis,* sp. nov. Holotype. × 2/3.

The incisors of this new species are peculiar in that they have accessory cusps on their internal and lateral surfaces, with the exception of I^3. I^1 has an internal inferiorly bifurcated cusp, as well as a small external lateral one near the tip, while I^2, in addition to the internal bifurcated cusp, has a lateral cusp on each side, the outside one being the larger and nearer the base. P^2 is rotated inward, being placed at an angle of about 45° from the sagittal plane. It has both anterior and posterior basal tubercles and posterior cusp. P^3 is nearly parallel to the sagittal plane, has a prominent posterior cusp but small basal tubercles. P^4 is oblique to the sagittal plane, its metacone is deep and wide, and the deuterocone is small. M^1 is typical of the genus. M^2 is much smaller than that of *E. stenocephalus* and but slightly larger than that of *E. crassidens*. The infra-orbital foramen is above the extreme posterior edge of P^3 and is vertically oval.

This species differs from *E. crassidens* chiefly in smaller size; wider P^3; larger M^2; different outline of superior dental series; different incisor forms; smaller deuterocone of P^4; more posterior position of infra-orbital foramen; larger orbit; more robust malar below orbit; and slightly more elongate face.

Measurements of Holotype.

		mm.
Length of skull, partly estimated		150
Width of postorbital constriction		28
Length of superior dentition		75
Width of six incisors		25.5
Diameter of canine, ant.-post.	11 mm.; transverse	8.2
Diameter of P^2, ant.-post.	8.7 min.; transverse	5
Diameter of P^3, ant.-post.	11.6 mm.; transverse	7
Diameter of P^4, ant.-post.	19.2 mm.; transverse	11.6
Diameter of M^1, ant.-post.	10.1 mm.; transverse	15.5
Diameter of M^2, ant.-post.	4 mm.; transverse	5

Tephrocyon rurestris (Condon).

This genus and species is represented at Yale mainly by superior and inferior teeth of several individuals, all from the Mascall formation of the John Day Valley.

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Art. XIII.—*The Crystallographic and Atomic Symmetries of Ammonium Chloride;* by Ralph W. G. Wyckoff.

Introduction.—It was early observed that the maximum symmetry of the arrangement of the atoms of certain crystals, as determined from a study of their X-ray diffraction patterns, was not in accord with the symmetry assigned to these crystals as a result of the purely crystallographic observations of the occurrences of faces and of etch-figure formation. Typical of these apparent discrepancies between the results of the formal crystallography and of the X-ray investigations were potassium chloride (sylvine) and cuprous oxide (cuprite). In both of these instances, however, the symmetry of the arrangement of the atoms was greater than that arising from the crystallographic observations, so that it was always possible to avoid a direct conflict between the results of the two methods by assuming that one or more of the kinds of atoms entering into these compounds had about them fields of force of such a shape as to impart to the atomic aggregate the necessary lower degree of symmetry. In view of the absence of any information concerning the shapes of atoms such observations clearly had a certain measure of justification.

The determination of the probable structure of ammonium chloride, however, brings forward another case of discrepancy which cannot be dismissed by similar assumptions. It is the purpose of this paper to show that not only is the structure which has been assigned to this crystal incompatible with its described symmetry; but that there is no possible structure, possessing the symmetry required by the recorded crystallographic observations and at the same time permissible from the standpoint of the chemistry of ammonium chloride, which is in even approximate agreement with these X-ray data. As a consequence it seems necessary to conclude either (1) that the very considerable data relating to the symmetry of ammonium chloride are incorrect, or else (2) that information concerning the occurrences of forms upon crystals and more especially the symmetry of etch-figures does not in all cases furnish an indication of the internal symmetry of the crystal. The second of these conclusions is so difficult to practical crystallography that a further investigation of the symmetry of ammonium chloride seems imperative.

The observed Symmetry of Ammonium Chloride.—Ammonium chloride is assigned to the enantiomorphic hemihedry of the cubic system both upon the basis of observed face development and because of the symmetry of etch-figures. Pentagonal icositetrahedral forms such as (875) and (943) have been reported on crystals from different sources. The type of etch-figure described as occurring upon such faces as (211) points definitely to the absence of any planes of symmetry.[1]

The X-ray Data upon Ammonium Chloride.—Both spectrometer measurements[2] and powder reflections[3] conclusively indicate that the ratio $n^3/m = 1$, where n is the order of the reflection and m is the number of chemical molecules within the unit cell. On this basis a "body-centered arrangement" has been assigned to the nitrogen and chlorine atoms of the crystal. From the results of the theory of space groups it is readily shown that if there is thus one molecule in the unit, the placing of the four hydrogen atoms associated with each nitrogen atom requires that the symmetry of this arrangement be that of the space group T_d^1. According to this structure the co-ordinate positions of the atoms in a unit cube are:

(1) Cl: $\frac{1}{2}\frac{1}{2}\frac{1}{2}$,
N: 000,
H: uuu; $\bar{u}u\bar{u}$; $u\bar{u}\bar{u}$; $\bar{u}\bar{u}u$.

This structure is tetrahedral cubic, a degree of symmetry incompatible with its recorded crystallographic characteristics.

The diffraction data concerning ammonium chloride which have been collected have been used for no other purpose towards determining its crystal structure than to evaluate[4] the ratio of n^3/m. From these data there is no

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[1] A summary of the crystallographic information is given in Groth, Chemische Krystallographie, I, 182 (Leipzig, 1906).

[2] W. H. and W. L. Bragg, X-rays and Crystal Structure, p. 110 (London, 1918).

[3] G. Bartlett and I. Langmuir, J. Am. Chem. Soc., 43, 84, 1921.

[4] It is readily shown by approximate calculations of intensity carried out in a manner previously outlined (Ralph W. G. Wyckoff, this Journal, 2, 239, 1921) that all of the diffraction data are in accord with this simple

immediate method of selecting between values of $n = 1, 2, 3,$ or 4, with corresponding values of $m = 1, 8, 27,$ and 64, and it is natural to look to a more complicated structure arising from one of these for the apparently necessary reconciliation between the symmetry of atom arrangement and face development.

It has, however, already been intimated that in this particular instance no such more complicated arrangement is available. This can be shown as follows. There is a maximum of 96 equivalent positions in the unit for any space group having an enantiomorphic cubic hemihedry. This means that if we make the apparently chemically necessary assumption that all of the nitrogen and all of the chlorine atoms in ammonium chloride are alike, there may be as many as 96 nitrogen and 96 chlorine atoms in the unit. If furthermore these atoms lie upon elements of symmetry their number within the unit will be some sub-

TABLE 1.

Special cases of the enantiomorphic cubic space groups.

Group	Equivalent positions in unit cell						
	One	Four	Eight	Twelve	Sixteen	Twenty-four	Thirty-two
O^1	2	—	1(1)	1(1)	—	1(3)	—
O^2	—	2	1(1)	1(1)	—	1(3)	—
O^3	—	2	1	—	—	1;1(1)	1(1)
O^4	—	—	2	—	2	—	1(1)
O^5	—	—	1	1;1(1)	1(1)	1(1)	—
O^6	—	2	1(1)	1(1)	—	1(3)	—
O^7	—	2	1(1)	1(1)	—	1(3)	—
O^8	—	—	2	2	1(1)	1(1)	—

Explanatory Note: If a number in the preceding table is not followed by a parenthesis, the positions in the corresponding arrangement are completely determined by the symmetry considerations; the parenthesized values give the number of variable parameters possessed by the various arrangements to which they refer.

structure for ammonium chloride. Thus these calculations yield for the strongest diffractions that are recorded the following calculated intensities:

Indices of Plane	Order	Intensities	
		Estimated	Calculated
110	1	10	3,050 arbitrary units
111	1	1	220
100	2	2	679
210	1	1.5	359
211	1	3	1,690

multiple of 96. In other words, the number of atoms of nitrogen and of chlorine in a unit cube must be 96 or some submultiple thereof. Neither 64 nor 27 are such submultiples so that it must be concluded that either one or eight molecules of ammonium chloride are associated with the unit cube. These two groups of possible arrangements are most readily studied with the aid of table 1.[5] It will be observed that there is no space group isomorphous with O (the enantiomorphic hemihedry) having special cases which permit the placing of one molecule of ammonium chloride within the unit. All possible arrangements for the atoms of ammonium chloride that will have the desired symmetry are as follows:

(2) From O^4:

N: $000;\ \frac{1}{2}\frac{1}{2}0;\ \frac{1}{2}0\frac{1}{2};\ 0\frac{1}{2}\frac{1}{2};\ \frac{1}{4}\frac{1}{4}\frac{1}{4};\ \frac{3}{4}\frac{3}{4}\frac{1}{4};\ \frac{3}{4}\frac{1}{4}\frac{3}{4};\ \frac{1}{4}\frac{3}{4}\frac{3}{4}.$
Cl: $\frac{1}{2}\frac{1}{2}\frac{1}{2};\ 00\frac{1}{2};\ 0\frac{1}{2}0;\ \frac{1}{2}00;\ \frac{3}{4}\frac{3}{4}\frac{3}{4};\ \frac{1}{4}\frac{1}{4}\frac{3}{4};\ \frac{1}{4}\frac{3}{4}\frac{1}{4};\ \frac{3}{4}\frac{1}{4}\frac{1}{4}.$
H: Thirty-two points one of which is uuu.

(3) From O^8:

N: $000;\ 0\frac{3}{4}\frac{1}{4};\ \frac{1}{4}0\frac{3}{4};\ \frac{3}{4}\frac{1}{4}0;\ \frac{1}{2}\frac{1}{2}\frac{1}{2};\ \frac{3}{4}\frac{1}{2}\frac{1}{4};\ \frac{1}{2}\frac{1}{4}\frac{3}{4};\ \frac{1}{4}\frac{3}{4}\frac{1}{2}.$
Cl: $\frac{1}{4}\frac{1}{4}\frac{1}{4};\ \frac{1}{4}\frac{1}{2}0;\ 0\frac{1}{4}\frac{1}{2};\ \frac{1}{2}0\frac{1}{4};\ \frac{3}{4}\frac{3}{4}\frac{3}{4};\ \frac{3}{4}0\frac{1}{2};\ \frac{1}{2}\frac{3}{4}0;\ 0\frac{1}{2}\frac{3}{4}.$
H: Two groups of 16 equivalent positions obtained by assigning two different values of u to groups of points one of which is uuu.

(4) From O^1:

Eight equivalent positions:

$uuu;\ u\bar{u}\bar{u};\ \bar{u}u\bar{u};\ \bar{u}\bar{u}u;\ \bar{u}\bar{u}\bar{u};\ u\bar{u}u;\ \bar{u}uu;\ uu\bar{u}.$

N: At $u = u_1$,
Cl: At $u = u_2$,
H: At $u = u_3$, and at 24 other positions which may be chosen in various ways.

(5) From O^2:

Eight equivalent positions:

$uuu;\ \bar{u}u\bar{u};\ u\bar{u}\bar{u};\ \bar{u}\bar{u}u;\ \frac{1}{2}-u,\frac{1}{2}-u,\frac{1}{2}-u;$
$u+\frac{1}{2},\frac{1}{2}-u,u+\frac{1}{2};\ \frac{1}{2}-u,u+\frac{1}{2},u+\frac{1}{2};$
$u+\frac{1}{2},u+\frac{1}{2},\frac{1}{2}-u.$

N: At $u = u_1$,
Cl: At $u = u_2$,
H: At $u = u_3$ and at 24 other points which can be chosen in several ways.

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[5] This table and the discussion which follows is based upon material contained in a book entitled "An Analytical Expression of the Theory of Space Groups," as yet unpublished. A similar table will be found in P. Niggli, Geometrische Krystallographie des Discontinuums, p. 410.

(6) From O^6:

Eight equivalent positions:

$uuu;\ u+\frac{1}{2},\frac{1}{4}-u,\frac{3}{4}-u;\ \frac{3}{4}-u,u+\frac{1}{2},\frac{1}{4}-u;\ \frac{1}{4}-u,\frac{3}{4}-u,u+\frac{1}{2};$
$\bar{u}\bar{u}\bar{u};\ u+\frac{3}{4},\frac{1}{2}-u,u+\frac{1}{4};\ \frac{1}{2}-u,u+\frac{1}{4},u+\frac{3}{4}:\ u+\frac{1}{4},u+\frac{3}{4},\frac{1}{2}-u.$

N: At $u = u_1$,
Cl: At $u = u_2$,
H: At $u = u_3$, and 24 other points which can be chosen in different ways.

(7) An arrangement can be deduced from O^7 which is enantiomorphic with that from (6). It does not require a more detailed treatment.

Comparison of possible Structures with the Diffraction Data.—The diffraction effects to be expected from each of these crystallographically possible structures[6] can be calculated in the usual fashion[7] and then compared with the observed reflections from various planes. The scattering power of the hydrogen atom is negligible compared with the scatterings of the nitrogen and chlorine atoms, so that they may be omitted from these calculations of intensities. Such a comparison leads to the following results.

Possibility (2): For planes whose indices are two even and one odd there should be no reflection until the fourth order. Planes such as (100) and (210) give second order reflections, however, so that this structure must be ruled out as impossible.

Possibility (3): This arrangement must be excluded for the same reason.

All of the remaining arrangements lead to structures which are chemically highly improbable. Particularly (3) and (4) yield structures that are from the standpoint of the chemist utterly inconceivable in that they group together about one point in the unit all of the ammonium groups and about some other point all of the chlorine atoms. In view of the close agreement that exists between the observed diffraction effects and those calcu-

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[6] An arrangement of atoms having holohedral symmetry, but to which an enantiomorphism might be ascribed by assigning to its atoms certain dissymmetries, could be developed from the space group O^3 which would produce the desired diffraction effects. In such a structure, however, though all of the ammonium radicals were alike, four of the chlorine atoms would be different from the other four. From the standpoint of its chemistry such a structure is scarcely permissible and may be eliminated upon such grounds.

[7] Ralph W. G. Wyckoff, this Journal, 50, 317, 1920; etc.

lated for the simple body-centered arrangement, (1), it would be anticipated that the correct structure approximates it quite closely. Inspection, however, shows that none of the arrangements can be made to approach this grouping of atoms. To discuss satisfactorily the diffraction effects from each of these possibilities it is necessary to assign to each of the variable parameters a range of values covering the entire unit cell and to calculate therefrom the intensities of reflection from various planes. These rather laborious calculations can be carried out with the aid of a graphical method which is an obvious extension of that one previously used in discussing the various possible arrangements for the atoms in periclase (MgO).[8] A rigorous treatment of these arrangements is scarcely attainable because of the somewhat qualitative character of diffraction data and of the assumptions upon which their discussion is based. It can, however, be shown that none of these arrangements will furnish reasonable structures which can account for the observed diffractions.

Such, then, are the results which lead to the impasse outlined in the introduction to this paper. The simple structure which is in agreement with the X-ray data is possessed of a tetrahedral hemihedral symmetry while the crystallographic information points to an enantiomorphic hemihedry. There is, furthermore, no chemically permissible arrangement of atoms, no matter how complicated we may wish to choose it, which will account for these diffraction data and will be capable of possessing in any way an enantiomorphic hemihedry.[9]

The issue thus appears to be sharply drawn. If previous observations upon crystals of ammonium chloride are correct in giving it pentagonal icositetrahedral faces, there seems to arise some uncertainty as to the value of the symmetry assignments commonly made by crystallographers upon their interpretations of face development. The more or less obvious interpretation of the sides of etch-figures as solution faces upon a crystal leads, in its application to the present case, to the same conclusion. An attempt to account for this discrepancy by

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[8] Ralph W. G. Wyckoff, this Journal, 1, 138, 1921.

[9] This statement is true no matter what symmetry characteristics may be assigned to the constituent atoms.

attacking the assumed mechanism of X-ray diffraction is not likely to yield results of value for the following reasons. The datum[10] which has been used here to establish the impossibility of an enantiomorphic hemihedry for ammonium chloride is simply the value of the ratio n^3/m. The correctness of this determination rests simply upon the idea of atoms as diffracting centers for X-rays, upon the correctness of the determination of the wave-lengths of X-rays, which itself is a consequence of the application of the quantum principle, and upon an approximately correct determination of the number of molecules in a gram-molecular weight of any substance. As a consequence the denial of the determined value of n^3/m must involve the denial of one of these fundamental factors, the general validity of any one of which is reinforced from many directions in physical science.

It is of great interest to all students of general crystallography to know whether there are any discrepancies between the external symmetry and the structure of crystals. To this end a further study of the external symmetry of ammonium chloride crystals is now needed.

Summary.—It is shown that not only is the symmetry of the structure that has been assigned to ammonium chloride in conflict with its observed symmetry but that there is no other possible structure which will possess the requisite symmetry. As a result the necessity of further study of the crystallography of this salt is urged.

Geophysical Laboratory,
Carnegie Institution of Washington,
November, 1921.

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[10] The chemically requisite assumption that in a crystal chemically identical atoms must be related in the same way to other atoms is of course likewise involved.

ART. XIV.—*The Crystal Structure of Silver Oxide (Ag_2O)*; by RALPH W. G. WYCKOFF.

Introduction.—Little is known of the crystallography of silver oxide (Ag_2O) other than that it crystallizes as a powder in microscopic isotropic crystals and can be grown as small octahedrons.[1] It is thus impossible to assign silver oxide crystals to any particular one of the classes of cubic symmetry.

Diffraction Data and the Number of Molecules within the Unit Cell.—Because of the difficulty of producing other than microscopic crystals the available diffraction data have been limited to those to be had from powder reflections. Powder photographs obtained in the customary manner showed lines of marked intensity. Measurements (upon two separate films) of the first four of them—all that are required to establish the structure of this crystal—are given in table 1.

The density of silver oxide[2] has been determined as 7.52. Because of the impossibility of immediately identifying the different lines as reflections from particular planes of atoms, the indices of the planes causing these reflections and the number of chemical molecules to be associated with the unit cell (or more precisely, the value of m/n^3) can be obtained only by assuming different values for m, calculating therefrom the spacings of simple planes in the corresponding unit and seeing whether the observed reflections can be identified in positions with some of these possible planes. Since as m is varied the resultant spacings change as the cube root, while the relative spacings of different planes stand in the ratio of the square roots, it should theoretically always be possible to make such an identification uniquely.[3] A determination of m for silver oxide by this procedure showed that if $m = 2$ the reflections observed in the photographs correspond with simple planes (see table 1). Since, furthermore this agreement would be equally well obtained from any unit having the

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[1] Vogel, Poggendorffs Ann. **118**, 145, 1863.

[2] Biedermann, Chem. Kalender, 1, 53, 1914.

[3] The actual spectrum lines are so wide, however, that such a manner of determining the number of chemical molecules in the unit need be entirely satisfactory only in case the correct indices of the planes actually producing the reflections are simple.

same value of m/n^3, where n may be chosen as any integer, it is evident that m for Ag_2O can just as well be equal to 16.

TABLE 1. *Measurements upon two Silver Oxide Films.*

Distance of line from central image		d_{hkl}/n in A. U.		hkl	d_{100} in A. U.	
Film 1.	Film 2.	Film 1.	Film 2.		Film 1.	Film 2.
2.86 cm.	2.85 cm.	2.75^5	2.75^8	111(1)	4.775	4.779
3.30^5	3.30^5	2.38^5	2.38^5	100(2)	4.770	4.770
4.72^5	4.73^5	1.67^3	1.67^0	110(2)	4.758	4.752
5.55	5.54^5	1.42^6	1.42^7	113(1)	4.768	4.770
				Mean	4.768	4.768

The value d_{100} is of course the length of the side of the unit cube.

The Possible Structures for Silver Oxide.—If $m = 2$: There is but one way of arranging two molecules of Ag_2O within a unit cell so that the resulting structure will have any form of cubic symmetry.[4] It is as follows:

Arrangement (*a*): Oxygen atoms at

$000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$.

Silver atoms at

$\frac{1}{4}\frac{1}{4}\frac{1}{4}; \frac{1}{4}\frac{3}{4}\frac{3}{4}; \frac{3}{4}\frac{1}{4}\frac{3}{4}; \frac{3}{4}\frac{3}{4}\frac{1}{4}$.

This grouping can be deduced from the space groups T_h^2,O^2 or O_h^4.

If $m = 16$: If the two silver atoms in the molecule of Ag_2O are chemically (and hence crystallographically) alike, there are three ways of arranging sixteen molecules of Ag_2O in a unit cube so that the resulting structure has cubic symmetry.[5] They are:

Arrangement (*b*): In this arrangement, which can be deduced from the space groups T_h^4,O^4 and O_h^7, the sixteen oxygen atoms lie in unique positions; the thirty-two silver atoms possess one variable parameter and are upon trigonal axes.

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[4] These results are taken from tables which form a portion of a book entitled "An Analytical Representation of the Theory of Space Groups" which is shortly to be published by the Carnegie Institution of Washington. Some of them are also given in P. Niggli, Geometrische Krystallographie des Discontinuums (Leipzig, 1919).

[5] If it were assumed that the two silver atoms could be different, then the several space groups having as special cases sixteen equivalent positions with one variable parameter would introduce additional possibilities. Such an assumption finds no justification from the chemistry of the compound and would run counter to the general trend of crystal structure determinations thus far made.

Arrangement (*c*): This grouping, deducible from the space group O^8, is simply a twice scale enlargement of arrangement (*a*).

Arrangement (*d*): In this arrangement, derived from O_h^{10}, the oxygen atoms lie in unique positions, the silver atoms upon trigonal axes.

The Choice of the Correct Structure.—An approximate calculation of the intensity of reflection from any plane for any of these possible structures can be made by the method already outlined.[6] For this purpose use was made of the expression

$$I \propto (A^2 + B^2) \cdot ({}^d/_n)^{2.35} \cdot p,$$

where I is the intensity of a line in the powder photograph, p is the number of planes of the reflecting form, d/n is the ratio of the spacing of the reflecting planes to the order of the reflection and $(A^2 + B^2)$ has the meaning previously given to it.

Arrangement (*a*): For this grouping

If n is odd:

When the indices of the reflecting plane are 2 odd and 1 even,

$A = 2\bar{O}$, $B = 0$;

Indices: 2 even, 1 odd,

$A = 0$, $B = 0$;

Indices: all odd,

$A = 0$, $B = \pm 4\overline{Ag}$.

If n is even:

Indices: 2 odd, 1 even,

$A = 2\bar{O} + 4\overline{Ag}$, $B = 0$;

Indices: 2 even, 1 odd or all odd,

$A = 2\bar{O} \mp 4\overline{Ag}$, — when $n = 2$, + when $n = 4$, $B = 0$.

In these computations $\bar{O}$ and $\overline{Ag}$, the scattering powers of oxygen and silver, respectively, are taken equal to the atomic numbers. A comparison between the estimated intensities of the four principal lines of the photograph and the intensities of these lines calculated for this arrangement is given in table 2; the other planes appear-

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[6] Ralph W. G. Wyckoff, this Journal, 2, 239, 1921; Jour. Wash. Acad. Sci. 11, 429, 1921.

ing in the photograph fit about equally well. The agreement is as good as could be expected in view of the uncertainties involved in these calculations.

TABLE 2.

Indices	Intensity (arbitrary units) Estimated	Calculated for arrangement (a)
111 (1)	10	77,800
100 (2)	7	34,900
110 (2)	7	43,200
113 (1)	6	50,500

Arrangements (*b*), (*c*) and (*d*).—Because of its identity with (*a*), *grouping* (*c*) requires no further treatment. Because of lack of knowledge of the laws of scattering, an entirely satisfying elimination of (*b*) and (*d*) can scarcely be made with these data. It can, however, be shown that they are both improbable.

These observations then have shown that there is but one simple structure, (*a*), the "cuprous oxide structure," which is in agreement with powder measurements obtained from silver oxide. Furthermore they have shown that neither of the two more complicated groupings which are possible structures from the determination of the value of the ratio m/n^3 are probable. In all likelihood, then, the atoms of silver oxide are arranged as defined by (*a*).

It is of interest that silver as oxide agrees with its analogue, monovalent copper, in departing from the perhaps more common cubic arrangement of two atoms of one kind and one of another, the "calcium fluoride structure." Since arrangement (*a*) can be deduced from space groups possessing either paramorphic or enantiomorphic hemihedry, or holohedry, this determination of the structure of silver oxide has not succeeded in defining uniquely its crystallographic symmetry. On the basis of recorded face development it has been customary to assign to cuprous oxide, with the same structure, an enantiomorphic hemihedry. It has been suggested[7] that this enantiomorphism could be explained if one or both of the kinds of atoms occupied positions slightly displaced from that of (*a*). Since in the arrangement of their atom positions,

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[7] W. H. and W. L. Bragg, X-rays and Crystal Structure, p. 157 (London, 1916).

not only the simple grouping (*a*) but likewise all of the more complicated groupings possess holohedral symmetry, it is evident that, assuming as we have that the two silver atoms of Ag_2O are equivalent, this explanation is untenable. If a real enantiomorphism exists in the case of cuprous oxide, it must be traced to some other cause than symmetry of the arrangement of the atoms.

Summary.—Employing the method of powders, it is shown that silver oxide has the same structure as that assigned to cuprous oxide. The length of the side of the unit cube is determined to 4.76^8 A. U.

Geophysical Laboratory,
Carnegie Institution of Washington.
December, 1921.

ART. XV.—*Carboniferous Plants from Peru;*[1] by EDWARD W. BERRY.

Just south of the port of Pisco the peninsula of Paracas, celebrated in the War of Independence, juts out into the Pacific, forming a bold wind-and-wave-swept headland (Lat. 13° 55′ S., Long. 76° 33′ W.). It is about 220 km. south of Callao and 25 km. southwest of the port of Pisco, and is of great geological interest since it is largely made up of continental Carboniferous sediments and constitutes one of the very few deposits of this character in South America, and the only known occurrence of rocks of this age on the West Coast of South Africa.

The outcrop of coal-bearing rocks on Paracas was discovered by F. C. Fuchs, who published a brief account[2] of it in 1900. Fuchs made a considerable collection of the fossil plants, which are now in the Museum at Lima, where I had the privilege of seeing them. He identified the following forms: *Calamites suckowii, Sphenopteris hartle benii, Lepidodendron sternbergii, Sigillaria tessellata, Stigmaria ficoides* and *Baiera pluripartita,* and considered the deposit to be of Upper Carboniferous age.

The true *Sphenopteris hartlebenii* of Dunker, which has since been referred to *Ruffordia goepperti,* is a characteristic species of the Wealden, and the Paracas form which Fuchs thought represented this species is *Palmatopteris furcata,* a rather widespread Carboniferous fernlike plant of the Sphenopterid group. Fuchs's *Baiera pluripartita* is not a Baiera but a species of the genus Eremopteris, his Sigillaria I was unable to identify from an inspection of the material, and as there are no true Sigillarias in my collections I cannot say whether his specific name is correct or not. His Lepidodendron is not *Lepidodendron sternbergii* but represents both of the species recorded from this locality in the present paper. His Calamites and Stigmaria appear to be correctly determined.

The scarcity of coal at tidewater on the West Coast aroused a great local interest in Fuchs's discovery, pertenencias were quickly taken out and much money was

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[1] A fully illustrated account of this flora will be published at a later date. George Huntington Williams Publication, No. 9.

[2] Fuchs, F. C., Nota sobre el terreno carbonífero de la peninsula de Paracas, Bol. de Minas Industria y Construcciones, tomo 16, No. 7, Lima, 1900.

spent in putting down concrete-lined shafts and in diamond drilling, although the complete section is admirably exposed along the south shore of the peninsula. Prospecting has not resulted in economic development, since the coal seams are thin and the coal contains a prohibitive percentage of ash.

Subsequently Fuchs gave a brief account of the geology of this general region in his paper on the copper deposits around Ica and Nazca.[3] In this report he considers that the Carboniferous at Paracas is continuous to the eastward beneath the Pleistocene and recent deposits that form most of the surface of the country in the belt lying between the igneous rocks of the Western Range of the Andes and the present coast, i. e. the Pampa de Condor, Pampa de Chunchanga, Pampa de Pisco and Tablazo de Ica. Another account of the Paracas Carboniferous without, however, adding anything to our knowledge concerning it, was published by Dorca in 1909.[4]

Steinmann, who did not visit Paracas, saw Fuchs's collection at the Cuerpo de Ingenieros de Minas in Lima. In a short note published in 1910 he makes the interesting generalization that the plant-bearing Carboniferous in South America is Lower and the invertebrate-bearing Carboniferous is Upper in age.[5] He states, with his usual assurance, that the Paracas forms represent:

Archaeocalamites radiatus.
Lepidodendron cf. Veltheimi.
Lepidodendron cf. Volkmanni.
Sphenopteris affinis = S. furcata.
Rhodea filifera.
Rhabdocarpus.

None of these forms is represented in the large collections which I made at Paracas, nor did I see any of them in the Fuchs collection.

Finally in 1917 in Lisson's admirable compilation of Peruvian fossils[6] the two species *Lepidodendron rimosum* and *Lepidodendron obovatum* are listed from Paracas, the determinations being by the late Professor Zeiller,

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[3] Fuchs, F. G., La Región Cuprífera de los Alrededores de Ica y Nazca; Cuerpo de Ingenieros de Minas, Bol. 29, Lima, 1905.

[4] Dorca, I. R., Estudio sobre los Yacimientos Carboniferos de Paracas, Bol. Soc. Ingenieros, vol. 11, pp. 104-130, Lima, 1909.

[5] Geol. Rundschau, Bd. 1, p. 50, 1910.

[6] Lisson, C. I., Edad de los Fósiles Peruanos y Distribución de sus Depósitos en Toda la Republica, pp. 20-21, Lima, 1917.

and the age is given as Westphalian. Both of these species are represented in my collections.

The question of the age of the Paracas deposits and their relation to the widespread Carboniferous limestones of the Andes is one of great importance. It was apparently some conversation with Señor Bravo, the Director of the Cuerpo de Ingenieros de Minas regarding the Paracas continental Carboniferous that was the basis for the beautiful diagrams of the relations of land and sea during Carboniferous time published by Bowman,[7] which he unfortunately located at Pacasmayo which is 805 km. north of Paracas in a region of crystalline rocks.

There was not time for a detailed study of the Carboniferous of Paracas during my visit, necessarily short since the peninsula is a practically uninhabited desert. The wide and desert coastal plain, interrupted only by the irrigated valley of Ica, that extends from the igneous foothills of the Western Range to the ocean, consists of wind-blown sands, desert pavement gravel, and paper shales. Similar deposits form the neck of the Paracas peninsula, which is thus the result of the block-faulted Carboniferous and apparently bears no relation to westerly spurs from the Andes or igneous intrusions in the Coastal Plain.

Following is a measured section of the easternmost fault block and was repeated in the next block to the southwest.[8] The horizons from which fossil plants were collected are indicated and there is no chronologic change in the flora from top to bottom although fossil plants are more varied in the lowermost horizon.

Thin to heavy bedded rather coarse greenish-gray sandstone,	13
Greenish-gray massive and crossbedded sandstone with varying amounts of shaly intercalations with Lepidodendron. (N. 21 E, 26 E)	75
Dark shale with sandstone layers less than a foot in thickness	55
Sandstone with a shale parting in the middle	35
Sandy and somewhat carbonaceous fossiliferous shale	80
Sandy shale (tunnel)	22
Massive sandstone passing into thin-bedded sandstone along the strike. (N. 9 E, 25 E)	30

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[7] Bowman, I., The Andes of South America, p. 19.

[8] Measured by Professor Joseph T. Singewald, Jr.

Massive greenish-grey somewhat arkosic sandstone	15
Thin-bedded sandstone	10
Thin-bedded sandstone with dark shale (no coal) toward the top (tunnel in shale)	32
Alternating sandy and carbonaceous shale with 6 inch coal at top, abundantly fossiliferous (tunnel)	38
Massive greenish-gray somewhat arkosic sandstone	20
Shale carbonaceous above, sandy below (N. 20 E, 25 E) (tunnel)	10
Greenish-gray sandstone, thin-bedded above	5
Gray shale	2
Interbedded thin sandstones and shales	3
Shale	1
Gray arkosic sandstone	5
Sandy shale	18
Thin-bedded sandstone and sandy shale with more massive sandstone at base	70
Dark carbonaceous shale with 2 to 3 inches of coal at top, abundantly fossiliferous (N. 5 , 25 E) (tunnel)	18
Massive greenish sandstone	15
Sandy shale	13
Pleistocene	585

Section repeated by faulting to the southwest.

The materials are relatively coarse throughout and would seem to indicate rapid deposition. Between 53 and 54 per cent of the total thickness is described as sandstone, which is often coarse and arkosic. Of the 273 feet described as shale 192 feet are distinctly sandy, so that less than 14% of the total thickness, including the so-called coal seams, is fine-grained shale and even the coal contains much silty impurities. No underclays with rootlets, or upright stems were observed and the coaly layers have every appearance of having been formed of drift material, which also appears to have been the case in the probably contemporaneous and very similar continental Carboniferous examined on the Copocabanya Peninsula on Lake Titicaca in Bolivia.

The Flora.

The flora comprises the following forms:

Pteridophytes or Pteridospermophytes.

1 Palmatopteris furcata (Brongn.)
2 Eremopteris whitei Berry.
3 Eremopteris peruianus Berry.

Arthrophyta—Calamariales—Calamariaceae.

4 Calamites suckowii Brongn.
5 Calamostachys sp.

Lepidophyta—Lepidodendrales—Lepidodendraceae.

6 Lepidodendron rimosum Sternb.
7 Lepidodendron obovatum Sternb.
8 Lepidophyllum sp.
9 Lepidostrobus sp.
10 Stigmaria sp.
11 Knorria sp.

It is thus extremely limited, although some of the elements are exceedingly common, and this is especially true of *Palmatopteris furcata, Eremopteris whitei, Calamites suckowii* and *Lepidodendron rimosum*. I imagine that the coarseness of the sediments and the apparent drifting of the material is mainly responsible for the absence of a more representative flora. Thus the present collections contain no traces of Sigillaria, Cordaites, Sphenophyllum, calamite foliage, nor of any Neuropterids, Pecopterids, Alethopterids or Lonchopterids. It is this feature of the flora which is undoubtedly responsible for the opinon of Steinmann, quoted on a preceding page, that the Paracas flora is of Lower Carboniferous age.

A somewhat similar situation is furnished by the flora of the Kuttung series of New South Wales, where the so-called Rhacopteris flora appears to be wholly lacking in Neuropteris, Alethopteris and Pecopteris. Walkom, however, and quite rightly I believe, correlates this Kuttung flora with the Westphalian stage of the European section.

The nearest known occurrence of marine Carboniferous in Peru is at Huanta, Dept. of Ayacucho, 277 km. N.E. of Paracas. The only known outcrop of the marine Carboniferous west of the Western Range is at Cotahuasi, Dept. of Arequipa. This is about 150 km. inland from the present coast and about 395 km. S.E. of Paracas.

Continental Carboniferous, mostly of unknown age, is more widely distributed in South America than has been suspected. Thus there are some continental sediments in the lower part of the section on the Copacabanya peninsula, and Titicaca Island, at the Cerro de Lacctacucho, Sicuani, Dept. of Cuzco, at the Pongo Mainique on the Urubamba, Dept. of Cuzco. Steinmann (Geol. Rundschau, Bd. **2**, pp. 50-51, 1910) records Lepidodendron and *Rhacopteris inaequilatera* Göppert from near Huichaycota on the Rio Huallaga in the Eastern Range 1 km. south of Huánuco in the Department of that name. In the same publication similar deposits, said to contain *Archaeocalamites radiatus* and *Lepidodendron* cf. *Volkmanni* are recorded from Retamito, which is between San Juan and Mendoaz in the Argentine Cordillera.

I think that there can be no doubt that the Paracas Carboniferous is younger than the Dinantian stage of the European section and that it corresponds to the Westphalian stage. The marine Carboniferous of the Andes is usually considered to be of Uralian age, that is to say, Stephanian in terms of the continental section. Whether or not the marine series represents more than Uralian has not yet been definitely determined. The finding of one at least of the Paracas plants in the lower part of the section on the Copacabanya peninsula, Bolivia, several hundred feet below the fossiliferous limestones, would lead to the inference that the Paracas plant-bearing Carboniferous is older than the bulk of the marine Andean Carboniferous and especially the highly fossiliferous portion of the latter.

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Baltimore, Md.

ART. XVI.—*Melanovanadite, a New Mineral from Mina Ragra, Pasco, Peru;* by WALDEMAR LINDGREN, L. F. HAMILTON and CHARLES PALACHE.

Introduction.—Late in 1920 Mr. W. Spencer Hutchinson, consulting engineer for the Vanadium Corporation of America, brought to the attention of the senior author three specimens of a mineral collected by him at Mina Ragra, Peru. He suspected that it was a new mineral, and this opinion was proved correct by chemical and optical examination. The formula appears to be $2CaO.2V_2O_4.3V_2O_5$ and the name of *Melanovanadite* is proposed for it, in allusion to it being practically the only vanadium mineral of a deep black color.[1]

Description.—The mineral was collected from No. 1 tunnel in the lower part of the great patronite deposit at Mina Ragra, below the strongly oxidized zone and 90 feet below the surface. This tunnel extended out into the surrounding black shale from the so-called Veta Madre, or main, lower section of the deposit. Mr. Hutchinson believes that the ore is not conformable with the dip of the slates but forms a crosscutting body. The mineral occurred along fractures in the shale, not far from the main body, and there was enough of it to be mined as rather high-grade vanadium ore. One of the specimens showed a compact brownish gray shale rich in gypsum. On a joint plane were flat radial or divergent aggregates of a black lustrous mineral of prismatic habit and near these the shale was blackened.

The best specimen, about 12 by 8 by 6 cm., is composed of a soft porous black material evidently altered shale traversed by brecciated openings or fractures coated by closely massed divergent and velvety bunches of small acicular black crystals, with a maximum length of 3 or 4 mm. These bunches are easily removed and a quantity of about 2 grams was obtained which, for purposes of analysis, was hand-picked under the binocular microscope. The product was almost pure, containing only a few particles of altered shale and of pascoite. Regarding the paragenesis and the nature of the altered shale see below.

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[1] The ending "vanadite" is an obsolete form of "vanadinite," but there can scarcely be any objection to using this form in the present case.

Crystal Form.—The greater thickness of the needles is about 0.5 mm. ranging down to 0.1 and 0.01 mm. The color is black, luster almost submetallic, streak very dark reddish brown, the hardness is 2.5, the specific gravity 3.477 at 20° C. The habit of the crystals is prismatic, parallel to *c*, with monoclinic symmetry. The principal faces consist of a flat striated prism, the longer diagonal being parallel to the *b*-axis, minor pinacoidal faces and usually well-developed terminal faces of pyramids and smaller domes. There is a perfect cleavage parallel to the clinopinacoid. Although small the crystals can be measured.

Optical Properties.—Under the microscope the crystals remain black except in very thin prisms which are translucent with brown color. Flat cleavage pieces parallel to the clinopinacoid only become translucent when the thickness is about 0.003 mm. and then show maximum extinction of about 15°. Resting on the prism the crystals become brown translucent with a thickness of about 0.03 mm. and then show lower extinctions of 12° to 13°, while these resting more nearly on the orthopinacoid extinguish at lower angles ranging down to 0°. The perfect cleavage being perpendicular to the poorly developed orthopinacoid extinctions of 0° are rarely seen. Exact optical measurements are difficult on account of the deep color. Obscure hyperbolæ show on the prism faces and it is probable that the plane of the optic axes is perpendicular to the perfect cleavage (010). The absorption is very strong. The α ray is visible with dark yellowish brown color through the prism faces and the orthopinacoid and has according to a determination kindly made by Professor C. H. Warren a coefficient of refraction of a little less than 1.74; while the β and γ rays are somewhat higher but cannot be measured exactly on account of the strong absorption. The β and γ rays therefore lie in the 010 plane of perfect cleavage and their absorption is so strong that such cleavage pieces only become translucent in extremely thin plates, with dark reddish brown color, β and γ differing slightly in depth of tint. The double refraction is strong.

Composition.—An analysis by L. F. Hamilton gave the following composition:

V_2O_5	52.61
V_2O_4	33.34
CaO	9.89
MgO	.27
Al_2O_3,Fe_2O_3	1 89
Silica	1.66
	99.66

The calcium was determined by fusion with sodium carbonate and leaching with sodium carbonate water, leaving $CaCO_3$, $MgCO_3$ and $Fe(OH)_3$ insoluble. The residue was dissolved in HCl; $Fe(OH)_3$ was removed with ammonia, calcium precipitated as CaC_2O_4, filtered, dissolved and titrated with standard permanganate. MgO was determined in filtrate by usual process.

For total vanadium the fusion and titration method outlined by A. H. Low in his "Technical Methods of Ore Analysis," 8th ed., 1919, p. 279, was followed. The vanadyl was determined by direct solution of mineral in H_2SO_4 and in atmosphere of CO_2 followed by titration with standard permanganate. V_2O_5 was obtained by difference.

The mineral had been kept for several months in a dry warm atmosphere, the analysis being completed in January, 1921. All determinations were made in duplicate and some repeated. The determinations gave an actual figure of 0.42% for total water on a sample of about 0.12 gram, which is only a gain in weight of a chloride tube of 0.0005 grams or an allowable error in weighing a tube of 10 to 12 grams capacity.

Assuming the alumina and iron oxides and magnesium and silica to be impurities from the admixed shale, the analysis may be recalculated to:

V_2O_5	54.90
V_2O_4	34.78
CaO	10.32
	100.00

From this we calculate

$$V_2O_5 \ldots\ldots \frac{54.90}{182} = 0.302$$

$$V_2O_4 \ldots\ldots \frac{34.78}{166} = 0.209$$

$$CaO \ldots\ldots \frac{10.32}{56} = 0.184$$

$$V_2O_5 : V_2O_4 : CaO = 303 : 209 : 184$$

or approximately 3 : 2 : 2. The formula would, therefore, be

$$2\ CaO.3\ V_2O_5.2\ V_2O_4$$

The calculated composition of this would be

V_2O_5	55.16
V_2O_4	33.54
CaO	11.30
	100.00

Before the blowpipe the mineral fuses very easily to a brown liquid but gives no flame reaction for calcium. It gives strong bead reaction for vanadium. It is easily soluble in dilute HNO_3, HCl, and H_2SO_4, with apple-green color. In concentrated HNO_3 it dissolves with evolution of red fumes to a dark brown solution. Upon evaporation it gives a red or brown residue. It is also easily decomposed by KOH with brownish color.

In May, 1921, a small sample of the mineral was sent to Dr. W. T. Schaller of Washington. The material had then for some time been exposed to a warm damp atmosphere. Dr. Schaller stated in a letter that the mineral appeared to contain much water. In view of this, the following re-examination was undertaken. A dry tube test showed at once that this was now true, an abundance of water being given off. The larger part was driven off upon drying at 105°, but equally large amounts were lost in desiccator above sulphuric acid. A sample in desiccator lost 10.26% H_2O in twelve days; the weight was taken for six more days, but remained constant. The dried material took up water rapidly after being removed from the desiccator, even while it was being weighed.

The most representative results showed a loss of 10.7% H_2O upon drying at 105° C. About 5.9% was held above 105°, making a total water content of 16.6. The exact point at which this last water was given off was not determined on account of the very low fusion point of the mineral.

A sample carefully cleaned and finely ground and dried for two days at 105° C. gave the following figures:

Total vanadium as V_2O_5	86.07	
V_2O_4		33.48
V_2O_5		49.38
CaO		10.65
$Fe_2O_3 + Al_2O_3$		1.39
H_2O+		5.90
		100.80

SiO_2 and MgO not determined.

It is certain that this mineral has hygroscopic qualities very similar to the uranium micas and is strongly influenced by atmospheric moisture or dryness.

In regard to the 5.9% held above 105° C. the results seem difficult to harmonize, but we have the definite assertion of the chemist that when first analyzed in the winter of 1921, the mineral was practically anhydrous. This is supported by the senior author's statement that the mineral then gave no water in closed tube. Just what the condition of the material was when formed in the deposit is not easy to say. In view of the uncertainty still attached to the part played by water in this mineral we have decided to let the formula stand as based upon the first and complete analysis.

Paragenesis.—In places the black acicular crystals are coated with a yellow powder, and sometimes larger masses of an orange-yellow substance cover the terminal edges or are embedded between the black prisms. This orange mineral, which is easily soluble in water, was identified as pascoite ($Ca_2V_6O_{17}.11H_2O$) and agrees in its optical character with that substance. It is clearly a product of hydration of melanovanadite.—[The above by W. Lindgren.]

It remained to examine more closely the dark altered shale upon which the bunches of melanovanadite were attached.

Quite generally, this material gave a stong vanadium reaction and also gave off more or less SO_2 in open tube. It also contained organic matter. To test for the presence of native sulphur the powdered material was digested with CS_2. Upon evaporation the solution yielded a resinous product but no sulphur. The residue was washed with alcohol and leached with water. It gave a yellowish solution containing vanadium doubtless from finely divided pascoite. The residue gave a strong sulphur reaction in open tube and then dissolved in HNO_3 giving a green color and strong vanadium reaction. It was assumed, therefore, that a sulphide was present and to determine it if possible many polished sections were made.

The polished sections showed in a dark gray gangue one or two minute grains of pyrite, several minute grains of hard greyish white color, not definitely determined. Some bright scales of native copper were also observed. The vanadium was present in the form of two minerals. Minute prisms of melanovanadite were distributed through the mass, clearly replacing the shale material (largely gypsum). There were also veinlets of the same substance. In oblique reflected light the melanovanadite shows a blackish, submetallic luster, but in vertical illumination it is rather bright greyish white with a tinge of purple. It is very soft and gives a brown streak and is instantly blackened by HNO_3, HCl, and KOH. Included in veinlets and masses of melanovanadite are irregular masses of a metallic soft mineral of a brighter gray color which undoubtedly is a vanadium sulphide though I am not at all sure that it is patronite. The minute size and fine intergrowth of the minerals tend to make a definite identification difficult. The original vanadium mineral was then a sulphide. Oxidation converted this to a blue vanadyl sulphate (Minasragrite) which even now is abundantly present in the mine water. Reaction with $CaCO_3$ in the water and further oxidation produced the calcium vanadyl vanadate, melanovanadite, and the hydration of the latter resulted in the orange-colored pascoite. The process was carried out in the lower part of the oxidized zone.

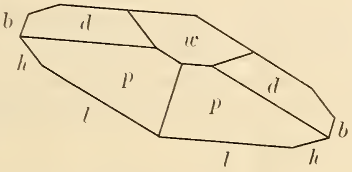
The real patronite is a black mineral of fine grain and metallic luster. In polished section it is shown to consist of a very fine-grained mixture of three minerals. The first and most abundant constituent is purplish gray and is sometimes developed in rudely prismatic, thick forms. The other two constituents are respectively light gray and darker gray in color, and are developed in irregular grains. All three minerals are doubtless sulphides.

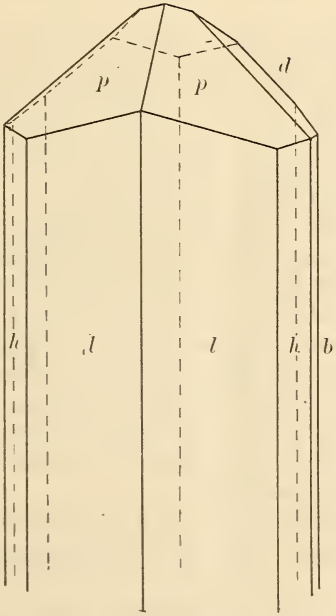
The description given by Davy and Farnham (Microscopical Determination of Opaque Minerals) does not apply to the pure patronite but to some intermediate product of alteration. It is believed that Hillebrand's analysis of patronite was made on partly altered material.

Crystal Form of Melanovanadite (by C. Palache).

System Monoclinic.

Axial Ratio $a : b : c = 0.4737 : 1 : 0.5815$ $\beta = 88° \, 37\frac{1}{2}'$
$p_0 = 1.227$ $q_0 = 0.581$ $\mu = 88° \, 37\frac{1}{2}'$





Four crystals were measured on the two-circle goniometer. They proved little suited to accurate measurement, the prism zone being badly striated and the terminal faces, while apparently bright and plane, giving faint and often multiple signals. The figure reproduces the habit of most of the crystals.

Description of the forms:

b (010) is always present, generally as a narrow, bright face. The cleavage parallel to it is so perfect that it is difficult to detach or even handle a crystal without developing cleavage surfaces.

a (100) is represented on every crystal by a rather broad curved surface which gives a train of reflections, none of which is from a true face.

c (001) is not present as a face. The inclination of the clino-axis, to which it would be parallel, was calculated from the other terminal faces present.

h (230) forms narrow but distinct faces on every crystal. Its faces are far more perfect than other forms of the prism zone except *b*.

(530*) is the dominant prism form; its faces are broad but badly striated and their position-angles show wide variations.

Poor reflections were obtained from numerous other prism faces but were too uncertain to be regarded as indicating definite forms. None were found at all near to the position of the unit prism which would naturally be expected to occur rather than the two prisms with rather complex indices given above.

p (111) is the dominant terminal form. Its faces are generally bright and often developed to such an extent as to reduce other terminal faces to mere lines.

s $(\bar{1}21)$ was observed but once as a minute face; it has therefore been omitted from the figure.

d (032) is always present and its faces have a better quality than any others on the crystals.

g (012) was present on each crystal measured but with faces so small as scarcely to be measureable. It was not figured therefore.

w $(\bar{1}01)$ is quite large on most crystals but its faces are always curved so that the position-angles are widely variable.

The table contains the observed angles with their limits of variation and the angles calculated from the derived elements.

		No. of faces	Measured		Limits		Calculated	
			ϕ	ρ	ϕ	ρ	ϕ	ρ
b	(010)	6	00°34′	90°00′	00°00′ – 1°12′		00°00′	90°00′
h	(230)	10	55 00	90 00	54 12 – 55 49		54 37	90 00
l	(530)*	7	74 30	90 00	73 32 – 75 40		74 08½	90 00
w	$(\bar{1}01)$	4	–90 35	50 17	87 05 – 95 35	49°56′ – 50°33′	–90 00	50 17
g	(012)	3	2 33	16 25	0 14 – 4 44	15 25 – 17 10	4 13	16 16
d	(032)	5	1 53	41 32	0 36 – 4 23	41 24 – 41 42	1 34	41 06½
p	(111)	7	65 34	54 00	64 51 – 66 51	53 28 – 54 55	65 05	54 05
s	$(\bar{1}21)$	1	–45 00	59 33			–45 59	59 09

* This prism should probably be replaced by the prism with the simpler indices (210). The latter gives excellent zonal relations with the terminal planes which is not true of (530) The crystal has been drawn as though the form were (210) which requires an angle ϕ of 76° 41′. The observed angles showed none as large as this, however, and the exact symbol of this form must remain in doubt.

Art. XVII.—*The Ceratopyge Fauna in Western North America;* by Percy E. Raymond.

The determination of the boundary between the Cambrian and Ordovician systems in the West has proven as difficult a problem as it is in the East. The following contribution to the discussion of this question is based primarily upon a collection made by Mr. Francis P. Shepard, a graduate of Harvard, in the course of the investigation of the structure of the Rocky Mountain Trench.

The determinable fossils in his collections, from four localities, in the Columbia River Valley, B. C., are:

Lingulella moosensis Walcott,
L. ? allani Walcott,
Obolus mollisonensis Walcott,
Eoorthis desmopleura (Meek),
Eoorthis sp. ind.,
Dalmanella hamburgensis (Walcott),
Syntrophia nundina Walcott,
Raphistoma nasoni Walcott,
Arthrorachis sp. ind.,
Hystricurus tuberculatus (Walcott),
Cyphaspis ? brevimarginata Walcott,
Symphysurus cleorus (Walcott),
S. elongatus (Walcott),
Hemigyraspis mcconnelli Raymond,
H. caribouensis (Walcott),
Megalaspis shepardi sp. nov.[1]
Menocephalus sp. ind.

This is a good *Ceratopyge* fauna, comparable to that which is found at the base of the Ordovician at many localities in Europe. It lacks both *Euloma* and *Niobe,* but as is well known, there is great variation in the composition of this fauna in the different regions in which it is found. Broegger long ago[2] called attention to its presence in the Eureka District, in the lower part of the Pogonip. More recently Walcott[3] has noted the same zone in British Columbia, but listed only a very few species. The importance of this fauna in the determination of the boundary between the Cambrian and Ordovician is so great as to justify a review of its distribution in western North America.

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[1] Not to burden this paper with detailed descriptions of fossils, *Megalaspis shepardi* may be characterized briefly as follows: Known from pygidia only. That shield elongate, sub-triangular, pointed behind. Axial lobe not prominent, contracted near the middle, with about six faintly defined rings. Pleural lobes nearly smooth, with one pair of obscure ribs. Shell strongly punctate. Holotype collected by Mrs. Francis P. Shepard and now in the Museum of Comparative Zoology.

[2] Nyt. Mag. for Naturvidensk, vol. 35, p. 229, 1896.

[3] Smithson. Miscl. Colls., vol. 57, No. 7, p. 229, 1912.

Eureka District,[4] *Nevada.*

The faunas of the lower part of the Pogonip are but imperfectly known, yet there is more evidence of the *Ceratopyge* zone than was noted by Broegger. *Illænurus eurekensis* is a *Symphysurus,* and *Dikelocephalus finalis* an *Apatokephalus,* as pointed out by Broegger. *Symphysurus? goldfussi* Walcott belongs to the genus *Ceratopyge* itself, and *Asaphus caribouensis* is a *Hemigyraspis* (cranidium and free cheek only; the pygidium associated is that of *Symphysurus eurekensis*). *Ptychoparia* (*Euloma*) *affinis* is, however, probably not a *Euloma.*

The ranges of the fossils in the Pogonip are not very definitely established. Hague gives the thickness of the formation as about 3,000 feet near Eureka, and at White Pine over 5,000 feet. Near the base are such important species as *Syntrophia nundina, Hemigyraspis caribouensis,* and *Symphysurus eurekensis.*

"Several hundred feet higher," the fauna contains, among others:

Schizambon typicalis, Dalmanella hamburgensis, Syntrophia nundina and *Apatokephalus finalis.*

From Hague's descriptions, it may be judged that the lower several hundred feet, and probably more than a thousand, hold the *Ceratopyge* fauna. *Receptaculites, Maclurites* and other genera suggestive of Beekmantown appear about midway in the Pogonip, according to him. In one list, *Receptaculites, Syntrophia nundina* and *Symphysurus* are found together and other lists indicate a mingling of *Ceratopyge* and Beekmantown faunas to within 800 feet of the top. This indicates a much greater vertical range for this assemblage than is known anywhere in Europe. In the lower part of the Pogonip, there is a strong admixture of Upper Cambrian species.

Utah.

Walcott has described a section in the House Range, Millard County,[5] western Utah. The highest formation of the Upper Cambrian is named the Notch Peak. No fossils were found in place, but a drift-boulder supposed

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[4] Walcott, Mon. 8, 1884; Hague, Mon. 20, 1892, U. S. G. S.

[5] Smithson. Miscl. Colls., vol. 53, p. 173, 1908.

to have been derived from strata in the upper 640 feet, contained the following species (names corrected to agree with later publications by Walcott):

Eoorthis desmopleura (Meek), *Schizambon typicalis* Walcott, *Agraulos* sp. ind., *Solenopleura* ? sp. ind., *Tsinania cleora* Walcott.

The last species is really a *Symphysurus*. Walcott[6] proposed the genus *Tsinania* for trilobites of the type of *Illaenurus canens* Walcott, a Chinese species which has a cranidium similar to that of *Symphysurus,* but more nearly hemispherical, and a pygidium which is nearly as long as wide. This latter feature is the most distinguishing one for the genus, and is not shared by any American form. *Tsinania cleora,* as shown by Walcott's figures, has the short pygidium of the typical *Symphysurus.*

The Blacksmith Fork section in the Wasatch Mountains of northern Utah was also described by Walcott.[7] Both the Lower Ordovician, and the upper 190 feet of the St. Charles formation, referred to the Upper Cambrian, contain the *Ceratopyge* fauna, although some of the more characteristic trilobites are lacking. Important species in the St. Charles are: *Eoorthis desmopleura* (Meek), *Syntrophia nundina* Walcott, *Schizambon typicalis* Walcott, *Menocephalus* sp. ind., and *Illaenurus* [*Symphysurus*] sp. ind.

According to Tomlinson,[8] Beekmantown fossils are present in strata 1,260 feet above the top of the St. Charles formation.

Richardson[9] has described briefly a section in the Randolph quadrangle in Northern Utah. This is east of the section on Blacksmith Fork, and the Cambrian sequence is the same.

Resting on the St. Charles is the Garden City limestone, with a thickness of 1,000 feet, which contains a fairly large fauna, partially identified by Kirk. Although the aspect is in general that of the Beekmantown, one can find suggestions of the Ceratopyge fauna.

Above the Garden City is the Swan Peak quartzite, 500 feet thick, from which some fossils have been obtained. Among them Kirk has identified *Symphysurus goldfussi*

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[6] Smithson, Miscl. Colls., vol. 64, No. 1, p. 43, 1914.

[7] Smithson. Miscl. Colls., vol. 53, p. 191, 1908.

[8] Jour. Geol., vol. 25, 1917.

[9] This Journal, vol. 36, p. 406, 1913.

Walcott. Since this is a *Ceratopyge,* the identification, if correct, would be of the utmost importance.

British Columbia.

I first suspected the presence of the *Ceratopyge* fauna in British Columbia when I described from isolated specimens which had long been in the collection of the Canadian Geological Survey, the trilobite *Hemigyraspis mcconnelli.*[10] It was collected three miles east of Golden, and it is interesting to find it in Mr. Shepard's collection.

Professor Daly found, 2 miles west of Donald Station, B. C., two trilobites of this fauna which have been described by Walcott[11] as *Dikelocephalus ? dalyi* and *Tsinania elongata.* The latter is a *Symphysurus,* and was found also by Mr. Shepard.

Professor J. A. Allan has given the name Goodsir to a formation, 6,000 feet in thickness, which overlies the Upper Cambrian in the Ottertail Range, and occurs on both sides of the Beaverfoot Range. The strata which are found on the eastern side of the Columbia Valley at Golden belong to this formation.[12]

From the lower portion of it, at a locality 10 miles southeast of Leanchoil, B. C., Allan collected a small fauna from which Walcott described[13] the following new species: *Obolus mollisonensis, Lingulella moosensis, L.* (?) *allani,* and *Ceratopyge canadensis.* While there can be no doubt that this is a faunule of the Ceratopyge zone, the trilobite is hardly sufficiently like the European representatives of the genus to be included in *Ceratopyge.* Walcott states that "This species differs from *Ceratopyge forficula* Sars in the greater length of the frontal limb of the cranidium, longer palpebral lobes, and narrower fixed cheeks. The pygidium differs most in having a short median lobe, broader border, and the side spine springing from the first instead of the second segment."

All this is true, and it should also be added that the glabella is not definitely outlined, and tapers forward in *C. canadensis,* while it is strongly outlined, truncated in

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[10] Geol. Sur. Canada, Mus. Bull. vol. 1, 1913, p. 41.

[11] Smithson. Miscl. Colls., vol. 57, 1914, p. 367 and ibidem, vol. 64, p. 228, 1916.

[12] Sum. Rept. Geol. Sur. Canada for 1912, 1914, p. 171.

[13] Smithson. Miscl. Colls., vol. 57, p. 229, 1912.

front, and expands forward in the typical Ceratopyge. The Canadian form has no glabellar furrows, while *C. forficula* always shows at least the posterior pair. A most important difference is in the course of the facial sutures in front of the eyes. In *C. forficula* they diverge and quickly intersect the margin, whereas in *C. canadensis* they turn but little outward, then inward, so that the anterior part of the cranidium is pointed, as in Isotelus.

The position and origin of the spines on the pygidium are fundamentally different from those of *Ceratopyge.* In *C. forficula* these spines are, as Dr. Walcott has said, the continuation of the second segment, but they are firmly welded into the pygidium, so that they appear as projections of the margin. In *C. canadensis* the spine-bearing first segment of the pygidium is so nearly severed from it, that it would be almost as true to say that the last segment of the thorax was laterally extended into spines, as that the first one of the pygidium was spinose.

It is difficult to place this trilobite. The general aspect is that of the Asaphidae, and were there not 10 (or 11) segments in the thorax, one would be inclined to refer it to *Asaphellus.* The most nearly allied form which I have seen described seems to me to be *Dolichometopus* (*Housia*) *varro* Walcott, from the Upper Cambrian of the House Range in Utah.[14] This trilobite is, unfortunately, itself imperfectly known and of uncertain affinities.

In order to avoid giving a new generic name, however, I would suggest that the trilobite from the Goodsir be called *Housia canadensis*, unless it can be shown to be generically distinct from the type of *Housia*:—neither is very suggestive of *Dolichometopus.*

In the Robson Peak district on the border between British Columbia and Alberta, Walcott[15] has referred the Robson limestone to the Ordovician and found at the base an assemblage in which "there is a commingling of the lower Ordovician and Upper Cambrian faunas." From Billings' Butte, north of Mount Resplendent, he has identified, among others:

> *Eoorthis desmopleura* (Meek), *Syntrophia nundina* Walcott, *Agnostus* sp., *Triarthrus* sp. ind., *Peltura* (pygidia), *Apatokephalus,* and two species of *Illaenurus* [*Symphysurus*].

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[14] Smithson. Miscl. Colls., vol. 64, p. 374, 1916.
[15] Smithson. Miscl. Colls., vol. 57, p. 336, 1913.

This is a very good *Ceratopyge* fauna, and the presence of *Peltura* is especially interesting.

SUMMARY.

It appears that with the exception of *Symphysurus,* the trilobites characteristic of the *Ceratopyge* fauna, such as *Ceratopyge, Apatokephalus* and *Hemigyraspis* are not sufficiently abundant to be very useful as guide fossils, although diagnostic when present. Among the brachiopods, *Syntrophia nundina* and *Eoorthis desmopleura* are ubiquitous and easily identified, so that an association of *Symphysurus* with these may be used as a guide to the fauna. On this basis, it seems that the *Ceratopyge* fauna occupies a position at the base of the Ordovician from Robson Peak in Canada southward to the Eureka District in Nevada, on the western side of the Rocky Mountains. It is somewhat doubtful if it will be found in that part of Montana east of the Continental Divide, but further south it may extend across New Mexico and Texas to the Appalachians, although no trace of it has yet been reported. In the east it is known only in Pennsylvania, New Jersey and New York, until the northeastern Atlantic coast is reached. There seem more possibilities of a connection across the southern than the northern part of the continent, however, judging from the distribution of the Beekmantown.

One very important point is the notable admixture of Upper Cambrian fossils found in the *Ceratopyge* zone, especially in Nevada and the Mount Robson district. In no case is there either physical or faunal evidence of emergence between Upper Cambrian and Lower Ordovician. Richardson has outlined some physical evidence of an unconformity between the St. Charles and Garden City formations in the Randolph quadrangle in Northern Utah, but since the upper part of the St. Charles has a *Ceratopyge* fauna, and the lower part of the Garden City a very similar one, the unconformity is in the wrong place.

Walcott[16] has tentatively suggested that the lower Pogonip contains a representative of the "Ozarkian," and has described *Calvinella tenuisculpta,* a member of the Dikelocephalidae, stating that it was probably from

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[16] Smithson. Miscl. Colls., vol. 57, p. 359, 1914.

about the same horizon as *C. ozarkensis*. *C. tenuisculpta* was found associated with *Apatokephalus finalis, Symphysurus eurekensis,* and other typical fossils of the *Ceratopyge* zone. *Saukia marica* (Walcott) and *Osceolia osceola* (Hall), the only other described Dikelocephalids in the Eureka district, are found in the Dunderberg shale, beneath the Pogonip, associated with what appear to be Upper Cambrian faunas.

Either the Ozarkian (Ulrich, non LeConte) is not represented in this area, or else it is represented by the zone with *Ceratopyge*. The latter alternative would be in accordance with my view of twelve years ago,[17] when I urged that the *Ceratopyge* zone of the Eastern states might be joined with the Ozarkian. Later studies in the Appalachians have however convinced me that so far as Eastern North America is concerned, there is no Ozarkian System, and the evidence of the *Ceratopyge* fauna indicates the same for the West.

Museum of Comparative Zoology,
Cambridge, Mass.

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[17] This Journal, vol. 30, p. 344, 1910.

Art. XVIII.—*The Pitts Meteorite;* by S. W. McCallie, State Geologist of Georgia.

The fall of the Pitts meteorite here described was the most striking phenomenon of its kind heretofore observed in the State of Georgia. The meteorite fell in a negro settlement in the western part of Wilcox County near the town of Pitts about 9 o'clock a. m. (Eastern time) April 20, 1921. At the time of the fall no clouds were in view and the sun was shining brightly. It was seen as far north as Sunny Side, in Henry County, 36 miles south of Atlanta, and as far south as Moultrie, in Colquit County. In addition to the above towns that appear to mark the north and south limits of its visibility, it was also seen at Camilla, Albany, Seville, Cordele, Hawkinsville, Perry, Macon, and Alma. It was no doubt plainly visible over an area of several thousand square miles, and could have been distinctly seen by fully a quarter of a million people had they been looking in the proper direction.

My attention was first called to the occurrence by press notices on April 21 and on the 22d I received a specimen of the meteorite from Colonel W. H. Dorris, of Cordele, Ga., accompanied by a short description of the phenomena. On April 24 I visited Pitts, with a view of securing at first hand all data possible concerning the exact locality, the attending phenomena, etc. The citizens of the town rendered invaluable service in securing the information desired, and also obtained for me for examination and study all of the fragments of the meteorite except one, which specimen was later secured from the owner by personal request of Governor Dorsey. Several hours were spent in the vicinity of the fall interviewing eyewitnesses of the phenomena and in making a diagram showing the relative position at which the fragments struck the ground.

The Phenomena.

The attendant phenomena witnessed by the observers of the meteorite were similar to those noted in meteorite falls in general and were as follows:

(1) The rapidly moving fire ball was the first phenomenon that attracted the attention of the observers. It was described by eyewitnesses at Albany as a rapidly moving

body about the size of a man's head, appearing in the sky in a northeasterly direction. At Moultrie it was referred to as a brilliant body moving downward in zigzag course, looking as if it might fall in the northern part of the city. At Sunny Side, more than a hundred miles from the place where it fell, it was seen in a southeasterly direction, falling nearly perpendicular at a rapid rate.

(2) The dense smoke in the wake of the flaming fire ball was referred to by the Albany and Moultrie witnesses as a luminous trail following the flaming ball. Colonel Dorris, who was in the vicinity of Pitts, speaks of the smoke as a zigzag trail, lingering for some minutes and assuming various shapes. These shapes were thought by some to be in the form of letters. Several persons in the immediate vicinity of the fall described the smoke as white or gray in color, and in the form of puffs and very dense.

(3) The first sound heard was compared to that of thunder, and to many it was the first warning that any unusual occurrence was taking place in the sky above. At Cordele, 15 miles west of Pitts, the sound resembled that of a heavy explosion, distinctly heard by several people on the street. In the country, four miles east of Cordele, two terrific explosions were noted, louder than thunder, which so terrified the farm hands that they ran frightened to their homes. At Hawkinsville it was thought that an aeroplane had exploded above the city. In the immediate vicinity of Pitts the sound was described as several loud explosions, causing the earth to tremble, followed in quick succession by a number of lesser explosions.

(4) The roaring and whizzing noise and the impact of the falling fragments were heard only in the immediate vicinity of the fall.

Description of Individual Fragments.

The location and relative distribution of the points at which the fragments (four in number) of the Pitts meteorite fell are shown on the accompanying diagram. The largest piece weighing 57 ounces fell within less than 75 feet of Nancy Brinson's house where it was dug up a few minutes later still warm, but not red hot as first reported. The fragments entered the freshly plowed sandy soil to a depth of about 16 inches forming an inconspicuous hole less than 18 inches in diameter and scarcely half so deep. The fragment was irregular, rhomboidal in shape, the three greater dimensions being 5.7, 3.2, and 2.3 inches respectively. More than two-thirds of the surface showed the natural pitted characteristics of an iron meteorite coated with black iron oxide through which in places were to be seen shining patches of silvery white nickel-iron. The remaining parts of the surface were rough and angular with more or less sharp projecting points showing evidence of recent rupture from other fragments. This part of the surface was more or less smoked but it had not the thick coating of the other part of the surface. The fragment was made up almost entirely of nickel-iron throughout which, in irregular masses or veins, occurred the stony material. The latter consisted mainly of gray minerals interspersed with an occasional greenish granule. Polished surfaces of the iron portion of the fragment when treated with dilute nitric acid showed the typical Widmanstätten figures.

A second fragment fell by the roadside within a hundred feet of Jim Harden's house which is 700 feet southeast of the Brinson house. This specimen buried itself about 8 inches in the ground. It weighed 42½ ounces and differs from the fragment above described mainly in showing more stony material and in being more irregular in shape. It also showed less of the naturally pitted surface but correspondingly more of the freshly fractured surface. This specimen fell within three feet of a negro boy walking along the road, who was covered with flying earth.

The third fragment fell about 4,000 feet southwest of the second fragment and within 100 feet of where a negro man and a boy were working in a cotton field. Only a part of this specimen was seen by the writer as it had been cut in pieces. However, judging from the fragments it probably weighed less than 30 ounces. It entered the ground only about seven inches and like the other fragments was warm when dug up.

The fourth fragment was picked up in a public road approximately 5,000 feet southwest of fragment No. 1. No one saw this fragment fall, nevertheless it was at once recognized by the finder who had seen other fragments.

This specimen was irregular, pear-shaped, and weighed less than two ounces. The proportion of stony material in this fragment seems to be greater than in any of the others but it is otherwise similar. This was the only fragment that did not bury itself in the ground which is accounted for by its falling on the hard road surface.

An attempt was made to fit the different pieces together but without success indicating that only a part of the meteorite had at that time been found.

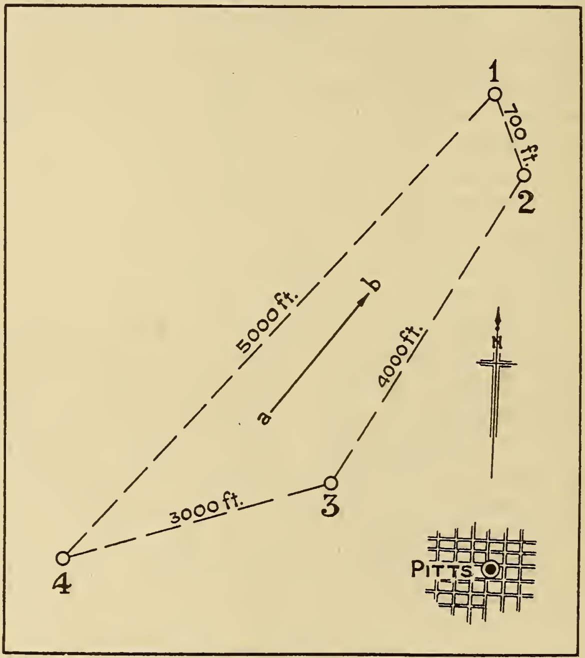

Fig. 1.—Diagram showing locations of the falls of the different fragments of the Pitts meteorite. 1. Nancy Brinson's house. 2. Jim Harden's house. 3. King's field. 4. Slater's house.

By examining the diagram, it will be seen that four fragments which had been found at the time of my visit, were scattered over an area approximately a mile long and possibly a quarter of a mile wide. It will further be noted that the heavier fragments travel at a greater distance than the smaller ones; this indicates that the meteorite was moving in a northeasterly direction, which fact was confirmed by several observers.

Mineral Composition.

The composition of the meteorite, as shown by analyses made by Dr. Edgar Everhart, acting chemist, of the State Geological Survey is as follows:

Analyses of Pitts Meteorite.

Constituents	Stony Part	Metallic Part
Iron	.09	91.50
Nickel	.32	6.67
Tin	.20	.04
Copper	.00	trace
Silicon	.00	1.40
Sulphur	28.30	.02
Cobalt	trace	.45
Manganese	.00	.05
Manganese oxide (MnO)	.27	
Soda	1.17	
Potash	.32	
Magnesia	5.96	
Alumina	.30	
Ferrous oxide	65.52	
Phosphorus pentoxide	.07	
Silica	8.46	
Carbon by difference	2.32	

Reckoning the sulphur and iron as pyrrhotite (FeS) the stony material contained 77.62 per cent of pyrrhotite, the rest, omitting carbon, corresponding most nearly to hypersthene.

Dr. George P. Merrill of the National Museum, who made an examination of the stony part of one of the fragments, advised me that by optical and chemical methods he was able to make out the following minerals: olivine, diopside, and a plagioclase feldspar.

Fully 90 per cent of the four fragments was metallic, specific gravity 7.23.

Atlanta, Georgia.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *The Reduction of Ferric Salts with Mercury.*—LeRoy W. McCay and William T. Anderson, Jr., of Princeton University, have applied this method of reduction to the volumetric determination of iron with very satisfactory results in regard to convenience and accuracy. It appears that the fact that metallic mercury will reduce ferric chloride to the ferrous salt has been known since 1842, and that Bovar suggested its analytical application in 1911, but the method seems to have attracted little attention.

The present investigators carried out the reductions by shaking solutions of ferric chloride containing hydrochloric acid with about 20 cc. of pure mercury in a long, narrow, glass-stoppered bottle of about 800 cc. capacity. The shaking should be vigorous, so as to break up the mercury into tiny globules, and it should be continued for about 5 minutes. After filtering the liquid and washing the residual mercury and mercurous chloride the iron was titrated, either by the Zimmermann-Reinhardt modification of the permanganate method or by the dichromate method, with excellent results as shown by the test-analyses.

The authors found that solutions of ferric sulphate containing sulphuric acid were only partially reduced by the operation, but that when a little more than the theoretical amount of sodium chloride was present the reaction was complete with the formation of mercurous chloride.

It appears that this rapid and accurate method is worthy of extensive practical application, for it has the advantage over the use of zinc, for instance in the Jones reductor, in the fact that titanic acid is not reduced by mercury, and also because the mercury process seems to be freer from accidental sources of error.

The authors have found that when shaken with mercury in the presence of hydrochloric acid reduction takes place with ferricyanides, chromates, molybdates, vanadates, and antimonates, and they are investigating some of these reactions.—*Jour. Amer. Chem. Soc.*, **43**, 2372. H. L. W.

2. *Synthetic Gasoline.*—A German process for making gasoline, called the Burgess process, has been developed by the originators of the Haber process for the fixation of atmospheric nitrogen by combining it with hydrogen. In carrying out this process hydrogen is passed over carbon at 200 atmospheres pressure and at a temperature of 700° C., whereby hydrocarbons are formed. It is stated that the process has been examined by an American engineer, who has reported that the method is in actual operation

and is producing motor fuel on a small scale. If this process should succeed in competing with gasoline from petroleum it would be of great industrial importance.—*Jour. Indus. Eng. Chem.*, **14**, 165. H. L. W.

3. *The Precipitation of Arsenic as Sulphide from Solutions of Arsenates.*—It has been found by J. H. Reedy that this precipitation is greatly hastened by the presence of a small quantity of a soluble iodide in the acid solution. This catalytic effect is doubtless due to the reduction of arsenic acid to arsenious acid or chloride by hydriodic acid and the continuous conversion of the iodine thus set free to hydriodic acid by the hydrogen sulphide.

This observation has been made use of in connection with work in qualitative analysis by adding one or two cubic centimeters of normal ammonium iodide solution just before passing in hydrogen sulphide in the regular course of analysis. The complete precipitation of pentavalent arsenic is thus facilitated, and the chances are much lessened that the student will fail to detect arsenic because of non-precipitation at this point. The apparent complications that mercury and copper may be precipitated as iodides are rectified by the digestion with ammonium polysulphide which changes the iodides into the higher sulphides.—*Jour. Amer. Chem. Soc.*, **43**, 2419. H. L. W.

4. *Colorimetric Analysis;* by F. D. Snell. 12mo, pp. 150. New York, 1921 (D. Van Nostrand Company).—In this book an attempt has been made to collect for ready reference all the colorimetric methods which experience has shown to be practical. The first three chapters deal very satisfactorily with a classification of the methods, the apparatus used and the calculation of the results; then the processes are described individually, according to the substances to be determined. The book is a useful one for reference use by analytical chemists, and while it appears that some of the methods are not described with sufficient clearness and fulness of detail, it may be said that references to the literature are usually supplied. As an example of lack of detail in the description of a process it may be pointed out that the directions given for the determination of small amounts of potassium, involving the precipitation of the platinic chloride, would not lead to a proper precipitation and collection of this salt, but of course, an experienced analyst would known how to modify the directions. H. L. W.

5. *Fluid Resistance.*—The phenomena which occur in the motion of a real fluid are so complicated that theory alone is capable of dealing with none but the simplest cases, and progress in practical applications, as for example in the law of resistance to the motion of a body through a fluid, can only be made by careful experimentation. The following is a report of a study by C. Wieselsberger of the resistance experienced by a cylinder

when struck by a current of air directed at right angles to its axis. The expression which has been commonly used to formulate the resistance to motion in a fluid is $F = 1/2\ cA\rho v^2$ where v represents the velocity of the body, A the area of the outline of the body projected on a plane normal to this direction, ρ the density of the fluid and c is a coefficient to be experimentally determined, and presumably depending only on the nature of the medium and the geometric form A, but independent of its absolute magnitude and of the velocity v, in which case the formula once completed would be applicable to geometrically similar bodies and different velocities in the same medium. It is however now known that c is constant only for similar flow lines and these may differ even with geometrically similar figures.

The condition for geometrically similar flow lines was first determined by Osborne Reynolds and requires that the expression $\mathrm{R} = v\rho d/\mu$ shall be the same for cases to be compared. Here μ is the viscosity, d, some similar linear dimension of the body and v and ρ have the previous signification. It is thus evident that c will not in general be a constant but will vary with v, and the size and shape of the body. The smallest departure is found to occur in the case of bodies with sharp edges which stand at right angles to the direction of the current, as for example, flat disks met perpendicularly by an air stream. Here, for a considerable range in the values of R the coefficient c remains constant at about 1.1. On the other hand bodies with rounded convex surfaces show notable variation. When R is small compared to unity the resistance, as in Stokes' law for falling spheres, increases linearly with the velocity.

The aim of the author's experiments was to trace the connection between c and R throughout a large range of the Reynolds' number. They were carried out upon cylinders of circular cross-section which were suspended transversely to a plane current of air, i. e., the stream lines were the same in all planes at right angles to the axis of the cylinder. The air velocities ranged from 1.2 to 36 meters per second which is from about 4 to 80 miles an hour. Nine cylinders were used varying from .05 to 300 mm. in diameter so that the range of the Reynolds' number investigated was from 4.2 to 800,000. The resistance for the small cylinders was measured by weighting them and observing the pendulum displacement from the vertical. In the case of the larger ones the force was determined by the aid of a system of threads connected to a balance. Any disturbance due to the effect of the ends was corrected by a proper experimental arrangement. The results show a number of interesting things: 1st, that the formula of Lamb derived on the theory of fluid friction, is applicable only when R is small compared with unity. 2d, c is a decreasing function of R for values of the latter up to about 2,000 where a notable minimum occurs. 3d, From $R = 15{,}000$ to 180,000 the quadratic law of resistance is sensibly followed as c remains at 1.2. At $R = 200{,}000$ a rapid fall of c begins which does not stop till it reaches 0.3. A similar phenomenon has been noted in experiments on spheres and the Reynolds number is said to have a critical value at the beginning of this interval. The decrease of the coefficient of resistance in this region is so great that the absolute value of the resistance experienced by a cylinder fell off considerably as the air velocity increased. To indicate how great a departure from the quadratic law occurs, it was found that with a cylinder 30 cm. in diameter the resistance fell from 4 to 2.5 kilograms as the velocity was increased from 15 to 20 meters per sec.

Considerable light is thrown upon the preceding results by a study of the actual stream line forms under different circumstances. With small values of R and where the viscosity is the predominant factor, the stream lines, though less concentrated on the downstream side, are smooth. In the region of $R = 100$ an oscillation of the stream lines behind the body begins and with higher numbers a well developed turbulence sets in. The existence of this condition was detected by acoustic methods up to $R = 100{,}000$.

The stream lines which separate the region of turbulence from the irrotational region may be called contact lines and the points where the latter leave the cylinder contact points. The breadth of the turbulent region in a way corresponds to the magnitude of the resistance. As the critical value of R is passed it is noted that the contact points approach on the downstream side, thus indicating a decrease of the resistance.

It was also found that the roughness of the surface has a marked effect on this phenomenon as does also the geometrical form of the body. A discussion of some of the results in this category is also given in the paper.—*Physik. Zeitschr.* **22**, 321, 1921.

F. E. B.

6. *Les Fondaments de la Geometrie;* by HENRI POINCARÉ, Paris, undated (Etienne Chiron).—This essay first appeared in *The Monist* in January 1898. As the French original was not preserved, and the fundamental concepts of geometry are very much in evidence at present, the time has been thought opportune for the publication of a translation of the English text. The author's thesis is that the Euclidean metric is simply convenient and its axioms nothing more than conventions. This after all seems more than a play upon words than a matter of debate, for if with Poincaré we define geometry as the study of the formal properties of a certain continuous group, then since there may be various mathematical groups which are continuous there will be various geometries, all of which are true. The

physicist naturally chooses the one which most nearly corresponds to the more or less rough group in a material body and that has been up to the present the Euclidean geometry. Whether physical space is warped by one or two parts in a million may be left for the future to decide.

In the author's view geometry is not an experimental science but merely the result of reflection upon our experience, and to ask whether the geometry of Euclid is true and that of Lobatchewsky false is as absurd as to ask if the metric system is true and that of the foot and inch is false. F. E. B.

II. GEOLOGY AND MINERALOGY.

1. *James Hall of Albany, Geologist and Palæontologist, 1811-1898;* by JOHN M. CLARKE. Pp. 565, portraits and charts, Albany (S. C. Bishop), 1921 ($3.70 net).—This is truly a remarkably interesting study of the great state geologist of New York and international man of science, James Hall, by a versatile son of the same state. No geologist will fail to read it, and all well-informed men of science should do the same. It is not only a faithful portrayal of an extraordinary man, who turned out a prodigious amount of geologic work, but as well a setting forth of North American geology as it was emerging from the Wernerian stage into full manhood. It is a true picture of the pioneer days of the earth sciences in this country.

Hall was a tall, well-set-up, blue-eyed man, decidedly dynamic, sensitive to an extraordinary degree, irascible, and with surpassing ambition. He was rarely ever sick, and yet in his own mind, his physician tells us, he was "a dying man for fifty years." Feverish, with unrestrained impulses, he appears to be always in trouble with most of his associates, and yet often misled by his confidence in those less close to him. It seems a curious commentary that he lost much money in mining.

In 1837 Hall began his survey of the wonderful Fourth District, at the western end of New York State, and spent five years in the study of its geology, "the most excellent piece of field work he ever did." From this work he gradually rose to be the master mind in the State Survey, and for sixty-two years he dominated the Paleozoic geology, and especially the paleontology, of North America, leaving as his monument thirteen great quarto volumes besides many other works in paleontology. The *Palæontology of New York* was the dominant note of his long life. Curiously, though he was an evolutionist thirteen years before the appearance of *The Origin of Species,* yet he never wrote anything on this subject. "It was ever conditions not theories that confronted him and he went on heaping up new facts to the end."

As one reads the book, it becomes apparent that New York has been the greatest mother of geologists, the training ground for most American workers in the science between 1843 and 1890. Moreover, due to Hall's great influence, interwoven with the growth of geologic knowledge in New York is the development of the geology of the entire Mississippi Valley. Hall "guided official geologic movements in every state where they were inaugurated and in many his own hand took a helmsman's part." Not the least valuable feature of the book are the many letters quoted wholly or in part, with their interesting side-lights on the eminent writers and the times in which they lived.

Doctor Clarke has made full use of his unique opportunity to know Professor Hall and his history, and he is to be heartily congratulated on the results he has attained. C. S.

2. *The Problem of the St. Peter Sandstone;* by CHARLES L. DAKE. Univ. of Missouri School of Mines and Metallurgy, Technical Series, Bull., vol. **6**, No. 1, 225 pp., 30 pls., August, 1921.—This thorough and clearly presented study of the environment under which the St. Peter was laid down is based on the very wide distribution of this formation throughout the Mississippi valley. Starting out with the prevalent idea in modern times, the author "was biased in favor of the desert origin of the sandstone," but finally became convinced "that the formation is in fact of marine origin." The rounded and frosted nature of the sand grains is found to be of antecedent origin and was not produced during the time of the St. Peter deposition. This character of the sands is inherent in those of the Upper Cambrian (Croixian) and it is from this northern formation, once of far wider distribution than at present, that the sands of the St. Peter were derived. Similar sands occur in other Ordovician formations. Finally, the St. Peter is a well bedded formation of cleanly washed sands (almost 99 per cent silica), and even though fossils are rare, a considerable fauna was obtained by Sardeson in the midst of this series in Minnesota, which is farthest away from the source of the marine transgression. In the south, the equivalent formations of the St. Peter more often yield marine fossils.

Incidentally the report records much information as to the formations beneath the St. Peter, and more especially those above it. Two valuable correlation tables and many excellent views of outcropping formations accompany the book. The author is to be congratulated on his excellent work, which constituted his dissertation for the doctorate at Columbia University. C. S.

3. *A Geological Reconnaissance of the Dominican Republic;* by T. W. VAUGHAN, WYTHE COOKE, D. D. CONDIT, C. P. ROSS, W. P. WOODRING, and F. C. CALKINS. Geol. Survey Dominican Republic, Memoirs, vol. **1**, 268 pp., 23 pls., 1921.—This important publication, the joint work of the Dominican Republic and the U. S. Geological Survey, describes the geography, geology, strati-

graphic paleontology, water resources, and economic geology of the Dominican Republic. The geologic sequence begins with the "basal complex" of unknown age, followed by Upper Cretaceous and Cenozoic marine formations.

4. *A Manual of Seismology;* by CHARLES DAVISON. Pp. xii, 256, with 100 text figures. Cambridge University Press, 1921.—In writing this text book the author has purposely sought to present the subject of seismology in its geological aspect. As he points out, "until near the close of the last century, seismology was regarded as a department of geology, but while its growth in that direction has by no means ceased, the more recent advances have been largely the work of mathematicians and physicists." But inasmuch as the present volume was written to constitute one of the Cambridge Geological Series, the mathematical and physical sides of the subject have in consequence been almost completely omitted.

The book gives an admirable outline of the present status of the science. It deals with the phenomena of earthquakes in general, and therefore it gives no detailed descriptions of individual earthquakes. The presentation of the subject is well-balanced, concise, and lucid, and consequently makes easy reading. The more speculative matters have been eschewed and the presentation generally sticks to the reasonably assured ground of seismology. Most of the chapters are preceded by a list of sources, which can be profitably consulted by the reader who desires fuller information.

It may perhaps be suggested that the practical deductions of seismologic study might have been more fully treated. The author's concern is essentially with the purely scientific side of the subject. The practical deductions are indeed mentioned, rather casually on the whole, but they would seem worthy of inclusion in a separate chapter, both in view of their importance and in order to make them more readily available. Probably the author's attitude is unconsciously revealed by his placing in a foot-note an interesting suggestion as to the probable immunity of the Panama Canal cuts to earthquake damage. The facts and practical deductions of seismology are of unusually wide popular interest, more so probably than those of any other branch of geology, and some cognizance of this interest might well be taken. By providing the chapter suggested, the author would aid geologists in meeting this demand.

In conclusion, this excellent book gives us an epitome of the science of seismology in its geological bearings, and by its succinctness and its admirable simplicity of treatment makes attractive much of what would otherwise be abstruse matter. It is a welcome addition to the Cambridge Geological series.

ADOLPH KNOPF.

5. *Earth Evolution and its Facial Expression;* by WILLIAM HERBERT HOBBS. 8vo, pp. 178, 84 illustrations. New York, 1921 (The McMillan Company).—Professor Hobbs states that the purpose of this volume is to assemble and make available for the non-technical reader the author's ideas on certain questions of theoretical geology. He favors the planetesimal hypothesis of Chamberlin, but suggests an order of accretion which will account for the peculiar distribution of densities in the earth. He believes that the present figure of the earth resembles a tetrahedron, but that this figure has developed slowly as a result of secular cooling, the form at the end of the Paleozoic era suggesting a huge twinned crystal. Igneous magma is formed by the fusion of shale at a moderate depth on relief of pressure during folding or faulting. Thus laccolites develop essentially in place, and are the result rather than the cause of the doming in overlying strata. All arcuate mountains have been made by underthrusting of sediments against continental masses, the active force resulting from subsidence of ocean floors. Some regions in and bordering the Pacific ocean are at present suffering rapid change, as indicated by earthquakes, volcanic activity, terraces, and fore-deeps. The book closes with the suggestion that investigations in the Pacific will cause a great reduction in present estimates of geologic time. C. R. L.

6. *West Virginia Geological Survey;* I. C. WHITE, State Geologist. Morgantown, W. Va.—Recent publications include the following:

Detailed Report on Nicholas County; by DAVID B. REGER. 1921. Pp. xx, 847; with 34 half tone plates and 22 text figures. Accompanied by a separate case of topographic and geologic maps. In the preparation of this exhaustive report Mr. Reger, assistant geologist, has had the assistance in the field of W. Armstrong Price, paleontologist, and in the office work, of R. C. Tucker and J. D. Sisler. Mr. Tucker has had charge of the preparation of the maps and the calculation of the areas and tonnage of the various coal beds.

The coal development of Nicholas County has only just begun because of partial lack of rail facilities. It contains three important coal formations extending across the county, from northeast to southwest. These are the New River Coal Group, the Kanawha Group, and the lower members of the Allegheny Series. The report contains a chapter on the paleontology of Nicholas County and a short description of the chert deposits of West Virginia. The price, including case of maps (delivery charges paid), is $3.00. Extra copies of topographic map, 75 cents; of the geologic map, $1.00.

New Edition of Coal, Oil, Gas, Limestone, and Iron Ore Map.—This map has been thoroughly revised, showing oil and gas pools, many anticlinal lines not heretofore shown. It includes also booklet giving the names and post-office addresses of all the principal coal mining operators in West Virginia up to July 1st, 1921. Scale, 8 miles to the inch. Price, folded in strong envelope and delivered by mail, $1.00; 6 copies for $5.00.

A Soil Survey of Fayette County has also been issued by the Geological Survey in co-operation with the U. S. Department of Agriculture; this is by J. A. KERR, and contains a large Soil map on a scale of 1/62,500; contour interval 50 feet.

7. *Virginia Geological Survey;* THOMAS L. WATSON, Director. Charlottesville, 1921.—Bulletin XXI (pp. 224; with 18 plates and 21 text figures). This is by ALBERT W. GILES and discusses the geology and coal resources of Dickenson County.

8. *Wisconsin Geological and Natural History Survey;* W. O. HOTCHKISS, Director. Madison, Wisconsin, 1921.—Bulletin 58 (pp. 252, with 2 maps and 93 text figures) is by R. H. WITBECK and describes the geopraphy and economic development of Southeastern Wisconsin.

9. *Dana's Textbook of Mineralogy. Third Edition;* by WILLIAM E. FORD. Pp. ix, 720, with 1,050 text figures. New York, 1922 (John Wiley and Sons).—After an interval of nearly twenty-four years a third edition of the Textbook has been published, the task of revision and of incorporating the advances in mineralogy during the past two decades having been undertaken by Professor Ford. The general character of the book has been retained, but the addition of the new matter required to bring the book abreast of the times has necessitated lengthening it by 127 pages. In spite of this increase in the number of pages, the actual bulk of the new volume does not exceed that of the former edition, owing to the thinner and better paper employed.

In the section on Crystallography the methods of stereographic and gnomonic projection have been introduced. Much of the section on Optical Characters of Minerals, long recognized as the best concise, adequate presentation of this subject in English, has been rewritten, expanded, and brought into closer relation with the actual working methods of microscopical technique. The many excellent figures added here should do much to render the subject matter more easily assimilable by the student.

In the part on Descriptive Mineralogy the reactions in polished sections of many of the opaque minerals are given. All species newly recognized since the previous edition are briefly mentioned in their proper places. The largely increased amount of optical data given for the various minerals reflects the greatly enhanced importance that the immersion method of determining minerals has assumed in recent years. The great wealth of information concisely presented in the new edition makes it an exceedingly valuable compendium of mineralogy. ADOLPH KNOPF.

10. *A new Meteoric Iron.*—A beautifully fluted 425 lb. (193.17 kilogr.) meteoric iron found in Owens Valley, California in 1913 and not yet described has recently been added to the National Collections through the generosity of Mr. Lincoln Ellsworth of New York City. The iron, an octahedrite, has been analyzed in great detail by Professor S. R. Brinkley of Yale University and a description of the same by the writer will appear in a forthcoming number of the Memoirs of the National Academy of Sciences. G. P. MERRILL.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Foundation for the Advancement of Teaching. Sixteenth Annual Report of the President,* HENRY S. PRITCHETT, and *Treasurer,* ROBERT A. FRANKS, *for the Year ending June 30, 1921.*—The total resources of the Carnegie Foundation now amount to $25,513,000, of which $15,192,000 belong to the permanent general endowment, $8,206,000 to a reserve fund to be spent in the retirement, during the next sixty years, of teachers now in associated institutions, $1,250,000 to the endowment of the Division of Educational Enquiry, and $570,000 to a reserve fund to be expended in aiding universities and colleges to adopt the new plan of contractual annuities. In the sixteen years of the existence of the Foundation, a total sum of nearly nine million dollars has been distributed in retiring allowances and pensions to 999 individuals. Of this sum former teachers of Harvard have received $705,000, of Yale, $609,000, of Columbia, $525,000, of Cornell, $407,000; the remainder has gone to eighty-five different institutions. There are now operative 379 retiring allowances and 230 widows' pensions, 90 of which were granted during the last year, entailing an annual expenditure of $959,690. The average allowance paid is $1,575.

It is particularly interesting to note that the Teachers Insurance and Annuity Association of America, which was established by the Foundation through a gift of $1,000,000 to provide insurance and annuity protection for college teachers without overhead charges, has written for teachers in 300 different institutions 982 insurance policies covering $4,973,000 of insurance and 776 annuity contracts providing $917,000 annual income at retirement. A plan has been provided for the participation of policy-holders in the management of the Association. Sixty-two institutions have formally adopted the new plan of contributing toward contractual retiring allowances for their teachers.

The work of the Foundation, however, extends far beyond the distribution of pensions to retiring teachers. Some of the prominent subjects studied and discussed involve the critical examination of the medical schools of the country; of the training for the legal profession; of College entrance requirements; and especially important of the various pension systems introduced by institutions of learning, by the different states and by large business corporations. Of the subjects mentioned, to the first have been devoted the special Bulletins IV and VI; it is further discussed in the present report. The legal matter is the subject of Bulletin VIII, and XV by Alfred Z. Reed, the latter published the past year (see this Journal, vol. **2**, p. 236). The development of pension systems has been ably handled in many annual reports and in none more so than the present (pp. 115-157); "a very slow growth in the critical attitude on the subject" by the authorities involved is a conclusion much to be regretted.

2. *A Monograph of the Existing Crinoids;* by AUSTIN HOBART CLARK. Vol. **1**, *The Comatulids.* Quarto. Part 1, pp. 1-406, with 513 text-figures and 17 plates; part 2, pp. 1-795, with 949 text-figures and 57 plates. Bulletin **82**, U. S. National Museum. Washington, 1915 and 1921 (Government Printing Office).—This is a complete monograph of all that is known about living crinoids, based upon a study of the material contained in all the principal museums of the world as well as that collected by the author himself on various expeditions. That the crinoids are in no sense the rare creatures that they are popularly imagined is indicated by an enlightening paragraph in the introduction. "During the 1906 cruise of the Albatross I handled tens of thousands of specimens; several times I saw the forward deck of the steamer literally buried under several tons of individuals belonging to a species exceeding any fossil form in size; everywhere we went we found crinoids; we dredged them at all depths. My ideas of the comparative importance of the recent forms underwent a total change; surely a group so abundant, even though very local and very unevenly distributed over the sea floor, can not be considered as decadent or degenerate. From my observations at sea I became convinced that the recent crinoids are in every way as much of a factor in the present day marine biology, and play fully as important a part, as the echinoids, the holothurians, or the asteroids; ecologically they are more interesting than any of these because of their sessile mode of life and curiously specialized method of procuring food."

The first part treats exhaustively the relationships of the crinoids, the general features of their organization and a detailed comparison of certain of the calcareous structures of all the known species.

The second part completes the account of the calcareous structures and gives a full description of each of the other organ systems of the body, including the digestive, circulatory, nervous, and reproductive systems, sexual differentiation, spawning, embryology, larval development, metamorphosis and growth. This part also includes all that is at present known regarding the habits and reactions to stimuli of the various species, with an account of their very abundant parasites and commensals and a detailed discussion of their coloration.

So exhaustively is the subject treated and so well executed and elucidative are the illustrations that the crinoids may now be removed from their former association with the little-known groups of animals and placed among those most thoroughly investigated. W. R. C.

3. *Source Book for the Economic Geography of North America;* by CHARLES C. COLBY. Pp. xi, 418; with 11 maps in black and white. Chicago, 1921 (The University of Chicago Press).—This volume is a compilation of 119 articles, from nearly as many different authors and statistical sources, assembled here in 14 chapters. The first chapter, entitled Regional Concepts of Canada, contains six articles dealing successively with the size, agricultural regions, land and water areas, climate, mineral resources of the major physiographic provinces, and the population of Canada. Chapter II deals with the resources and industries of Canada, and is followed by five chapters dealing with the separate geographic subdivisions: Maritime Canada (and Newfoundland), St. Lawrence Lowland, Laurentian Upland, Prairie Provinces, and Pacific Canada. A similar procedure is followed for the United States and Mexico.

The purpose of the book is to furnish source material for an introductory study of the geography of North America and to introduce students to the literature of the subject. A large amount of interesting, valuable, and highly diversified information has been assembled, ranging from the apple industry in Nova Scotia to the genesis of the ores at Butte, Montana. It will be seen that ample scope is left for the ingenuity and resourcefulness of the instructor to unify so broad a body of information.

ADOLPH KNOPF.

4. *Ueber die Vorstellungenen der Tiere: ein Beitrag zur Entwicklungspsychologie;* von HANS VOLKLET. 126 pp. Leipzig und Berlin, 1914 (Wilhelm Engelmann).—This is the second part of a series of studies on the origin and evolution of mental processes and the psychology of human actions. The present volume on animal intelligence analyses the presumable perceptions and conceptions of various types of animals with regard to the hypothesis of total environmental complexes. W. R. C.

5. *Le Movement scientifique contemporain en France:* 1, *Les sciences naturelles;* par GEORGES MATISSE. Pp. 160. Paris, 1921 (Payot & Cie.).—This little book indicates the recent development of the natural sciences in France by summarising the work of such eminent biologists as Delage on heredity and parthenogenesis, of Bataillon on artificial parthenogenesis, of Houssay on dynamic morphology, of Cuénot on preadaptation, of Bohn on tropisms, and of other French investigators who are leaders in various branches of biology. W. R. C.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

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THE

AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. XIX.—*Minor Faulting in the Cayuga Lake Region;*[*]

by E. Tatum Long.

Introduction.

The drought of the summer of 1921 caused many of the creeks in the vicinity of Cayuga Lake to run almost or entirely dry. Advantage of this condition was taken to make a rather detailed study of rock exposed in their beds and on their banks, with a view to adding if possible some information as to the nature of the numerous small faults of the region, and in particular to a very unusual manifestation of faulting shown on a small scale in Salmon Cr. at Ludlowville, N. Y. (See map, fig. 1.) For some time these faults had caused considerable speculation but weather conditions made field investigation impossible.

As it soon became evident that knowledge of the general structure of the region would give little clue to the particular features here exposed, the beds of some thirty odd creeks covering a distance about 20 miles to the north of Ludlowville and 4 miles to the south, were traversed, in addition to the whole of the east shore of Cayuga Lake, except the lower nine miles. The Lehigh Valley Railway tracks for this same distance and about six continuous miles of the west shore above Taughannock, with a few additional shorter stretches to the north, were also covered on foot so that all details could be closely observed and contact readings made of the dip of the strata. A launch was employed in order that sight readings could be made on both shores, a distance of about 30 miles being covered in this way. These readings proved more accurate and more representative, as several feet instead of inches could in this way be covered by the clinometer of a Brun-

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[*] Grateful acknowledgment is herewith given Prof. A. J. Eames and Prof. V. E. Monnett for helpful criticism of the manuscript.

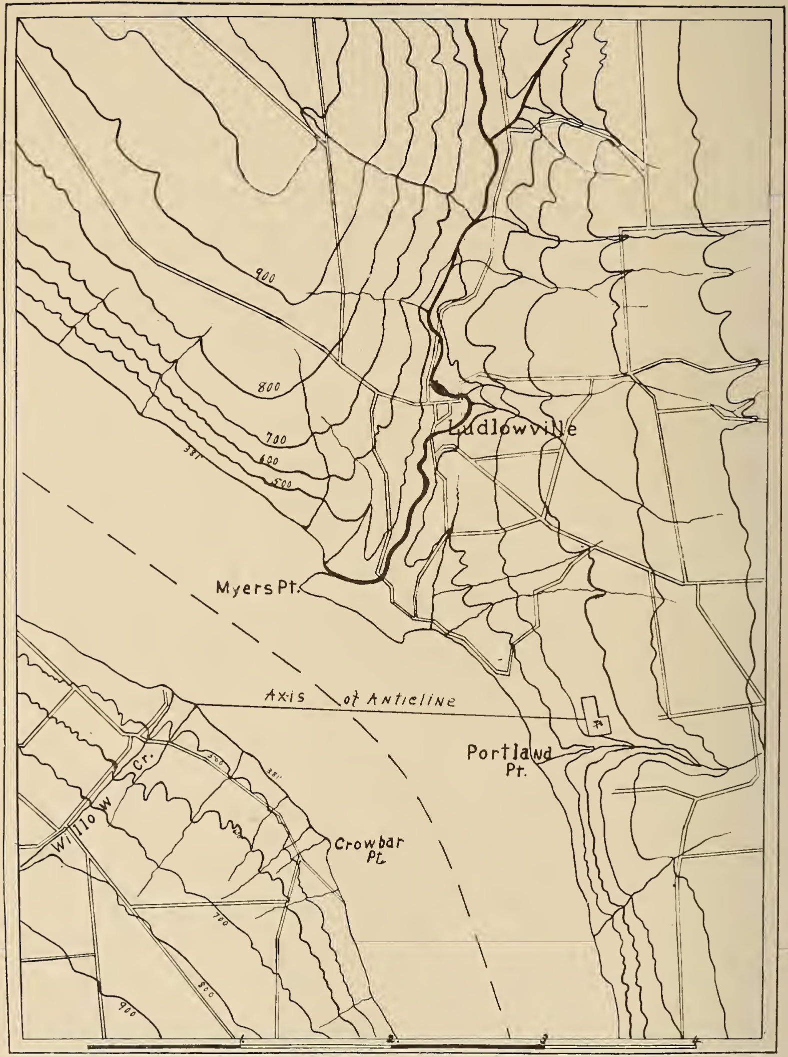

Fig. 1.—Sketch map showing the vicinity of Ludlowville, N. Y. Taken from the Genoa topographic sheet.

ton which was used for most readings. An average dip of a little less than 1° (about 60′) was thus established over by far the greater part of the lake shore. The dip being so gentle it is almost impossible to get accurate readings even by sighting with a level clinometer on a telescope, hence the impracticability of contact readings.

The presence or absence of cliffs, as well as that of the terraces, in some places so conspicuous, is due to the nature of the formation exposed at a given locality, whether hard or soft. The height of the cliffs and terraces, sometimes over 100′ above the lake-level, is due to the position of the two dominatingly hard layers of the district—the Tully limestone immediately overlying the Hamilton shale, and the Encrinal bed of the Hamilton, somewhat over 100′ below. These two resistant layers form waterfalls in all creeks which cross their outcrops, the height of the fall being dependent upon the elevation of the hard ledge.

Fig. 2.—The Tully Limestone between Portland Pt. and Idlewood, east shore of Cayuga Lake. The Tully is here shown capping the Hamilton with the usual southerly dip. Though but 20′ thick it forms a conspicuous terrace with a corresponding dip to the south.

Major Structural Features.

The Watkins Glen.—Catatonk folio deals with the region south of a point called Esty's Glen which is located about four miles north of Ithaca. To the north of this point little work has been done, but one would expect to find a continuance of the large features as shown, by E. M. Kindle,[1] to exist in the region to the south, including not only south central New York but northern Pennsylvania as well. This structure is considered by him to be the northward dying out of the results of the Appalachian Mountain making whose trend and characteristics it shares. The sinuous axes of the broad low folds of the Chemung and Portage of this area are given in a sketch map on page one hundred of the folio, as well as on the Areal Geology sheet. The average trend is slightly N-E to S-W of a true east-west line and would imply pressure from a direction S.SE resistance being encountered in a N.NW direction. Eastward they swing to a more nearly E-W course. From the south to the north end of Cayuga Lake successively older rock are continuously met, the general dip being to the south, though it is not constantly so. The order of succession is: Portage at Ithaca and to the north, until the Genesee appears in the bottom of the cliffs about half a mile south of Esty's. Something over a mile to the north of this the Tully emerges from the Lake and though seldom over 20′ thick, dominates the cliff face of Cayuga Lake (see fig. 2) with but one break at the mouth of Salmon Cr., for a distance of 14 miles to the north, after which for three more miles it makes falls heading deep ravines in the Hamilton shale beneath. The steepness and occasional great height of the cliffs of Cayuga Lake are therefore all the more remarkable since they are cut in the soft shale of the Hamilton for over half of the 40 miles of its shore line.

The quarry in the Tully limestone at Portland Pt. seems to be located on the crest of the major anticline of the whole Cayuga area at an elevation of 640′. Beds dip away from this point to the south for a short distance at the rate of 6°, but after ¼ mile assume the usual dip of about 1°. This continues with but slight variation to the south end of the lake. To the north, the beds dip a little

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[1] Watkins Glen-Catatonk folio **169**, U. S. G. S., pp. 98-111.

less than 1° northward for about a mile, when they assume approximately a horizontal position for another mile or so, before again dipping to the north at a rather higher angle than before. This is again followed by a horizontal area at Ludlowville. A short distance northwest of the boundary of the accompanying map the dip is reversed and the beds continue a southerly dip to the northern end of the lake, some thirty miles distant.

The major fold will here be spoken of as the Portland Point anticline, from the present name of the point, though it was formerly known as Shurger's Point and is so named on the topographic sheet. Its axis across Cayuga Lake trends nearly 5° south of E-W with a westerly pitch of about 44′ per mile, that is, about ½°. This westward pitch of the anticline combined with the general southerly dip of the strata serves to give an ever increasing height to the strata in a northeasterly direction.

Faults in the Encrinal limestone.

Faulting, like the other dynamic movements of the region, is on an unobtrusive scale and would deserve little or no attention were it not for the possibility of throwing some light on the history of the region, indicating something of the nature and direction of the forces applied, and illustrating in nature, even though in miniature, some of the principles involved in rock movement. All of the faults under observation occur in the Hamilton shale. The difference in physical properties between the Enclinal bed of the Hamilton and the vastly greater shaly portion throw the faults therein occurring into two obvious classes, though both are of the "low-angle" type. Those in the Encrinal are conspicuous enough to one on the lookout for them, but undoubtedly there are distributed through the shale countless thousands, the existence of which one will never guess. Vast thicknesses of the shale have no visible bedding planes and even *in situ* are so broken up into small flat lenses, often less than an inch in either direction, that only by virtue of an offset in some of the numerous joint planes is the presence of a fault detected. But little is therefore known of the movements within the shale, for its tendency to split up into this multitude of lamellæ at once destroys any record which might have been preserved on the fault plane. It is almost impossible to get data for the third dimension and impressions are correspondingly vague.

Quite the reverse is the case in the Encrinal layer. In the locality of Ludlowville and on the opposite shore, faulting is more frequent than farther north, and the Encrinal bed here consists of nearly two feet of coarsely comminuted crinoid fragments containing well-preserved fossils of good size. It is hard and compact, though coarsely crystalline, forming ledges or waterfalls as the conditions determine; a typical "competent" bed, in which the faults conform to the laws of shearing under horizontal compression, where the direction of least resistance is both upward and downward into the comparatively mobile shale. The fault planes dip both to the north and the south at angles varying from 20°-30°, and on both sides of the plane show striated columnar structure produced by movement under pressure (see fig. 3). The most numerous collection of these faults is found on the west shore of the lake midway between Crowbar and Willow Cr. and in a second strip of Encrinal

Fig. 3.—Striated columnal structure due to movement under compression along fault planes in the Encrinal layer between Crowbar and Willow Cr., west shore Cayuga Lake.

north of Willow Cr., the first on the south limb of the anticline, the second on the north limb, the dip on both being slightly less than 1°.

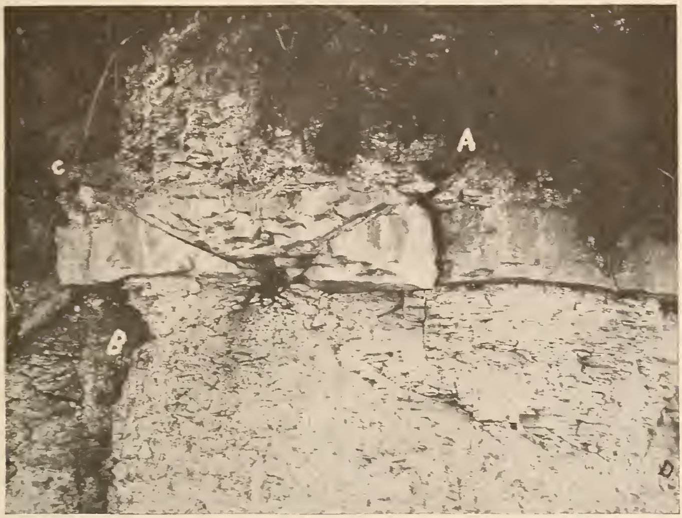

Fig. 4.—Intersecting faults in the Encrinal layer between Crowbar and Willow Cr. west shore Cayuga Lake. Notice the change in angle of dip as the faults enter the underlying shale, as well as the wedge-shaped block lifted up by the horizontal pressure.

Fig. 4 will bear repetition here as giving, from nature, an example of faulting strikingly similar to the results of one of Daubrée's famous experiments, as shown in fig. 5.[2] The block subjected to direct pressure from both ends was a mixture of plaster, beeswax and resin, made to approach natural conditions as nearly as possible and in which were developed fractures formed at angles of about 45° to the direction of compression. The wedge shape of the fault block produced in the Encrinal, though of such small size as to almost forbid comparison, seems to illustrate a movement similar to that suggested by Mr. R. T. Chamberlin in his article on "The Appalachian Folds of Central Pennsylvania."[3]

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[2] Fig. 5 is a photograph of plate II, fig. 3 accompanying a discussion on p. 316, taken from "Etudes synthétiques de géologie expérimentale, vol. I, by A. Daubrée.

[3] Chamberlin, R. T., Jour. Geol., vol. 18, No. 3, 1910 (especially pp. 246-259).

In the Encrinal bed the dip of the fault plane is 22° to the north and 30° to the south, but as soon as it enters the shale below it swings around and within a couple of feet has assumed a 20° dip to the north instead of 30° and a 10° dip to the north instead of 22°. At the intersection of the faults some of the rock is broken away, which may give a false impression, but by projecting the fault planes across the intersection it would appear that the plane C D was the older, though older possibly only by the time it takes to make a fault, for it seems to be cut by the plane A B with a slight offset of not more than 1″. The wedge has been raised about three inches and the striated columnar structure indicates movement in a direction about N 15° E, the strike of the planes being approximately N 75° W. Owing to the position of this and several nearby faults accurate measurements were impossible. A comparison of fig. 4 with fig. 10 in the article on "Low-Angle Faulting" by Mr. R. T. Chamberlin and Mr. W. Z. Miller[4] will at once prove interesting and instructive. Here in nature is a striking demonstration of the trustworthiness of their experiments. Of course one of the intersecting faults must be eliminated in one's mind to make the analogy really good.

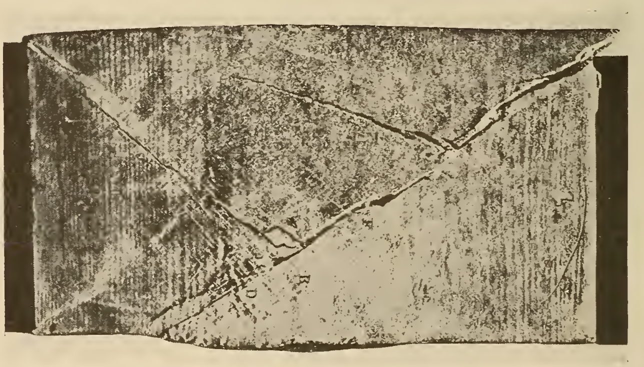

Fig. 5.—Results of pressure applied to a block of plaster, wax and resin, in an experiment of A. Daubrée. Notice the wedge block so similar to Fig. 4 above.

But this little fault goes even farther. Traced back and

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[4] Chamberlin, R. T., and Miller, W. Z., Jour. Geol., vol. 26, p. 27, 1918.

upward into the overhanging vegetation on the south side for a few inches there is evidence that after leaving the hard Encrinal bed below, the fault again lowers its dip in passing into the shale above. This is a very unusual exposure as the shale in other observed cases has been cut from under the hard limestone layer and all trace of faulting obliterated.

Fig. 6.—Outcrop of Encrinal layer at the beginning of the high dip just south of Portland Pt., east shore of Cayuga Lake.

Just opposite Crowbar and ¼ mile south of Portland Pt. the Encrinal appears emerging from the lake with a dip rather steeper than usual. This 5° dip to the south corresponds with the increased dip of the Tully above while approaching the nearby crest of the anticline at Portland Pt., ¼ mile north (fig. 6). In it one fault was seen with a dip of 30° north and striations trending about N 8° E. The position was such as to make an accurate reading of the striated columnar structure impossible.

On the north limb of the anticline about one mile north of its crest and just north of the bridge over Salmon Cr. near its mouth at Myers, the Encrinal appears in the west bank some feet above the village street with a dip of 1° N. Joints and what appear to be faults occur, but the cliff is too steep to make this part of the bed accessible. Around the second turn up stream it again appears in the other bank with a cliff facing N 48° E. This is most accessible and where it crosses the bed of the creek gives a contact reading for dip of nearly 2° N. This is undoubtedly too high. Of all observed, here was found the best one for measurements, along with several imperfect ones. Just before the Encrinal layer crosses the creek a fault with a dip of 25° N is exposed. Only the foot wall remains, thus greatly facilitating the reading of both dip and striated structure. The latter is N 4° E, the only positively accurate reading for the direction of movement as shown by the columnar structure on the fault planes. This reading as all others is corrected for a magnetic declination of 8°, according to the U. S. G. S. quadrangle for the area.

The following table will give some idea of an average in the faults:

	Faults dipping south		Faults dipping north	
	angle of dip	direction of striæ	angle of dip	direction of striæ
1.	20°-25° S.	about N. 6° E.	20° N.	about N. 6° E.
2.	25° S.		28° N.	N. 8° E.
3.	30° S. strike about N. 75° W.	N. 15° E.	22° N. strike about N. 75° W.	N. 15° E.
4.			25° N. strike N. 86° W.	N. 4° E.
5.			30° N. strike N. 72° W.	N. 8° E.

Nos. 1, 2 and 3 occur just north of Crowbar where cliff and shore line = N. 40° W.

No. 3 is shown in fig. 5.

No. 4 is in Salmon Cr.; readings accurate within a fraction of a degree.

No. 5 is at Portland Pt.

For a discussion of the origin and results of rotational strain, to which type of faulting the above appear to belong, the reader is referred to C. K. Leith's "Structural Geology" and to the above mentioned article on "Low-Angle Faulting." An attempted summary would not do the subject justice, but two points may be emphasized. It is known that the great forces, which raised thousands of feet of sedimentaries into the Appalachian Mts., were applied in a practically horizontal direction. "The planes of greatest tangential stress should therefore dip at angles somewhere in the neighborhood of 45° and may plunge downward or upward."[5] This angle of

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[5] Chamberlin, R. T., Appalachian Folds of Central Pa., Jour. Geol., vol. **18**, p. 247, 1910.

45°, however, may be modified and greatly reduced by a number of conditions. Two in particular apply to the case in hand. As brought out in the article on Low-Angle Faulting, 1. to lower the angle of the fault plane means, to decrease resistance by friction as produced by normal compressive stress; hence the avenue of least resistance will be taken. 2. "Rotational strain may be developed from horizontal compressive stresses, in heterogeneous material by bedding or similar structure, which present differences in competency."[6]

Deductions.

From the above facts as shown by the faults of the Encrinal layer of the Cayuga Lake region it may be assumed that the forces which produced them worked approximately horizontally and came from a direction between 4° and 15° west of south. This is a rather surprising development in view of the preceding statement that the region belonged to the outskirts of the Appalachian province and had shared its history even though in less active form than the mountainous tract. Some intimation of the fact might have been discerned in the progressively changing curve of the axes of the anticlines as shown in folio No. 169 page 100 as they turn from a general SSW-NNE to an easterly direction. So ingrained, however, is the idea that all pressure as applied to the Appalachians must come from the southeast that the warning passed unnoticed.

In northwestern central Pennsylvania, as well shown on the U. S. topographic map, there occurs a sharp turn in the trend of the Appalachians, with convexity N-W, swinging them across northern Pennsylvania and south-central New York in a nearly east-west course. This soon again turns and they pass northward through New England in the usual NNE direction. Lines drawn at right angles to the trend of the second curve which occurs in south-eastern New York would converge not far east of Cayuga Lake, which means that this region is practically due north of the east-west segment. The fact that the axis of the Portland Pt. anticline crosses Cayuga Lake

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[6] Chamberlin, R. T. and Miller, W. Z., Low-Angle Faulting, Jour. Geol., vol. 26, p. 44, 1918.

a few degrees NW-SE of a true E-W line is, therefore, in keeping with the other surprising fact of the direction whence came the pressure developing the faults of the Encrinal layer, and in reality is what should be looked for, if truly related to the Appalachian Chain.

A dike which gives some collateral evidence.

A feature which, on first sight, might in some respects seem at variance with the previously expressed facts, is the presence of a peridotite dike on the crest of the major anticline. It was exposed five or six years ago in the eastern end of the quarry operated by the Portland Cement Company at the point given its name. Rising from the Hamilton, which forms the floor of the quarry and cutting entirely through the Tully limestone it intrudes several feet into the Genesee shale above. For the region it is quite sizable, varying from 12″ to 18″. The strike of the dike, N 3°-6° W, is not in conformity with the postulated direction of movement, which however is to be accounted for by the fact that the dike is obviously here following the course of one of the numerous joints belonging to the N-S system. Its contact with the country rock is often very close, there being no evidence of filling, but on the other hand there are many places where the contact is ragged, streamers of the magma having entered the limestone and in some cases pieces of the Tully being broken off and incorporated in the peridotite. (See fig. 7.) Con-

Fig. 7.—Inclusions of Tully limestone in a weathered peridotite (serpentine) dike at Portland Point. Notice the fine bedding planes of the limestone.

tact metamorphism is not conspicuous but a gradation of texture is frequently noticed and the limestone is often indurated for an inch or more. Calcite has very nearly filled all the cavities opened up and on this soft medium is recorded the usual N-S horizontal movement of the region. So evidence other than faulting falls in line. The north and south walls of the quarry very nearly parallel the axis of the fold so that the curved lines of dip shown in these two walls as well as the eastern, together with discrepancies in dip indicate a torsional movement, elevation at no two corners corresponding.

Fig. 8.—Horizontal faulting in the Hamilton shale at the big Falls, Ludlowville, N. Y. The fault plane is just above the surface of the pool.

Faults in the Hamilton Shale.

Quite another type of faulting from that already discussed is found in the shaly members of the Hamilton. Here faults occur which are either movements along bedding planes or parallel with them, on through various angles up to those very nearly vertical. One good example of the horizontal type is shown at the water level of the pool at the foot of the big Falls at Ludlowville, north of the village, and just below the dam. (See fig. 8.) The displacement is probably six inches. As the pool does not dry up even in time of drought and no boat is provided for the convenience of visitors it was impossible to get nearer the fault than a hundred feet or so. It is about 35′ below the Tully, the movement offsetting joints of the N-S system, so that the upper mass was moved eastward relative to the lower mass. This offset of the joints is only the apparent displacement. The cliff faces very close to due south, its trend being E-W, with no dip in either direction which could be detected with a Brunton clinometer or a telescope clinometer even by distant sighting. As the streams always hug the north sides of their courses it is to be inferred that a slight northerly dip must be present. Taking the direction of pressure as previously calculated at an average of about 10° west of south, the chief movement will be in a general N-S direction, the E-W component representing only the very small part played by the 10° deviation from N-S. As the fault does not persist for any very great distance it is safe to infer that the maximum displacement is nowhere great. This locality is about two miles north of the crest of the anticline at Portland Pt. and hence on the northern limb, the dip of which is very far from constant. It appears to be located on a second horizontal area, another level district occurring about 100′ higher and half a mile nearer it. Instead of being due to pressure this fault may possibly, though not at all probably, be due to local relaxation and hence belong to a type intimately connected with valleys and which will be discussed in connection with the wedge fault block to follow.

Mr. G. C. Matson in an article on "Peridotite Dikes near Ithaca, N. Y."[7] calls attention to several dikes not here considered. One group of four is above the high fall over the Genesee shale, in a tributary to Salmon Cr. just northeast of Ludlowville. "Three of these have been faulted; the fourth does not reach up to the fault plane. The amount of displacement is about two feet."[8] From

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[7] Jour. Geol., vol. 13, p. 265, 1905.

[8] Ibid.

this reference a horizontal fault is to be inferred and judging from the small offset a displacement similar to the fault at the big Falls from which this is but a half mile distant in a direction nearly due east.

Immediately east of the bridge crossing Salmon Cr. on the road entering Ludlowville from the south is a fault of most unusual appearance. The face of the bluff in which it occurs trends N 73° E. that is, it faces in a general northerly direction. Running from a point somewhere under the bridge for over 100′ to the east there is another horizontal fault which ends abruptly against a joint plane. This too is at low-water level but over 20′ below the first one mentioned. Just across the sluice to the east of the bridge and 9′ above the horizontal fault another fault plane has been developed which dips down at an angle of 8° and meets the lower one just where it encounters the joint plane. Cutting the face of this bluff are a number of well-marked joints belonging to the N-S system. The two faults form a wedge-shaped block between them, which as seen in fig. 9 is thrust inward, that is to the east, but exhibits no evidence of crushing at its point. The

Fig. 9.—Wedge-shaped block between a horizontal fault just above water-level, and an oblique fault dipping toward the left margin of the photograph. Easily detected by the offset of the joints.

amount of offset, as measured in this case, is quite uniformly 6″ on both faults. The junction of the two faults with the joint plane has made a point of weakness in which the creek has cut a miniature cave of a few inches but in the absence of a brecciated zone and a decrease in the offset of the joints in approaching the point of the wedge it seems that the force applied must have been oblique to the section exposed rather than parallel with it. At the intersection of some of the joints with the upper fault plane a curved surface has been developed on the joint planes, suggesting a drag movement so often seen in connection with faulting. The direction and amount of offset is easily seen, owing to the presence of the joints, and corresponds quite closely with the fault at the Falls.

The face of the bluff trending as it does N 73° E gives a very small angle of about 11° between it and a section along the strike of the structure of the region, the axis of the main fold being taken at N 85° W. One would, therefore, expect as in the previous case that by far the largest part of the movement would not be disclosed. As the sluice ran at right angles to the bluff it was hoped that some information in the third dimension might be gained but the broken character of the shale had erased any evidence if such ever existed. It was finally noticed that at the intersection of one of the east-west and one of the N 8° E joints where crossed by the dipping fault plane about two square inches of the surface of the fault were exposed; this showed an unmistakable dip into the bank, that is to the south, but the surface was too small and poorly situated to get any accurate readings. However the dip south was apparently not less than 8° at the line of outcrop. Presuming that this dip continues, regardless of what its angle may be, it doubtless ultimately joins the horizontal fault, from which it seems likely that it is a branch. This being the case we have here a transverse section of the two faults rather than a longitudinal section as at first appeared. The movement of the wedge block was therefore not primarily in and eastward, but was northward. The deviation to the west, of the forces coming from the south which produced the faulting, plus a slight torsional movement, would swing the joints out of alignment to the extent of six inches and the comparitively mobile shale would accommodate itself to the oblique pressure when it could hardly have done so in the face of direct compression.

The occurrence of the three above faults in such close association with a large sized stream of extensive cutting power brings up a question which may be raised by some. Along the banks of many of the streams in the vicinity of Cincinnati, Ohio, there occur in the Eden shale small overturned folds, sometimes advanced to the stage of thrust faulting. (Fig. 10.) These are usually found on the under-cut side of terraces and are beginning to be recognized as produced by relaxation due to rock removal by stream erosion, rather than by direct pressure. These streams are all post-glacial whereas Salmon Cr., N. Y., runs in a valley recognized as pre-glacial. The horizontal fault at the Falls has certainly no connection with a terrace though the one by the bridge has some such relation and to a post-glacial terrace at that. However, they appear to be so in accord with the rest of the evidence concerning the diastrophic history of the region that it hardly seems necessary to call in outside evidence for their explanation.

Fig. 10.—Fold in Eden shale, West Fork Cr., Cincinnati, O. Supposed to be due to relaxation resulting from stream erosion.

A second type of faulting as shown in the shale members of the Hamilton is a compound or slice fault developed on the south side of Stony Point some 25 miles down Cayuga Lake. At this point a hard layer of limy shale, much more compact and resisting than the surrounding shale is sharply turned up at a 10° angle with dip to the south. The faults occur just at the start of this high dip, the greatest measured. For 200′ along the shore south of the point, the N 12° W joints show horizontal faulting with displacement of 1″ to 1½″ of the joints of the E-W system. The movement has pushed forward each successive block between two faults from west to east. That is, the western part of the zone has not moved so far north as the eastern part. The N-S joints dip west a few degrees from the vertical but the angle was not measured. It probably does not exceed three degrees as other joints of the region which are not vertical show a dip very generally around 2°. The faulted area covers the entire width of the shore as exposed at this point and may exist over an even greater width and length. The rocks of the whole point and near to it are broken up by an excessive number of subsidiary joints at all angles and often much curved.

Mr. W. H. Bucher published an article on ‘‘The Mechanical Interpretation of Joints,’’ in the Journal of Geology for December of 1920. To one not acquainted with the laws of mechanics the ‘‘interpretations’’ sound quite convincing. His main thesis is, that in brittle substances the lines of greatest pressure will bisect the acute angle formed by the shearing planes. He then applies this law to three areas, one of which happens to be the Cayuga Lake region. Not being acquainted in person with the area, he relies for his calculations upon the data given in an article by Miss Sheldon.[9] His conclusions, put into figures, being that the compressive forces, must lie in a general N 35° E direction since this line must bisect the angle between the two major joint systems of the region, the average of the greater part of whose angles will run at about N 74° E and N 5° W. This application is here made to only the northern part of the area which he discusses, but the results as stated are only a few

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[9] Sheldon, P.; Some Observations and Experiments on Joint Planes, Jour. Geol., vol. 20, No. 1, 1912.

degrees at variance with those for the larger area. As proof of the applicability of his theory, he cites the presence of buckling as shown by a raised area in the northeast part of the Catatonk quadrangle, and of a depression in the central portion, near Jenksville. These are unquestionably present and quite possibly bear some relation to the joints of the region, but they are not the only domes and depressions which occur in the two quadrangles.[10] Following the axis of the Watkins anticline as he suggests, the Portage-Chemung contact, starting at about 1520′ near the western boundary of the map, dips toward Seneca Lake valley, and at Texas Hollow, to the east, has risen to an elevation of 1480′ whence the beds continue horizontal to a point two miles southwest of Enfield, the last exposure west of Cayuga valley, along this line. To the north near Reynoldsville, on the crest of the Firtree anticline this contact is 1600′ as it is on the crest of the Alpine anticline to the south and near Cayuga L. The first contact shown east of Cayuga valley following the axis of the Watkins anticline as stated, is at Pleasant Hill, six miles east of Ithaca and 14 miles east of Enfield where the contact is 1720′ or 240′ above the contact at Enfield. Were the secondary synclinal fold in which Cayuta Lake lies disregarded, there would be in this 14 miles a rise of but 17′ to the mile, whereas the rise to the north from the depression at Jenksville mentioned by him is over 43′ per mile for 16 miles. The average of a number of southerly dips north of the big bend of Cayuga Lake is about 45′ per mile, steeper dips developing as the datum plane of the Tully limestone is followed north. Owing to the lack of geological and especially structural knowledge of the area to the north of the Watkins and Catatonk quadrangles, it seems hardly possible to form a very reliable opinion of a district so near to the unknown. Work to the north along Cayuga Lake this past autumn, together with observations of the mapped quadrangles, would seem to indicate that the greater southerly dips, even discounting what is due to the folding process, are entitled to equal, if not greater,

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[10] In a personal communication Mr. Bucher claims two sets of movements, that producing the joints and buckling being prior to the one which developed the major folds and their accompanying faults. The horizontal fracture planes he thinks may have originated during the first activities, only the movement taking place later.

significance than the pitch of the anticlines and synclines and dips associated with a buckling process.

Judging from field evidence and acquaintance with the region, Mr. Bucher's results imply a large latitude in the angle of his bisectrix as well as the presence of some modifying or secondary forces not yet understood. Nevertheless the old idea of compressive forces acting from the southeast will apparently have to be revised in favor of a southwesterly direction. This is probably due to the lack of recognition accorded the short east-west segment and may be considered a local exception. Here, two entirely independent arguments, aiming to demonstrate different ideas, have developed conclusions more closely allied with each other than is either one with the usual conception of the movements of Appalachian folding.

Ithaca, N. Y.

Art. XX.—*Description of a new Species of Fossil Herring, Quisque bakeri, from the Texas Miocene;* by David Starr Jordan.

Quisque bakeri, new species.

Family Clupeidæ.—Body oblong, compressed, rather short and deep. Head heavy, about equal to depth, 3¼ times in length to base of caudal, the snout bluntish; eye large, nearly as long as snout, 3 3/5 in head; mouth large, oblique; maxillary about reaching to below middle of eye; the lower jaw projecting, its tip entering profile which is nearly straight. Vertebræ rather strong, striate, hour-glass shaped, about as deep as long, with strong ribs, neurals and hæmals; the number of 13 + 13 = 26 with perhaps three additional vertebræ crushed into the base of the caudal; interneurals and interhæmals obscure, the first interhæmal evident, rather well developed. Pectoral rather short, placed low, eight rays traceable. Dorsal fin short, apparently median, the rays obliterated; anal short, nearly obliterated;

Figs. 1, 2.—*Quisque bakeri* Jordan.

caudal broken, only the base preserved, the lower half with about twelve rays; ventral fins lost; no trace of scales and no indication as to whether ventral or dorsal outline is serrated.

The type of this species, Catalogue number 401, Yale University Museum, is a tiny fossil herring, with broken fins, a little over an inch long, and about 1 1/3 inches to tip of caudal, if complete. It was obtained by Mr. R. F. Baker, from an oil well at a depth of 3,098 feet, at West Columbia, Brazoria County, on the Gulf Coast of Texas. It is in bluish clay shale, of the Lower Miocene, either the Fleming or the DeWitt formation, and is part of a boring of the Texas Company Hogg Well No. 63. The species is named after Mr. R. F. Baker, geologist of the Texas Company.

The specimen was sent to the writer for study by Professor Charles Schuchert. With it is a smaller fragment, the reverse of the best preserved side, showing the posterior part of the head, a pectoral fin and the vertebral column to about the middle of the anal fin.

The obliteration of scales and scutes makes it impossible to locate the genus with accuracy. Among the small herrings of the Miocene, it seems to come nearest to the genus *Quisque* of the Southern California Miocene; the large head, stout bones and large oblique mouth agreeing with *Quisque gilberti* Jordan from El Modena, California, the type of the genus.

ART. XXI.—*A New Genus of Fossil Fruit;* by EDWARD W. BERRY.

Several families of the order Sapindales, which contains about 20 families and over 3,000 existing species, are abundantly represented in the geological record. This is notably true in the case of the families Sapindaceæ, Ilicaceæ, Celastraceæ, and Anacardiaceæ, which are also the largest existing families of this order.

A family that has not heretofore been recognized in the fossil state is the Icacinaceæ. In the existing flora this family consists of about 40 genera and 150 species, of which only 8 genera with less than 30 species are found in the Western Hemisphere, where they are, for the most part, confined to the tropics. None of these American genera except Mappia is found in any other continental region, and in this genus the American forms are grouped in the sub-genus Eumappia and confined to the Antillean region, and the Asiatic forms are segregated in the subgenus Trichocrater and confined to the region between Ceylon and Farther India. It seems very probable that these two sub-genera are not directly filiated but exhibit convergent characters resulting from similar modifications of unlike ancestors.

The family is distinctly oriental at the present time, and makes its greatest display around the borders of the Indian Ocean, and its present representation in Africa on the West and Australia on the East suggests an Asiatic ancestry, with migrations from that region southwestward over the now submerged Gondwana bank, and southeastward through the East Indian region. For example, although there is only a single monotypic genus in addition to Trichocrater confined to Asia, there are 15 genera with over 60 species found in the region extending from southeastern Asia to Australia, and 3 genera with 20 species common to Asia and Africa. Africa has 10 genera and about 35 species confined to that continent, and Australia has 3 endemic genera with about 6 species.

There is only a single monotypic genus in northern South America, and there are at least nine such in the Old World, Three are African, one is Asian, two are East Indian, one is confined to New Guinea, and two are confined to the limited and otherwise peculiar region of New Caledonia.

Some years ago I received casts of an unknown fruit from a sandstone in the Wilcox Eocene exposed at the Butler Salt dome in Freestone County, Texas. These defied determination for several years, and I could find no recent fruits at all like them until 1919. At that time, in collecting fruits on the Pacific coast of Panama I obtained a recent form that was very close to the fossil fruit. In seeking to determine the former at the National Herbarium I found that it was identical with material from Mexico and Costa Rica which Messrs. Standley and Stafford were describing as a new genus, and referring it, with some hesitation, to the family Icacinaceæ. This has since been described as the genus Calatola, and three species—all trees, are recognized. Two of these are Mexican and the third is Costa Rican and Panamanian.

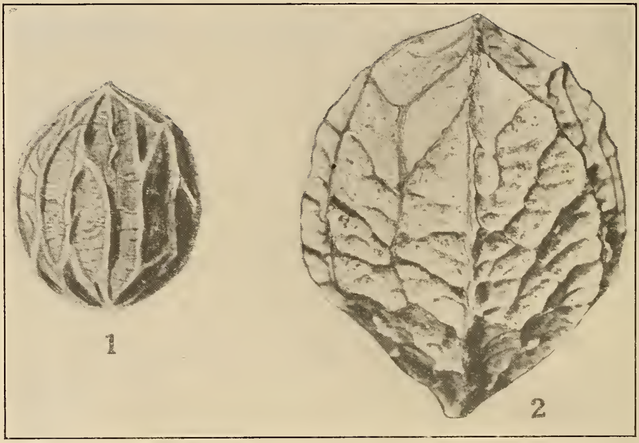

Fig. 1.—Calatoloides eocenicum Berry.
Fig. 2.—Calatola fruit from Panama, both natural size.

The fossil form from the Eocene of Texas is clearly allied to this recent Central American genus, but in view of the incompleteness of the material, and the impossibility of verifying the identity in all particulars, it has seemed best to propose the new genus *Calatoloides* for the reception of the fossil form—the name chosen serving to suggest an ancestral relationship to the existing forms, further borne out by the smaller size of the Eocene form. It may be described as follows:

Calatoloides eocenicum gen. et sp. nov.

Based on fruit, which, as restored from casts, is a moderately prolate spheroid in form, 2.5 to 3 centimeters in length and about 2.25 centimeters in diameter, broadly rounded proximad and bluntly pointed distad. The sclerotesta, which in life appears to have been covered by a thin sarcotesta, is ligneous, and shows a characteristic ornamentation similar to that of the fruits of the three existing species of Calatola. It is marked by a somewhat irregular, prominent, branching and anastomosing series of longitudinal ridges and these are connected by low, subordinate, irregularly transverse, ridges. If it was like the existing Calatola it contained a single large seed. The Panama specimen was found in the sea drift on the shore of Panama Bay, but the seed was dead and we know nothing of the ability of the fruits of this genus to withstand journeys by sea, although the dry fruits appear to be buoyant and impervious to sea water, so that ocean currents may have been a factor in the distribution of the Eocene ancestor.

In shape and ornamentation there is no difference between the Eocene and the existing species except that the fruits of the extinct genus are only one-half the size of those of the existing genus, and the transverse ridges between the longitudinal ridges are less prominent in the fossil.

Any consideration of the origin and past distribution of the members of this family must await a knowledge of its fossil representatives, but it is not without great interest that the exclusively Central American genus Calatola, not recognized until 1921, should be represented by a closely related form in the lower Eocene of northeastern Texas in a flora, a large proportion of which I have regarded as having spread northward into southeastern North America from equatorial America during the emergent interval which followed the withdrawal of the Upper Cretaceous sea from that area.

Johns Hopkins University,
Baltimore, Md.

Art. XXII.—*The Relations Between the Purcell Range and the Rocky Mountains in British Columbia, Canada;* by Lancaster D. Burling.

During a trip along the Canadian Pacific Railway from Field to Glacier, British Columbia, in 1915, the writer formulated a working hypothesis to explain the stratigraphic and structural interrelations of the Rocky Mountain and Purcell Range sections. This differs from those which have been proposed but succeeding observations have more and more convinced him that the hypothesis has elements of plausibility which warrant its presentation, together with such corroborative evidence as he is able to recall.

In order that we may understand the general relations it may be stated briefly that the Rocky Mountains and the Purcell Range, two mountain systems lying respectively east and west of the Columbia River Valley at Golden, differ markedly in the lithologic character of the rocks of which they are composed. The western rocks are marked by igneous intrusions, the sandstones are not so clean, and there has been considerable metamorphism. In the Rocky Mountains to the east there is little metamorphism and igneous activity appears to be confined to single small centers such as the Ice River valley occurrence south of Field.

Speaking generally the Rocky Mountains section (to the east) is dominantly calcareous; the Purcell Range section (to the west and nearer to the source of the sediments) is dominantly arenaceous. And between the two there is a relatively narrow belt of crumpled shales in which the Rocky Mountain (Kootenay-Columbia River valley) trench has been cut.

In the western portion of this intervening shale zone is a fault-contact which represents the trace of the plane along which the shales have been overthrust by the clastics of the Purcell Range. (Students will recall that Termier has here postulated thrust faulting of large magnitude to account for the relations of the rocks of the Purcell Range to those farther west.) Between the shale zone and the Purcell clastics the change in lithology is abrupt; eastward the change from shale to limestone is gradual and progressive.

For a long time the rocks in the Purcell Range were believed to be unfossiliferous, but there has been gradually accumulated by the members of the Canadian Survey considerable evidence that these rocks are at least in part of Upper Ordovician (?), Devonian, and Upper Palæozoic age. Palæozoic fossils younger than the Cambrian have thus been collected near Laurie, Lardo, Wardner, etc., but so far as the writer is aware no Cambrian fossils have been found west of the fault contact which we have described as occurring between the clastics of the Purcell Range and the shale series trenched by the Columbia River. This contact lies at a considerable elevation above and to the west of the actual river, however, and in the shaly series outcropping upon the slope between the fault contact and the river are strata which have yielded both Middle and Upper Cambrian fossils.

These two Cambrian fossil horizons were discovered by Ami and Daly, respectively, in the section exposed by the Canadian Pacific Railway, west of Donald, in the gorge by which the Columbia River leaves its trench and crosses over to the west some ten or fifteen miles north of Golden. The Middle Cambrian fossils found by Ami are in the collections of the Canadian Geological Survey. They are preserved as whole specimens and are curiously similar to if not identical with the *Ptychoparia kingi* occurring in the Middle Cambrian Wheeler formation of the House Range in Utah (Smithsonian Misc. Coll., vol. **53**, No. 5) even to the cone-in-cone structure of the matrix surrounding the fossils. The Upper Cambrian fossils found by Daly are also to be found at Ottawa and include forms described by Walcott as *Dicellocephalus dalyi* and *Illaenurus elongatus* (Smithsonian Misc. Coll., vol. **64**, No. 13, pp. 367-368). They were collected from an outcrop occupying unknown relations to the rest of the section and are correctly referred to the Upper Cambrian by Walcott. But the horizon of Daly's Upper Cambrian fossils has been found by the writer in place in the Goodsir formation which Walcott has referred to the Ordovician (Smithsonian Misc. Coll., vol. **57**, No. 7, 1912, pp. 233-234, pl. 35). This does not mean, however, that the reference is to be changed from Upper Cambrian to Ordovician, for a large part of the 6,000-foot Goodsir formation, including the beds carrying the so-called "Ceratopyge fauna" of Walcott, is of Upper Cambrian age. The Upper Cambrian fossils found by Daly west of Donald are to be correlated, together with the "Ceratopyge fauna," with the Orr formation of the House Range section in Utah (Burling, Summary Rept. Geol. Survey Canada for 1915, pp. 98-99, 1916). This places them fairly well down in the Upper Cambrian instead of in the Ordovician. Less than one mile east of Golden, in the gorge cut by the Kicking Horse River, the writer has collected Normanskill graptolites similar to those discovered by McConnell at Glenogle, 15 miles farther to the east.

We have, therefore, close together in the Rocky Mountain (Columbia River) trench at Golden, and within the single shale series which we have described as separating the clastics of the Purcell Range from the calcareous rocks of the Rocky Mountains, indisputable evidence of the presence of strata representing the Middle Cambrian, the Upper Cambrian, and the Ordovician.

This Cambro-Ordovician shale series is closely folded and micaceous in places, and we have no evidence regarding the thickness of strata here intervening between the Middle Cambrian and Ordovician horizons above described, but we do know that the same faunal horizons are, in the Rocky Mountains less than 30 miles to the east, separated by many thousands of feet of massive limestones.

The conclusion we are about to draw must already be evident to the student but it will be necessary first to speak of Daly's correlations of the rocks in the Purcell Range with those in the Rocky Mountains. By him the thick clastics of the Purcell Range are correlated with the clastic basal or lower Cambrian portion only of the Rocky Mountains section, a correlation based upon so much study, both in the field and office, that we have hesitated to question it. But the only gap in the evidence we have in favor of a different conception of the relations is the failure, so far, to find Middle or Upper Cambrian fossils in the Purcell Range clastics. And the other evidence is so strong that we would suggest the view that the deposition of the clastics of the Purcell Range (western), the shales of the Rocky Mountain trench (central), and the dominantly calcareous rocks of the Rocky Mountains (eastern) was essentially contemporaneous and that the stresses to which the central shales have been subjected has been relieved by crumpling in the shales themselves and by the overthrusting of the more competent but equivalent strata to the west.

London, England.

Art. XXIII.—*Some Complex Chlorides containing Gold. I. Pollard's Ammonium-Silver-Auric Chloride;* by Horace L. Wells.

[Contribution from the Sheffield Chemical Laboratory of Yale University.]

Since numerous investigations upon double and triple salts have been carried out in this laboratory by the writer and his associates, attention was attracted to the description by William Branch Pollard[1] of a new triple chloride to which he gave the formula $(NH_4)_8Ag_3Au_4Cl_{23}$. Since this formula appeared to be a rather complex one, and because Pollard used apparently drastic methods in preparing the salt for analysis, including extracting it with ether and heating it sufficiently to volatilize ammonium chloride, a new investigation of it was undertaken.

The salt was readily obtained, by following Pollard's directions, from a solution of 25 g. of gold in 50 cc. of nitric and 150 cc. of hydrochloric acid, to which were added 30-35 g. of ammonium chloride and 3 g. of silver nitrate dissolved in 10 cc. of water. When a few more crystals of ammonium chloride were added the silver chloride precipitate that was present was gradually transformed into the dark triple salt. Then upon heating the salt with its mother-liquor there was a separation of silver chloride which, upon cooling, was replaced by the triple salt.

This method of preparing the salt for analysis did not appear to be very satisfactory on account of the concentrated condition of the solution and also on account of the possible danger of the entanglement of silver chloride in the product. It was found in the present investigation that when solutions somewhat similar to the one recommended by Pollard were diluted largely, perhaps with an equal volume or more of 1:1, or stronger, hydrochloric acid, it was easy to obtain clear, boiling solutions from which the triple salt could be obtained either by cooling or evaporation to crystallization on the steam-bath, and both methods of preparation, under wide variations of conditions, have been used in obtaining the products for analysis. The crops of crystals were usually washed to some extent by pouring off most of the mother-liquor, diluting the remainder rather largely with hydrochloric

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[1] Jour. Chem. Soc., 117, 99, 1920.

acid, agitating and draining. In one case (analysis VI) where the crop had been deposited from a solution diluted to an unusual extent with concentrated hydrochloric acid no washing was done, for the sake of comparison. In all cases the products were rapidly pressed between smooth filter papers until the latter were no longer moistened by the operation and then they were dried in the air. There was practically no further loss in weight upon drying at 100°.

The crystals obtained were always very small, usually not over 1 or 2 mm. in diameter. The larger ones were very dark brownish-red in color, but evidently transparent, while the smaller ones were not so dark. Pollard has called the color purplish-brown. The crystals are beautiful and brilliant, and a description of their orthorhombic form is given in Pollard's article.

The salt is quickly decomposed by water, but it appears to be stable in the presence of strong hydrochloric acid, as was observed by Pollard.

The following analyses of separate crops were made:

	Prepared by hot evaporation		Prepared by cooling				Calculated for $(NH_4)_6Ag_2Au_3Cl_{17}$
	I.	II.	III.	IV.	V.	VI.	
NH_4 ..	7.02[a]	....	7.09[a]	....	....	....	7.13
Ag ...	14.31	14.19	13.61	14.03	14.47	14.16	14.21
Au ...	38.89	38.80	39.67	38.84	38.54	38.62	38.96
Cl	39.47	....	39.82	....	....	....	39.70
	99.69		100.19				100.00

[a] Calculated from the excess of chlorine.

	Pollard found	Calculated for $(NH_4)_8Ag_3Au_4Cl_{23}$	Pollard's formula differs from new one
NH_4	6.88	6.97	— 0.16
Ag	15.58	15.62	+ 1.41
Au	37.99	38.06	— 0.90
Cl	39.44	39.35	— 0.35
	99.89	100.00	

The analyses in the present investigation were made by decomposing the salt with a liberal amount of water by the aid of heat, cooling, collecting the silver chloride in a Gooch crucible and weighing it, precipitating the gold in the hot filtrate by means of ammonium oxalate, and, after hot digestion until the liquid was perfectly clear, collecting and weighing the gold in a Gooch crucible, then acidifying the last filtrate strongly with nitric acid, precipitating silver chloride by means of silver nitrate, and collecting and weighing the precipitate in the usual way. Of course the chlorine in the first precipitate of silver chloride was added to this.

From the evidence presented here it is believed that the new formula is the correct one. It is true that Pollard's results agree very closely with his formula, but he gives only one analysis, which may possibly represent selected results, while his method of preparing the salt for analysis, already alluded to, would probably not remove any silver chloride from the salt, but might remove small quantities of the other constituents. In fact, it was his object to remove any gold chloride and ammonium chloride that adhered to the crystals, so that his results may reasonably be expected to show too much silver chloride.

The new formula varies but slightly from Pollard's, and it has little advantage over his in regard to simplicity. The new investigation, therefore, confirms the fact that this ammonium-silver-auric chloride has a composition corresponding to a rather complex formula which appears without doubt to be $(NH_4)_6Ag_2Au_3Cl_{17}$.

In view of the frequent similarity of ammonium and potassium salts, an attempt was made to prepare a potassium-silver-auric chloride, but after many experiments under wide differences of conditions no evidence of the existence of such a triple salt was obtained.

When cesium chloride was used, however, a triple salt was easily obtained, and several other triple chlorides containing cesium and gold, as well as a new double salt of these two metals, have been prepared. This work will be described in subsequent articles in this Journal.

New Haven, Conn.,
February, 1922.

Art. XXIV.—*Studies in the Cyperaceæ;* by Theo. Holm. XXXIV. *Carices aeorastachyæ: Glaucescentes* nob., and *Limosæ* nob. (With 14 figures drawn from nature by the author.)

Glaucescentes.

C. glaucesens Ell. (Figs. 1-3).

The section seems, so far, to be monotypic, and *C. glaucescens* Ell. is confined to the southern States: Virginia west to Missouri, and south to Florida. Regarding the affinity of the species Drejer[4] writes:

> "Affinitatem mihi accuratius inquirenti mox apparuit, ad gregem *Caricum aeorastachyarum.* Habet enim spicam masculam solitarium; bracteas foliaceas (saltem infimas), evaginatas, subauriculatas; spicas femineas cylindricas, densifloras, pedunculatas, arrectas demum pendulas; perigynia membranacea, nervata, arcte caryopsin includentia; rostrum brevissimum subemarginatum. *C. glaucescens* a ceteris sui gregis satis distincta est squamarum insigni forma, quamquam nisus in eam in squamis *C. rariflorae* apparet. Inter americanas nullam scio, quam huic proxime affinem posuerim, neque inter europaeas; in India orientali autem plures affines videntur habitare."

By Kükenthal[2] the species is a member of his *Paludosæ* (*minime* Fries), and placed between *C. brasiliensis* St. Hil. and *C. paludosa* Good; nevertheless this same author considers *C. Joorii* Bailey to belong to the remote section *Maximæ,* although *C. Joorii* is identical with *C. macrokolea* Steud. and this *C. macrokolea* Steud. is by Kükenthal reduced to a mere form of *C. glaucescens*—the inevitable result of compilation without material for comparison.

Drejer gives an excellent illustration of *C. glaucescens,* and from his diagnosis the points as follow may be quoted:

> "Perigynia matura squamis latiora et longiora, ovato-trigona, crassa, caryopsin arcte includentia, membranacea, laevia, tenuissime granulata, rostro brevissimo subemarginato. Caryopsis brevis, crassa, obovata, trigona, lateribus excavata, stylo longo, robusto, laevi, continuo, semper exserto terminata."

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[1] Symbolæ Caricologicæ. Copenhagen, 1844, p. 14.

[2] In Engler: Das Pflanzenreich, Leipzig, 1909. 733.


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According to Gray's New Manual of Botany (1908) *C. macrokolea* Steud. is considered specifically distinct from *C. glaucescens* by the squamae being short-awned, and the perigynium strongly ribbed; moreover the figure (l. c. p. 248) shows the pistillate spikes to be always sessile; the geographical distribution is the same, but extends to Texas. The section is thus confined to the Southern States, and shows in several respects some affinity to the *Limosae* as regards the phyllopodic culms, the bracts being evaginate, etc., as already pointed out by Drejer (l. c.); but the habit is much more robust, similar to large specimens of *C. cryptocarpa*.

Limosæ.

In this section we have *C. littoralis* Schw., *C. limosa* L., *C. laxa* Wahlenb., *C. rariflora* Sm., *C. stygia* Fr., and *C. Magellanica* Lam. They all are phyllopodæ, and bog plants. With regard to their geographical distribution *C. littoralis* is a very local plant in the Atlantic States from Connecticut and southward, Maryland for instance. *C. limosa* is widely distributed in the northwestern corner of this continent: Yukon, British Columbia, Washington, Idaho and Oregon; it occurs also in the Atlantic States, in arctic Europe (Finmark and Russia) and Siberia; farther south the species reaches Great Britain, the Alps and Pyrenees, Altai and Baikal Mountains, Korea, etc. *C. laxa,* on the other hand, is a very rare species in Northern Europe: Finmark, Lapmark south to Jamtland, arctic Russia, eastern Asia from Amur-district south to Japan.

C. rariflora is circumpolar, and rare outside the arctic regions; it has, however, been found in Quebec, Maine (Mt. Katahdin), and in eastern Asia it extends as far south as northern Japan. Its near ally *C. stygia* is not rare in Alaska, and has recently been found in British Columbia (Queen Charlotte Island); in Europe it is known from a few stations in Finmark and arctic Russia. A very extensive distribution is shown by *C. Magellanica,* throughout the northern hemisphere, including the arctic coast of Finmark and Russia; as indicated by the name the species occurs also in the most southern part of South America.

Thus with the only exception of *C. littoralis* all the other species are known from the arctic coasts, and as stated above, *C. rariflora* is even circumpolar; it evidently originated in the polar regions. The remarkably scattered distribution of *C. stygia* with no intermediate stations between Alaska and arctic Scandinavia is an excellent example of homologous endemism, where the same species seems to have originated at two points, extremely remote, but, nevertheless, associated with several, closely related types; and these types are identical at both stations. *C. laxa* shows a similar disconnected distribution, being absent from northern Asia, except the northeastern corner, being also absent from this continent and Greenland; the occurrence of the species in Japan may indicate the possibility of its existence also on this continent; it closely resembles *C. limosa*, and may have been overlooked.

With reference to *C. limosa* and *C. Magellanica* these are undoubtedly of southern origin, having reached the arctic region during the glacial epoch. Regarding *C. littoralis* we have in this species a genuine American type of very local distribution, and developed singularly distinct from the other species, yet inseparable from these, to the best of our judgment.

By examining these types more closely, we shall see that the general habit and structure is very uniform; indeed the only characters of prominence, which appear as really important from a taxonomic point of view, depend upon the more dense-flowered spikes in *C. littoralis,* the sheathing bracts in *C. laxa,* and the gynaecandrous spikes in *C. Magellanica.*

C. littoralis Schweinitz (Figs. 4-7).

According to Schweinitz and Torrey[3] *Carex Barrattii* Schw. et Torr. is the plant named *C. littoralis* by Schweinitz in 1824 (ibidem). It is also the same species which by Carey[4] was referred to *C. flacca* Schreb. (*C. glauca* Scop).

A very complete diagnosis and figure is given by Boott,[5] from which the quotation as follows:

[3] A monograph of the North American species of *Carex* (Ann. of New York Lyceum of Nat. Hist., vol. 1, p. 361, 1825).

[4] Gray's Manual of Botany, 1857, p. 519.

[5] Ill. genus Carex, vol. 1, p. 69, tab. CLXXXIX.

"Spicis 4-5 rarius 3-6 cylindricis pedunculatis subapproximatis, mascula saepius 1 purpurea demum ferruginea elongata erecta vel 2, reliquis foemineis apice masculis pendulis vel nutantibus rarius erectis purpureis vel ferrugineis viridi pictis simplicibus vel inaequalibus geminatis; bracteis evaginatis, superioribus breve cuspidatis, infima angustissima spica breviori, vel rarius foliacea plus minus vaginata; stigm. 3; perigyniis ovalibus vel ovali-lanceolatis obtuse triquetris saepe oblique divergentibus erostratis obtusis vel abrupte vel sensim rostellatis, ore integro vel subemarginato, granulatis glabris leviter nervatis demum lutescentibus apice ferrugineis, squama ovata obtusa vel subacuta mutica fusco-purpurea vel ferruginea margine pallido nervo concolori longioribus."

The rhizome is very slender, stoloniferous; the phyllopodic culms measure a height of about 30-50 cm., and are longer than the very narrow, glaucous leaves. We found this interesting species in a cane-brake near Stony Run, Md., where it was associated with *C. stricta, folliculata* and *canescens;* it was quite abundant, and showed some variation with respect to the size of the perigynia, some specimens having the pistillate spikes heavier than others; the habit was the same, however.

It is interesting to notice, as stated by Boott (l. c.), that the pistillate spikes sometimes occur in pairs from the same leaf-axil: "vel simplices, vel una vel altera vel omnes geminatæ, rarius ternatae, quarum una abbreviata, sessilis."

C. limosa L.

The subterranean stem is ascending, relatively slender, rooting at the nodes; there is generally one or two long and thick brown roots at each node, beside some thinner ones, more amply ramified; the subterranean leaves are scale-like, and of a dark color. The length of the subterranean stem may average about 40 cm. There are two types of shoots: some, that develop a fascicle of long, green leaves surrounding the terminal bud, which develops into a floral stem during the next year; the other type of shoots develops mostly scale-like leaves, and one or two green ones, beside a flower-bearing stem. The latter type of shoots thus resembles the aphyllopodic, but differs from this by the culms being actually central instead of axillary. We may thus observe the same rhizome to bear purely vegetative shoots (the first season), vegetative shoots with a central inflorescence (the second season), and finally floral shoots with only a very few, one or two, green leaves, but with the base covered with several brown, scale-like.

Regarding the inflorescence there is only one staminate spike, and one or two lateral, pistillate; the subtending bracts are not sheathing. Some deviations have been observed, namely: the terminal spike may be androgynous or gynaecandrous; the terminal spike may be the only one developed, and is then purely staminate; the lateral spikes are sometimes androgynous. While the pistillate squamae are of a reddish-brown color in the typical plant, there is also a form in which the squamae are very pale, light-brown or yellowish. This pale form is mentioned by Anderson[6] as occurring in Scandinavia, and it has also been found in New York, near Frankfort, Herkimer County, by Dr. Joseph V. Haberer.

C. laxa Wahlenb. (Figs. 12-14).

In his Flora Lapponica (1812) Wahlenberg gives an excellent characterization of this species: "Spicis pendulis subdensifloris remotis, bracteis vaginantibus foliatis, capsulis oblongis obtusiusculis depressis squamas obtusas aequantibus." . . . "totum gramen flavescens est atque valde molle et laxum fere ut in *C. pallescente.* Culmus adeo tenuis et flaccidus ut fere decumbit." The rhizome is very slender; it is horizontal and stoloniferous; the very thin stolons bear small, scale-like leaves, shorter than the internodes, and they grow, close to the surface, in a horizontal direction. With regard to the root-system, the old rhizome bears many long, very thin roots. The floral shoot shows the typical phyllopodic structure, none being apparently aphyllopodic, as is the case of *C. limosa.*

According to Hartman[7] the terminal spike is sometimes gynaecandrous, and in specimens from Lapmark we notice also this spike to be androgynous; in other specimens there may be from one to three single, pistillate flowers in some distance below the terminal, staminate spike. The oblong-elliptic perigynia are faintly nerved, and a little longer than the oblong-ovate, obtuse or mucro-

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[6] Skandinaviens Cyperaceer. Stockholm, 1849, p. 87.

[7] Handbok i Skandinaviens Flora. Stockholm, 1879.

nate squamae. In *C. limosa* the pistillate scales are a little longer than the perigynia, and frequently cuspidate.

C. rariflora (Wahlenb.) Sm.

In this species the horizontally creeping rhizome is more robust, and prominently stoloniferous; several very long, thick, brownish roots proceed from the rhizome. From the same rhizome several vegetative and flower-bearing shoots may be developed, and the culms are typically phyllopodic. There is only one staminate spike, and from one to four pistillate, but two are the most frequent. The pistillate squamae are broadly ovate, obtuse to mucronate, almost black, enclosing the broadly ovate, faintly nerved perigynia.

Several forms have been described; according to Hartman (l. c.) the terminal spike is sometimes androgynous, and Norman[8] describes the forms as follows:

> "a. var *firmior:* Culmus robustior, elatior, usque ad 31 cm. v. ultra longus. Spicae femineae ovales v. oblongae, sat dense 10-17 florae, squamis saturatius rufofuscis (non piceis). Spica mascula dilute flavo-fusca."
>
> "b. forma *rufescens:* Squamae spicae femineae rufo-fuscae (non piceae)."
>
> "c. forma *expallida:* Spicae pallide flavo-fuscae, feminea solitaria."
>
> "d. forma *baeostachya:* Spicae femineae obovato-rotundatae, minimae vix 7 mm. superantes, 2-4 florae."

Finally Meinshausen[9] mentions a variety "*brevipedunculata,*" in which the three to four pistillate spikes are short-peduncled and contiguous.

C. stygia Fr. (Figs. 8-11).

In describing this species Fries[10] suggested that *C. rariflora* might represent a depauperate form; some years afterwards Fries enumerated both as distinct species,[11] and his diagnosis of *C. stygia* reads:

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[8] Norman, J. M. Florae arcticae Norvegiae species et formae nonnullae novae vel minus cognitae. (Christiania Vidensk. Selsk. Forhdlgr. for 1893. No. 16.)

[9] Die Cyperaceen der Flora Russlands. St. Petersbourg, 1901, p. 131.

[10] Novitiæ Floræ Suecicæ, Mantissa III. Upsala, 1842, p. 141.

[11] Summa vegetabilium Scandinaviæ. Upsala, 1846, p. 234.

"Spica mascula solitaria erecta, femineis tristigmaticis 2-3 oblongis compactis longe pedunculatis pendulis, bracteis brevissime vaginantibus subaphyllis, fructibus globoso-ovatis marginato-ancipitibus turgidis nervosis obtusis, rostello tereti apiculatis, squamis late ovatis convexis obtusis mucronatis obvolutis, culmo acutangulo, foliis linearibus planis." And under *C. rariflora* Fries states the reason why he keeps them separate: "Praecedentis quasi forma reducta, vix spithamam alta, nulli tamen adsunt transitus et facie mox distincta. Squamae in utraque conformes, piceae."

The species shows exactly the same habit as *C. rariflora,* but is remarkably robust, some culms from Queen Charlotte Islands measuring a height of 65 cm. The number of pistillate spikes is mostly two, in nineteen specimens out of twenty seven, all from Alaska and Queen Charlotte Islands. It is remarkably constant wherever it occurs, and the very local occurrence in contrast with its near ally *C. rariflora,* not speaking of the total absence of intermediate forms, seems to speak in favor of the opinion of Fries that it is a species distinct from *C. rariflora.*

C. Magellanica Lam.

That *C. paupercula* Michx., and *C. irrigua* Sm. are merely synonyms we have discussed in a previously published paper[12]; we have also called attention to the fact that the lateral spikes are gynaecandrous, as mentioned already by Schkuhr, Boott and nearly all other caricographers. The Scandinavian authors Anderson (l. c.), Hartman (l. c.), Blytt,[13] and Hjelt[14] do also point out that the terminal spike is not always purely staminate, but frequently gynaecandrous.

Besides by the distribution of the sexes the species differs from the others of this section by the more compact, almost caespitose growth; by the leaves being broader; the lowest bract reaching above the inflorescence; by the pistillate squamae being spreading at maturity, and lanceolate, with a long point. Moreover the perigynia are broadly oval, much shorter than the squamae, and faintly nerved.

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[12] Types of Canadian Carices. (Canad. Field. Nat., vol. 33, p. 75, 1919.)

[13] Norges Flora, Christiania, 1861.

[14] Conspectus Floræ Fennicæ. Helsingfors, 1895, p. 298. (Acta Soc. Fauna et Flora Fennica, vol. 5.)

A variety *pallens* has been described by Fernald, with scales green with pale brown or yellowish margins, and this has also been reported from Finland by Hjelt (l. c.); some specimens from Quebec, Ontario and Michigan belong also to this variety.

It is thus characteristic of *C. Magellanica* that all the spikes, at least the lateral, are gynaecandrous, and at the same time being tristigmatic the species must be considered as the most evolute of the grex: *Aeorastachyæ.*

Clinton, Md., August, 1921.

EXPLANATION OF FIGURES.

Fig. 1. Inflorescence of *Carex glaucescens* Ell. natural size.
Fig. 2. Pistillate scale of same; enlarged.
Fig. 3. Utriculus of same; enlarged.
Fig. 4. *Carex littoralis* Schw.; the inflorescence; natural size.
Fig. 5. Pistillate scale of same, taken from the lower part of the spike; enlarged.
Fig. 6. Pistillate scale of same, from the upper part of the spike; enlarged.
Fig. 7. Utriculus of same; enlarged.
Fig. 8. Inflorescence of *Carex stygia* Fr.; natural size.
Fig. 9. Staminate scale of same; enlarged.
Fig. 10. Pistillate scale of same; enlarged.
Fig. 11. Utriculus of same; enlarged.
Fig. 12. Inflorescence of *Carex laxa* Wahlenb.; natural size.
Fig. 13. Pistillate scale of same; enlarged.
Fig. 14. Utriculus of same; enlarged.

Art. XXV.—*Collophane, a Much Neglected Mineral;* by Austin F. Rogers.

Collophane, amorphous calcium carbonate-phosphate or carbonophosphate, must rank as one of the important minerals, for it is the main constituent of phosphorite or so-called phosphate rock, the production of which in the United States for 1920 amounted to a little over 4 million long tons, valued at about 25 million dollars. That it is also a common and widely distributed mineral results from the fact that fossil bones consist of collophane, as was announced by the writer[1] in 1917.

The principal constituent of phosphorite[2] is usually regarded as an impure massive variety of apatite, but those that so treat it fail to realize that a given mineral name connotes certain physical properties as well as a given chemical composition. Apatite is the name used for a hexagonal calcium fluophosphate mineral with a specific gravity of about 3.2 and indices of refraction of 1.63-1.65 or in a wider sense for a group of minerals including, in addition to the above, the corresponding: chlorophosphate (chlorapatite), carbonophosphate (dahllite), and oxyphosphate (voelckerite), all crystalline and with about the same physical properties.

Now the chief constituent of most of the phosphorites is amorphous and not crystalline. Both its specific gravity and index of refraction are too low for apatite. It always contains an appreciable amount of water which is lacking in apatite[3] and besides, its carbonate content is much higher than that of apatite. It is clear, then, that the name apatite, either as a species name or a group name, can not be used for the substance under consideration.

Some authors treat the amorphous calcium carbonophosphate in an appendix to apatite, and do not recognize it as a definite mineral. Dana, for example, in the sixth

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[1] Jour. Geol., 25, 531. A paper on the mineralogy of fossil bone is soon to appear in the Williston Memorial Volume.

[2] Hereafter the term phosphorite is used as a rock name instead of the more cumbersome term phosphate rock.

[3] As shown by the writer (Mineral. Mag., 27, 155, 1914), oxygen and not hydroxl replaces fluorine and chlorine in some specimens of the apatite group. To a mineral in which the compound $3Ca_3(PO_4)_2.CaO$ predominates, the name voelckerite is used.

edition of the System of Mineralogy,[4] says: "Besides the *definite mineral phosphates,* including normal apatite, phosphorite [used here as a variety of apatite and not as rock name], etc., there are also extensive deposits of amorphous phosphates, consisting largely of bone phosphate ($Ca_3P_2O_8$), of great economic importance, though not being a definite chemical composition and hence not strictly belonging to pure mineralogy. Here belong the phosphatic nodules, coprolites, bone beds, guano, etc."

Does the amorphous substance that makes up the bulk of the phosphorites deserve recognition as a distinctive mineral? A mineral may be defined as a naturally occurring, homogeneous, inorganic substance of definite or fairly definite chemical composition and with characteristic physical properties. Since the time that Dana's System of Mineralogy was written, it has come to be recognized that all minerals do not have a definite chemical composition and that some variability must be allowed. Among prominent examples may be mentioned pyrrhotite, chalcocite, tetrahedrite, and nephelite. The main constituent of phosphorite like all amorphous minerals is admittedly variable in composition but it is definite within certain limits as can be seen from the tabulated analyses on a later page. Its properties are so characteristic that it may be recognized by physical tests alone. The fact that the phosphorites grade into phosphatic limestones and shales is no argument against the recognition of collophane as a distinctive mineral, for opal grades into opal shale and psilomelane grades into indefinite manganese dioxides.

The amorphous equivalents of crystalline minerals, with the single exception of opal, have not been given recognition as distinctive minerals until Cornu's work in 1909. Recently the writer[5] has urged the adoption of Cornu's plan, though he believes that distinctive names should be used instead of some of the names proposed by Cornu. If such names as opal, psilomelane, limonite, and halloysite are used for amorphous substances of variable composition, then a distinctive name also should be used for the amorphous calcium carbonophosphate. It bears the same relation to crystalline dahllite ($3Ca_3P_2O_8.CaCO_3$) that opal does to chalcedony or quartz.

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[4] P. 769, 1892.

[5] Jour. Geol., 25, 515-541, 1917.

The name, Collophane.

In 1870 Sandberger gave the name *Kollophan* to an amorphous mineral containing calcium phosphate, calcium carbonate, and water from the island of Sombrero (West Indies). The calcium carbonate was believed to be an impurity and so was deducted from the analysis which on recalculation gave the formula, $Ca_3P_2O_8.H_2O$.

As Lacroix[7] first pointed out, the calcium carbonate is an integral part of the mineral. Specimens free from admixed calcite effervesce vigorously when treated with hot nitric acid. On calculation the Sombrero mineral yields the formula $3Ca_3(P_2O_8).CaCO_33H_2O$, but it is simply a coincidence that the amount of water is 3 molecules. Analyses of specimens from other localities prove that the water is variable. The ratio of calcium phosphate to calcium carbonate is also variable and some specimens contain fluorine and the sulphate radical.

Dana changed Sandberger's name *Kollophan* to *collophanite*. The writer prefers *collophane*, which is simpler and more euphonious. As Cole[8] has well said: " . . . the terminology of minerals formerly possessed, for the founders of the science, as agreeable a variety as that of other branches of natural history. There seems no need to make technical language harsh by the undue repetition of sounds that have no historic warrant."

Synonyms of Collophane.

Kollophan, Sandberger, 1870.
Apatite (in part). Most authors.
Collophanite, Dana, 1892.
Colophanite, Lacroix, 1910.
Fluocolophanite, Lacroix, 1910.
Collophane, Rogers, 1917.
Pyroclasite, Shepard, 1856.
Pyroguanite, Shepard, 1856.
Glaubapatite, Shepard, 1856.
Sombrerite, Phipson, 1862.
Monite, Shepard, 1882.
Floridite, Cox, 1890.
Quercyite, Lacroix, 1910.
Odontolite (Bone turquois)
Nauruite, Elschner, 1913.

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[6] Neues Jahrb. Min., 308, 1870.
[7] Comptes Rendu, 150, 1213, 1910.
[8] Outlines of Mineralogy for Geological Students, p. 169, London, 1913.

It is reasonably certain that all of the above listed minerals are one and the same. Some of the names have priority over collophane (Kollophan), but one of the limitations of the law of priority set forth by Dana[9] is that a name may properly be set aside when it "has been lost sight of and has found no one to assert its claim for a period of more than fifty years. . . ." Collophane, or rather its equivalent, collophanite, on the other hand, has been given prominence by Lacroix in his excellent treatise[10] on the minerals of France.

Pyroclasite and pyrogaunite are simply varieties of hard guano. As they contain about 80 per cent of tricalcium phosphate, they are doubtless collophane. In a later paper Shepard says that glaubapatite is the same as pyroclasite.

Monite is an earthy variety of collophane. Shepard's analysis does not show any carbon dioxide but specimens free from admixed calcite examined by the writer show decided effervescence in nitric acid. The sulphur trioxide, which was deducted by Shepard, is probably an integral part of the mineral, for specimens free from admixed gypsum give a good microchemical gypsum test. The collophane from other localities sometimes contains the sulphate radical and so does apatite also for that matter.

Sombrerite is from the type locality for collophane, but it is a phosphatic replacement of coral, while the original collophane is an opal-like substance not due to direct replacement. A specimen of sombrerite in which coral structure is evident has been examined by the writer. It agrees in all essential respects with collophane. For example, it is soluble with effervescence in nitric acid, but is entirely free from calcite.

Quercyite is undoubtedly a variety of collophane and not a mixture of collophane with a crystalline substance. A specimen in my possession agrees exactly with Lacroix's[11] description and figures, but the apparently crystalline layers, though doubly refracting, are really amorphous. The analyses of quercyite together with the microscopic examination prove its identity with collophane.

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[9] System of Mineralogy, 6th edition, p. xliii, 1892.
[10] Mineralogie de la France et de ses Colonies, vol. 4, pp. 561-586, 1910.
[11] Mineralogie de la France, pp. 579-581, figs. 1-2, 1910.

Odontolite, also known as bone turquois or occidental turquois, is an aluminous variety of collophane, according to Lacroix.[12]

The nauruite of Elschner[13] is typical collophane. The formula $3CaP_3O_8.Ca(OH,F)_2$ is assigned to it, but specimens presented to Stanford University by Dr. Elschner contain about five per cent carbon dioxide and are entirely free from calcite, aragonite, or dolomite. This beautiful brown, banded, resinous mineral from the island of Nauru is the best and most typical form of collophane that it has been my privilege to see.

The Chemical Composition of Collophane.

There are very few complete analyses of phosphorites on record; most of the analyses are evidently commercial ones in which insufficient care was made in selecting the material. The writer has with some difficulty succeeded in collecting five fairly complete analyses of collophane, which were probably almost free from mechanical impurities.

Analyses of Collophane.

	CaO	MgO	Fe_2O_3, Al_2O_3	P_2O_5	CO_2	F_2	SO_4	H_2O	Insol.	Total
1.	50.70	0.80		39.10	3.96			5.02		99.58
2.	52.47	0.21	0.53	38.72	1.88	1.60	0.22	5.00		99.65
3.	49.73		0.50	37.40	3.75	0.88		7.05		99.24
4.	51.85			37.60	4.00	1.50		4.80		99.12
5.	50.97	0.22	0.76	36.35	1.72	0.40	2.98	1.05	1.82	99.04*

1, Sombrero. 2, Nauru. 3, Pouzillac, France. 4, Mouillac, France. 5, Crawford Mts., Utah.

*Includes 2.00 Na_2O, 0.47 K_2O and 0.30 SiO_2.

Ratios from Collophane Analyses.

	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	CO_2	F_2	SO_4	H_2O
1.	904	25	—	—	275	90	—	—	278
2.	936	5	—	—	272	43	84	3	278
3.	886	—	2	3	263	85	46	—	392
4.	924	—	2	3	264	91	39	—	266
5.	908	5	2	6	256	39	21	37	58;

$Na_2O = 32$; $K_2O = 5$.

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[12] Mineralogie de la France, p. 577, 1910.

[13] Corallogene Phosphat-Insel Austral Oceanien und Ihre Produkte, Lübeck, 1913.

On combining these, they yield the following:†

1. $3\ Ca_3(PO_4)_2 \cdot 0.98\ CaCO_3 \cdot 0.01\ CaO \cdot 3.02\ H_2O.$
2. $3\ Ca_3(PO_4)_2 \cdot 0.47\ CaCO_3 \cdot 0.46\ CaF_2 \cdot 0.03\ CaSO_4 \cdot 0.37\ CaO \cdot 3.05\ H_2O.$
3. $3\ Ca_3(PO_4)_2 \cdot 0.97\ CaCO_3 \cdot 0.26\ CaF_2 \cdot 4.45\ H_2O.$
4. $3\ Ca_3(PO_4)_2 \cdot 1.03\ CaCO_3 \cdot 0.21\ CaF_2 \cdot 0.25\ CaO \cdot 3.02\ H_3O.$
5. $3\ Ca_3(PO_4)_2 \cdot 0.46\ CaCO_3 \cdot 0.13\ CaF_2 \cdot 0.45\ CaSO_4 \cdot 0.94\ CaO \cdot 0.68\ H_2O$

The above may be written in another form:

1. $3\ Ca_3(PO_4)_2 \cdot 0.99\ Ca(CO_3) \cdot 3.02\ H_2O.$
2. $3\ Ca_3(PO_4)_3 \cdot 1.33\ Ca(CO_3,F_2,SO_4) \cdot 3.05\ H_2O.$
3. $3\ Ca_3(PO_4)_2 \cdot 1.23\ Ca(CO_3,F_2) \cdot 4.45\ H_2O.$
4. $3\ Ca_3(PO_4)_2 \cdot 1.29\ Ca(CO_3,F_2,O) \cdot 3.02\ H_2O.$
5. $3\ Ca_3(PO_4)_2 \cdot 1.98\ Ca(CO_3,F_2,SO_4,O) \cdot 0.68\ H_2O.$

The ratios vary from $3\ Ca_3(PO_4)_2.CaX$ to $3\ Ca_3(PO_4)_2.2\ CaX$.

That these formulae represent the chemical composition is confirmed by three analyses of collophane of fossil bone with only 0.1 to 0.2 per cent of impurities recently made by K. S. Boynton under the writer's direction. On calculation the following formulae are obtained:

$$3\ Ca_3(PO_4)_2\ .0.99\ Ca(CO_3,SO_4,O).\ 3.03H_2O$$
$$3\ Ca_3(PO_4)_2\ .1.48\ Ca(CO_3,F_2).\ 2.18H_2O$$
$$3\ Ca_3(PO_4)_2\ .1.78\ Ca(CO_3,F_2).\ 1.88H_2O$$

It seems clear that we have here a case of solid solutions of calcium carbonate, etc. in tricalcium phosphate. In one of these analyses (No. 5) calcium oxide predominates over calcium carbonate, and Artini[16] has described a "fluocollophanite" from Palestine which is near fluorapatite in composition. The sulphate radical is present in some specimens of collophane and it is probable that a crystalline mineral with the formula $3\ Ca_3(PO_4)_2.CaSO_4$ will be found some time. Such names as fluocollophane are not advisable. The fine distinctions made with crystalline minerals, for example, voelckerite, dahllite, etc., are hardly warranted in the case of amorphous minerals. So, then, collophane may be used for the amorphous equivalent of any member of the apatite group, in which the compound $3\ Ca_3(PO_4)_2$ predominates.

The Sombrero collophane is almost exactly $3\ Ca_3(PO_4)_2.CaCO_3$ and several of the others approach $3\ Ca_3(PO_4)_2.Ca$

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†In computing these ratios magnesium, iron, aluminum, sodium, and potassium have been combined with calcium.

[16] Abstract in Zeit. f. Kryst. u. Min. lv, 320, 1915.

(CO_3,F_2,SO_4,O). Dahllite, which is crystalline, has the formula $3\,Ca_3(PO_4)_2.CaCO_3$. The fact that most amorphous minerals approach in chemical composition their crystalline equivalents was brought out by Cornu.[17] This principle he called the law of ''homoisochemite'', and the minerals themselves, ''pseudostochiolite.''

The water evidently is also variable. Water is variable in all amorphous minerals, on account of their colloidal origin. When the colloid is first formed the water may be absorbed but during the hardening of the gel the water probably becomes diffused through the dispersed material and thus in time a solid solution is formed.

Collophane, then, may be regarded as a solid solution of calcium carbonate, calcium fluoride, calcium sulphate, and water in tricalcium phosphate.

Physical Properties of Collophane.

Collophane is usually massive, but sometimes has an oölitic or concretionary structure. As is the case with other amorphous minerals, colloform[18] crusts may be present in cavities.

The specific gravity of collophane varies from 2.6 to 2.9; the variation is due to variation in porosity as well as to difference in chemical composition.

The hardness varies from 3 to 5. The index of refraction varies about 1.57 to 1.63, but is usually 1.59 to 1.61. The determination of the index of refraction is one of the best means of identifying the mineral, for, with the exception of the very rare silicate, eudialyte, it is practically the only amorphous or weakly doubly-refracting mineral within these limits for its index of refraction. Like other amorphous minerals of colloidal origin collophane often shows double refraction due to strains set up in the hardening of the gel. In colloform and oölitic forms, the double refraction causes the mineral to take a spherulitic appearance. These pseudo-spherulites, however, lack the fibrous structure of true spherulites.

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[17] Zeit. f. Chem. u. Ind. d. Kolloide, 4, 15, 89, 1909.

[18] This term was coined by the writer to designate the rounded, more or less spherical surfaces assumed by amorphous and microcrystalline substances in open spaces. It is a general term to cover mammillary, botryoidal, etc.

Pyrognostic and Chemical Tests.

Before the blowpipe, collophane fuses with difficulty on the edges, glows, and turns white. In the closed tube it turns dark (on account of organic matter) and gives a fair amount of water.

It is soluble in cold nitric acid with fair effervescence and in hot acid there is vigorous effervescence.

Summary.

The principal constituent of phosphorites or so-called phosphate rocks and also of fossil bones is an amorphous substance with properties sufficiently characteristic to be entitled to recognition as a distinct mineral. It may be called *collophane.*

Collophane consists largely of tricalcium phosphate ($Ca_3P_2O_8$) with smaller amounts of calcium carbonate, calcium fluoride, calcium sulphate, and calcium oxide. It may be regarded as a solid solution of the latter-named substances in tricalcium phosphate. Like most other amorphous minerals it is of colloidal origin and contains an indefinite amount of water. The formula of collophane may be written $3Ca_3(PO_4)_2.n\,Ca(CO_3,F_2,SO_4,O).(H_2O)_x$, where n is an indefinite number varying from 1 to 2. The carbonate radical usually predominates over the other minor constituents and thus it often approaches crystalline dahllite ($3Ca_3P_2O_8.CaCO_3$) in composition.

Sp. Gr. $=2.6$–2.9; H $=3$ to 5; $n=1.57$ to 1.63, often with weak double refraction.

Collophane is soluble in nitric acid with effervescence.

Stanford University, September, 1921.

ART. XXVI.—*A New Genus of Oligocene Hyænodontidæ*;

by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTION.

All of the North American species of hyænodonts are of Middle Oligocene age. This group embraces diverse forms, one of which it is now proposed to place in a new genus, herein designated as *Neohyænodon*. The Yale specimen, Cat. No. 12766 (see figs. 1 and 2), and Leidy's "*Hyænodon horridus*," figured in 1869 (pl. III), are selected as cotypes.

Three skull forms are represented among the American Hyænodontidæ: (1) the strongly dolichocephalic form, which is typical of *Hyænodon*, found in species seldom exceeding the wolf in size; (2) the mesaticephalic form, typified in the New World by *H. paucidens;* and (3) the large dolichocephalic type with a great range of vertical jaw movement and a considerable development of the canines, with skull modifications, similar in many respects to those of the sabre-tooth cat *Smilodon*. This third group is the one now termed *Neohyænodon* by the author. The first group might well be subdivided, separating out the species with the extreme posterior opening of the choanæ, the group that is represented by *H. leptocephalus*.

The smallest species of *Hyænodon* now known, *H. mustelinus*, is apparently not represented in the Yale Collection. The short-faced group, of which *H. paucidens* is the only American example, is by no means plentiful in this Museum, whereas there are many individuals of the long and slender-jawed type, representing all but the smallest species. *H. minutus* Douglass is omitted from the synoptic table, for the type consists of only a right M_2 and the taxonomic position of the species is uncertain. Matthew has referred it to *Pseudopterodon,* and yet Scott believes that this genus was established on the milk dentition of *Hyænodon.* This M_2 probably belongs to a creodont, but its reference to *Hyænodon* seems to me to be doubtful.

DESCRIPTION OF SPECIES.

Neohyænodon, gen. nov.

Distinguishing Characters.—Larger than *Hyænodon,* dolichocephalic, glenoids far below basicranial plane, basicranial region foreshortened, dentition similar to *Hyænodon,* except for the antero-external buttress on the paraconid of M_3.

Neohyænodon horridus (Leidy) 1853.

(FIGS. 1, 2.)

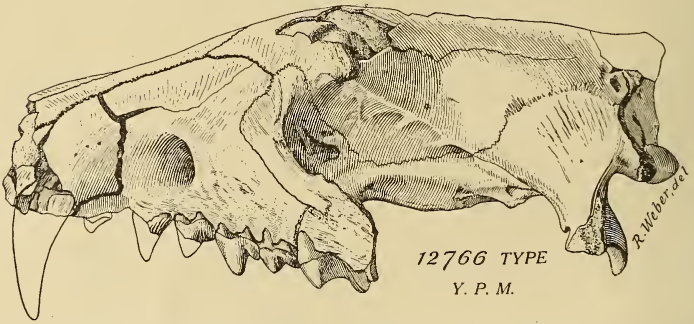

FIG. 1.—*Neohyænodon horridus* (Leidy). Left lateral view of skull. × about 1/3.

Two very excellently preserved skulls with jaws represent this genus and species in the Marsh Collection. Cat. No. 12766 has been selected as a cotype of the genus. It was collected in South Dakota, and, while fully mature, yet its sutures are clearly shown in detail. The other specimen, Cat. No. 10074, collected near Red Cloud, Nebraska, is an old individual and is unique in that it is the largest complete skull of this species so far reported.

The total skull length is 345 mm., and the length from the prosthion to the occipital condyles inclusive is 318 mm. The bone is very heavy and massive, and in places quite rugose, as, for example, on the postorbital processes of the frontals.

The condition of wear of the teeth is noteworthy in that it shows such marked differential abrasion. One of the most interesting conditions is shown by the left P^4 which now consists of but three rounded stumps, the entire crown having been worn away, while the left M^1, although considerably worn, yet descends at least 15 mm. below the surface of P^4. On the same side, the P^3 shows about twice as much wear on the anterior half, or it is worn so that the crown has a decidedly oblique surface sloping forward and upward. Both P^3 are placed obliquely in the maxillary, with the anterior part inward. All of the superior teeth are crowded, except both P^1, which are isolated, the minimum diastema being posterior, with a diameter of 4 mm.

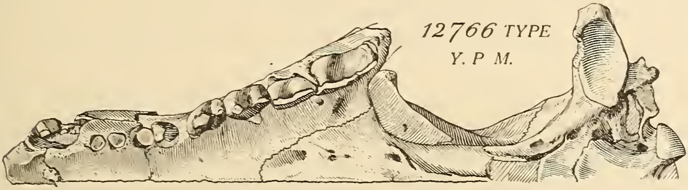

FIG. 2.—*Neohyænodon horridus* (Leidy). Left half, palatal view. × about 1/3.

All of the inferior teeth are crowded, except P_1. The third lower molar has a very effective shearing surface, although the crown is considerably shortened vertically by wear, so that all trace of the fore and aft divisions is obliterated and the remaining surface is one long, nearly level blade. The second lower molar is low and rounded, with no trace of a shearing surface, while M_1 consists of two rounded stumps nearly level with the alveolar parapet. The contrast is quite striking between this stump of M_1 and the almost unworn contiguous right P_4, extending upward 21 mm. higher than M_1. The length of the symphysial suture is 116 mm. This great length is a compensatory mechanical device for overcoming the slenderness of the rami. The posterior position of I_2 is typical of the creodont carnivorous type. It is quite probable that this skull and jaws belonged to a male.

Measurements of Dentition.

(Cat. No. 10074, Y. P. M.)

	mm.
Superior molar-premolar series, length	137
Superior molar series, length	50.5
Inferior molar-premolar series, length	141
Inferior molar series, length	66

A single right M_3, in part of the jaw No. 12765, Y. P. M., from White River, Nebraska, indicates an individual approximately as large as the one described last above. It measures 35 mm. fore and aft, with a maximum transverse diameter of 13.5 mm.

The cotype, No. 12766, Y. P. M., shows very clearly the cranial foramina. The auditory bullæ are lacking and I am not sure whether or not any were ever present. If this genus did have them, they were circular in basal outline, with a diameter of approximately 18.5 mm. The maxillo-palatine suture is obtuse at its anterior margin, which lies opposite the middle of P^4; the postorbital constriction is at the coronal suture; the posterior nasal bones are acute, extending nearly to a line through the middle of the orbits; the lacrymal is relatively small, extending somewhat in front of and below the orbit, and bears a slight depression, which appears greater than it actually is due to the elevation of the orbital margin on which is a prominent lacrymal tubercle; the infra-orbital is quite large; and the hamular process is represented by a distinct rugosity, approaching very close to a tubercle in character.

Comparison with Hyænodon.—Neohyænodon differs from *Hyænodon* in several distinct ways, among others in the development of an external buttress-like ridge on the paraconid of the last lower molar, but the most important difference lies in the structure of the basicranial and contiguous regions. The superior part of the glenoid articular surface is more than 15 mm. below the basioccipital, and in part lies below the bulla, while the postglenoid tubercles are on a line only 14 mm. anterior to the basion.

In other words, the basicranial area is foreshortened and the glenoid surfaces are far below the basioccipital. In *Hyænodon,* these articular surfaces are practically in a plane with the basisphenoid, that is, they are much higher and more anterior, and the relations are much more typically mammalian and carnivoroid than in *Neohyænodon.*

Comparison with Smilodon.—This new genus exhibits many details of structure like those in *Smilodon,* but at present we shall consider only similarities and differences which are due to the mechanics of the jaw movements. For comparison I have used a fully adult skull, Cat. No. 10204, Y. P. M., of *Smilodon californicus* Bovard, from the Rancho La Brea, California. The glenoid articulations lie much below the level of the basicranial plane, and the zygomatic arches are short and relatively weak in both *Neohyænodon* and *Smilodon.* The lowering of the glenoid permits a wide gape of the jaws before the projection of the angle impinges upon the posterior surface of the postglenoid tubercle. This tubercle in both genera has the same form below the glenoid surface, i. e., it is moderately long internally, and its inferior margin slopes upward externally to the level of the articular surface. Moreover, there is no inflection to the mandibular angle in *Neohyænodon,* and it does not turn outward to the same extent as in *Smilodon,* but the former genus did not need to open the jaws so widely as did the latter.

The coronoid process is rather small and not high, a feature which is correlated with the other changes tending to allow the required great gape. The temporalis muscle, attached to the coronoid, and originating on the occipital and sagittal crests and on the parietal and squamosal bones, was of great length and therefore probably of small leverage, but compensation for this is in part accomplished by the posterior position of the cutting teeth. The masseteric fossa is moderately large and rather shallow, while the zygomatic arch is short and weak, from which it would seem that the masseter muscle had similar power and functions both in the creodonts and in the true Carnivora. The pterygoid muscles, acting mainly with the masseter, originated slightly more anteriorly than in *Smilodon.* Of the three sets of muscles, temporalis, masseter, and internal pterygoid, each alone was relatively weak in the power of closing the jaw, but the three acting in unison were powerful. They are all situate near the glenoid, and afford a great arc with comparatively small muscular contraction and expansion, except in the case of the temporalis.

The paroccipital process lies considerably posterior to the glenoid, and furnishes the digastric muscle with an origin well adapted for wide jaw gape. The mastoid in *Neohyænodon* is very small and located on a line with the anterior part of the occipital condyles. In contrast to *Smilodon,* its small size must indicate a rather weak development of the cleido-mastoid and sterno-mastoid muscles, the chief function of which is to pull the head downward upon the neck.

Comparison with Dinoceras.—Although *Neohyænodon* and *Smilodon* are of widely separated geologic horizons and of different orders, yet they were both carnivorous in habit and had developed skull characters of great similarity. Now let us examine a representative of another group, totally distinct in genetic relationships and habits from either of the above, namely, *Dinoceras,* several skulls of which in the Marsh Collection have served for comparison. This genus possessed long superior canines and was therefore compelled to have a wide jaw gape. In this form the peculiar glenoid articulation is shown, although it has not descended below the basicranial plane. The temporalis muscle was long and of small leverage, while the zygomatic arch is apparently relatively smaller than normal in herbivorous animals. The condyle of the ramus shows a peculiar modification, as well as the outward curvature of the whole ramus just in advance of the condyle, to permit of a wide gape. An interesting development of the ramus is the hoplophoneoid character shown in the long decurved processes for the protection of the superior canines when the mouth is closed. *Protoceras* is analogous to *Dinoceras* in these jaw mechanics.

The primal cause for the necessity of a wide jaw gape is great canine length. *Smilodon* and *Dinoceras* possessed very short inferior canines relative to the great length of the superior, whereas the upper and lower canines of *Neohyænodon* were of more nearly equal length. In *Dinoceras mirabile* the combined length of the upper and lower canines is 195.5 mm., the superior being

176 mm. long; in *Smilodon californicus* the total length is 174 mm., with the superior canine 154 mm., while the total length in *Neohyænodon horridus* is 100 mm., about equally divided between superior and inferior canine. Another point of comparison is in the mesaticephaly of *Smilodon* as compared with the dolichocephaly of *Dinoceras* and *Neohyænodon.* Still another point to consider is that the condyle of the ramus is situated a little below the superior edge of the alveolar parapet in *Smilodon* and in *Neohyænodon,* but on a line with the tooth-row in *Dinoceras.*

In short, we see in these genera how a certain specific end-result—the accomplishment of great jaw gape—was attained by three different modes of skull and jaw mechanical modifications. In the three genera there are similar modifications, but the divergences are equally well marked. In *Neohyænodon* the basicranial area is foreshortened, the glenoids are lowered and the mandibular condyle is but slightly above the angle. In *Smilodon* the basicranial region is not foreshortened, but the cranium elevated, the glenoids lowered, relative to the basicranial plane but not to the palatal, while the mandibular condyle is likewise low. *Smilodon* evidently was the only one of these genera under consideration that struck downward, hence the form of the skull. In *Dinoceras* the basicranial region is somewhat foreshortened, to a lesser extent than in *Neohyænodon,* while the glenoid has not lowered, but the mandibular condyle has become elevated with respect to the tooth-row.

Hyænodon Laizer and Parieu 1839.

Hyænodon cruentus Leidy 1853.

A skull and anterior part of both rami (Cat. No. 12762, Y. P. M.) of this species were collected near Red Cloud, Nebraska. It is a young individual, with the permanent canines just beginning to appear. The lower incisors show that the first was not more than half the size of the second, which was nearly as large as the third. The two second incisors have their usual position posterior to the line of the others and are separated from each other by a diastema of only 1.5 mm.

Another specimen, Cat. No. 12764, Y. P. M., from Chadron, Nebraska, has but slightly worn dentition and the lower third molar shows a very small incipient external buttress on the anterior lobe, but it is not of the same character as in *N. horridus*.

Hyænodon montanus Douglass 1901.

Both jaws of two individuals are referable to this species. One pair of rami, Cat. No. 12767, Y. P. M., was collected at White River, Nebraska, and the other pair, Cat. No. 12768, Y. P. M., in Gerry's canyon, Gerry's ranch, Colorado. The latter has nearly all the teeth present, and shows the characters mentioned by Douglass as differentiating this species. The second incisor is as large as the third. Its anterior part is wedged between the posterior parts of I_1 and I_3, that is, it is not situated so far posteriorly as in *N. horridus* and *H. cruentus.* The premolars especially, and the molars to a less extent, are relatively higher crowned than in the other species of this genus.

Hyænodon crucians Leidy 1853.

Part of a left ramus with P_4, M_1, and M_3, Cat. No. 12770, Y. P. M., collected at Gerry's ranch, Colorado, is referable to this genus.

Specimen No. 10076 Y. P. M., collected near Hermosa, South Dakota, consists of a skull, jaws, many vertebræ, and many parts of the appendicular skeleton. These bones do not show any marked deviations from the description, given by Scott in 1894, of the osteology of this genus.

Hyænodon leptocephalus Scott 1887.

A well preserved skull with jaws, together with an atlas and one lateral metatarsal, Cat. No. 10075, Y. P. M., are referred to this species, as the skull exhibits the long narrow cranium and the sutural union between the pterygoid processes of the alisphenoid bone. Measurements of the type of this species are lacking, and for these we must derive our information from the statement that "in size it slightly exceeds the *H. crucians* of Leidy" (Scott 1887, p. 152).

Nearly all sutures in the Yale specimen are plainly visible, including the diagnostic character of the union of the pterygoids *posterior* to the suture joining the alisphenoid with the palatine bones. The hamular process is represented by a prominent rugosity. The lacrymal bone is more triangular in outline and relatively of somewhat smaller extent than in *N. horridus.* The external wall of the infra-orbital foramen bears a forward-projecting lip which is not present in any other species, so far as I am aware, and certainly not in any examples of them which I have seen. The postorbital processes of the frontals, and the temporal ridges nearly to their junction, are very rugose. The anterior orbital margin is but very slightly elevated above the general surface of the lacrymal bone. The posterior part of the nasal bones is more obtuse than in *N. horridus.* A peculiar character of these nasals in this specimen lies in the peninsula of these bones extending into the frontals near the maxillary suture, so that a traverse on either side just posterior to the divergence of the nasal and maxillary bones would pass in succession toward the sagittal plane through maxillary, frontal, nasal, frontal, and nasal bones. This may be an individual variation, but if so, it is an interesting one.

Measurements.

(Cat. No. 10075, Y. P. M.)

	mm.
Axial length, ant. of canine to post. of glenoid process....	151.5
Width of skull at post. of M^2	87
Superior molar-premolar series, length.................	74
Superior premolar series, length	49
Maximum length of ramus	153.5
Inferior molar-premolar series, length	82
Inferior premolar series, length	51

SYNOPTIC TABLE.

Neohyænodon.

Glenoid articular surface far below basicranial plane; superior premolars four; dolichocephalic; size very large; antero-external buttress on paraconid of M_3.

Length of superior molar-premolar series 127-137 mm.
N. horridus

Hyænodon.

Glenoid articular surface on level with basicranial plane. No external buttress on M_3.

- A. Superior premolars three. Face short.
  - 1. Length of superior molar-premolar series 62 mm. *H. paucidens*
- B. Superior premolars four. Dolichocephalic.
  - 1. Palatines in contact throughout; pterygoid processes suturally joined. Length of superior molar-premolar series 74 mm. . *H. leptocephalus*
  - 2. Posterior nares opening between palatines.
    - a. Postorbital constriction in advance of coronal suture.
      - (1) Length of superior molar-premolar series 72 mm. . . . . . . *H. crucians*
    - b. Postorbital constriction at or behind coronal suture.
      - (1) Size large. Length of superior molar-premolar series 106 mm. *H. cruentus*
      - (2) Size moderate. Complete skull unknown. Length of superior molar-premolar series 83 mm. *H. montanus*
      - (3) Size small. Length of superior molar-premolar series 58 mm. *H. mustelinus*

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Art. XXVII.—*The Status of Homogalax, with Two New Species;* by Edward L. Troxell.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

Homogalax Hay constitutes a genus of odd-toed animals whose relationship to the early horses is both near and confusing. The older genus *Systemodon* Cope has been broken up, part going to form this newer genus, and part, including the genoholotype, being put under *Hyracotherium* Owen, one of the earliest of the Equidæ.

In 1875,[1] Cope made the species *Orohippus tapirinus,* which in 1877[2] he referred to *Hyracotherium;* in 1881[3] he made the distinct genus *Systemodon* for it, because he concluded from a study of additional material that the species showed the lack of a diastema, a new feature.

It is necessary to disregard Cope's later descriptions and figured specimens in attempting to determine what *Systemodon* and its type, *S. tapirinus,* really are, and the fragmentary character and limited amount of the holotype make accurate comparison impossible. Strangely enough, neither the original type nor any of the later referred specimens exhibit the feature on which the genus was supposed to be based.

In 1896[4] Wortman placed the species *S. tapirinus* again under *Hyracotherium,* which he considered a synonym of *Eohippus* Marsh. Hay therefore in 1899[5] proposed the name *Homogalax,* type "*S.*" *primævus* Wortman, and intended to have it include the species *S. semihians* Cope. There is ample justification for the erection of this new genus because of the imperfection of the holotype of *S. tapirinus* and because of fundamental differences, especially in the form of M_3 as judged from other material; but on account of the presence of diastemata, the small heel on M_3, and for other reasons, "*S.*" *semihians* can not be included in *Homogalax* Hay. It appears, moreover, that this species belongs to no known genus.

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[1] E. D. Cope, Systematic catalogue of Vertebrata of the Eocene of New Mexico. U. S. Geog. Surv. W. 100th Merid., p. 20.

[2] E. D. Cope, U. S. Geog. Surv. W. 100th Merid., 4, Palæontology, p. 263, pl. 66, figs. 12-16.

[3] E. D. Cope, Amer. Nat., 15, 1018.

[4] J. L. Wortman, Bull. Amer. Mus. Nat. Hist., vol. 8, 94-95, 1896.

[5] O. P. Hay, Science, new ser., 9, 593, 1899.

Cope's referred specimen, "*S. tapirinus*"[6] may belong to *Homogalax* cf. *H. primævus.* It is, in my opinion, not of *Systemodon.* Likewise the specimen referred to *H. tapirinus* by Wortman is clearly not of that species.

There is no doubt a close relationship between all these genera, including *Hyracotherium* and the early horses. *Homogalax* is separated from these allies by the total absence of a diastema, the lack of distinct tubercles on the cross lophs of the molars, and the general peculiar shape of the molars themselves.

Homogalax primævus (Wortman) is the genoholotype, from the Wasatch beds. The two new species made in the pages following are from the Bridger and Uinta, thus the three forms represent the lower, middle and upper Eocene respectively.

Homogalax bridgeresis, sp. nov.

Holotype, Cat. No. 12563, Y. P. M. Eocene (Bridger), Twin Buttes, Wyoming.

(Figs. 1-2.)

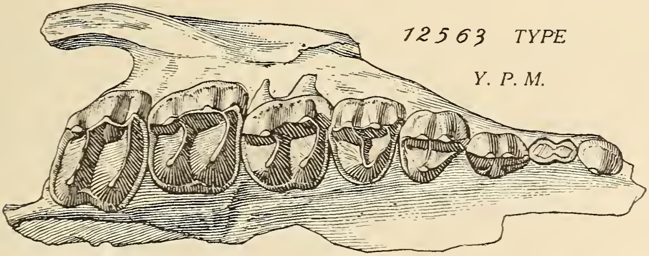

Fig. 1.—*Homogalax bridgerensis,* sp. nov. Holotype. Right maxillary with molars, premolars, and canine. Note especially the absence of a diastema, the oblong M^3, subquadrate $M^{1.2}$, and the narrower inner side of P^3. Nat. size.

This interesting type came to the Peabody Museum in separate shipments in 1874. It bears two distinct labels and was thought to be two individuals. Now it is found that the mandibular rami, accession No. 610, fit the maxillaries, No. 655, and furthermore, a small fragment of one of the latter was actually associated with the rami.

This new species is nearest *H. primævus* (Wortman), but differs from it in the narrower first upper molar, in

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[6] E. D. Cope, Rept. U. S. Geol. Surv. Terr., pp. 618-624, pl. 56, fig. 1, 1884.

the presence of a distinct metaloph on P^3 and the triangular form of this tooth, in the inner cusps of P^2, in the small upper canine, and in the presence of strong cingula on the outer side of the upper molars.

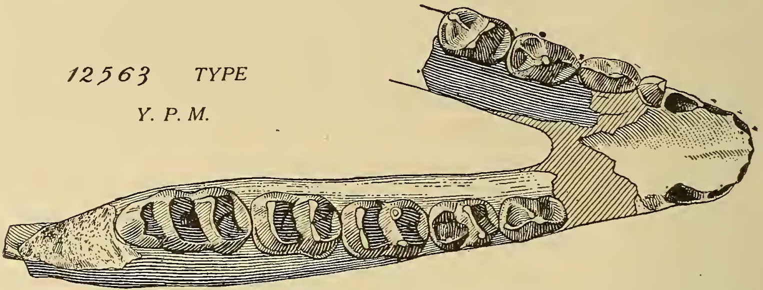

FIG. 2.—*Homogalax bridgerensis,* sp. nov. Holotype. Part of the lower jaws. Note the alveoli of the canines and incisors, and the close crowding of the teeth. Nat. size.

Both the upper and lower series of teeth, except the upper incisors which we do not know, are continuous throughout. We judge the lower canines and incisors from their alveoli. In the lower series the first and second premolars each consist of the simple protocone with ridges running to it. On P_3 there is a double central cone, the true protoconid with the deuteroconid isolated from it. The fourth premolar still has the single ridge on its broad posterior heel, but the two anterior cones have separated to form a transverse crest as in the molars.

The first and second molars have the two ordinary cross crests with the exterior extensions forward as in tapirs and rhinoceroses generally. On M_2 there is a strong antero-exterior cingulum. The teeth gradually increase in size and in the separation of the cross ridges back to the third molar.

The prominent heel of the third molar amounts almost to a cross ridge in the arrangement of its two cusps. This double cusp is distinctive of *Homogalax,* as contrasted with the single one of the original *Systemodon.*

So little remains of the skull of this rare specimen that it offers few criteria for its interpretation. The orbit lies over the molars, extending to a point above the first. Unlike that of *Helaletes,* the antorbital foramen is situated forward, over the third premolar, and there is other evidence that no facial vacuity existed as in that genus.

Homogalax uintensis, sp. nov.

Holotype, Cat. No. 12561, Y. P. M. Eocene (Uinta), mouth of the White River, Utah.

(Figs. 3-4.)

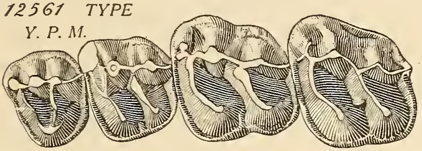

Fig. 3.—*Homogalax uintensis,* sp. nov. Holotype. Upper molars and fourth premolar of an Upper Eocene tapiroid. Nat. size.

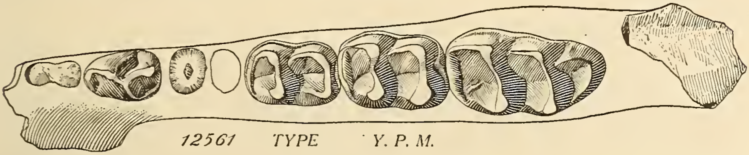

Fig. 4.—*Homogalax uintensis,* sp. nov. Holotype. Lower dentition and part of right ramus. Nat. size.

Another specimen in the Peabody Museum demands consideration, for it not only represents a new species of *Homogalax* Hay, but occurs in a totally different geological horizon from that of *H. bridgerensis* described above.

H. uintensis, as compared to *H. bridgerensis,* is much larger. The third upper molar is not so perfect a parallelogram in form, although it too is greatly elongated along the diagonal through the paracone and hypocone. The antero-posterior diameter is large compared to that of *H. bridgerensis.* The metaloph forms a continuous straight ridge with that part of the ectoloph leading to the paracone (antero-exterior). This cone is prominent, especially on M^3, while the double parastyle is very small. On M^2 this style is much larger. Each upper molar has a minute crista and all are notable for their short posterior side.

In the lower dentition, one sees that the heel of the last molar, although broad, is not definitely divided into two cusps. The third premolar shows a distinct separation of the metaconid (or deuteroconid) and sharp grooves separating the elements of the tooth.

Summary.

Systemodon Cope, an indefinite genus concerning which there is some confusion, is considered for the present, following Wortman, as a synonym of *Hyracotherium* Owen, but it is evident from the present study that both are distinct from *Eohippus* Marsh.

Homogalax primævus (Wortman) Hay is a species of tapiroids about the size of *Hyrachyus agrarius* Leidy; but it may be easily separated from this and from the early horses by the absence of diastemata, by the existence of a third lobe on the last lower molar, and by other generalized features. There is no evidence of a facial depression like that of *Helaletes*.

Two new species are here proposed: *Homogalax bridgerensis* and *H. uintensis;* these, together with *H. primævus,* the genoholotype, represent three localities distinct geologically and geographically. *H. bridgerensis* may be distinguished by the triangular P^3 with distinct metaloph, the small canine, the absence of diastema and the geological age. *H. uintensis* is notable for its larger rounded teeth, double parastyle and late Eocene age.

Measurements.

	H. bridgerensis 12563, Y.P.M. mm.	*H. uintensis* 12561, Y.P.M. mm.
Upper dentition		
Length of molar-premolar series	68	
Length of molar series	38	44.5
Lower dentition		
Length of P_3 to M_3 inc.	58.3	68.3
Length of molar series	41	47.3

Art. XXVIII.—*A Tantalate and Some Columbites from Custer County, South Dakota;* by William P. Headden.

The minerals presented in these notes are from Custer Co., South Dakota, with the exception of one columbite which was found near Harney City, Pennington Co. They were all collected by Mr. George B. Grant with the exception of the tapiolite which was collected by the writer many years ago.

The columbites have the habit and physical properties of this mineral as it occurs in other districts of the Black Hills, but there were very pronounced differences among them in specific gravity, color, and habit. They all showed the tabular form with striations. The fracture was uneven, inclining to granular; the color was brown or grayish black, with slightly shining sub-metallic luster but wholly free from iridescence.

The tantalate differed from these columbites in all of its physical properties. It is a pure black in color, with shining metallic to adamantine luster and a strong iridescence; it is brittle and harder than the columbites and has a higher specific gravity.

The fragments received were small, irregular in form, sharp angled, and showed no satisfactory cleavage surfaces. It is doubtful whether they actually show any cleavage surfaces at all. The fragments were freshly broken and clean, but there was a white, triclinic feldspar, apparently microcline, adhering to some of them. These fragments appear to have been originally parts of masses that had been cracked and the surfaces thus produced coated with a thin film of silica. Some of them contain small pieces of quartz, but only occasionally a flake of mica. The tantalate is all from one locality, the Old Mike Mica mine in the Minnehaha Gulch, 6½ miles north of Custer City, Custer Co., South Dakota. The columbite is from three localities, two of them in Custer Co.; these are the Old Mike Mica mine and Tin Mountain on Warren's Gulch; the remaining one is from Harney City, in Pennington Co. This last locality is not far from the Etta mine in the Harney Peak district which formerly furnished many fine specimens of columbite, some of which have been described in earlier numbers of this Journal. I never found nor learned that any sample of a tantalate was found at this locality, but the columbites occurring there were all of high specific gravity as were all of the columbites at other localities in the district. The sample from Harney City, as will be seen from a later statement, presents a striking case of a columbite with a high specific gravity but not so extreme as the sample from Tin Mountain in Custer Co.

The columbites from the Old Mike Mica mine differ from all the samples of this mineral that I have seen from the Black Hills, in that they are of low specific gravity. One sample has the lowest specific gravity that I have found for this mineral from any locality, viz. 5.201 at 4° C.

The tantalate was found at the Old Mike Mica mine and is, so far as my knowledge goes, the second instance of the finding of this mineral in place in the Black Hills. In 1889, or 1890, I found a single group of crystals at a prospect hole, also in Minnehaha Gulch, 3½ or more miles north of Custer City. The form of these crystals was subsequently determined by Prof. Penfield and found to be that of tapiolite. These localities are not more than three miles apart and in the same gulch. I found a tantalate of iron very sparingly present in stream-tin from the Grizzly Bear Gulch and also in that from Mitchell's bar, but the mineral found in these placer products may really have been from the same source, as the placers were only different parts of the same gulch. I supposed that the source of this tantalate was the Tin Queen lode, which lay above the placer working in the Grizzly Bear Gulch. The Minnehaha, Sunday, and Grizzly Bear gulches take their rise in the same general section and the tantalate previously found may have had its source farther up the gulch than I supposed, and may not have had the same origin as the tin-stone, though associated with it in the bed of the gulch.

The tantalate from the Old Mike Mica mine varies greatly in its specific gravity. The pieces sent were quite small; the largest of them weighed between 40 and 50 grams, but these were not clean. The clean pieces usually weighed less than 5 grams and seldom reached 10 grams. Determinations of the specific gravity, made with the Jolly balance, showed a variation from 6.9 to 8.0, and there was no distinguishable differences between the fragments. After observing this fact, I took individual pieces, broke them up and picked out enough of the clean mineral to make the determination of the specific gravity, using a pycnometer; the results varied as greatly as when I used the Jolly balance. There were a few pieces, weighing from 15 to 25 grams, that appeared to be clean and uniform. I determined the specific gravity of these by suspending them in water with the same results as before. In a few instances I found a line through the sample that suggested the possibility of a difference in the parts of the piece. I broke these samples on this line and determined the specific gravity of the separate parts. The greatest difference that I found in this way was in the case of a piece that weighed 15.4 grams. This piece showed a line dividing it into two parts which differed slightly in texture, color, luster and iridescence. On placing a sharp chisel on this line and giving it a quick tap, the piece split in two almost equal parts which were free from mica, etc. One piece was not so bright and clear a black as the other, had a slightly granular fracture and a weaker iridescence. The other piece had a pure, bright black color, conchoidal fracture, metallic adamantine luster with a strong iridescence. The specific gravity of the former piece was 7.019 and of the latter 7.878 at 4° C. While this is the extreme difference found in the specific gravity of two parts of a comparatively small piece of mineral, it is not the only instance of it. At first, I attributed this variation in the case of small individual pieces to a mixture of samples, that is, I supposed that several small masses had been broken out and put together as a general sample of the mineral. This may have been done but it does not follow from the variation in the specific gravity of the individual pieces. The columbites from the Etta mine showed clearly that this mineral, from the same locality, varies greatly in this respect. Even the individual crystals of a group may vary both in specific gravity and composition. The crystals at the Etta were large, weighing up to 10 or more pounds, and were distinct individuals which may have made a difference. In this case, the pieces are small and there is no distinction of individual or even groups of crystals. I have been unable to learn whether crystals of this tantalate occur at the Old Mike Mica mine or not.

Under these conditions one is compelled to use the identical piece for analysis that was used in determining the specific gravity. The description of the samples analyzed has been given in sufficient detail:

Analysis of a Tantalate from the Old Mike Mica Mine.

	Sp. gr. at 4° C.	Ta_2O_5	Cb_2O_5	TiO_2	SnO_2[d]	FeO	MnO	Total	At. Ratio Fe to Ta
1.[a]	6.954	69.55	8.63	1.50	5.29	10.84	4.19	100.00	1:2.06
2.[b]	7.019	76.08	5.49	2.84	0.22	14.16	1.21	100.00	1:1.96
3.	7.180	77.24	6.97	0.81	1.18	13.60	1.02	100.82	1:1.95
4.	7.468	78.28	5.56	1.33	0.28	13.35	1.22	100.62	1:2.05
5.	7.794	79.50	4.32	0.92	0.32	13.42	1.56	100.04	1:2.02
6.	7.878	81.40	3.69	0.58	0.12	12.55	1.73	100.07	1:2.03
7.	7.975	83.57	1.97	trace	0.10	13.28	1.19	100.10	1:1.99
Tapiolite from Prospect in Minnehaha Gulch.									
8.[c]	7.190	77.23	5.18	1.38	0.32	14.84	0.42	100.00	1:1.95

[a] Recalculated after deducting 1.52% tin-stone.
[b] Recalculated after deducting 1.56% tin-stone.
[c] Recalculated after deducting 0.88% tin-stone.
[d] SnO_2 includes traces of WO_3.

Analyses 2 and 6 are parts of the piece weighing 15.4 grams previously mentioned and show that they differ greatly in composition as well as in specific gravity. Analyses 3 and 4 are parts of another piece, that weighed 25 grams and they too show that they vary in the same manner.

Analysis 8 is a portion broken off of the crystals of tapiolite found not very far from this Old Mike Mica mine locality. The specific gravity of this group of crystals and of the pieces broken off of the base of them was determined several times at 18° and the deviation found was from 7.15 to 7.21. The specific gravity of the whole group was found to be 7.20. The average of all determinations made reduced to 4° C. is 7.190, which I have taken as that of the material analyzed. Analyses 3 and 8 have very nearly the same specific gravity and are almost the same in composition. These samples are not from the same locality, but the localities are not more than three miles from one another and are in the same gulch. The agreement in composition is what we should expect if the relation between the specific gravity and composition in these minerals is as intimate as we suppose it to be; but it does not prove the mineralogical identity of the two samples though it may reasonably be taken to suggest this.

Methods of Analysis.—There is no need to discuss these as they were well known, conventional ones, except, perhaps, the determination of titanic acid which was effected by fusion with potassic bisulphate powdering the melt and dissolving it in a mixture of sulphuric acid and hydrogen peroxide. I used 5 parts of sulphuric acid, made by diluting 3 parts of concentrated acid with 2 parts of water; and 4 parts of 3% hydrogen peroxide. This effects a perfect solution of the mineral which can be used in the colorimeter without filtering after standing to allow any bubbles of hydrogen peroxide to escape. This solution will remain clear for some hours, but eventually tantalic acid begins to separate. I tried to separate the acids from the salts introduced by this fusion by boiling as usual and dissolving the separated acids in hydrofluoric acid, precipitating the hot solution by ammonia and dissolving this precipitate in the acid hydrogen-peroxide mixture, but the acids did not go into solution. Both of the acids, tantalic and columbic, are contaminated by titanic acid as separated in this analysis and the titanic acid must be determined and deducted. I may remark that the platinum that goes into solution in the bisulphate fusions necessary in these analyses is an annoyance.

The determination of any cassiterite or quartz that may be present is most easily made by fusion with bisulphate and dissolving the melt in acid hydrogen peroxide. This is much more satisfactory than taking the residue from the solution of the mixed acids in hydrofluoric acid, which invariably contains a little platinum.

The analytical procedure was the same in the case of the columbites.

Columbites.

The columbites presented in these notes have not been described heretofore, and are from three localities; two of them are in Custer Co., the Old Mike Mica mine, and Tin Mountain; and one, Harney City, is in Pennington Co. The minerals are typical columbites in habit, cleavage, luster, etc. They are not quite so hard as the tantalates, and are not brittle like them. They vary in color from a brownish to a grayish black, in luster from submetallic, shining in the case of the Old Mike samples, to dull submetallic in those from Tin Mountain. These latter consisted of small fragments of plates, and one larger piece that weighed 17.33 grams. The specific gravity of these differed; that of the larger piece was 6.725 and that of the plates was 6.845 at 4° C. The characteristics of these pieces were those of typical columbites except that the fracture at the edge of the larger piece was distinctly conchoidal. The inner side and the surfaces exposed by cleaving this piece in two parts showed a fine granular fracture. I do not know the details of these occurrences. The specific gravity has a wider range than I have met with in other samples, namely from 5.201 to 6.845. The former is the lowest and the latter the highest that I have found for a columbite from any locality. The lowest that I have found for a tantalate is 6.954. The sample with this specific gravity differed as widely in its physical properties from the columbites as the tantalate having a specific gravity of 7.975 and was a fragment picked out of the same lot. Its composition is that of a tantalate having the formula $5FeTa_2O_6.FeCb_2O_6$ compared with $8FeTa_2O_6.7FeCb_2O_6$ for the columbite having the specific gravity of 6.845.

In the following table of analyses of columbites numbers 1, 2, and 3 are from the Old Mike locality, number 4 is from Harney City and numbers 5 and 6 are from Tin Mountain. Number 4 is from Pennington Co., the others are from Custer Co.

Analyses of Columbites.

	Sp. gr. at 4° C.	Cb_2O_5	Ta_2O_5	TiO_2	SnO_2[a]	FeO	MnO	Total	Ratio Fe:Cb
1.	5.201	68.00	9.88	0.53	0.88	5.45	14.79	99.53	1:1.99
2.	5.421	67.20	10.10	0.92	0.96	5.96	15.08	100.22	1:1.92
3.	5.496	63.90	13.74	0.80	0.54	5.92	14.95	99.85	1:1.91
4.	6.444	34.60	46.02	1.52	0.38	13.32	4.31	100.15	1:1.92
5.[b]	6.725	27.22	53.47	1.30	0.44	11.91	5.66	100.00	1:1.91
6.	6.845	28.81	53.67	1.63	0.38	12.00	5.20	100.69	1:1.98

[a] The SnO_2 contains WO_3 in quantity up to 50% of the SnO_2 present.

[b] Lime equal to 0.48% deducted.

These analyses show, if those of the columbites are placed first, a gradual increase in the specific gravity from 5.2 to 7.94 with a regular increase in the amount of tantalic acid. This is still true even when we pass the dividing line between distinct mineralogical individuals, for the tapiolite with a specific gravity of 7.19 is tretragonal and well crystallized.

Another thing that is shown is that the tantalate is an iron salt whereas the columbites with a tendency to a high manganese content are mixed. In the tantalate the ratio of Fe to Mn increases from 5.2 in the sample having a specific gravity of 6.954 to 11:1 in those having a specific gravity around 7.9, and to 35:1 in the tapiolite. This ratio in the columbites is reversed, being a little less than 3:1 in the Harney City columbite and 1:3 in those from the Old Mike locality. The columbite from Tin Mountain is a different mixture in which the Fe:Mn is as 4:2, but at the same time the tantalum present has risen to an amount equal in atomic equivalence to the columbium. The columbites from the Harney Peak district that I have studied are all intermediate in respect to these ratios, ranging for Cb:Ta from 1:1 to 6:1 while the Fe:Mn ratio is from 8:1 to 1:1. There is one instance in which it is reversed and becomes 1:2 in a sample that represents a single mass of columbite in the Sarah mine. These relations hold for such of the Black Hills columbites as I have examined. This mineral from different districts has a different, but for the district in general, a characteristic composition. This does not apply in comparing the mineral from the Black Hills with samples from other localities, even in cases in which the specific gravities are approximately the same. In the case of a columbite from Morrison, Colo., with a specific gravity of 5.383, we have practically no tantalic acid and an Fe:Mn ratio of 8:7 whereas a columbite from the Old Mike with a specific gravity of 5.421 and very little tantalic acid has an Fe:Mn ratio of approximately 1:3. It would be inadmissible to compare minerals of different specific gravities.

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SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *The Separation of the Isotopes of Mercury.*—The idea that isotopes exist not only in radioactive elements, but that their occurrence is general among the elements appears to have been well established by a number of recent investigations. J. N. Brönsted and G. von Hevesy, of Copenhagen, have previously made preliminary announcements of their partial separation of metallic mercury into its isotopes by means of fractional distillation, and their observations have been confirmed by W. D. Harkins in this country. They have now published a full account of their work. Their method of evaporating the mercury, which they call "ideal distillation," is interesting, since it is carried out in the exhausted space between double flasks at a temperature of about 40°, while the evaporated mercury is condensed in the solid condition by means of liquid air in the inner flask. This operation was repeated with the distillates and the residues, about 17 or 18 times in the last case, until the fractions became very small. The resulting fractions were submitted to specific gravity determinations with remarkably satisfactory results. The extreme specific gravities found were 1.00023 and 0.99974, and in connection with the description of the work are very convincing as to the existence of isotopes of mercury.

The authors describe also some experiments upon the diffusion of mercury vapor through small openings, and obtained an indication of a separation in this way.—*Zeitschr. Physikal. Chem.*, **99**, 189. H. L. W.

2. *The Color of Ferric Ammonium Alum.*—It is well known to chemists, especially those who have supervised its preparation by students, that this salt usually has a violet color, but is sometimes colorless or nearly so. Ostwald advanced the theory that the colorless product is the pure form, while the color of the other is due to the presence of manganese. Jane Bonnell and Edgar Philip Perman have now carefully investigated this matter. They were unable to detect manganese in a sample of the colored variety, and they carried out the operation of separating any manganese in this salt by precipitating the iron as basic acetate, converting the precipitated iron into the alum, and even after repeating the purification a second time in the same way, they obtained the violet product in the presence of a considerable excess of sulphuric acid.

It was then shown experimentally that the colorless crystals were not due to the presence of ferrous sulphate which had been found in a certain sample of the colorless crystals, but it was shown conclusively that the lack of color was due to the presence of ferric hydroxide produced by hydrolysis upon boiling solutions containing but little free sulphuric acid and producing a brown color practically complementary to the violet one and thus hiding it.—*Jour. Chem. Soc.*, **119**, 1944. H. L. W.

3. *The Persulphides of Hydrogen.*—James H. Walton and Llewellyn B. Parsons, of the University of Wisconsin, have made an interesting study of hydrogen disulphide, H_2S_2, and the tri-sulphide, H_2S_3, which are constituents of the oily liquid produced by the action of hydrochloric acid upon alkali or alkali-earth polysulphides. The existence of these two compounds had been established, so that the results of the present extensive investigation have been improvements in the method for the preparation of the pure compounds and a more extended knowledge of their properties and reactions. Only a few of the results can be referred to here.

It was found that while hydrochloric acid gives the well-known yellow oily liquid with sodium polysulphide solution, the other common acids, acetic, phosphoric and sulphuric acids, do not give any of the oil, but a complete decomposition into hydrogen sulphide and sulphur. It was found that the crude oil could be dried most satisfactorily by the use of phosphorus pentoxide which has no action upon it. The crude oil upon analysis gave results corresponding closely to the formula H_2S_5, but it is believed to be really a solution of sulphur in the sulphides of hydrogen. The nearly pure disulphide and trisulphide of hydrogen were obtained by a single distillation under low pressure by the use of two successive receivers, the first cooled by running water, the second by ice and salt. Quartz vessels were used for the distillation as well as for containers of the persulphides, since it was found that quartz decomposed them far less rapidly than glass. A very satisfactory method was devised for the analysis of the persulphides. It consisted in dissolving the sample in carbon disulphide, adding acetone which caused a catalytic decomposition into hydrogen sulphide and sulphur, evaporating to dryness at 90° and weighing the sulphur.—*Jour. Amer. Chem. Soc.*, **43**, 2539. H. L. W.

4. *A Separation of Germanium from Arsenic.*—John H. Müller, of the University of Pennsylvania, who has recently determined the atomic weight of germanium and in connection with that work has called attention to the difficulty of removing the last traces of arsenic from germanium, has now solved this problem very satisfactorily.

The distillation process from aqueous hydrochloric acid in the presence of chlorine, which has been recommended, did not give satisfactory results, as it was found that minute quantities of arsenic passed into the distillate when the conditions were suitable for volatilizing the germanium chloride, although this method separates germanium from all the other metals and semi-metals. It was found, however, that arsenic and germanium can be quantitatively separated by the action of hydrogen sulphide upon solutions of their oxides in the presence of a large excess of hydrofluoric acid, for under these conditions the arsenic is precipitated while the germanium is not affected. A series of test analyses made with known quantities of the two elements gave most excellent results by this method.—*Jour. Amer. Chem. Soc.,* **43**, 2549.

H. L. W.

5. *Asymmetry of the Gaseous Molecule.*—According to the theory developed by the late Lord Rayleigh, the color of the blue sky may be explained by light which is scattered by the gaseous molecules of the air, and, according to the simple theory, if the molecules were spherical this scattered light should be completely polarized. It was suggested by R. J. Strutt, the present Lord Rayleigh, that any departure from complete polarization would indicate that the molecule had certain preferential directions of vibration. Experiments designed to test the degree of polarization were devised by Strutt in 1919 and showed that none of the seventeen gases and vapors examined exhibited complete polarization of the scattered light. This was what might have been anticipated, for the modern view of the structure of atoms would not lead us to expect that the atom would behave as if possessing spherical symmetry, even apart from the grouping of the atoms in the molecule.

The gas under examination was placed in a metal tube with crossed arms which were properly blackened on the inside. A strong beam of light was sent through one of the arms and the scattered light was viewed through a double image prism in the end of the transverse arm. One of these images contained the scattered light which had been polarized and whose vibrations were perpendicular to the traversing beam, while the other contained light belonging to the unpolarized portion and on emergence possessed vibrations parallel to the original beam. To compare the intensities of these images, which were widely different, a set of absorbing films of varying opacity was prepared. These were interposed in the path of the stronger beam and the two images photographed side by side. When the result showed two images of sensibly the same intensity it was possible from the calibrated scale of the absorbing diaphragms used to estimate the relative intensities of the polarized and the unpolarized light.

These investigations of Strutt have now been repeated and considerably extended, with various improvements in the form of the apparatus, by R. Gans. The degree of asymmetry may be represented to the eye by constructing an ellipsoid of revolution, but with the understanding, of course, that this is in no sense to be identified with the actual contour of the molecule. The author has calculated and in a few cases drawn, not only the form of but the absolute sizes of these ellipsoids. In confirmation of the earlier work by Strutt the ellipsoid for helium is an exceptionally elongated, or spindle-shaped ellipsoid, indicating that this molecule approximates a linear resonator.

Both the Kerr effect and the Faraday rotation of the plane of polarization are theoretically dependent upon the asymmetry of vibration in the molecule and the author has calculated the amount of each of these effects which would be predicted from his measurements on the polarization of scattered light. The observed Kerr effect in different gases is in satisfactory accord with the predicted amount but the agreement of the Faraday effect is only fair.—*Annal. der Phys.* **65**, 97, 1921. F. E. B.

6. *L'Atome;* by DR. ACHALME. Pp. 244. Paris, 1921 (Payot et Cie.).—The author, who is not otherwise designated than as the Director of the laboratory of *l'École des Hautes Études,* has attempted with much ingenuity to explain the structure and form of atoms. Although his book exhibits considerable acquaintance with the writings of many physicists, his speculations are, unfortunately, based too largely upon the phenomena of chemical statics to be convincing. The trend of current thought is all in the direction of the Rutherford-Bohr atom, which hypothesis, together with the spectroscopic evidence and its intimate connection with atomic structure, are completely ignored.

It is to be apprehended that the author has run into a stereochemic *cul de sac.* F. E. B.

7. *Calculus and Graphs;* by L. M. PASSANO. Pp. vii, 167. New York, 1921 (The Macmillan Company).—The purpose of the author has been to write a brief and elementary course on the calculus which would make this branch of analysis available to students of physics, of chemistry and of other sciences where some knowledge of mathematics is required. As is indicated in the title, the presentation has been made chiefly from the standpoint of coordinate geometry, but it does not presume any knowledge of formal analytical geometry or the properties of functions. Although as a text, it is one which would not be selected by those who desire more than an introduction to the subject, its mastery would connote the full equivalent of the ordinary scientific student's knowledge of analysis. F. E. B.

8. *The Manufacture of Optical Glass and of Optical Systems;* by Lieut. Col. F. E. WRIGHT. Pp. 309. Washington, 1921 (Government Printing Office).—At the outbreak of the war the production of optical glass in this country was nil, the small amount required by instrument makers being procured from abroad and chiefly from Germany. With the declaration of war by the United States in 1917 the embarrassment of the government became so acute that it was necessary to requisition both the

scientific and the technical resources of the country to supply the needs of the naval and military forces. This volume has been prepared by the Ordnance Division of the War Department and is designed to present a record of the investigations made and the results obtained at that time. The introductory chapter outlines the personnel of the work undertaken, the factories engaged and the production achieved. Chapter 2 is devoted to the composition of optical glasses and their various physical characteristics with extensive tables and diagrams showing the chemical analysis and optical constants. The third chapter describes the technical processes involved in mixing, melting, and annealing the glass, and is illustrated with numerous photographs of these operations taken in the factory. In chapter 4 the methods used for the inspection and detection of defects are explained. Chapter 5 describes the processes by which the lenses and the prisms are shaped, ground and polished. The sixth chapter explains the ways in which the completed optical train is tested for satisfactory performance. The last chapter contains a review of the optical instrument situation during the war and the success which was attained in the production of these instruments.

The book will be a highly informing one for any person who is at all interested in optics and contains much data probably not accessible elsewhere. F. E. B.

II. GEOLOGY.

1. *Notes on Arctic Ordovician and Silurian Cephalopods;* by AUG. F. FOERSTE. Bull. Denison Univ., vol. **19**, pp. 247-306, pls. 27-35, 1921. *Revolution vs. Evolution: The Paleontologist Renders his Verdict;* by KIRTLEY F. MATHER. Ibid., pp. 307-323.—The first paper is a detailed study of twenty-eight nautilids, of which seventeen occur in Arctic America, Bear Island or Spitzbergen. There are ten new forms and two new genera, *Ellesmeroceras* and *Leurorthoceras*. This work is a praiseworthy beginning toward a revision of all American Ordovician and Silurian cephalopods, which the author has in contemplation. The second paper is philosophical in nature, dealing with the course animal life has taken in its evolution throughout the geological ages. The author's conclusions are in part:

''The crisis recorded in the rocks of latest Paleozoic Age, was forced upon the land animals by changes in climate and environment; it was successfully passed by creatures who specialize in the adaptation of their bodies to cold and drought, and who escaped from the crowded confines of the sea to the almost uninhabited silences of the land. The 'revolution' involved in the dethronement of the reptiles and the exaltation of the mammals at the close of the Mesozoic Era was likewise precipitated by external changes over which the mammals themselves had no control; it bettered the condition of creatures who specialized in the care of their young and the use of their brains. Each group which prospered had for some time displayed the very characteristics which proved efficacious in the time of stress; the 'revolution' afforded the opportunity for the testing and the rewarding of the products of progressive evolution. . . . As in the past, so in the twentieth century, the impelling forces of progress are inherent in the environment; the response must be dependent upon virtues intrinsic in the creatures who are to be thus tested. Some will undoubtedly be found wanting; for them the penalty has always been either extinction or stagnation. Others—and in the past it has generally been a minority—will respond with habits that will prove to be their salvation; they, and they alone, will profit by the revolution." C. S.

2. *Stratigraphy of the Pennsylvanian Formations of North-Central Texas;* by FREDERICK B. PLUMMER and RAYMOND C. MOORE. Univ. of Texas Bull. No. **2132.** Pp. 237, 27 pls., 19 text figs., 1921 (1922).—It is highly pleasing to note that this careful and detailed work on the Pennsylvanian strata of north-central Texas was done by the geologists of the Roxana Petroleum Company, and donated to science through the Texas Bureau of Economic Geology and Technology. It is coöperation of this kind that is to the advantage of humanity in practical and intellectual ways. We congratulate all concerned.

The maximum thickness of the Pennsylvanian here is about 6,800 feet, embracing the Bend, Strawn, Canyon, and Cisco groups of formations. The report contains a large geologic map, eleven photogravure plates of typical fossils, many other illustrations, and a complete list of the known Texas Pennsylvanian faunas, totalling about 354 forms. No new species are described. Of cephalopods there are forty-three species and of these no fewer than twenty-seven are goniatites and ammonites. C. S.

3. *Recent Mollusca of the Gulf of Mexico and Pleistocene and Pliocene Species from the Gulf States. Part 2, Scaphopoda, Gastropoda, Amphineura, Cephalopoda;* by CARLOTTA J. MAURY. Bull. Amer. Paleontology, No. **38,** 142 pp., 1922.—This is a list of the Scaphopoda, Gastropoda, Amphineura, and Cephalopoda of the regions and geologic times mentioned in the title. The bibliography of each species is given, along with the distribution, and there are also occasional notes on the forms.

4. *Handbuch der Regionalen Geologie, 23. Heft, Aegypten,* by MAX BLANCKENHORN; *24. Heft, Die Nordatlantischen Polarinseln,* by OTTO NORDENSKJÖLD. 1921.

5. *The Topographic and Geological Survey of Pennsylvania;* GEORGE H. ASHLEY, State Geologist.—The following bulletins,

chiefly of economic character have been received; the director of the Survey is the author unless otherwise stated:

No. 1. Effect of the war on the price of coal in Pennsylvania.

No. 2. Oil and gas in Southeast Pennsylvania.

No. 3. Development and probable life of gas pool at McKeesport, Penn.

No. 4. Decline of McKeesport oil pool.

No. 7. A high-grade building stone in Greene Co., Penn.

No. 12. Gas wells on Pollock Run, Westmoreland Co., Penn.; by J. French Robinson.

No. 14. Future Sources of power.

No. 16. Geology of oil and gas in relation to coal.

No. 23. Coal beds in Cambrian Co., Penn.; by J. D. Sisler.

No. 24. Coal beds in Greene Co.; by J. D. Sisler.

No. 25. Coal reserves in Greene Co.; by John F. Reese.

6. *United States Bureau of Mines;* H. Foster Bain, Director.—In addition to the usual bulletins, technical papers and miners' circulars (See, **50**, 470, 1920; **1**, 288, 1921). The following contribution especially deserves notice:

Summarized Reports of principal Investigations being conducted by the Bureau of Mines for the year beginning July 1, 1921; compiled by J. D. Secrest, Washington, September, 1921 (a manifolded edition of 185 pages, including list of investigators). The fact that the alphabetized list of these investigations covers thirteen pages in this edition gives some idea as to the variety and extent of the work of the Bureau. This embraces the whole field, from the subject of mine disasters, their causes and means of prevention, to researches about radium and the rare gases. The substance of each of the papers here included is given in clear, condensed form.

Recent Bulletins issued are as follows:

No. 117. Structure in Paleozoic bituminous coals; by Reinhardt Thiessen. 250 pp., 160 pls. (80 cents.)

No. 183. Abstracts of current decisions on mines and mining, reported from May to August, 1919; by J. W. Thompson. 167 pp.

No. 184. The manufacture of sulphuric acid in the United States; by A. E. Wells and D. E. Fogg. 216 pp., 13 pls. 36 figs. (40 cents.)

No. 185. Pennsylvania mining statutes, annotated; by J. W. Thompson. 1921. 1221 pp. ($1.00.)

No. 189. Bibliography of petroleum and allied substances in 1918; by E. H. Burroughs. 180 pp.

No. 191. Quality of gasoline marketed in the United States; by H. H. Hill and E. W. Dean. 270 pp., 22 figs.

No. 194. Some principles governing the production of oil wells; by Carl H. Beal and J O. Lewis. 58 pp., 2 pls., 8 figs.

No. 195. Underground conditions in oil fields; by A. W. Ambrose. 296 pp., 11 pls., 52 figs.

No. 198. Regulation of explosives in the United States, with especial reference to the administration of the Explosives Act of October 6, 1917, by the Bureau of Mines; by C. E. Munroe. 45 pp.

No. 205. Flotation tests of Idaho ores, by C. T. Wright, J. G. Parmelee, and J. T. Norton. 70 pp., 8 pls., 1 fig.

No. 206. Petroleum laws of all America; by J. W. Thompson. 448 pp. (40 cents.)

Prices are given for the last received bulletins.

7. *Metamorphism in Meteorites.*—A recent number of the Bulletin of the Geological Society of America (volume **32**, page 395), contains an article by Dr. G. P. Merrill of the National Museum on the origin and structure of chondritic meteorites which is worthy of note here. He thinks to show that the chondritic meteorites are all of a volcanic and tufaceous origin and their varying textural peculiarities due to metamorphism in which both heat and pressure have had a part. It is pointed out that the most perfect chondroidal forms are found in those meteorites the fragmental nature of which is the most apparent, and that they are less perfect in the crystalline forms. The clear interstitial glassy material, sometimes isotropic and sometimes doubly refracting, he considers, as have others before him, to be feldspathic, but argues that it is due to metamorphism and to have been the last mineral to congeal, representing the closing act in the series of changes through which the stone has passed. The dark glassy material sometimes surrounding the chondrules, in stones of the Parnallee type, is considered secondary, the result of a partial refusion of a fine interstitial material. The metal is also of secondary origin, this conclusion being based upon its distribution and manner of enwrapping certain of the fragments and chondrules, as would occur in the case of secondary precipitation, and also from the fact that in stones of the Cumberland Falls type metal of two distinct generations can be readily traced.

The idea of the author seems to be that this study having reference to the original structures of the stony meteorites and the secondary changes which they have undergone may throw some light upon the sources from which they have been derived and their subsequent wanderings.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Institution of Washington. Year Book, No. 20, 1921.* Pp. xxii, 475. Washington, February, 1922.—The twentieth year of the lines of research conducted by the Carnegie Institution is an important point in its remarkable history. Hardly

less noteworthy is the fact that Dr. Robert S. Woodward, who has guided the Institution so wisely for many years, has retired and his place has been taken by Dr. John C. Merriam, until recently of the University of California. An adequate knowledge of the work accomplished the past year can only be gained by a study of the summaries given by the directors of the different departments, ten in number, which fill pages 43 to 357 of this Year Book. To these large grants nearly $1,000,000 of income have been devoted In addition to these are the minor grants, calling for an expenditure of about $140,000; the results of which are noted in pp. 359 to 464.

The number of volumes issued during the year is 18, with an aggregate of over 4,000 octavo and nearly 1,400 quarto pages. A total of 442 volumes have been published since the beginning with a total of over 124,000 pages. Of the many lines of original work discussed in this report, of especial importance is the first measurement of the diameter of a fixed star, accomplished at the Mount Wilson Observatory; for this Drs. Michelson and Pease with the Director, Dr. Hale, deserve great credit. The star first measured is the well-known Betelguese and its linear diameter was found to be 215,000,000 miles. The diameters of Arcturus and Antares were found to be about 21,000,000 and 400,000,000 miles respectively. Some uncertainty as to these values arises from the fact that the parallaxes of these stars are not absolutely known, but the epoch-making character of the work can be in part appreciated even by the layman. It is also to be noted that the magnetic survey of the oceans has been practically completed by the non-magnetic ship *Carnegie,* which since 1909 has voyaged nearly 300,000 miles.

Recent publications of the Carnegie Institution are noted in the following list (continued from vol. **3**, p. 157, February, 1922):

No. 175. Bauer, L. A., in collaboration with J. A. Fleming, H. W. Fisk and W. J. Peters. Land Magnetic Observations, 1914-1920, and special reports by J. A. Fleming, H. W. Fisk, and S. J. Barnett. (Researches of the Department of Terrestial Magnetism, vol. IV.) Quarto. Pp. vi, 475, 9 pls., 17 text figs. ($7.25).—This volume presents, in continuation of the previous volumes of researches (No. 175, vols. I, II and III), the results of magnetic observations made by the Department of Terrestrial Magnetism, 1914-1920, and four special reports:

No. 306. Contributions to the Geology and Palaeontology of the West Indies; by T. W. VAUGHAN and R. T. JACKSON. Octavo. Pp. iv, 122 pp., 18 pls., 6 text-figs.—R. T. Jackson's paper gives an account of all the species of Echini which have been so far found occurring as fossils in the West Indies, with keys for the identification of genera and species showing their geographical and geological distribution. T. W. Vaughan's paper gives in succinct form, for the use of geologists, what is definitely known of the stratigraphic occurrence of the species of Echini described in Doctor Jackson's paper.

No. 308. Plant Habits and Habitats in the Arid Portions of South Australia; by W. A. CANNON. Octavo. Pp. viii, 139, 32 pls., 31 figs. ($2.75).—This is a careful investigation of the physical environment of the vegetation of different sections of South Australia, with details as to rainfall, evaporation, relative humidity, etc. Dr. Cannon has previously issued a somewhat similar work on the Algerian Sahara (publication No. 178).

No. 311. Shallow-water Foraminifera of the Tortugas Region; by J. A. CUSHMAN. (Papers from the Department of Marine Biology, Vol. XVII.) Octavo. Pp. 85, 14 pls. ($1.50).—This work gives the results of the study of some of the living foraminifera which have been very rarely studied in tropical waters. The relationships of the fauna to other regions is discussed and a general systematic treatment of the local foraminifera is given in detail. The new and rare species are illustrated by numerous plates.

No. 314. The Behavior of Stomata; by J. V. G. LOFTFIELD. Octavo. Pp. 104, 16 pls., 54 figs. ($1.50).—This treatment of stomatal behavior falls into three divisions. The first is descriptive, and deals with the hourly stomatal movement for a 24-hour day of a considerable number of species, including trees, shrubs, and a wide variety of herbs, both cultivated and native and of different ecological character. The second deals with causes of changes in stomatal movement from day to day, as well as during the daily march. The third deals with the effect of stomatal movement upon transpiration.

2. *Proceedings of the First Pan-Pacific Scientific Conference, held under auspices of the Pan-Pacific Union.* Three volumes, 1921.—It is well known that the first Pan-Pacific scientific conference, held in the summer of 1920 at the Bishop Museum in Honolulu, was a far-reaching and stimulating success, and something of the results there attained are here set forth in printed form. The three volumes contain about 180 papers, totalling 949 pages, relating to almost every phase of science in the realm of the Pacific and its bounding continents and continental islands. Most of them are suggestive of things yet to be done, but many record valuable observations. The feeling of the chairman of the Conference, Herbert E. Gregory, is one of optimism that men and means will be found to unravel, if not all, at least most of the major problems connected with the natural history of the Pacific region. C. S.

3. *A Laboratory Manual for Comparative Vertebrate Anatomy;* by LIBBIE H. HYMAN. Pp. xv, 380. Chicago, 1921 (The University of Chicago Press).—In nearly all laboratories

giving a course in vertebrate anatomy the comparative study of the organ systems has in large measure supplanted the older study of the entire anatomy of selected types. By the newer method the student more readily grasps the significance of morphological details and secures a more substantial conception of the course of evolution.

To accompany such a laboratory study this manual is eminently fitted. One of the primary objects of the book is to compel the student to become self-reliant in his work, and the directions and descriptions are so explicit that he no longer has an excuse for calling on the instructor for an unreasonable amount of assistance. This is certain to be of benefit both to student and instructor; to the former because of the superior mental discipline involved, and to the latter because of a relief from constant appeals for help. The book has already met the test successfully.

W. R. C.

4. *The Vitamins;* by H. C. SHERMAN and S. L. SMITH. Pp. iii, 273 pp. New York, 1922 (The Chemical Catalog Company. Price, $4.00).—This is an excellent review of a subject which has acquired pronounced interest for the biochemist, the physiologist, the biologist, the bacteriologist, the physician, the agriculturalist, and the food manufacturer during the past decade. It is not an easy task to prepare a critical summary of the history and status of a new chapter in science that already encompasses an enormous literature which is growing at a rapid rate; but Sherman and Smith have succeeded. The volume is certain to become an almost indispensable reference book on the subject of vitamins. It presents encyclopedic information in a readable style. Although the book includes elaborate compilations of data about vitamins, there is scarcely a page that does not help to awaken an interest in the newer aspects of food values or point to the problems raised thereby.

L. B. M.

5. *Publications of British Museum of Natural History, London, 1921.*—Recently issued are the following:

Catalogue of the fossil Bryozoa (Polyzoa) in the Department of Geology. The Cretaceous Bryozoa. Vol. III, the Cribrimorphs, part 1; by W. D. LANG. Pp. cx, 269, with 115 text figures and 8 plates.—This work has been carried along the lines laid out by Dr. J. W. Gregory. The volume is divided into two sections: Part I includes the Introduction, which is (A) Biological; (B) Terminological; (C) Historical. Part II is Systematic, giving (1) the characters of the families; (2) doubtful species; (3) the systematic account (pp. 16-255). Two indexes close the volume. The excellent drawings for the plates have been made by Miss Gertrude M. Woodward; those of the text figures mostly by the author.

Catalogue of the Selous Collection of Big Game; by J. G. Dollman. Pp. vii, 112; with a frontispiece portrait (1906) by Leo Weinthal of Frederick Courteney Selous.

Economic Series.—No. 2.—The Louse as a menace to man. Its life-history and methods for its destruction; by James Waterston. Pp. 20, with one plate and 2 text figures. 1921.

No. 12. The Cockroach: its life history and how to deal with it; by Frederick Laing. Pp. 18, with 2 text figures and 3 figures on the frontispiece plate.

6. *Register zum Zoologischer Anzeiger, begründet von* J. Victor Carus. Herausgegeben von Prof. Eugen Korschelt. Band xxxvi-xl und *Bibliographia Zoologica,* vol. xviii-xxii. Pp. 605. Leipzig, 1922 (Wilhelm Engelmann. Price 280 marks, with addition for foreign countries).—This monumental work follows essentially the lines laid down in earlier indexes already published. The six hundred pages, closely printed and in clear but small type, give in one alphabetical series both the name of the author and his various articles with the names of the individual species. The extent of this work and, at the same time, its value to the zoologist, may be in a measure understood from the rough estimate that the Index includes something like 60,000 separate entries.

7. *Georg Weber's Lehr- und Handbuch der Weltgeschichte. Twenty-third edition, volume I, Altertum; bearbeitet von* Prof. Dr. E. Schwabe. Pp. xv, 793. Leipzig, 1921 (Wilhelm Engelmann).—Weber's well-known and widely used *Weltgeschichte* was first issued in 1846, seventy-six years ago. Since then many new editions have been published, and the interesting history of the development of this remarkable work is given in the preface to the 21st edition issued in 1902 by Professor A. Baldamus. The 22d and 23d editions have been carried through by Professor E. Schwabe; the latter bears the date of April, 1921. It is not to be wondered at that the subject, once covered in a single volume, has now extended to two volumes of which the first is now before us. This embraces the period from the earliest records of prehistoric man and his work down to the Imperial period of Rome, about 400 A.D. It is to this wide range of history that the present volume is devoted.

The opening 25 pages give a concise summary of prehistoric man, his development, speech, religious and political forms so far as they can be learned from the imperfect records in existence. Subsequent chapters of part I (I to VII) deal with the people of the East: the Chinese, East Indians, Babylonian-Assyrians. the Semitic people in general and the Israelites in particular, and finally the Persian. The second part, in four chapters, discusses in detail Grecian history from 1500 B. C. to 190 B. C. Part third takes up Roman history from its beginning to 366 B. C. (chapters I and II). The third chapter (366 to 133 B. C.) carries Rome to its position as the controlling power of the Mediterranean, while the fourth and fifth chapters extend to the close of the Republic (133-30 B. C.) and on to the Empire (30 B. C. to 395 A. D.).

The closely printed pages of this remarkable volume contain an almost bewildering mass of information, systematically arranged; the scope of this can only be appreciated by a detailed study of the whole. It is truly noteworthy that so soon after the end of the World War it has been possible to bring out in Germany so exhaustive a work.

8. *Observatory Publications.—Publications of the Leander McCormick Observatory of the University of Virginia;* S. A. MITCHELL, Director. 1921. Vol. II, part 5. Pp. 157-164.—First stellar parallax measures (reprinted from the *Astrophysical Journal,* **42,** 263-270, 1915). Vol. II, part 7, pp. 201-268. This includes 349 parabolic orbits of meteor streams and other results.

Publications of the Washburn Observatory of the University of Wisconsin; GEORGE C. COMSTOCK, Director. Vol. X, part 4. Pp. 167. Observations of double stars, 1907-1919. Madison, Wis. 1921.

9. *Tables and other Data for Engineers and Business Men.* Compiled by CHARLES E. FERRIS, University of Tennessee. Twenty-fourth edition; 160 pp. Knoxville, Tenn. (University Press; price seventy-five cents).—This volume of engineering tables, though small in size and modest in price, contains a large amount of information of great value to the practical man. First issued in 1905, and repeatedly noticed in these pages, it has now reached its 24th edition. This fact alone testifies to the value set upon it by those who use it.

10. *Bibliotheca Zoologica II. Verzeichnis der Schriften ueber Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861-1880 selbständig erschienen sind;* bearbeitet von DR. O. TASCHENBERG. Lieferung 25. Leipzig (Wilhelm Engelmann.)—Parts 21 to 23 of this important work were noticed in June 21, 1920; part 20 in July, 1921, and part 24 in January, 1922. Part 25 is now issued under the date of February, 1922 (price 82 marks). It includes signatures 795-804, or pp. 6393-6472. See No. 6 above.

11. *Mentally Deficient Children: Their Treatment and Training;* by G. E. SHUTTLEWORTH and W. A. POTTS. Pp. 320. Philadelphia, 1922 (P. Blakiston's Son and Company.)—This is the 5th edition of an old standard which was first published in 1895. The authors have had impressive experience in the medical, educational and administrative aspects of the problem of mental deficiency, and they speak with authority. To American readers the concrete references to the administration of the Mental

Deficiency Act of 1913 will be particularly interesting and helpful. There is generous reference to much that has been done in America, in both the psychological and administrative fields, but the authors do not give notice to the New York system of providing colony and institutional care for the feeble-minded which is one of the most contributive developments in this country.

The chapter on diagnosis is strongest on the medical side. There is more than the usual emphasis on syphilis as an etiological factor.

The volume is compact, convenient, well illustrated and well arranged, and useful alike to teachers, physicians and lay students of the problem.

OBITUARY.

Dr. John Casper Branner, president emeritus of Leland Stanford University, died on March 1 at the age of seventy-one years. Professor Branner was active in several lines of geological work. He was especially interested in Brazil, beginning his work there in connection with the Geological Commission in 1875, and as special botanist in 1880-81. He returned to Brazil in 1899, and again in 1907 and spent much of his time there till 1911. His other connections were also varied. He was topographic geologist of the survey of Pennsylvania (1883-85) and later state geologist of Arkansas (1887-93). He was professor of geology in Indiana University from 1885 to 1892; from 1892 on he was connected with the Leland Stanford University: first as professor, later as acting president and finally president, becoming emeritus January 1, 1916. Branner's wide experience in Brazil and in the United States enabled him to make many contributions to science; of these a considerable number are to be found in the pages of this journal. It is not strange that his labors won for him recognition by election to a number of scientific societies at home and abroad.

Dr. James Francis Bottomley, distinguished for his original work in chemistry and physics, died on January 16 at the early age of forty-seven years. His death is a serious loss to science and to certain lines of administration, in which he was of great value to his country. Probably his most important work was that of silica fusion for which he received gold medals at Brussels (1910) and Turin (1911). Few men, as noted by *Nature* (Feb. 16, p. 212), have their gifts and tastes so definitely determined by heredity. He was the great-grandson of Dr. James Thomson, professor of mathematics at Glasgow; Lord Kelvin, and James Thomson (of Queens College, Belfast and Glasgow University) were his great-uncles. Further his father, Dr. James Thomson Bottomley, is now on the staff of Glasgow University.

Professor Max Verworn, the distinguished physiologist, died at Bonn on November 23, at the age of fifty-eight years. He was Silliman lecturer at Yale University in 1911 and his lectures on the physiological relations of irritability were of special value; these were later published in book form.

Dr. Giacomo Luigi Cimician, professor of chemistry in the University of Bologna, died on January 2. His work was of great value and chiefly in organic chemistry.

Dr. Boynton Wells McFarland, assistant professor of Chemistry in Yale University, died in New Haven on March 13.

Dr. Charles W. Waidner, chief physicist of the Bureau of Standards, died in Washington on March 11.

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Established by BENJAMIN SILLIMAN in 1818.

THE
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FIFTH SERIES

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AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. XXIX.—*Some Complex Chlorides containing Gold;* by H. L. Wells.

II. *Cesium Triple Salts.*

[Contribution from the Sheffield Chemical Laboratory of Yale University.]

In a preceding article[1] a re-investigation of Pollard's ammonium-silver-auric chloride was described, and the formula $(NH_4)_6Ag_2Au_3Cl_{17}$ was ascribed to it. Upon extending the investigation to the employment of cesium chloride in the place of the ammonium salt a triple compound, not corresponding to the ammonium salt, but with a simpler formula, $Cs_2AgAuCl_6$, has been obtained, while several other triple salts apparently isomorphous with this and forming an analogous series with it have been prepared.

The formulas of these five new triple chlorides, with their colors, are as follows:

$Cs_4Ag_2Au'''_2Cl_{12}$.	Very black opaque, powder black.
$Cs_4ZnAu'''_2Cl_{12}$.	Yellow,[a] transparent, powder pale yellow.
$Cs_4HgAu'''_2Cl_{12}$.	Orange, transparent, powder yellow.
$Cs_4CuAu'''_2Cl_{12}$.	Crystals black, powder pale brown.
$Cs_4Au'_2Au'''_2Cl_{12}$.	Very black, opaque, powder black.

[a] Sometimes red.

The simplest formulas for the silver and aurous salts have been doubled in order to make them correspond to the others, for it has been found that the silver and zinc salts evidently crystallize isomorphously, since the crystals of their mixtures are uniformly black in color, even when they contain a large proportion of the yellow zinc compound, and there is similar isomorphism with the mercuric and aurous salts. This series of salts, therefore,

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[1] *This Journal,* April number, 1922.

shows interesting cases of isomorphous replacement between two univalent atoms and one atom that is bivalent.

The very intense black colors of the two salts containing univalent silver and aurous atoms is very remarkable. They form precipitates as black as precipitated lead sulphide, while the crystals of the aurous salt sometimes show a coppery luster similar to that often displayed by solid dyestuffs.

An attempt was made to prepare a cesium-calcium-auric chloride, but no such compound was found under a wide range of conditions. There is little doubt, however, that other bivalent metals besides those that have been used in the present investigation would yield triple chlorides with cesium and auric gold.

In preparing these triple chlorides by crystallization a large excess of cesium chloride, over the theoretical quantity, is usually desirable, but the solutions should generally be very dilute in respect to gold in order to avoid the deposition of the sparingly soluble double salt $CsAuCl_4$. Although some of the compounds have been obtained from practically neutral solutions, the presence of much hydrochloric acid, even up to the full strength of the concentrated liquid, is favorable to their formation, apparently by making them more stable and less soluble. In several instances, where a solution deposited a triple salt mixed with $CsAuCl_4$, it was only necessary to dilute considerably with concentrated hydrochloric acid in order to obtain a pure crop of the triple salt after dissolving the mixture by heating and then cooling.

It is characteristic of these triple salts, and also of Pollard's ammonium compound, that they form very minute crystals, usually less than 1 or 2 mm. in diameter, whether they are formed by the slow cooling of the solutions or by evaporation on the steam-bath. The crystals of the double salt $CsAuCl_4$ that are frequently deposited with them are invariably of far greater size. The triple salts are evidently very sparingly soluble in their cold mother-liquors, for the latter usually show by their pale yellow colors that very little gold is left in solution in the usual, preferable cases where the gold is subordinate to the other constituents in its proportion.

All of the analyzed products were shown to be evidently homogeneous by careful microscopic examination. In some cases the crops of crystals were washed to some extent by diluting the last part of the mother-liquor with strong hydrochloric acid, but usually this was considered unnecessary and was not done. In all cases the products were carefully dried with filter paper and then in the air. Further drying at 100° in all cases gave insignificant losses, amounting usually to about 0.01 to 0.05%.

In all cases experiments were made under widely varying conditions, but no evidence was obtained of the existence of more than a single compound of the same three simple salts, such as occur, as the writer has shown,[2] to the number of three or four with the thiocyanates of cesium, zinc and silver, and also those of cesium, cadmium and silver.

Cesium-Silver-Auric Chloride, $Cs_4Ag_2Au_2Cl_{12}$.—The very minute, black crystals of this salt frequently show brilliant faces under the microscope, or they sparkle when viewed with the naked eye, but sometimes a crop was found to consist chiefly of rounded particles, probably crystal-aggregates, showing no distinct faces.

The compound appears to be stable in contact with strong hydrochloric acid, but it is slowly decomposed by cold water, more rapidly by the hot liquid, with separation of silver chloride, and frequently also of yellow $CsAuCl_4$.

The following analyses of separate crops were made:

	I	II	III	IV	V	VI	VII	VIII	Calculated for $Cs_4Ag_2Au_2Cl_{12}$
Cs	....	....	33.95[a]	....	....	....	....	34.39	33.90
Ag	13.60	13.11	13.65	13.54	13.47	13.40	13.49	13.11	13.77
Au	25.17	24.73	25.15	24.84	24.93	24.73	25.05	25.74	25.17
Cl	....	....	27.25	....	....	....	....	26.76[a]	27.16

[a] By difference.

The first three analyses represent crops produced by cooling from solutions containing 20, 160 and 10 g., respectively, of cesium chloride, 3 g. each of gold as $HAuCl_4$, 1.5 g. each of silver nitrate, and each in a volume of about 1000 cc., made up of about equal volumes of concentrated hydrochloric acid and water. The other crops were prepared under widely varying conditions, some of

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[2] Amer. Chem. Jour., 28, 278; 30, 144.

them by cooling hot solutions and others by evaporation to crystallization on the steam-bath.

The method of analysis for silver, gold and chlorine was the same as that described for Pollard's salt in the previous article.[3] The cesium was determined by weighing the chloride after removing the other metals and evaporating to dryness.

Cesium-Zinc-Auric Chloride, $Cs_4ZnAu_2Cl_{12}$.—This salt gave somewhat larger crystals than the other members of the series. The crystals were prismatic in habit, and sometimes as much as 3 or 4 mm. in length. Some of the crops were yellow in color, but other products showed a reddish or even a dark red color, and the red crops frequently showed variations in the individual crystals from yellow through various shades of red. There was no appreciable difference in the composition of the yellow and red products. It appeared that solutions which gave red crops when rather dilute gave yellow ones upon concentration by evaporation. The cause of the changes in color is not definitely known, but it is suspected that the red color was caused by a slight contamination, due to the reducing action of filter-paper, with the very strongly colored salt $Cs_4Au'_2Au'''_2Cl_{12}$, which has been found to give strong color-effects with the mercuric triple salt, as will be explained further on in this article.

It was found that this zinc salt can be prepared in the presence of a considerable excess of zinc chloride, as well as of cesium chloride. This is due to the fact that the double chlorides Cs_3ZnCl_5 and Cs_2ZnCl_4, described[4] in this laboratory long ago, are so readily soluble as not to interfere.

The salt is decomposed by cold water with the precipitation of $CsAuCl_4$, but the latter dissolves in the presence of sufficient water.

The following analyses of separate crops under varying conditions were made:

	I Yellow	II Yellow	III Reddish	IV Red	V Red	Calculated for $Cs_4ZnAu_2Cl_{12}$
Cs	....	....	....	....	....	37.51
Zn	5.23	4.83	4.72	5.82	4.84	4.61
Au	27.46	27.68	27.48	27.80	27.88	27.84
Cl	....	....	....	....	....	30.04

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[3] Loc. cit.

[4] Wells and Campbell, *This Journal*, 46, 431, 1893.

The analyses were made by dissolving in water, precipitating gold with ammonium oxalate in the presence of a little oxalic acid, and precipitating zinc in the boiling filtrate with sodium carbonate. Both precipitates were collected, ignited and weighed in Gooch crucibles.

Mixtures of $Cs_4Ag_2Au_2Cl_{12}$ *and* $Cs_4ZnAu_2Cl_{12}$.—When the investigation of the first of these compounds was begun it happened that the gold employed in the work was accidentally and unsuspectedly contaminated with a little zinc. This led to perplexing results, for in most cases the zinc compound crystallized with the silver salt, evidently isomorphously, for all the crystals were very black and usually had a perfectly uniform appearance under the microscope. A great many analyses of such crops were attempted, and these showed wide variations in silver which made it appear that several triple salts existed, while attempts to determine cesium in them, either by weighing the chloride or the sulphate, were mysteriously unsatisfactory. Since the pure zinc salt contains only 4.61% of that metal there was only a very small amount of it in many of the mixtures, and hence much work was done before it was detected.

It may be said that a few crops from this impure material, especially such as were obtained by hot evaporation or by partial cooling, were practically free from zinc and led to the correct formula for the silver salt before the impurity was discovered.

A few partial analyses of the mixtures, arranged according to their percentages of silver, are given here to show the wide range reached by the experiments, where fractionation was freely used:

	I	II	III	IV	Calculated for $Cs_4Ag_2Au_2Cl_{12}$	Calculated for $Cs_4ZnAu_2Cl_{12}$
Cs	....	....	....	....	33.90	37.51
Ag	10.71	8.80	5.78	1.28	13.77	None
Zn	....	....	....	....	None	4.61
Au	26.62	26.44	28.15	27.50	25.17	27.84
Cl	....	....	....	....	27.16	30.04

When certain crops containing very little silver, like IV, were obtained some pale crystals were noticed, and then a careful qualitative analysis revealed the presence of the zinc.

Cesium-Cupric-Auric Chloride, $Cs_4CuAu_2Cl_{12}$.—Starting with the beautiful garnet-red double salt $CsCuCl_3$, a large sample of which has been preserved in this laboratory since its preparation by L. C. Dupee,[5] experiments were made at first with cupric chloride and with auric chloride in excess in various proportions, but the triple salt did not appear until a rather large excess of cesium chloride was used. In such solutions, when they are cold, it forms a pale brown precipitate upon the addition of concentrated hydrochloric acid, but the minute crystals that form upon cooling hot solutions are very black, although their streak is pale brown.

Four distinct crops prepared by cooling were analyzed. The first two were made from rather concentrated, slightly acid solutions the first of which contained much more copper than the second and gave somewhat variable results, while the others were obtained from the same solutions after dilution with about equal volumes of concentrated hydrochloric acid:

	I	II	III	IV	Calculated for $Cs_4CuAu_2Cl_{12}$
Cs	....	....	37.20[a]	37.40[a]	37.55
Cu	4.16	3.88	4.68	4.92	4.49
Au	26.89	29.91	27.94	27.66	27.88
Cl	....	....	30.18	30.02	30.08

a By difference.

In making the analyses the gold was precipitated by means of ammonium oxalate in the presence of a little free oxalic acid, and the copper was precipitated in the filtrate with hydrogen sulphide and weighed as Cu_2S. After boiling off the H_2S the chlorine was determined by the usual gravimetric method.

Cesium-Mercuric-Auric Chloride, $Cs_4HgAu_2Cl_{12}$.—It is easy to prepare this salt in a pure condition by cooling strong hydrochloric acid solutions that are very dilute in respect to auric chloride and especially to mercuric chloride, but which contain a considerable excess over the theoretical amount of cesium chloride. It is preferable also to have a very little nitric acid present in order to avoid the reduction of auric chloride to the aurous condition by the action of filter-paper or dust.

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[5] Wells and Dupee, *This Journal,* 47, 91, 1894.

It forms minute, transparent, orange-red crystals, three crops of which gave the following analyses:

	I	II	III	Calculated for $Cs_4HgAu_2Cl_{12}$
CsCl	43.45	43.41	42.75	43.37
$HgCl_2$	18.14	17.66	19.72	17.50
$AuCl_3$	38.41	38.93	37.53	39.13
Total Cl	....	....	26.65	27.42

The principal constituents were very conveniently determined by heating the substance in a Rose crucible in a stream of hydrogen, gradually, and finally considerably below a red heat. The loss in weight gave the mercuric chloride and the chlorine combined with the gold, while the residue consisted of metallic gold and cesium chloride. This last mixture was treated with water and the gold was collected and weighed, so that the three chlorides could then be calculated. The total chlorine was determined in a separate portion by the usual gravimetric method after the removal of the gold and mercury by precipitation.

The pure salt, however, was not obtained at the first attempts to prepare it. Three successive crops were obtained from a solution, the composition of which varied from step to step on account of the removal of portions of the crops and the effect of additions of mercuric chloride, and were approximately as follows:

	A	B	C
Cesium chloride	15g.	14.5g.	14g.
Mercuric chloride	2g.	2.5g.	3.5g.
Gold (as $HAuCl_4$)	1g.	0.9g.	0.8g.
Hydrochloric acid	a little	a little	a little
Volume, roughly	200 cc.	250 cc.	300 cc.

It is to be observed that, in addition to increased dilution, the principal variation of the solutions is an increased proportion of mercuric choride, which, even in the first case, is largely in excess of the amount required to form the triple salt with the gold that is present.

The crops obtained were in the form of small, prismatic crystals which varied in color from a light reddish-brown in A to a pale yellowish-brown in C, with B intermediate, but the individual crystals in each crop appeared to be exactly alike in color when examined microscopically. These crops gave the following results upon analysis:

	A	B	C	Differences A—B	Differences A—C
CsCl	40.51	39.43	38.37	+ 1.08	+ 2.14
$HgCl_2$	41.59	52.58	60.40	—10.99	—18.81
$AuCl_3$	17.90	7.99	1.23	+ 9.91	+16.67

It is evident from these results that these products probably represent mixtures of a compound containing gold with another containing none of that metal, and it is not difficult to calculate from the differences the composition of the compound without gold. The results of this calculation are as follows:

	From A–B	From A–C	Calculated for $CsHgCl_3$
CsCl	38.57	38.21	38.26
$HgCl_2$	61.43	61.79	61.74

The agreements with the calculation for $CsHgCl_3$ are remarkably close, and there can be no doubt about this constituent of the mixture. This double salt was described[6] in this laboratory long ago, together with Cs_3HgCl_5, $CsHgCl_5$ and $CsHg_5Cl_{11}$, all of which yield this salt upon recrystallization from water. It was found to be soluble only to the extent of 1.426 parts in 100 of water at about 17°, and since it is very probably still less soluble in cesium chloride solutions it is evident that any considerable excess of mercuric chloride should be avoided in the preparation of the triple salt.

The evident isomorphism of the double salt $CsHgCl_3$ with the triple salt $Cs_4HgAu_2Cl_{12}$, as shown by the uniform habit and colors of the crystals of their mixtures, makes it appear possible, unless this isomorphism is considered as merely accidental, that a multiple formula, $Cs_4Hg_4Cl_{12}$, should be given to the double salt, from which the triple salt may be derived by the replacement of Hg''_3 by Au'''_2.

Another complication was encountered in the further study of this triple salt, for with various experimental solutions the products obtained varied remarkably in color. Some of them were bright orange-red, some were dark brown or nearly black, although transparent, while others were very black and opaque. These differently colored products showed little or no variation in composition, and the cause of the changes in color was not under-

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[6] H. L. Wells, *This Journal*, 44, 225, 1892.

stood for a considerable time. It was finally found, however, that the dark color was due to the reducing action of filter-paper and the formation of aurous chloride. The solutions had been filtered frequently and extracts of the filter-papers that had been used for drying the crystals had been added to them. When a little nitric acid, left after dissolving the gold, together with free hydrochloric acid were present in the solutions the reduction was prevented, but otherwise a single filtration of a hot solution that had previously given an orange-red product caused the formation of a very dark one. The following analyses of some of these products were made:

	I Dark brown, transparent	II Nearly black, transparent	III Black, opaque	IV Black, opaque	V Black, opaque	VI Black, opaque	Calculated for $Cs_4HgAu_2Cl_{12}$ Orange-red
Cs	34.25	33.39	33.99	34.09	....	33.89	34.23
Hg ...	....	....	....	....	14.81	14.24	12.93
Au ...	24.99	26.19	25.07	25.15	24.32	24.52	25.42
Cl	....	....	....	....	26.48	26.72	27.42

The first four analyses were made by the method of heating in hydrogen, already mentioned, and on account of the presence of aurous chloride reliable results for mercury were not obtained. The determinations of mercury and chlorine were made by weighing mercuric sulphide and silver chloride.

The results show that the dark products differ but slightly from the pure compound in composition. The high percentages of mercury in the last two products indicate that too large a proportion of mercuric chloride was used in their preparation, resulting in the crystallization with them of a little of the isomorphous double salt $CsHgCl_3$.

Efforts were made to prepare the pure black compound, or to obtain some light upon its composition, by preparing products from solutions that had been subjected to long, hot digestion with filter-paper, but, on account of the instability of aurous chloride, metallic gold was usually precipitated during the digestion, and products of a constant composition were not obtained in this way. After the pure black triple salt had been prepared in a pure condition by another method, to be described in the next section of this paper, and its composition was known to correspond to the formula $Cs_4Au''_2Au'''_2Cl_{12}$ it was possible to calculate the composition of the mixtures obtained by reduction with filter-paper. In the case where the product showed the greatest variation from the orange-red salt in its composition, the original solution was prepared from 6 g. of the orange-red compound, 10 g. of cesium chloride and about 300 cc. of water. Then a single 10 cm. filter-paper was added and the whole was heated in a covered beaker upon the steam-bath for 24 hours. The filter-paper and a considerable quantity of gold that had precipitated were then removed by filtration and a crop of very black and opaque, apparently homogeneous crystals was obtained by cooling. It is evident, from the composition of the original solution and the fact that gold was removed by precipitation, that the product was formed in the presence of an excess of mercuric chloride, and consequently that it was likely to contain the salt $CsHgCl_3$ as an isomorphous constituent. The results of the analysis and the calculation are as follows:

		Calculated for			
		10 %	20 %	70 %	
	Analysis	$Cs_4Au'_2Au'''_2Cl_{12}$	$CsHgCl_3$	$Cs_4HgAu'''_2Cl_{12}$.	Total
Cs	33.23	3.04	6.04	23.96	33.04
Hg	17.55	....	9.12	9.05	18.17
Au	22.22	4.52	....	17.79	22.31
Cl	26.29	2.44	4.84	19.19	26.47

The amount of the aurous compound was calculated from the deficiency of chlorine, 0.78%, shown by the analysis, below the amount required to give $AuCl_3$ with the gold. Then the percentages of $CsHgCl_3$ and $Cs_4HgAu_2Cl_{12}$ were calculated by finding the proportions of these that would bring the gold to the amount found. In this calculation the required proportions of the constituent salts are given only approximately, but the fair agreement of the total with the analysis is a satisfactory one. The assumption, therefore, that this product was composed of three isomorphous salts appears to be a plausible one.

Cesium-Aurous-Auric Chloride, $Cs_4Au'_2Au'''_2Cl_{12}$.—When a concentrated solution of cesium chloride, best in 1:1 or stronger hydrochloric acid, is mixed with solid aurous chloride the result is very striking, for an intensely black precipitate is instantly formed, while metallic gold is also deposited. The black compound is the triple salt under consideration. It is not easy to obtain it in a pure condition, free from metallic gold and the yellow double salt $CsAuCl_4$, but occasionally it can be recrystallized satisfactorily.

A good crop was obtained by treating 5 g. of aurous chloride, made by heating $HAuCl_4$, with 30 g. of cesium chloride dissolved in a little 1:1 hydrochloric acid, then diluting with the same acid to about 400 cc., heating to boiling, filtering and cooling. Another satisfactory crop was prepared by evaporating on the steam-bath, until crystallization took place, a similar, but somewhat more concentrated solution. The first product was simply dried by pressing on paper, but the second one was washed to a considerable extent, before drying, by largely diluting the last part of the mother-liquor with hydrochloric acid.

The salt forms very minute black crystals which are rapidly decomposed by water with the formation of cesium-auric chloride and metallic gold, but they appear to be very stable with strong hydrochloric acid.

The results of the analyses of the two crops that have been mentioned are as follows:

	I	II	Calculated for $Cs_4Au'_2Au'''_2Cl_{12}$
CsCl	38.83	37.89	38.56
Au	44.86	45.92	45.19
Cl	16.31	16.19	16.25

The analyses were made by heating the substance (dried at 100°) in a Rose crucible in a stream of hydrogen. The loss in weight gave the chlorine, while the residue consisting of gold and cesium chloride, was treated with water and the gold was collected and weighed.

An attempt was made to prepare this triple salt, the simplest formula for which is $CsAu''Cl_3$, by heating the double salt $CsAu'''Cl_4$. The latter became intensely black at about 320°, but the loss in weight at this temperature was only 1.68% instead of the theoretical 7.51%, so that the change, if it did take place, was only superficial or partial. Upon heating to the melting-point without measuring the temperature, a reddish liquid was formed which became intensely black upon solidification, but the loss was then 9.56%, while chlorine was still being given off when the heating was stopped. The pure triple salt, therefore, was not prepared in this way, but the intense black color of the product makes it appear that it is probably formed to a considerable extent at least.

Some potassium auric chloride, $KAuCl_4$, was heated in a similar manner, but, although the product became very dark brownish-red, no intense black color was observed, as in the case of the cesium salt, and hence it seems doubtful that a potassium-aurous-auric chloride can be prepared in this way.

Summary.—It has been shown in this and the preceding article on Pollard's salt:

That the ammonium triple chloride $(NH_4)_6Ag_2Au_3Cl_{17}$ does not correspond in its type of formula to the cesium salt $Cs_4Ag_2Au_2Cl_{12}$.

That no corresponding potassium triple chloride could be prepared.

That a series of cesium triple chlorides, $Cs_4Ag_2Au_2Cl_{12}$, $Cs_4Au'_2Au'''_2Cl_{12}$, $Cs_4ZnAu_2Cl_{12}$, $Cs_4HgAu_2Cl_{12}$, and $Cs_4CuAu_2Cl_{12}$ can be prepared, which show evident isomorphism where two univalent silver or aurous atoms are replaced by a bivalent atom.

That two of these new salts, $Cs_4Ag_2Au_2Cl_{12}$ and $Cs_4Au'_2Au'''Cl_{12}$ possess an astonishingly black color in comparison with the salts containing bivalent metals.

That the double salt $CsHgCl_3$ is isomorphous with $Cs_4HgAu_2Cl_{12}$ and with $Cs_4Au'_2Au'''_2Cl_{12}$, thus indicating, perhaps that the multiple formula $Cs_4Hg_4Cl_{12}$ should be ascribed to the former.

That no cesium-calcium-auric salt could be prepared.

Note: The next article in this series will describe a new cesium-auric chloride, and this will be followed by one dealing with a general discussion of triple salts, as well as another on a chromophore grouping, suggested by the black salts described here, and a consequent theory of the cause of the colors of substances.

New Haven, Conn., March, 1922.

ART. XXX.—*An American Spirulirostra;* by EDWARD W. BERRY.

In 1906 Emil Böse[1] described certain Tertiary molluscan faunas from the Isthmus of Tehuantepec in southern Mexico. These faunas as described comprised less than fifty species, and included no Cephalopoda, and the erroneous conclusion was reached that they indicated a lower Pliocene age.

Through the courtesy of the Transcontinental Oil Company I have received large collections of invertebrates from Tehuantepec, and it may be definitely stated, that this fauna, imperfectly described by Böse, is a rich tropical shallow-water fauna of several hundred species, and is clearly of Miocene age, as was recognized in the field by Dr. Bruce Wade, the paleontologist of the Company. It is hoped, that in the course of time a fully elaborated account of this interesting fauna will be published by one of my students in paleontology. Meanwhile I wish to call attention to one of the more spectacular elements of this fauna.

I refer to unusually good material of a new species representing the genus Spirulirostra which constitutes the first record of this interesting genus in the Western Hemisphere. The material is more complete even than the celebrated *Spirulirostra bellardi* described by d'Orbigny from the upper Miocene of Superga, near Turin, Italy—a reproduction of d'Orbigny's figures of which have embellished nearly every textbook of conchology and paleontology that has been published between 1842 and the present time.

This new species from Mexico may be called *Spirulirostra americana.* Upwards of a dozen specimens have been found. These usually represent merely the more resistant guard or rostrum with a part of the included phragmocone, and they are generally much worn by wave action. The best specimen, which is also slightly above the average in size, is scarcely worn, and shows a nearly complete guard with its contained phragmocone, and a large part of a proostracum; and it is this specimen from which the accompanying illustrations have been drawn.

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[1] Böse, E., Bol. Inst. Geol. Mexico, No. 22, 1906.

The guard or rostrum terminates behind as a smooth conical point. As it expands forward the rounded ventral face develops into a prominent boss, above which it is excavated below, and widened on either side into wide thick flanges, which form a sweeping forward curve to where they unite with the proostracum in front of the phragmocone. The boss of the rostrum and the margins of its wings are prominently mammilated, the surface reflecting the vascular structure of the enclosing mantle of the adult animal.

On the dorsal side the rostrum commences to flatten at a point about opposite its ventral boss, resulting in diverging rounded shoulders, flat top, and flattened sloping sides. The surface of the top becomes smooth as it is continued forward but the sides show subordinate vascular markings. The forward continuation of the rostrum forms a thick wall about the phragmocone, the earlier chambers of which form a subordinate boss, centrally located in the ventral concavity of the rostrum, some distance in front of the prominent ventral boss. The former is usually broken in the fossils, and the earlier chambers of the camerated shell can be seen through the resulting opening.

The protoconch is bulbous like those of the ammonites, and is not embedded in the ventral boss of the rostrum as it is in the other known species of Spirulirostra. The conch for the first five or six chambers is tightly coiled, endogastrically, but there is no impressed zone. The diameter of the chambers increases very rapidly as they curve upward away from the nepionic coiled portion, and then forward, as shown in the accompanying diagrammatic longitudinal section. In all there appear to have been 15 or 16 septa, which were probably transverse and nearly straight in profile, although they are broken away except near the sutures in every specimen seen. The siphon was small and followed the ventral wall. The phragmocone is circular throughout in cross section.

The proostracum is a thick, spatulate forward projection from the dorsal part of the rostrum, nearly flat above, with rounded edges, and mammilated surface, which becomes more conspicuously so toward its anterior rounded margin. Viewed from below it shows two flat lateral wings, each occupying about one fourth of its total width, and with the usual vascular markings. The central half of its ventral face gradually rises from the general surface in front of the phragmocone until at its anterior end it projects downward a distance twice as great as the proostracum is thick. This broad central keel is excavated to form a shallow arch, curving slightly forward and downward as a continuation of the arched dorsal part of the phragmocone, but there is no trace of ventral or side walls or any vestiges of there ever having been any septa. The anterior end of this squarish keel is broken away below the anterior margin of the proostracum as though in life it had continued forward a greater or less distance beyond the dorsal rounded margin of the proostracum as a sort of gladius or pen.

Dimensions:

Total length, 5.1 cm.

Distance from tip to center of ventral boss, 1.15 cm.

Distance from the tip to the boss marking the initial chambers of the phragmocone, 1.8 cm.

Length of the phragmocone, 1.7 cm.

Greatest diameter of the phragmocone, 6 mm.

Greatest distance between the later formed septa, 1.5 mm.

Length of proostracum, 2.6 cm.

Maximum width of the proostracum, 1.1 cm.

Maximum height of the rostrum in the region of the ventral boss, 1.0 cm.

The various features that I have attempted to describe in the foregoing paragraphs are well brought out in the accompanying dorsal, ventral, and lateral views[2], and in the two diagrammatical, partly sectional drawings.

This species is clearly distinct from previously known forms. From the best known of these, *Spirulirostra bellardi,* it differs in being slightly larger, with less sharply conical guard, its coiled early chambers, more flattened and much larger proostracum, and in having the phragmocone iniated as an internal protoconch some distance in front of the ventral boss, and not ventrally from a protoconch imbedded in this ventral boss. I am writing in terms of the finished product, and it should be understood that ontogenetically, the phragmocone preceded the guard and proostracum in order of development.

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[2] The two best of these I owe to the skill of G. S. Barkentine.

In addition to the type of the genus, *Spirulirostra bellardi*,[3] I know of four additional records. These are *Spirulirostra hoernesi*, described by von Koenen[4] from the Miocene of northern Germany; *Spirulirostra szajnochae*, described by Wojcick[5] from the *Clavulina szaboi* beds (Oligocene) of Galicia. This last is represented by a much worn rostrum showing traces of 7 septa of the phragmocone; there is no ventral boss to the rostrum and the specimen is smaller than the American form and much like *Spirulirostra hoernesi*. It may represent the same species as Roemer's record from the Oligocene of Westphalia. The third is *Spirulirostra curta* Tate[6] represented by rare, much worn specimens from the marly limestone of Janjukian age (Miocene) of Victoria, Australia. I fail to see any material differences between Tate's species and *Spirulirostra bellardi* d'Orbigny. The fourth is an obscure specimen from the Oligocene of Westphalia, named *Spirulirostra* sp., by Roemer[7], and of undetermined affinity.

Spirulirostra hoernesi was based upon two specimens from Dingdan, in western Westphalia. This species is shorter and stouter than the American form, with a more prominent and forward projecting ventral boss, with the phragmocone starting in the ventral boss as in *Spirulirostra bellardi*, and with a suggestion of a proostracum in the short, narrowed and truncated dorsal forward extension of the rostrum.

These occurrences suggest something of the probable habits of the animal. If we consider merely the Miocene records, which are more or less nearly synchronous, the unusual and rare occurrence of these fossils, at such widely removed localities as the Roman Mediterranean, North Germany, the Caribbean region, and Australia, appear to indicate that the animal was a pelagic form. Whether it had the habit of resorting to shallow water seasonally to deposit its eggs, as do some of the existing

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[3] d'Orbigny, A., Ann. Sci. Nat., 2 sér., tome 17, p. 374, pl. 11, figs. 1-6, 1842. I have counted 28 reproductions of d'Orbigny's figures in various text-books, and this probably does not exhaust the record.

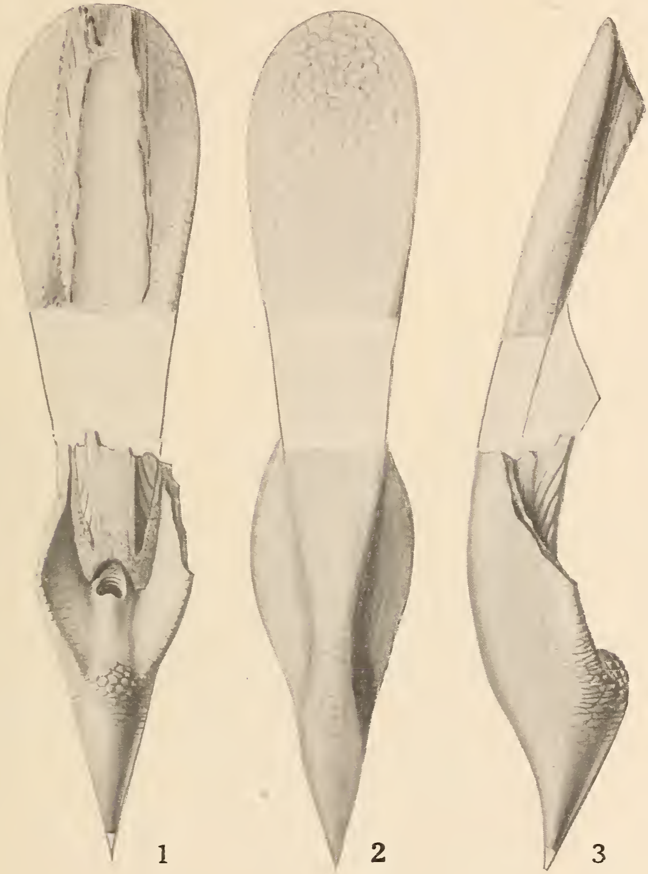
[4] Koenen, A. von, Palaeont., Band 16, p. 145, pl. 14, fig. 6a-h, 1869.

[5] Wojcick, M. K., Bull. intern. acad. sci. Cracovie, No. 10, 1903, p. 802, pl. 17, fig. 32, 1904.

[6] Tate, R., Proc. Roy. Soc. N. S. Wales, vol. 27, p. 170, pl. 1, fig. 1, 1893.

[7] Roemer, F., Neues Jahrb., 1851, p. 576.

FIGS. 1-3.



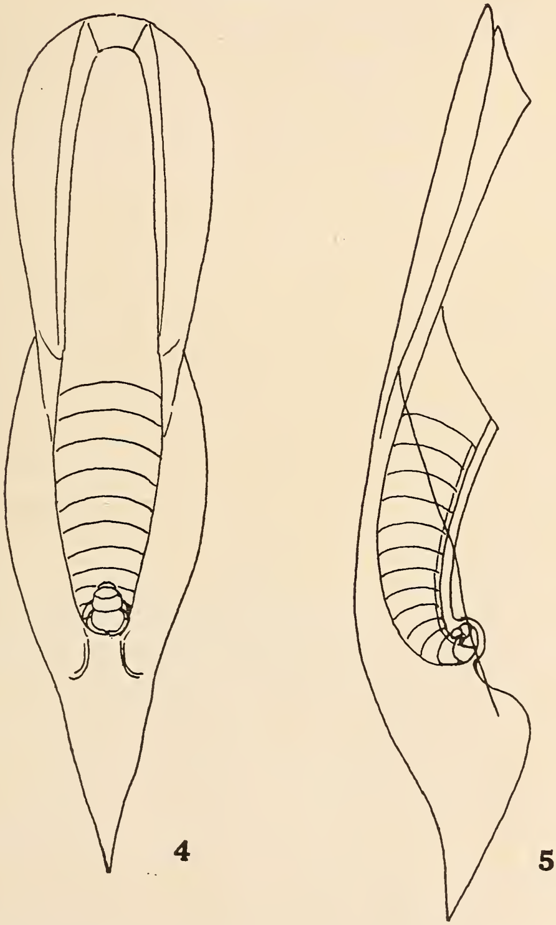
FIGS. 1–3.—Ventral, dorsal and lateral views of *Spirulirostra americana* Berry, × 2

cuttles that habitually pass their time in deeper water, or whether the shells were postmortem additions to the littoral faunas in which they are found, cannot certainly be determined. We can dismiss the idea advanced by one writer on Spirula, that air in the shells is responsible for the occurrence of that form on tropical sea beaches, as rather far fetched. The common European Sepias, which normally live in from 10 to 40 fathoms, come into shallow water during the summer to deposit their eggs, but it would seem that if such a habit were invoked to account for the presence of the Spirulirostra shells they ought to be discovered more frequently. On the other hand if chance drifted specimens from the open sea account for their occurrence in the fossil record, it is difficult to see why a single collection like that from Tehuantepec should contain the remains of a dozen individuals.

The habits of the existing Spirula might throw some light on the habits of Spirulirostra, but unfortunately little is known of the former, and the number of spirulas that have been taken could be enumerated on one's fingers, although the shells are common enough in the warmer parts of the Atlantic, Pacific and Indian oceans. The single animal taken during the extended cruise of the Challenger came from between 300 and 400 fathoms, but appeared to have been partially digested in a fish stomach, so that it sheds no light on the problem. It leads, however, to the suggestion of another possible means of transportation from deeper water, namely, in fish stomachs. Fishes are fond of the existing cuttles, and the habit of voiding undigestible hard parts is a common enough one on the part of fishes.

Without reaching any conclusion as to the source of the Spirulirostra remains in the deposits where they have been found, I think the conclusion is warranted that the animals were normally active pelagic types. The existing Spirula is unknown in the fossil record, and its openly coiled phragmocone shows no traces of having ever had a guard or proostracum. Some students have emphasized this point as though it were evidence of more direct relationship with the original ammonite stock than with the belemnoids. Such a line of reasoning, assuming that Spirulirostra is related to Spirula, which seems

FIGS. 4, 5.



FIGS. 4, 5.—Diagrammatic, partly sectional ventral and lateral views of *Spirulirostra americana* Berry, × 2.

probable, would necessitate considering Spirulirostra as a more evolved type than Spirula which had secondarily acquired a rostrum and proostracum. This is an absurdity for which the evidence is so rare, if indeed there is any instance, that it has led to the formulation of what is known as Dollo's law of the irreversibility of evolution. I think it may be concluded that both Spirulirostra and Spirula show vestiges of their more remote ammonite ancestors in their protoconch and ventral siphon, but that their more immediate ancestors were some unknown belemnoid forms, and that Spirulirostra might well serve as a prototype of the existing Spirula which subsequently lost all traces of the guard and proostracum, features whose loss may possibly be correlated with the modification of body form from more graceful lines in the direction of the short, stout bodied and truncated hind end of the existing Spirula.

Art. XXXI—*Meteoric Iron from Odessa, Ector Co., Texas;*[*] by George P. Merrill.

The fragment of an iron meteorite described below was brought to the writer's attention by Dr. A. B. Bibbins of Baltimore who states that it was found by a ranchman at the west side of a "blow out" about nine miles southwest of Odessa, a little east of Section 8, Block 43, Twnp. 3, S. Ector Co., Texas, and placed in his hands as a possible sample of iron ore. As received the fragment weighed 1,120 grains and was stated to have been cut from a larger mass—size not given. Exteriorly it was much weathered and oxidized and gave little indication of the customary pittings. The accompanying figure of a slice cut parallel with the greater dimensions is natural size. As will be noted, the structure is octahedral and of coarse crystallization (Og.). The etched surface is dull and lusterless and abundantly sprinkled with small, angular areas of schreibersite.

As the light is reflected from the etched surface at varying angles, the interior field gives the effect of having been cut parallel with the broad kamacite plates, while in the outer marginal portion they are cut more nearly at right angles. (See fig. 1.) The suggestion is that of an intergrowth of two portions of unlike orientation. Tænite plates are thin and inconspicuous as are plessite areas, the entire mass being composed mainly of the broad kamacite plates and the included schreibersite.

A slice of the iron freed from all crust and oxidation products and containing no visible troilite was turned over to Mr. E. V. Shannon of the Museum for analysis. He reports as follows:

"A portion of the iron weighing 13.3577 grams was dissolved in aqua regia and the nitric acid expelled by repeated evaporation with hydrochloric acid. The chloride solution was filtered on a Gooch filter, the residue being tabulated below as carbon. It possibly includes some other extraneous substances, as dust, etc. This residue was ignited after weighing and was practically all destroyed by the ignition. After ignition the asbestos mat was fused with potassium pyrosulphate, leached with

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[*] Printed by permission of the Secretary of the Smithsonian Institution.

water, the solution acidified and precipitated with ammonia, ignited and fused with sodium carbonate and potassium nitrate and leached with hot water. Only a doubtful and exceedingly faint trace of chromium was found.

The chloride solution of the entire 13.36 grams was precipitated with hydrogen sulphide, the precipitate being examined for copper and platinum. No platinum could be detected. The copper was thoroughly proven. The solution, after removal of hydrogen sulphide, was made up to 1 liter and portions of 50 cc. (.6679 gm.) were used for determination of iron, nickel, phosphorus and manganese, also soluble chromium. No manganese could be detected by the colorimetric method, nor could any soluble chromium be found. Cobalt was determined by the nitro-

Fig. 1.

Fig. 1.—Meteoric Iron, Odessa, Texas. Natural size.

sobetanapthol method on a 200 cc. portion of the solution (2.6716 gms.). Its identity was thoroughly established.

Sulphur was determined on a second portion of the iron weighing 13.4440 grams. This was dissolved in nitric acid, the sulphur separating in part as such in visible floating particles. This was oxidized with fuming nitric acid and determined as barium sulphate." The results of the analysis are as follows:

Iron	90.69
Nickel	7.25
Cobalt	.74
Copper	.02
Platinum	none
Chromium	trace
Manganese	none
Carbon	.35
Phosphorus	.23
Sulphur	.03
Total	99.31

These figures fall well within the limits of other analyses of iron of the coarse octahedrite group and need little comment. The small amount of material available for analyses is probably the cause of the apparent absence of platinum.

National Museum, Washington, D. C.

ART. XXXII.—*Some Sharks' Teeth from the California Pliocene;* by DAVID STARR JORDAN.

To Mr. H. Maus Purple, general manager of the Torrance Lime and Fertilizer Company of Los Angeles, I am indebted for the opportunity to examine a number of shark teeth of the man-eater type (*Lamnidæ*), surprising in the fact of their coming together in one place. These teeth were found in deposits of bones and shells of Pleistocene age, composing hills at Torrance and Lomita, suburbs of Los Angeles, between the city and the ocean. The shark teeth may be described in detail.

1. CARCHARODON BRANNERI Jordan.

Two specimens—both of extraordinary size, as large as the largest *Carcharodon megalodon* of deposits along the Atlantic.

The largest of these has the crown three inches in height, the oblique length of its distal margin six inches. It is somewhat oblique, the interior more convex and relatively vertical; tip rather blunt. Edges of the tooth somewhat irregular with obsolete serrations—but no well-defined serrations except near the base.

A second specimen shows about half the tooth, split lengthwise. It shows the long exterior margin about four inches long, the crown 2¾ inches high. This like the other is flat or a bit concave on the interior side, but the sharp edge is obviously but very finely serrated, the serræ blunt, 120 to 125 in number along the side.

These teeth may be provisionally identified with *Carcharodon branneri* described by me[1] from Bolinas Bay, California. These specimens are larger than even this giant species, and the serræ much finer. The type of *Carcharodon branneri* may however have been a median tooth of a smaller example, the teeth perhaps less worn.

In the collection from Torrance, there is another large tooth which corresponds almost exactly to *Carcharodon branneri*. The crown is 2¾ inches high, the long margin somewhat over three inches. The tooth is more erect

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[1] The Fossil Fishes of California, Univ. of California, Publ., V. no. 7, p. 116, 1907.

FIG. 1, *a* to *g*.

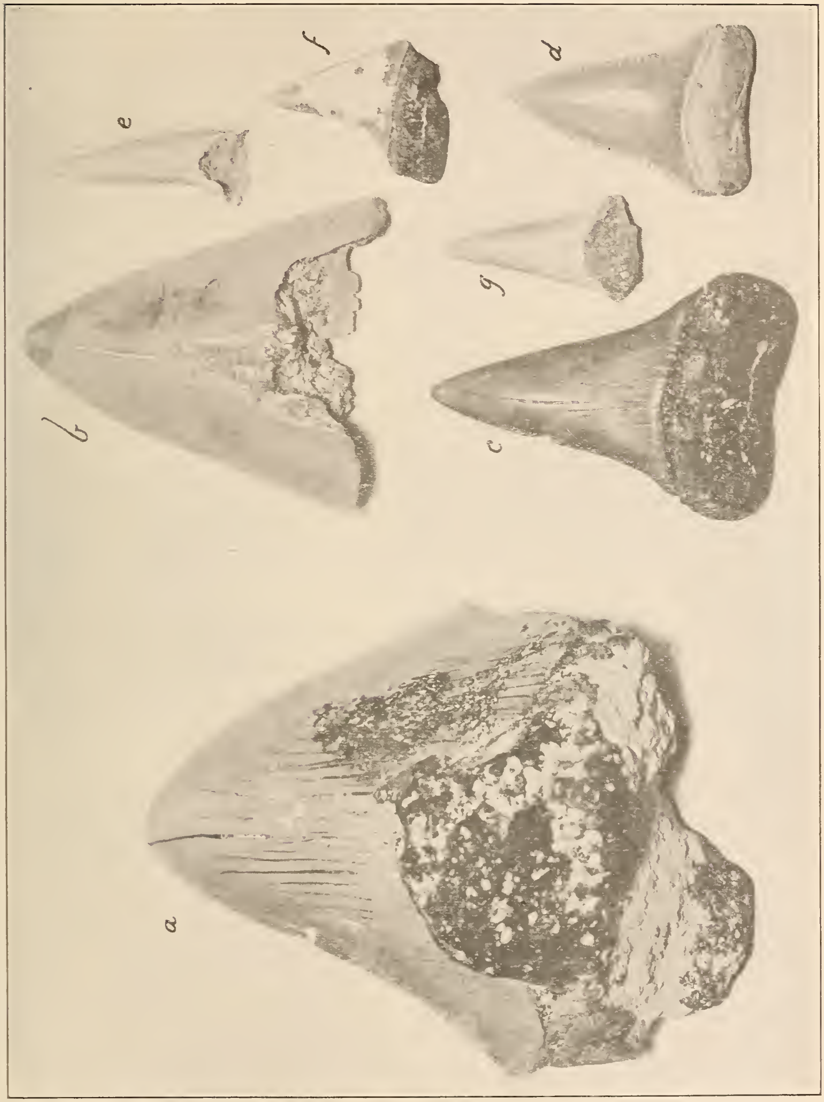

FIG. 1.—*a. Carcharodon branneri,* Jordan. *b. Carcharodon riversi,* Jordan. *c. Isurus planus,* submedian tooth, Agassiz. *d. Carcharodon carcharias.* L. *e. Isurus* (?) *glaucus,* submedian tooth, M. and H. *f. Isurus* (?) *glaucus,* lateral tooth, M. and H. *g. Isurus* (?) *glaucus,* median tooth, M. and H.

than the others, the interior edge quite flat and the exterior quite convex. The tooth is serrulate to the tip, the serræ coarser than in the larger examples, all bluntish and about eighty to be counted, twenty or more apparently broken off.

This tooth is plainly identical with the type of *Carcharodon banneri* but it may be different from the two larger examples. Perhaps the distinction is due to its being less worn and from a different part of the mouth.

From *Carcharodon megalodon* Charlesworth, the giant species of deposits along the Atlantic Coast, the present form is plainly different as in *C. megalodon,* the serræ are far larger and coarser.

In life, the present species must have reached a length of more than one hundred feet, as *Carcharodon carcharias,* the living species of "Man-Eater," reaching a length of thirty-five feet, has teeth barely an inch in height.

2. CARCHARODON ARNOLDI Jordan (*Carchorodon riversi* Jordan).

In the same collection from Torrance is a specimen which corresponds perfectly to the type of *Carcharodon riversi* Jordan, described by me on page 115, of the same paper, from Pliocene deposits near Santa Monica. In this example the crown is nearly two inches high, the tooth narrowly triangular, nearly flat, and about as high as broad at base. The denticles are coarse and blunt, the total number being about 45 on each side. This species is however very doubtfully distinct from *Carcharias arnoldi* described by me (p. 113) from the Pliocene of Pescadero, and since found in different deposits of the California Miocene at Lompoc, in Kern County, and elsewhere.

3. CARCHARODON CARCHARIAS (L.).

From the same deposits at Torrance, but possibly at a higher level I have a small tooth which must belong to the living "Man-Eater," still extant on the California Coast. It is an inch in elevation, 1¼ in slant height, narrower than *C. arnoldi* and with the edges more flexuous. The

FIGS. 2 and 3.

FIGS. 2, 3.—*Carcharodon branneri,* Jordan. Pleistocene: Torrance, California.

serræ are strong and sharp, much larger and sharper than in the extinct species found in California, about 32 on each side, besides eight or ten much smaller ones on the lower angle of the tooth, the median serræ much larger than those at the base and tip. Tip of the tooth sharper than in any of the others, the root less concave in outline, the crown narrower, its base 1¼ in its height.

4. Isurus planus (Agassiz).

(*Oxyrhina tumulus* Agassiz: *Isurus smithi* Jordan).

From the same deposit, I have the tooth of an *Isurus,* the crown of which is 1½ inches high, the tooth narrow and nearly erect, corresponding fairly to the figures of *Isurus smithi* Jordan (p. 11), but broader at the base than any of those figured, the base of the crown being two-thirds its height.

As in this genus, the teeth are very differently formed in different parts of the mouth. I do not lay stress on these differences, and I have no doubt of the identity of *Isurus planus, tumulus* and *smithi,* all from the Kern County beds. And these differ but slightly from *Isurus hastalis* (Agassiz) of Europe, with which Jordan and Beal, in a later paper (op. cit., vol. VII, 251, 1913), following Maurice Leriche, have identified them. In most of the specimens figured by Agassiz, however, as *hastalis,* the inner face of the tooth has an obsolete ridge. This appears on one or two only of our multitude of specimens of *Isurus planus.* In view of the fact that all these California fossils have been described as distinct species, it is better to retain these names until adequate comparison can be made with related species in European deposits. The living sharks along the Pacific Coast have yet to be critically compared with their Atlantic relatives, and in most cases where comparison has been made, the species are found to be distinct.

From Torrance, I have also three much smaller teeth which may be merely the young of the same species as they seem too large for the living Mackerel Shark, *Isurus glaucus* (Müller & Henle), still extant in the Pacific. These come from different parts of the mouth, one, a slender median tooth, being an inch high.

The genus *Isuropsis* Gill, represented in both oceans, has the teeth essentially as in *Isurus* proper (*Oxyrhina* Agassiz) but the lateral teeth are more slender. *Isuropsis* is probably not tenable as a distinct genus.

Stanford University, California.

Jour 71-30 — Lang 55

Art. XXXIII.—*An Upper Cambrian Fauna of Pacific Type in the European Arctic Region;* by Olaf Holtedahl.

During the recent Norwegian scientific expedition to Novaya Zemlya, the long, arched islands north of the Ural mountains, the present author, who was also the leader of the expedition, tried to clear up as much as possible of the stratigraphy and tectonics of that vast country.

I shall not here go into the question of the general geological structure of this old mountain range, folded in Permian time, nor into the stratigraphy of those Paleozoic formations which have been previously known to exist in these islands, viz., the Devonian and the Carboniferous, but will only bring to the attention of geologists the occurrence here of strata as old as the uppermost Cambrian. As our knowledge of Cambrian rocks beyond the 70th degree of latitude is exceedingly scarce, the find is of considerable interest. It may be useful, therefore, to give a short preliminary note of this discovery, as the working out of all of the fossils gathered during the expedition will take considerable time.

The fossils were found near the west coast of the southern island, on the peninsula between Bessimyanni and Gribovii fjords. The first fossils were found in the mountains 7 kilometers northwest of the head of Bessimyanni Fjord (about 73° N. L.) in a rather dark grey, fine-grained calcareous sandstone. By following the general strike of the rocks (here N.-S.) I found further north a fossiliferous sandstone of a somewhat different character, lighter colored and with thin layers of somewhat crystalline limestone. This rock continues down to the Gribovii Fjord. The preservation of the fossils is generally rather bad and their original form has commonly been altered by the tectonic pressure.

At the southern locality were found the following forms: a species of brachiopod that is by far the most common fossil and that belongs to *Huenella* Walcott, a genus known from the Cambrian of North America, China, and Australia. The form, of which illustrations are given in figure 1, in its general exterior features is very suggestive of *H. texana* Walcott from the Upper Cambrian of Texas. Indeed, there exist in my material many valves that do not in any respect differ from those shown in Walcott's illustrations (see fig. 1, p. 103 of Cambrian Brachiopoda, U. S. Geol. Surv. Mon. **51**, 1912). Rather often, however, the Arctic specimens show more acute cardinal angles (compare the cast of the dorsal valve figured here) and more numerous plications, these occurring rather evenly distributed both over sinus and fold and the lateral parts. This species reminds one strikingly of a small *Platystrophia biforata,* the dorsal valves being also *Spirifer*-like. The rather broad and evenly plicated type of this extremely variable Arctic species is very near to another North American species of the same genus, *H. lesleyi* Walcott, from the Upper Cambrian of Utah (see op. cit., text fig. 75). In the natural casts of the interior such as are commonly found (the interior characters can also easily be shown artificially by using acid), we notice the typical characters of the Syntrophiidæ. As to whether the interior of this Arctic species corresponds in every detail to that of the American forms mentioned, I can not tell, as I have seen no illustrations of the interiors of the latter.

Besides the *Huenella* two orthoid brachiopods occur, one of which may be identical with *Eoorthis? melita* Hall and Whitfield, while the other is of the type of *Eoorthis wichitaensis* Walcott so far as the dorsal valves are concerned; the ventral valves in the latter, however, do not have the even, gentle convexity of *Eoorthis,* but are flat, with elevated umbones reaching rather far beyond the hinge-line. In addition, there are fragments of inarticulate brachiopods, a *Hyolithus,* and traces of gastropods (of the type of *Pelagiella pagoda* Walcott). Fragments of trilobites also occur, commonly the central part of cephalons. At least four species are represented: one is probably a *Ptychoparia,* another a *Solenopleura* of a rather extraordinary type, with the frontal rim very broad and very prominent. In addition occur fragments of a *Ptychaspis* sp. and of a small *Illænus*-like form, with the dorsal furrows widely spaced and developed only in the posterior part of the head; the occipital furrow is well developed, differing in this respect from congeneric forms.

From the lighter colored fossiliferous calcareous sandstone a very large amount of material was collected, since the rock is exposed at the shore. The preliminary study shows, however, that there are only a few species represented. Exceedingly common is an orthoid that may be nearly related to *Billingsella coloradoensis* (Shumard). Very rarely represented is another species of orthoid, a reversed type, the general form of which is rather like that of the reverse shell mentioned from the southern locality. The surface characters of the former, however, are different, showing rather prominent, well rounded striæ, of fairly equal strength, set relatively far apart, and crossed by strongly marked and beautiful concentric lines of growth. It suggests a *Hebertella*. Of inarticulate brachiopods, there are fragments of an *Obolus* belonging to the subgenus *Westonia*, showing the characteristic transverse parallel lines of ornamentation. Of trilobites, one species is common, which for the present I will refer to *Anomocarella*, since the characters of both cephalon and pygidium correspond with types that Walcott describes in his paper on the Cambrian faunas of

Fig. 1.

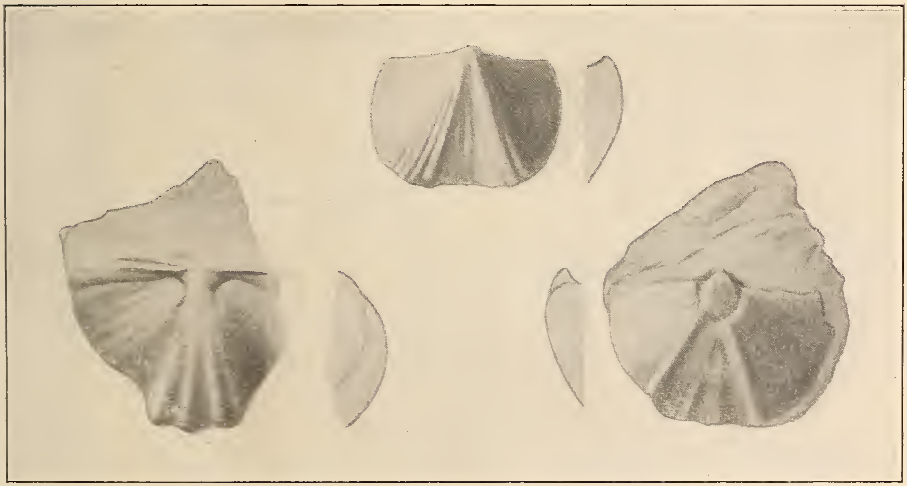

Fig. 1.—*Huenella* cf. *texana* Walcott, × 3. From Nova Zembla.
Above: exterior of a ventral valve.
Below: natural casts of interior of a dorsal and a ventral valve.

China (Research in China, 3, Washington, 1913). Yet the size of the pygidia seems to be somewhat larger in comparison with the associated cephalons than is general in *Anomocarella,* in this respect resembling *Asaphiscus* Meek. Besides these, there are two large fragmented cephalons that do not seem to differ from *Illænus,* a type of trilobite that we do not expect in the Cambrian. A nearly smooth pygidium with axis only faintly indicated may belong to the genus *Symphysurus* Goldfuss, or to *Tsinania* Walcott.

As to the age of the fossils from the southern locality, there seems to be no reason to doubt that the presence of *Huenella* indicates Upper Cambrian time. The genus is especially characteristic of this epoch and is not known to occur in the Ordovician. The two American forms that come nearest to the species from Novaya Zemlya both occur in the Upper Cambrian, and there is nothing in the character of the rest of the fauna that nullifies such a conclusion. That we are dealing with a time very close to the base of the Ordovician is indicated by the types of orthoids, especially the reversed type pointing to Ordovician relations.

In the fossils found in the light colored sandstone, this faunal relation to post-Cambrian (Ordovician) strata is still more emphasized by the occurrence of a species of *Illænus.* Yet the dominating trilobites are such that we should not expect the time to be younger than Ozarkian.

Even this preliminary study of the Novaya Zemlya fossils shows with great distinctness that the faunas in their general expression are highly different from those of the Upper Cambrian (and basal Ordovician) of the British-Scandinavian region and of the North American Atlantic area as well. They are essentially like those from the Cordilleran and Interior regions of North America, and from China. It seems evident that in Novaya Zemlya we are dealing with Upper Cambrian strata and fossils that belonged to a large, world-wide ocean, compared with which the North European Upper Cambrian sea with its relatively poor and monotonous trilobite fauna has a very local dispersion. The dominance of the "Pacific" realm of Upper Cambrian time, as compared with the restricted "Atlantic" one, now becomes still more accentuated, since the great Arctic region evidently belongs to the former.

In a short article on Paleogeography, written in Norwegian,[1] I mentioned as a probable supposition that the Scandinavian Middle and Upper Cambrian alum shales with their high content of bituminous and carbonaceous matter were deposited in a relatively closed basin, with no open connection into the Arctic Ocean. With the discovery in Novaya Zemlya of the fossils here discussed, I think this supposition has been considerably strengthened, since we must now assume a land barrier and not an open connection between the Novaya Zemlya sea and the Scandinavian one. We do not observe, in the Upper Cambrian faunas of Scandinavia, any marked difference when we pass from Scania northward into Jämtland, which is halfway the total length of the peninsula.

FIG. 2.

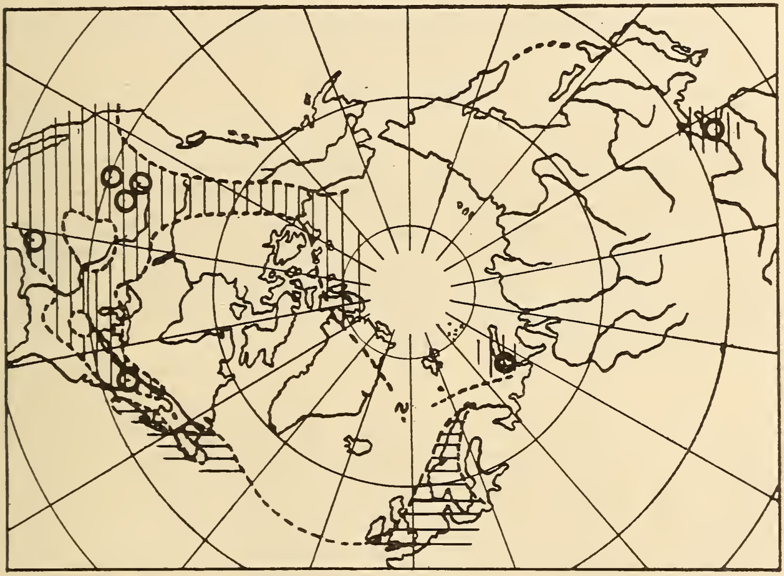

FIG. 2.—Map showing distribution of Upper Cambrian seas; vertical lines mean "Pacific"; horizontal ones "Atlantic" faunal realms. American conditions after Schuchert 1915. Rings mark occurrence of *Huenella*.

In the map, fig. 2, I have marked the known areas of Upper Cambrian seas, with an indication of the probable

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[1] Naturen, p. 81, 1919.

trend of the dividing land in the Arctic region as it appears to me. With what we knew before, it is now evident that, as regards the distribution of the two presumably separated oceanic realms, we are dealing here with phenomena of a rather general and not a casual character. I might recall that in another Arctic region just north of the coast of the European mainland, that is, Bear Island (between Norway and Spitzbergen), both the Lower and Middle Ordovician strata have an American and not a European fauna.[2]

For the probable paleogeography of these younger times I may refer to a recent article in this Journal.[3]

University of Kristiania, February, 1922.

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[2] See O. Holtedahl, Notes on the Ordovician fossils from Bear Island collected during the Swedish expeditions of 1898 and 1899, and On the Paleozoic series of Bear Island, especially on the Heclahook system, both papers printed in the Norsk geologisk Tidsskrift, 5, 1918-1919.

[3] O. Holtedahl, Paleogeography and diastrophism in the Atlantic-Arctic region during Paleozoic time. This Journal (4), **19**, 1, 1920. I will again take the opportunity to correct the bad error which was made during the printing of this aricle. The maps illustrating Upper Devonian and Upper Carboniferous time should be exchanged.

Art. XXXIV.—*The Great Dustfall of March 19, 1920;* by Alexander N. Winchell, Professor of Mineralogy and Petrology, University of Wisconsin, and Eric R. Miller, Meteorologist, U. S. Weather Bureau.

Object of the Investigation.—Since the dustfalls of March, 1918, that we reported in this Journal[1] and the *Monthly Weather Review*,[2] we have collected the solid precipitates from all storms, with the object of throwing light on (*a*) the probable origin of the dust, (*b*) the contribution of plant food to the soils of the Eastern States, and (*c*) the chemical relationships between American and European dustfalls. During the interval of more than three and a half years there has been only one unusually heavy deposit of atmospheric dust at Madison, Wisconsin, namely that of March 19, 1920.

Sources of Material and Information.—The dust was first noticed by us in the upper layers of a fall of 0.4 inch of snow and sleet, to which it gave a grayish tinge, on the morning of March 19, while the last of the fall was still coming down. We immediately collected samples from measured areas in various places, in Madison.

Professor Charles F. Marvin, Chief of the Weather Bureau, upon our request, very kindly sent a telegraphic request to the officials in charge of seven offices, to collect samples of the dust and send them to us. The places from which these samples were received, and the officials to whom we are indebted for material, and descriptions of the precipitate *in situ* are

Charles City, Iowa.	H. P. Hardin.
Dubuque, Iowa.	J. H. Spencer.
Green Bay, Wis.	F. W. Conrad.
La Crosse, Wis.	E. C. Thompson.
Ludington, Mich.	C. H. Eshleman.
Saginaw, Mich.	F. H. Coleman.
St. Paul, Minn.	J. N. Ryker.

At Charles City, Dubuque, and La Crosse the dustfall was noticed by the observers. At Dubuque it was

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[1] Vol. 46, p. 599, 1918, and vol. 47, p. 133, 1919.
[2] Vol. 46, p. 502, 1918.

observed as a gray coating that stuck to everything after the snow melted, and was considered the heaviest dustfall in fifteen years. At Charles City, it was yellow or straw-colored clay. At La Crosse, it appeared as a light brownish layer, first noticed in shoveling the snow off the walks in the morning. The dust-bearing snow rested upon an inch of pure white snow. At the other places the dust did not noticeably discolor the snow.

A postal inquiry was also sent to a hundred observers, mostly co-operative observers in small towns where the chance of local soot and dust was small. Sixty-seven replies were received, and the samples of dust accompanied reports from the following:

Carlisle, Pa.	C. E. Miller.
Louisville, Ky.	J. L. Kendall.
Westboro, Mass.	Emily W. Newcomb.

At Louisville there was a pronounced brownish haze in the sky. At Carlisle the dust was first noticed in the melting of snow from the snow gage for measurement. At Westboro the dust appeared on the surface of melting snow. Other observers, who had noticed the deposit, but did not collect samples reported as follows: C. D. Reed, Des Moines, Iowa, says "there was an appreciable deposit of yellowish clay on the roof of our building during this storm. The amount was not more than one-third as great as occurred in the storm of February 13-14, 1919." Mr. Wm. F. Baker, at Decorah, Iowa, reported that "there was a fall of 1.5 inches of snow, the first layer about .5 inch was pure white, the next half inch light brown, and the top was a layer of pure white. At Columbus, Ohio, Mr. William H. Alexander reported "no dust or mud deposit was noted at this office, but several telephone calls inquiring the cause of the mud deposit came from the southern section of the city." At Wilmington, Ohio, Mr. Erskine R. Hayes noted "March 19, 11:35 a.m. Muddy hail fell. When melted in a pan left quite a deposit of brownish-yellow loam, slightly gritty. Rain which followed was also very muddy, left quite a lot on roofs, and spattered sides of buildings." At Raquette Lake, N. Y. Mr. R. J. Dunning entered: "March 19: 5 p.m. a round hard snow, almost like hail, 4.3 inches, was dirty." Fifty of the replies were negative, the reporters not having noticed anything, and the traces having disappeared by the time the inquiry reached them.

The Origin of the Dust.—The meteorological conditions that produced this dustfall were quite similar to those of the dustfall of March 8-9, 1918. The dust-bearing winds accompanied Low V of Chart III, Monthly Weather Review, March, 1920. The track of this storm is reproduced in fig. 1 of this paper. Excepting the secondary center that developed in Arkansas on March 18, 1920, this track is practically identical with the track of the storm that brought the dustfall of March 8-9, 1918 (Compare fig. 1, Monthly Weather Review, November, 1918, page 502.)

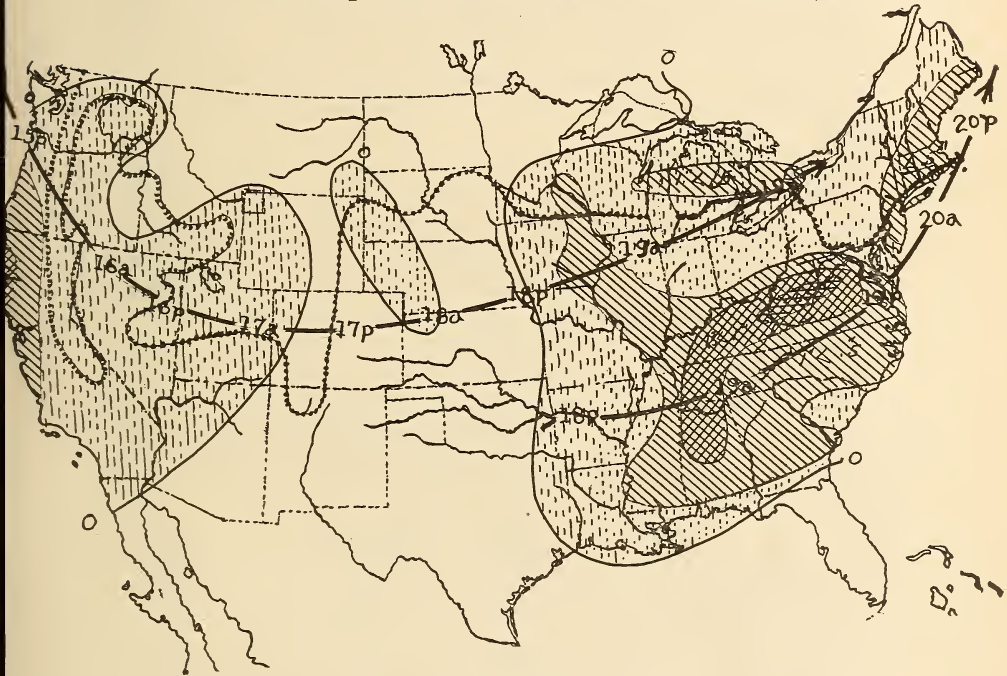

FIG. 1.—Dust-bearing storm of March 15-20, 1920, "17a," "17p," etc., show position of storm center at 8 a. m. and 8 p. m., March 17th, etc. Shaded areas show total precipitation of rain and melted snow during the storm, each shade corresponding to a range of half inch in depth of precipitation. Dotted line is limit of snow on ground 8 p. m., March 15, 1920.

The storm of March 18-19, 1920 was more severe on the High Plains, and less severe east of the Missouri valley than the storm of March 8-9, 1918. Throughout the region between Denver and Cheyenne the 1920 storm was recorded as the worst March windstorm since 1901. Barns, windmills, and telephone and telegraph poles were blown down by hundreds. Plate glass windows were blown in, winter grains were blasted by the driving sand. Many fires were started by the wind, Denver reporting 43, the greatest number in one day in the history of the fire department. The air was so filled with drifting snow in the mountains, and with drifting dust and sand on the plains that trains on the Moffat Road and the Colorado and Southern Railway were halted for hours. The dust clouds darkened cities in northeastern Colorado in broad sunlight on March 18, so that artificial light had to be used.

The dust storm prevailed as far east as St. Joseph, Kansas City and Little Rock, where it was reported that the "air was full of dust, sifting into offices, and covering books and papers." Haze was noted as far eastward as Nashville, Tenn., and Columbus, Ohio, where the haziness prevailed on the forenoon of the 19th so long as the wind was from the southwest, but disappeared with the change of the wind to the northwest.

This storm was competent to cause eolian erosion throughout its track from the Rocky Mountains eastward. It caused the highest winds of the month of March, 1920 at the following places:

	Velocity.	Direction.	Date.
Denver	51	W	18
Cheyenne	74	W	18
Topeka	50	W	18
Iola	36	W	18
St. Joseph	52	W	19
Kansas City	55	W	18
Little Rock	49	NW	19
Knoxville	36	SW	19
Thomasville	24	SW	19
Jacksonville	49	SW	19
Asheville	33	NW	20
Eastport	56	NE	20

The state of the ground as to snow cover as last reported before the passage of the storm is shown in fig. 1. All of the central and southern Plains and the southern Plateau region was exposed.

From the foregoing facts, we infer that the dust was mainly derived from the region of intensest wind, in northeastern Colorado and southeastern Wyoming, and that the supply of soil material in the air was augmented by smaller contributions from most of the southwestern states.

Distribution of the Dustfall.—The samples of dust that have been sent us, and the reports of observation of dust, are from far too few places to enable us to attempt to map the distribution of dust, as was done by Hellmann and Meinardus[3] and by Mill and Lempfert[4] for the European dustfalls of 1901 and 1903.

The rain area of the storm of March 15-21, 1920, shown in fig. 1, indicates that most of the eastern half of the United States was a region of possible precipitation of dust by washing down with rain or snow. It is interesting to note that the region of intensest blowing between the Rocky Mountains and the Missouri valley remained unwetted during the storm.

Chemical Composition.—In the chemical study of the samples of dust we have had the help of Dr. E. J. Graul, of the Department of Soils, University of Wisconsin, who determined the nitrogen, phosphorus pentoxide, the alkalies, and the water lost at 105°.

A grant of funds for additional chemical work was made from the research fund by the Regents of the University of Wisconsin. The analyses under the grant were made by Mr. Martin Tosterud, working under the direction of Professor A. R. Whitson, in the laboratories of the Department of Soils of the University of Wisconsin. Mr. Tosterud determined silica, alumina, iron, magnesia, lime, titanic acid, and water lost on ignition in three samples. By the additional determination of the total loss on ignition we are enabled to present the following relatively complete analyses of three samples.

In these analyses it was not practicable to determine the state of oxidation of the iron; total iron was determined and calculated to be ferrous oxide since the dust in mass is gray and not colored red or yellow by ferric iron. But it is recognized that some ferric iron is present, since its colors are distinct under the microscope.

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[3] Der grosse Staubfall, Abh. k. Preuss. Meteorl. Inst., II, 1901.

[4] The great dustfall of February, 1903, Quart. Jour. Roy. Met. Soc., 30, p. 57, 1904.

TABLE I.—*Analyses of three samples of dustfall at Madison, March 19, 1920.*

(Dried at 105° C.)

	I	II	III	Average
SiO_2	68.61	66.32	66.66	67.20
Al_2O_3	13.81	13.44	13.89	13.71
FeO[a]	2.24	2.10	2.17	2.17
MnO	.33	.42	.41	.39
MgO	1.63	1.71	1.94	1.76
CaO	1.81	1.83	1.59	1.74
Na_2O	1.64	3.04	1.64[b]	2.11
K_2O	2.22	2.11	2.56	2.30
H_2O+ (above 105°C)	2.55	3.47	3.63	3.22
TiO_2	.53	.53	.52	.53
P_2O_5	.14	.16	.16	.15
N	.37	.41	.37	.38
Ignition[c]	5.52	5.66	5.68	5.62
	101.40	101.20	101.22	101.28
H_2O-(below 105°C)	3.23	2.91	2.19	3.11

[a] Metallic iron determined and calculated to FeO.

[b] Not determined on account of lack of material; assumed to be the same as in sample I.

[c] Includes organic matter and CO_2, but not H_2O nor N.

I. Dustfall collected by E. R. Miller from one square meter of surface at 2125 Van Hise Ave., Madison, Wis., 19 March, 1920.

II. Dustfall collected by W. S. Fusch from one square yard of surface of ice about 1,000 feet north of Science Hall on Lake Mendota at Madison, Wis., 19 March, 1920.

III. Dustfall collected by A. N. Winchell from one square yard of porch roof at 200 Prospect Ave., Madison, Wis., 19 March, 1920.

It was hoped that special tests could be made to measure the tenor of water soluble salts, of organic matter, and of carbon dioxide,[5] but scarcity of material prevented, as it likewise prevented the determination of soda in sample number III. It is our opinion that sample number II is abnormally high in soda for some unknown reason; therefore, we have assumed for purposes of mineral calculations that sample III has the same tenor of soda found in sample I.

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[5] Sample I showed no visible effervescence when treated with warm HCl, but carbonates can be recognized in small amount in all the Madison samples under microscope.

It is remarkable that no chemical analyses of samples of American dustfalls are on record. Furthermore, analyses of foreign dustfalls are very uncommon and several of those published are too incomplete to be satisfactory for comparisons or for calculations of mineral composition. All the other chemical analyses of foreign dustfalls are assembled in the following table in which the average of the analyses of the Madison dustfall is included for convenience.

TABLE II.—*Analyses of foreign dustfalls compared with the average of the Madison analyses*:—

	I	II	III	IV	V	VI
SiO_2	67.20	53.68	45.94	45.40	41.43	36.32
Al_2O_3 ...	13.71	18.44	18.35	19.97	10.38	16.35
Fe_2O_3 ...		6.54	6.57	7.03	9.19	6.08
FeO	2.17					
MgO	1.76	1.52	1.86	3.13	.92	2.21
CaO	1.74	.95	8.64	6.50	14.10	6.24
Na_2O	2.11	1.67	1.16	2.61	1.66	2.59
K_2O	2.30	2.58	2.30	2.07	1.58	2.72
H_2O+ ...	3.22					
CO_2			6.10	3.46	8.45	3.68
TiO_2	.52					
P_2O_5	.15			.20		
MnO	.38					
N	.39		.16			.16
Ignition...	5.62	14.60	6.73	8.19	5.14	13.44
Total ...	101.28	99.98	100.00	99.73	99.00	100.00

I. Average of three analyses of dustfall at Madison, 19 March, 1920.

II. Analysis after air drying of dustfall at Otakaia, New Zealand, Nov. 14, 1902, which came about 1,500 miles from Australia. P. Marshall: Nature, **68**, p. 223, 1903.

III. Dust in "red rain" fall at Lamberhurst, England, 22 Feb., 1903. 2.19% of organic carbon included in total. T. E. Thorpe, Nature, **68**, p. 54, 1903.

IV. Dustfall at Naples, Italy, March 10, 1901. P. Palmeri: Rend. Accad. sci. fis. Naples, (3), **7**, p. 157, 1901.

V. Dustfall at Naples, Italy, 25 February, 1879. Analysis by Scacchi, quoted by P. Palmeri, *loc. cit.* p. 161. 4.16% of organic material and 1.39% "loss" included in total.

VI. Analysis (after air drying) of dustfall at Taormina, Sicily, 19 March, 1901. The fall amounted to 5½ tons per square mile. T. E. Thorpe, Nature, **68**, p. 222, 1903. 9.89% of organic carbon and 0.32% of CoO included in total.

The dustfall at Madison is the most siliceous of these analyses, but an incomplete analysis of a dust which fell in Tunis[6] in 1901 revealed 70.95% of silica, and the tenor of silica in siroccan dust from the Sahara reaches a maximum of 73.45%,[7] calculated on a water-free basis.

The dust from the Sahara is always red and produces the "red rain" or "rain of blood" sometimes noted in Europe. This is due to the thoroughly oxidized state of the iron which is unlike the condition found in the Madison dust. In the percentage of alkalies and alumina the latter does not differ markedly from the samples from the Sahara, but it contains far less lime and very little carbonic acid as carbonate, in contrast with the Saharan dust. In these particulars the Madison dust closely resembles that fallen at Otakaia, New Zealand, which was derived from the continent of Australia.

In some respects the Madison dustfall resembles, in chemical composition, the loess of the Mississippi valley more closely than it does the dust from the African desert. This is shown in the following table.

TABLE III. *Chemical composition of Mississippi valley loess compared with the average composition of the Madison dustfall.*

	1	2	3	4	5	6
SiO_2	64.61	67.20	70.11	70.86	72.68	74.46
Al_2O_3 ...	10.64	13.71	14.25	8.91	12.03	12.26
Fe_2O_3 ...	2.61	....	4.02	2.97	3.53	3.25
FeO	.51	2.17	....	.10	.96	.12
MgO	3.69	1.76	1.32	3.12	1.11	1.12
CaO	5.41	1.74	1.53	4.13	1.59	1.69
Na_2O	1.35	2.11	1.09	1.69	1.68	1.43
K_2O	2.06	2.30	2.03	1.18	2.13	1.83
H_2O + ..	2.05	3.22	2.48	1.10	2.50	2.70
CO_2	6.31	....	....	4.70	.39	.49
TiO_2	.40	.52	....	.59	.72	.14
P_2O_5	.06	.15	....	.40	.23	.09
MnO	.05	.38	....	.28	.06	.02
Total	100.06	101.28	100.33	99.98	100.22	99.83

[6] E. Bertainchand, *Compt. Rend.*, 132, p. 1153, 1901. According to L. Cayeux this dust contained quartz, staurolite, tourmaline, rutile, zircon, magnetite, yellow phosphate, and diatoms.

[7] E. E. Free, *U. S. Bur. Soils*, Bull. **68**, p. 95, 1911.

1. Loess from a stratum overlying residual clay, 350 feet above the Mississippi River, near Galena, Illinois. Chamberlin and Salisbury, 6th Ann. Rep. U. S. Geol. Survey, 1885, p. 282. Dried at 100° C. 0.13% of organic carbon, 0.11% SO_3 and 0.07% Cl included in total.
2. Average composition of Madison dustfall, March 19, 1920. 5.62% ignition loss and 0.39% N. included in total.
3. Loess from Kansas City, Mo. W. E. McCourt, Missouri Bureau Geol. & Mines, vol. **14**, p. 94, 1917. 3.50% ignition loss included in total.
4. Loess from depth of 8 feet at brickyard at Mt. Vernon, Ia. N. Knight, Am. Geol. **29**, p. 189, 1902.
5. Loess from 300 feet above the Mississippi River, 3½ miles north of Dubuque, Ia. Chamberlin and Salisbury: 6th Ann. Rep. U. S. Geol. Survey, 1885, p. 282. Dried at 100° C. 0.51% SO_3, 0.09% organic carbon and 0.01% Cl included in total.
6. Loess from Kansas City, Mo. Chamberlin and Salisbury: 6th Ann. Rep. U. S. Geol. Survey, 1885, p. 282. Dried at 100° C. 0.12% organic carbon, 0.06% SO_3 and 0.05% Cl included in total.

Except as to the state of oxidation of the iron the Madison dust is closely similar to the loess from Kansas City studied by McCourt; it is also much like the loess from Dubuque and that from Kansas City examined by Chamberlin and Salisbury; it differs from the loess of Galena, Illinois, and that from Mt. Vernon, Iowa, in the scarcity of carbonates of calcium and magnesium.

Mineral Composition.—The components of the dust are so extremely fine grained that it is quite difficult to make satisfactory determinations of the mineral constituents with the microscope and it seems to be wholly impracticable to attempt any quantitative determinations microscopically because so large a proportion of the material is too small for identification. However, samples from Madison contain abundant quartz grains in tiny angular forms and no other recognizable mineral in any important amount. Feldspar may be present, but if so twinning crossing the tiny particles is rare; biotite flakes are very uncommon; one shows an optic angle of about 40° (2E) and pleochroic colors with Z = brown and Y = yellow. Very rare fragments of calcite are also present. Still more rarely a fragment of microcline, a light-colored amphibole and a mineral resembling staurolite may be detected. In spite of the gray color in mass, the red and yellow colors of hematite and limonite are common under the microscope. Most of the material is cloudy and isotropic.

It is possible to calculate the approximate mineral composition from the gross chemical composition by making certain assumptions similar to those made in calculating the mineral composition of igneous rocks. Such calculations are greatly facilitated by the use of the circular slide rule for minerals devised by W. J. Mead.[8] In this way we have computed the mineral compositions of the Madison dustfall as well as that of European dustfalls and of Mississippi Valley loess. In these calculations, it is assumed that all the soda is in albite feldspar, all the potassium is in orthoclase feldspar, all the phosphoric acid is in apatite, all the titanic acid is in ilmenite, all the magnesia is in chlorite (if there is sufficient alumina—otherwise in enstatite), all the lime remaining after forming apatite and calcite is in anorthite, all the alumina remaining after forming feldspars and chlorite is in kaolinite and all the silica remaining after forming these silicates is in quartz. It must, of course, be admitted that these assumptions are not all true, but they are approximations and represent possible, even if not actual, combinations of the oxides into minerals. They furnish a useful means of comparing analyses, especially when the underlying assumptions are controlled as far as possible by microscopic study of the material. The results of these computations are given in the following table so far as they relate to dustfalls.

TABLE IV. *Calculated mineral composition of Madison and European dustfalls.*

	1	2	3	4	5	6	7	8	9
Quartz	39.91	32.82	36.87	36.47	18.36	13.34	5.75	17.32	....
Albite	13.87	25.80	13.87	17.89	14.21	9.82	22.14	14.04	21.98
Orthoclase .	13.16	12.52	15.21	13.69	15.32	13.64	12.28	9.38	16.15
Anorthite .	8.11	8.06	6.86	7.64	4.73	4.38	4.44	16.17	7.75
Kaolinite .	10.09	3.59	10.09	7.94	26.20	28.85	25.22	....	13.01
Chlorite ..	8.92	9.04	9.83	9.26	4.20	5.13	8.66	....	6.11
Enstatite ..	....	....	....	....	....	....	....	2.30	....
Calcite	....	....	....	....	....	13.86	7.85	19.17	8.36
Apatite ...	.33	.37	.37	.35	....	....	.46	....	....
Anhydrite .	....	....	....	....	....	....	2.33	....	....
Hematite .	....	....	....	....	6.54	6.57	7.03	9.19	6.40
Ilmenite ..	1.01	1.01	.99	1.01	....	....	....	....	....
Water, etc.	6.00	7.99	7.13	7.03	10.42	4.41	4.41	11.43	20.89
Total	101.40	101.20	101.22	101.28	99.98	100.00	100.57	99.00	100.65

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[8] Economic Geology, 7, p. 136, 1912.

1. Dustfall collected at 2125 Van Hise Ave., Madison, Wis., 19 March, 1920.
2. Dustfall collected from ice on Lake Mendota, Madison, Wis., 19 March, 1920.
3. Dustfall collected at 200 Prospect Ave., Madison, Wis., 19 March, 1920.
4. Average dustfall at Madison, Wis., 19 March, 1920.
5. Dustfall at Otakaia, New Zealand, 14 Nov., 1902, P. Marshall: Nature, **68,** p. 223, 1903.
6. Dust in "red rain" at Lamberhurst, Eng., 22 Feb., 1903. T. E. Thorpe: Nature, **68,** p. 54, 1903.
7. Dustfall at Naples, Italy, 10 March, 1901. P. Palmeri: Rend. Accad. sci. fis. Naples. (3), **7,** p. 157, 1901.
8. Dustfall at Naples, Italy, 25 Feb., 1879. P. Palmeri: loc. cit., p. 161.
9. Dustfall at Taormina, Sicily, 19 March, 1901. T. E. Thorpe: Nature, **68,** p. 222, 1903.

This table shows even better than the chemical analyses that the Madison dustfall is exceptionally rich in quartz; it contains about the same amount of total feldspar as in the dustfalls at Otakaia and at Naples; its content of kaolinite is much lower than in foreign dustfalls (except one at Naples) and the tenor of calcite is far lower than in the European dustfalls. The Madison dust contains more chlorite and less hematite than the others, but this is at least in part due to our assumption regarding the state of oxidation of the iron.

In order to show how much similarity in mineral composition there is between the Madison dustfall and loess of the Mississippi Valley computations of the latter made in the same way as those of the dust are presented in the following table.

This tabulation shows that while the Madison dustfall is quite unlike foreign dustfalls as shown by its tenor of quartz, of which it contains at least twice as much as the latter, it closely resembles the loess of the Mississippi Valley differing no more from some samples of loess than these differ from other samples of loess. It contains decidedly more feldspar and less kaolinite than the loess, but the high percentage of water not included in the calculated minerals suggests that these differences are more apparent than real; that is, the feldspar molecule is probably already hydrated though the alkalies have not been removed as thoroughly as in the loess. The only

Table V. *Calculated mineral composition of Mississippi Valley loess compared with that of the Madison dustfall.*

	1	2	3	4	5	6
Quartz	36.47	39.66	43.52	45.56	48.89	49.50
Albite	17.89	11.42	9.24	14.22	14.30	12.10
Orthoclase	13.69	12.20	12.03	12.62	6.98	10.86
Anorthite	7.64	....	7.60	2.19	....	4.74
Kaolinite	7.94	15.62	17.15	14.83	12.29	14.12
Chlorite	9.26	....	3.65	1.55	....	3.10
Enstatite	....	3.24	....	1.37	3.17	....
Calcite	....	9.39	....	.88	6.43	1.11
Magnesite	....	4.57	....	....	3.56	....
Apatite	.35	.14	....	.53	.94	.21
Gypsum	....	.22	....	1.10	....	....
Ilmenite	1.01	.76	....	1.37	1.12	.26
Hematite	....	2.17	4.02	2.71	2.97	3.25
Magnetite	....	.64	....	1.19	....	....
Water, etc.	7.03	....	3.12	.10	....	.58
Total	101.28	100.03	100.33	100.22	100.65	99.83

1. Average Madison dustfall of March 19, 1920.
2. Loess, Galena, Illinois. Chamberlin and Salisbury: 6th Ann. Rep. U. S. Geol. Survey, 1885, p. 282.
3. Loess, Kansas City, Mo. W. E. McCourt: Missouri Bureau Geol. & Mines, **14**, p. 94, 1917.
4. Loess, Dubuque, Ia. Chamberlin and Salisbury: loc. cit.
5. Loess, Mt. Vernon, Ia. N. Knight: Am. Geol., **29**, 1902, p. 189, 1902.
6. Loess, Kansas City, Mo. Chamberlin and Salisbury: loc. cit.

other difference between the dustfall and the loess that requires comment is the scarcity of carbonate in the former. But this scarcity is matched by the condition found by McCourt in the loess from Kansas City, and the other sample from that locality as well as the loess from Dubuque contain very little carbonate. It is noteworthy that four samples of European dustfalls are rich in carbonate as shown by numbers 6-9 in table IV. It seems very probable that the amount of carbonate in a dustfall would vary through wide limits depending largely upon the type of chief country rocks in the area of origin of the dust.

Accordingly, we find no fundamental distinctions in chemical or mineral composition between the Madison dustfall and the Mississippi loess; on the contrary, the two are more alike than Madison dust and foreign dust. The chief differences which exist are such as would be produced by weathering of the dust.

Physical Composition.—Dustfalls vary considerably in the average size of the component particles as well as in the range of size and the abundance of particles of various sizes. The dustfall at Madison in 1920 may well be compared in this respect with the dustfall of 1918 as shown in the following table.

Table VI.—*Size of constituents of dustfalls.*

	1	2	3	4
Clay, less than .005 mm.....	11.15	27.49	25.57	23.32
Fine silt, .005 to .010.......	22.01	66.86	11.91	70.11
Medium silt, .010 to .025....	56.17		44.09	
Coarse silt, .025 to .050.....	5.99		11.35	
Very fine sand, .05 to .10....	1.22	4.78	5.04	5.05
Fine sand, .10 to .25.......	1.04	.81	.87	.77
Medium sand, .25 to .50....	0.58	.03	.05	.04
Coarse sand, .50 to 1.00.....	0.29	.01—	.03	.03
Fine gravel, 1.00 to 2.00....	1.08	.00	.00	.00
	99.53	99.98	98.91	99.31

1. Dustfall at Madison, Wis., 9 March, 1918, this Journal, **46**, p. 602, 1918.
2. Sample 1 of dustfall at Madison, Wis., 19 March, 1920. Mechanical analysis of this and two next were made by Hazel Hankinson in Dept. Soils, Univ. Wis.
3. Sample 2 of dustfall at Madison, Wis., 19 March, 1920.
4. Sample 3 of dustfall at Madison, Wis., 19 March, 1920.

It is evident that the dustfall of 1920 is composed of even finer particles than that of 1918. This is probably due to the fact that the velocity of the wind east of the Missouri River was less in the later storm, though the recorded velocity west of that river was greater. We have no explanation of the fact that the 1920 dustfall contains about four times as great a tenor of very fine sand as that of 1918; the "fine gravel" of the latter consists largely of fragments of vegetation. In all these samples nearly 95 per cent of the material is finer than 0.05 millimeter. Unfortunately we know of no mechanical analyses of European dustfalls with which these may be compared. It is reported merely that the commonest size of the particles in the great dustfall[1] of March, 1901

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[1] Hellmann and Meinardus, *loc. cit.* p. 63-65.

was between .02 and .001 mm.; that is, most of the material would be classed as silt or clay. The largest particles carried long distances by the wind are thought to be only .07 to .08 mm.

There are many mechanical analyses of loess from this country with which these analyses of dustfalls may be compared, as illustrated in the following table.

Table VII.—*Size of constituents of dustfalls compared with loess.*

	1	2	3	4	5	6	7	8	9	10
<.005 mm.	11.15	10.7	25.57	24.5	26.7	28.9	26.4	32.0	17.1	10.5
.005– .010	22.01	85.0	11.91	66.5	64.8	63.9	56.4	63.4	67.5	42.3
.010– .025	56.17		44.09							
.025– .050	5.19		11.35							
.05 – .10	1.22	3.2	5.04	5.8	3.6	4.6	14.5	1.4	15.0	42.9
.10 – .25	1.04	0.2	0.87	1.0	1.8	1.3	1.4	1.1	0.3	3.6
.25 – .50	0.58	0.1	0.05	0.4	1.8	0.4	0.5	0.6	0.1	Tr.
.50 –1.00	0.29	0.0	0.03	1.2	1.4	0.6	0.1	1.1	0.1	0.1
1.00 –2.00	1.08	0.0	0.00	0.6	0.0	0.2	0.0	0.3	0.0	0.0
	99.53	99.2	98.91	100.0	99.9	99.9	99.8	99.9	100.1	99.8

1. Dustfall at Madison, 1918.
2. Loess, 6 ft. below surface at Edwards, Miss. E. W. Shaw: U. S. Geol. Survey, Prof. Pp. **108**, 135, 1918.
3. Dustfall at Madison, 1920.
4. Loess, 3 feet below surface, Muscatine Co., Ia. Field Oper. U. S. Bur. Soils, 1914, p. 1848.
5. Loess, 3 feet below surface, Harrison Co., Mo. Field Oper. U. S. Bur. Soils, 1914, p. 1960.
6. Loess, 3 feet below surface, Ringgold Co., Ia. Field Oper. U. S. Bur. Soils, 1916, p. 1918.
7. Loess, 3 feet below surface, Callaway Co., Mo. Field Oper. U. S. Bur. Soils, 1916, p. 1933.
8. Loess, 3 feet below surface, Grundy Co., Mo. Field Oper. U. S. Bur. Soils, 1914, p. 1991.
9. Loess, 6 feet below surface at Weeping Water, Neb. Alway & Rost: Soil Science I, 1916, p. 407.
10. Loess, 3 feet below surface at North Platte, Neb. W. W. Burr: Res. Bull. 5, Agr. Exp. Sta. Neb., 1914, p. 12.

The mechanical analyses of loess show that it varies considerably in percentage distribution of sizes present. The analysis of the loess from Edwards, Miss. (No. 2) is very similar to the Madison dustfall of 1918, while analyses 4, 5, and 6 are closely like the dustfall of 1920. These have been selected to show that loess may be of the same types as these dustfalls, but it is also commonly found of other types. Analyses 7, 8, and 9 illustrate loess differing distinctly, but not greatly, from the dustfall of

1920, while analysis 10 shows that loess may even differ very decidedly from the dustfall.

This table does not show that there is any close relationship between dustfall and loess; it merely shows that such a relationship can not be denied on the ground of differences in mechanical composition.

Organic Constituents.—In addition to the mineral components fragments of vegetation are visible; these include spores and shreds, but for more accurate data on the subject the samples were referred to Professor R. H. Denniston of the Department of Botany of the University of Wisconsin who very kindly supplied the following information: Spores of fungus are present which are probably to be referred to Alternaria; the hypha of a fungus is also found, as well as trichomes, starch grains, grass cells, and bits of charcoal.

Finally, diatoms are found in the dust which seem to be of three types including two like those found in the dustfall of 1918. For the examination of these diatoms samples of the dust were sent to Dr. Albert Mann, Plant Morphologist of the United States Department of Agriculture, who kindly reported as follows:

"I have examined the dust brought down by a snowstorm at Madison on March 19, 1920, and find that the diatoms contained are in general like those in the snowdust you collected two years ago. But there are some differences. In the 1918 sample the most abundant species was *Nitschia* (*Hantschia*) *amphioxus* (E.) W. S., much outnumbering *Navicula borealis* (E.) K. In this last sample the latter is more abundant, perhaps 3 to 1. As I then stated, both these are characteristic of cool sphagnum bogs and the moss on shaded tree trunks."

"I have found two other species in this material:—*Navicula pupula* K. (rather frequent) and *Cymbella turgidula* Grun (very scarce). The former is often found in cool and damp garden soil and on the under side of leaves in damp woods. The latter is widely distributed in cool fresh waters."

Quantity of Dust Transported.—In the storm which brought a heavy dustfall to Madison in 1918, we estimated from meager data that at least one million tons of dust were transported long distances. In 1920 the amount of dust deposited at several places in Madison and at some other points was determined with the following results.

TABLE VIII.—*Quantity of dust in storm of March, 1920.*

Sample	Weight of dust in Grams per square meter.	Weight of dust in Short tons per square mile.
Madison No. 1	7.87	22.4
Madison No. 2	10.30	29.3
Madison No. 3	9.56	27.1
La Crosse, Wis.	5.03	14.3
Dubuque, Iowa	4.53	12.9
Charles City, Ia.	8.34	23.7
Carlisle, Pa.	4.61	13.1

About twenty more samples of this dustfall from various parts of the country were sent to us, but the preceding table includes all those which are sufficiently pure to make exact records of value. The amounts may be compared with the dustfalls at other times and places as follows:

TABLE IX.—*Quantity of dust in other storms.*

Place.	Weight of dust in Grams per square meter.	Weight of dust in Short tons per square mile.
Madison, 1918	4.8	13.6
Naples, 1901	11.	31.3
Görz, Austria, 1901	11.2	31.8
Schemnitz, Hungary, 1901	1.9	5.4
Hamburg, 1901	1.67	4.7
Taormina, Sicily, 1901....	2.7	7.7

Except for Madison, the data are from Hellmann and Meinardus, loc. cit.

It is evident that the quantity of dust in the storm of 1920 is entirely comparable with that of the European fall of 1901 in all cases measured. The area of the latter was about 160,000 square miles while the area covered by the American dustfall of 1920 was at least as great and probably several times greater. The total dustfall in Europe in 1901 was at least 1,782,200 metric tons or 1,964,000 short tons; so far as the evidence goes it indicates that the American dustfall of 1920 involved at least as great a total, and probably several times as great a total amount of material transported.

Madison, Wisconsin, January 1, 1922.

Art. XXXV.—*Helaletes Redefined;* by Edward L. Troxell.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

The genus *Helaletes* Marsh constitutes a group of the smallest of the tapiroids. For two reasons I am prompted to redescribe this important genus: first, because it is very much misunderstood, and has no published drawings; and second, because some new features have come to my attention which Marsh himself had not noted.

The species *Lophiodon nanus* Marsh was the first one described; the holotype consists of both maxillaries. *Helaletes boöps,* however, is the genoholotype and is based on the greater part of the skull, jaws, and skeleton of one individual. Whether or not other existing species should be assigned to this genus is uncertain; two have been referred to it, perhaps with doubtful justification. These are *Dilophodon minusculus* Scott and *Desmatotherium guyoti* Scott.[1]

Dilophodon minusculus Scott is shown to have no posterior heel on M_3 and is therefore quite different from *H. boöps.* Only its small size and the absence of P_1 separate it from *Hyrachyus,* but these may be sufficient for a subgenus at least.

Desmatotherium guyoti, which has been referred to *Helaletes* by authors, differs from *H. boöps* in its much greater size, in the relatively greater M^3 and in the disproportion between the large molars and the premolars. On the other hand, the partial separation of the internal cusps on the third and fourth premolars and the diastema in front of C^1, likewise the general resemblance in the form of the molars, indicate relationship, but *Desmatotherium* should retain at least subgeneric distinction.

Hyrachyus nanus Leidy is frequently referred to *Helaletes* by writers who seem to be unaware of the species *Helaletes nanus* (Marsh) which precedes. Scott has referred Leidy's species to his genus *Dilophodon* because of the bilobed M_3 and the absence of P_1; if this is a cor-

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[1] W. B. Scott, Contrib. from E. M. Mus. Geol. & Arch., Princeton Coll., Bull. 3, 46-53, pl. 8, 1883.

rect reference it saves the species. *Helaletes nanus* Leidy does not exist and it is doubtful whether he intended to create a new species in his original description, for he mentioned *Lophiodon nanus* Marsh at that time.

Helaletes nanus (Marsh).

(Fig. 1.)

Holotype, Cat. No. 11080, Y. P. M. Eocene (Bridger), Grizzly Buttes, near Fort Bridger, Wyoming.

Lophiodon nanus was one of the first three lophiodonts described by Marsh; it is based on the two weathered maxillaries, the right one of which bears all the cheek teeth except P^1, whose root only remains (see Fig. 1). Following is the original description in part:[2]

"The molars differ especially from those of the two preceding species [*Hyrachyus bairdianus, H. affinis*], in having a much shallower valley between the two transverse ridges, and in having a strong basal ridge, or shelf, at the external posterior corner of the crown. The enamel of the whole series is very smooth. The species was probably about two-thirds the size of *L. modestus.*

Fig. 1.

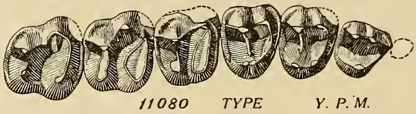

Fig. 1.—*Helaletes nanus* (Marsh). Holotype. First described by Professor Marsh over fifty years ago. Note the double internal cusp of the premolars. Nat. size.

Measurements.

Length of upper jaw, containing seven posterior teeth	26.0 lines	[55.0 mm.]
Length of same, with three last molars	13.7 lines	[29.1 mm.]
Antero-posterior diameter of last upper molar	5.0 lines	[10.6 mm.]
Transverse diameter of same	5.25 lines	[11.1 mm.]

"The remains now known to represent this species were discovered by C. W. Betts, H. B. Sargent, and the writer, in the Tertiary strata at Grizzly Buttes, near Fort Bridger."

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[2] Marsh, O. C., This Journal (3), 2, 37, 1871.

Helaletes nanus is notable for the rounded molars, the very prominent paracone and receded metacone, the small size, posteriorly, of the ectoloph, and especially for the double internal cusps on the premolars which are most separated on P^3. P^2 is wider than it is long (7 × 6.3 mm.); there is a postero-exterior cingulum on each molar, and a conspicuous protocone (antero-exterior) on the upper premolars.

In this species the maxillary presents a smooth border curved strongly inward above the anterior premolars, indicating a facial pit of a slightly different character from that of *H. boöps,* described later.

Helaletes boöps Marsh.

(Figs. 2-3.)

Holotype, Cat. No. 11807, Y. P. M. Middle Eocene (Bridger), Grizzly Buttes, Wyoming.

This genus is readily distinguished from *Hyrachyus* Leidy, as the latter is generally known, by the small size, the double internal cusps on the premolars, the long diastema in front of the upper canine, the compressed short incisors, the distinctive form of the rounded molars, the great antero-posterior diameter of M^3, the presence of a heel on M_3, the absence of connecting ridges between the crests of the lower molars, and finally by the presence of a great facial pit as shown by the smooth edge of the maxillary above the diastema and the premolars.

Fig. 2.

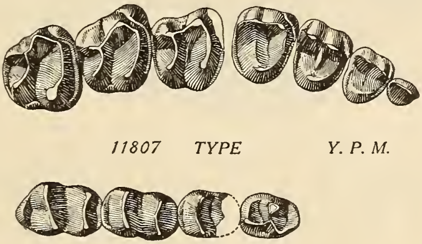

Fig. 2.—*Helaletes boöps* Marsh. Holotype. Showing the upper teeth complete, and the last premolar and three molars of the lower dentition. Nat. size.

As contrasted with *Helaletes nanus, H. boöps,* the genoholotype, lacks distinctly separated cones on the inner side of the premolars, while the two outer cones are nearly equal in size and prominence. The first premolar is very small. In this form the side of the maxillary rises vertically above the premolars and ends in a sharp edge to form the antorbital depression.

This last feature is one of great interest and heralds a peculiarity well known in fossil horses of later periods. The presence of a facial depression, so far as I know, has never been noted in an Eocene form; it was obscured in the type of *Helaletes,* because the skull was so crushed and so greatly distorted.

Fig. 3.

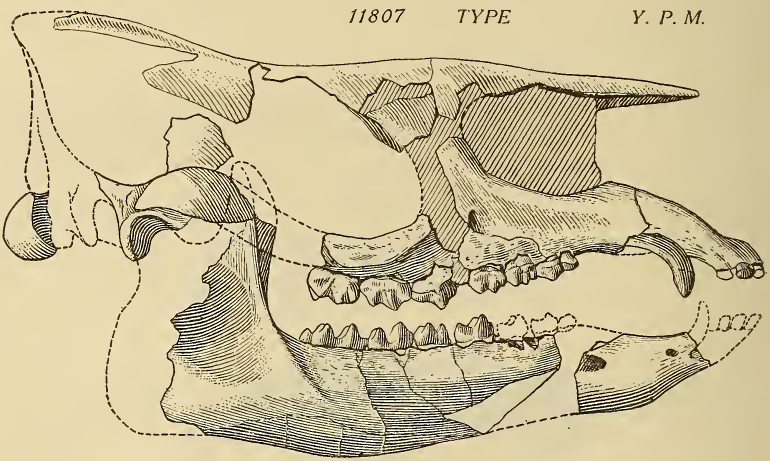

Fig. 3.—*Helaletes boöps* Marsh. Holotype. Skull restored from its previous crushed condition. It now shows a rising sagittal crest, long nasals, long diastemata in front of and behind the strong canine, the foramen over P^4, and an opening in the face over the maxillary. It is distinctly tapiroid. × 2/3.

Preparation of the Skull.—To develop this feature and others as well, it seemed eminently worth while to risk dismembering the rare skull to enable it to be restored to a form approximately normal. This was done and the result demonstrates these important points: the probable slope from the occiput to the frontals, the great width over the orbits, the position of the orbits far forward, the location of the antorbital foramen over P^4, the great length of the nasal bones, the narrowness of the maxillaries over the premolars, and the extent of the facial vacuity already mentioned.

Before the separate pieces were removed from the original crushed skull, a cast was taken of the whole; likewise a chart was made, and on both, as a double precaution, the pieces were marked by numbers corresponding to those on the skull itself. With this provision against confusing the separated parts, the skull was then almost completely dismembered; the small fragments were lifted from their abnormal position and restored to their right places by fitting the broken edges together. In most instances the original contact was found, in a few cases the matching is conjectural and only approximately correct, but, considering the number of parts preserved, i.e., the incompleteness of the skull, the results of the operation are quite satisfactory.

The elongated nasals are distinctly unlike those of the modern tapir, but the facial depression[3] may well have been the beginning of the receding nasal aperture in the tapirs and seems to link more closely these two races. In addition to the (1) large facial depression, one should note these features which are distinctly tapiroid: (2) the rising sagittal crest and the depression in the forehead, which seems to be clearly indicated by the curvature of the bones involved; (3) the position of the infra-orbital foramen over the fourth premolar and near the orbit; (4) the very narrow maxillary above the premolars; and especially (5) the form of the teeth. The skull of the young tapir lends itself particularly well to the general comparison, perhaps because it is more primitive than the adult and assumes more nearly the characters of the ancestor of its race. On a young tapir skull one can see the smooth upper edge of the maxillary bone sending a narrow projection backward and upward,

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[3] Its meaning is discussed in connection with the horses by W. K. Gregory (Bull. Amer. Mus. Nat. Hist., vol. 42, pp. 265-283), who concludes in his recent paper ''that the lachrymal fossa of extinct Equidæ did not lodge a sebaceous gland like the 'larmier' of the deer and antelopes,'' but ''probably did lodge a greatly enlarged nasal diverticulum'' as suggested by Osborn, or that the malar fossa (immediately above the premolars like that of the present *Helaletes*) probably marks the origin of the muscle which raises the upper lip.

which does not, however, join the frontals and nasals to form an arch over the front of the face, but rather the maxillary of the tapir recedes to a point well above the orbit, to form the border of the anterior nares.

Authors have postulated *Heptodon* Cope, as well as *Helaletes* Marsh, as a forerunner of the tapir. *Heptodon* is the earlier but larger form and it seems impossible to derive the small *Helaletes* directly from it.

SUMMARY.

A bold technique permitted the reconstruction of the skull of the holotype of *Helaletes boöps* Marsh, which, in its more nearly normal condition, at once showed features hitherto unknown in the genus.

A relationship to the tapir is indicated by nearly all the important characters of *Helaletes:* the position of the antorbital foramen, the rising of the sagittal crest, the trend toward molariformity in the premolars, the low maxillaries, and especially the presence of a pit in front of the orbit which may have given rise to the receded nasal aperture of the modern animal.

ART. XXXVI—*Aræocyon, a Probable Old World Migrant;* by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

In this Journal for June, 1921, I described the lower jaw of a carnivore, collected through the efforts of Professor Marsh, in Oregon, in 1874. For this carnivore I proposed the name *Pliocyon marshi.* Subsequently, I substituted the name *Aræocyon* to supplant my preoccupied *Pliocyon,* and a note to this effect was printed in the January, 1922, issue of this same journal.

The presence of this lower jaw in the New World is decidedly interesting, for to my knowledge no specimen comparable to it has been described or reported from among the ancient fauna of North America.

There are but two similar forms in the extinct world faunas with which we can make close comparison, and one of these is much closer than the other. The nearest ally of our American form is *Simocyon primigenius* Roth and Wagner, from Greece. This genus and species is probably somewhat more specialized, although it was preserved in strata of older geologic age than was the Oregon fossil. The two specimens show a curious admixture of specialized and generalized characters, and it is rather difficult to be certain which represents the later phase of evolutionary development. For example, *Aræocyon* has two incisors (specialized), *Simocyon,* three, while the former has two premolars and the latter but one (specialized). In other characters the Grecian genus is larger and differently proportioned.

The other European species of *Simocyon* is *S. diaphorus* Kaup, from Germany, and it very materially differs from the Grecian and American forms. In comparison with the Oregon specimen, Kaup's type possesses P_2 and P_3 (lacking in both of the other specimens under consideration); it has a larger and higher metaconid on M_1, and a smaller hypoconid; it has a shorter and lower P_4, with more prominent basal heel; M_2 is set in the ascending ramus, while in *A. marshi* it is nearly level with the tooth-row; and there are still other characters which differentiate it from both of the other forms.

The geologic horizon of *A. marshi* is Middle Pliocene. It was collected about one mile west of Cottonwood, on the East Fork of the John Day River, Oregon. The enveloping matrix was soft tuff, lying between the basal conglomerate and the capping rim rock of rhyolite, about 3 feet below the lower edge of the latter. Merriam has designated this formation by the name Rattlesnake.

Simocyon primigenius was found in the Pikermi beds near Athens, Greece, while the type of *S. diaphorus* came from the gravel deposits of Eppelsheim, Germany, the deposits of both localities being of equivalent age. There is a difference of opinion in regard to the geologic age of these formations. The German geologist, Lepsius, believes that these strata are unquestionably of the Lower Pliocene epoch, and that the Eppelsheim beds present the northern facies of the Pikermi beds. On the other hand, the members of the French school of geologists are equally positive that the entire series is Upper Miocene. Whatever geologic age we ascribe to these Pikermi and Eppelsheim formations, they must both be placed in the same period. I incline more to the French view of considering them Upper Miocene, but there is not sufficient space to go into details on this point. It should be noted that Von Zittel places *Simocyon* in the Upper Miocene.

According to Gaudry, Greece was most probably connected with Asia by vast plains, produced by the recession of the sea which began in the Middle Miocene and continued throughout Upper Miocene until the Mediterranean Sea had become nearly dry and had reached the stage where it was represented by only a series of brackish lakes, with the consequence that Europe and Africa were broadly connected by land masses. All of these Upper Miocene deposits were apparently laid down in shallow basins of fresh water, for the most part due to recurrent torrential flooding, after the manner of our own Oligocene deposits in the Great Plains region of North America.

The extent of these deposits shows how widespread were these conditions of deposition throughout Europe. The beds are more or less local areas, extending from western Portugal (Archino on the Tagus River) to Maragha in Central Persia, and northward to Tchernigow in south central Russia and to Eppelsheim, near

Worms, Germany. Taking the Pikermi region as an example, we must suppose that it consisted of grass-covered lowlands which alternated with great forests of beeches, bamboos and allied flora, in which lived rhinoceroses, bears and other carnivores, monkeys, great herds of hipparions, antelopes, chalicotheres, proboscidians and so on. There is a notable absence of small forms in these deposits, which may be accounted for by the conditions of their deposition. It is probable that stream currents sufficiently strong and swift to transport the bones of the larger animals were too powerful for the smaller ones and that these small bones were ground to pieces and destroyed by attrition.

Let us now look at the faunal affinities. The affinities of the Pikermi genera are with those of Africa rather than of modern Europe. There is a notable absence of wolf- or fox-like canids, both in Pikermi and in Eppelsheim, and the family is represented by the curious short-faced *Simocyon.* Eastward we find a similar faunal phase in Samos and Maragha. In general, the fauna of the latter approaches very closely to that of the Pliocene of the Siwaliks in southern Asia and of China. Samos possesses a hornless giraffine, *Samotherium,* a form very close to the present African okapi, while the aardvark is common to both these deposits and to Africa of to-day.

We have now briefly reviewed the physiographic conditions at the time of deposition of these European beds and also have considered the faunal phases and affinities of the animals of that time. We have seen unmistakable evidence pointing to African rather than to European allies of the fauna and the subsequent eastward trend or migration of these forms through India and China, and this leads us to the most probable explanation of the presence in the western coast region of North America of a *Simocyon*-like form.

In Pliocene times there is every reason to believe that Asia and North America were connected by land in the vicinity of Bering Strait and that hosts of animals passed and repassed over this strip of land. Of course we might argue that the theory of convergence could account for the similar development of faunal forms on both sides of the Pacific, but according to the laws of chance our argument would seem to be rather ill-founded. For example, the mastodons of both Europe and North America in the Pliocene were of two kinds, that is, some had three ridges on the intermediate molars (trilophodont) while the others were tetralophodont.

The order Carnivora are unquestionably of Holarctic origin, according to Matthew, and from this area they have spread to practically all parts of the world. The ancestors of *Simocyon* are obscure, but it would be reasonable to suppose that they may have lived in Africa, owing to the close similarity between the faunas of that continent and of Pikermi and Eppelsheim. On account of the considerable contrast between the Eppelsheim *S. diaphorus* and the Pikermi *S. primigenius,* it would appear that the northern species was aberrant and became extinct before or soon after the beginning of the Pliocene, whereas the southern form represented the stem stock and followed the faunal migration through India and China and across the Bering Strait land connection into North America. It is probable that there might have been a concentration of carnivore types in the region of this "game trail." It may have been some such concentration of mammals in a restricted area which produced the rise of the Carnivora in the beginning.

The early Pliocene is known to have been mild of climate, but during the entire epoch there was a very gradual cooling or lowering of temperature which slowly drove the animals southward, and may account for the presence in Oregon in Middle Pliocene times of this simocyonid.

It would seem to be a reasonable explanation to suppose that the above line of migration was the one followed by this phylum of carnivores from southern Europe to North America. It also could account for the differences and similarities in structure between the Old and the New World species of this same phylum, if we take into consideration the great lapse of time between Upper Miocene and Middle Pliocene.

The systematic position of *Aræocyon* and *Simocyon* ought to be considered together, for I think that they both were probably derived from the same genus. There are several structural characters which prevent us from considering these forms as being at all closely related to the Felidæ, such, for instance as the possession of the large M_2 which none of the post-Middle Oligocene felids retained. The first lower molar is not at all cat-like in structure, and the slenderness and general characters of the ramus all point to an origin not in the felid phylum. The evidence, however, does point unmistakably toward the dog-like phyla.

While it is stated above that there are no closely comparable American forms so far known, yet we might point out the essential differences and show wherein *Aræocyon* could have been derived from some autochthonous genus.

In the first place, the heel of the lower carnassial is trenchant, for the hypoconid is about medially situated on the talonid. This is also true of *Simocyon primigenius,* as shown in a very good cast (Cat. No. 11649, Y. P. M.) of the type. Therefore we must place them in the group which parallels the more typical canoid line of descent, namely, the assemblage of forms to which belong *Daphænus, Temnocyon, Enhydrocyon, Ischyrocyon,* and others up to and including the recent genera, *Cyon, Icticyon,* and *Lycaon.* Osborn has placed *Simocyon* also in the Dhole-like group, and *Aræocyon* should likewise be classified under this head.

If *Aræocyon* is an autochthonous form, then *Daphænus* and *Temnocyon* are most probably in the direct line of ancestry, while *Enhydrocyon* is apparently an aberrant side branch with which we are not at present concerned.

In the Upper Miocene (Loup Fork beds) there is a peculiar genus, *Ischyrocyon,* which is here provisionally placed in this group on account of the trenchant heels of the first two lower molars. The large size of the molars and the absence of the metaconids upon them show that it is, however, far removed from the large majority of the other known genera of the Canidæ, and especially so from *Aræocyon.* It probably represents another of the various aberrant forms in the canid phylum. According to Doctor Matthew, the general proportions suggest *Amphicyon* and *Dinocyon.*

In the later epochs, Pliocene and Pleistocene, of North America, we find more nearly contemporaneous forms, but if we examine them in detail we see that the similarities are more apparent than real. In these later formations there are various more or less hyænoid Canidæ, such as *Hyænognathus* Merriam, *Borophagus* Cope, *Chasmaporthetes* Hay, and so on. It is hardly probable that any true hyænids will be found in North America and it seems that these hyænid forms may be due to convergence.

Let us, however, compare one of these genera, for

Major Characters.

Hyænognathus pachyodon.[1]	*Aræocyon marshi.*
1. “Mandible short and massive.”	1. Mandible moderately long and slender.
2. “Alveolar margins greatly flared below P_3 and P_4.”	2. Alveolar margins but very slightly flared below P_4.
3. Dentition I_3, C_1, P_3, M_3.	3. Dentition I_2, C_1, P_2, M_2.
4. “P_2 and P_3 small.”	4. P_2 and P_3 absent.
5. “P_4 very large, conical, without accessory tubercles.”	5. P_4 relatively smaller, compressed, with prominent posterior tubercle and heel.
6. “M_1 massive; protoconid and paraconid forming a heavy shear, metaconid absent; heel short, with reduced hypoconid and entoconid.” (Heel basin-shaped.)	6. M_1 very large; protoconid robust; paraconid large and high; metaconid prominent; heel large with low hypoconid medially situated on talonid. (Heel trenchant.)
7. “M_2 and M_3 small.”	7. M_2 long and stout. No M_3.
8. P_1 lost.	8. P_1 present.
9. Premolars crowded.	9. Long diastema between P_1 and P_4.
10. Incisors spaced and none in front of canine.	10. Incisors crowded and outermost one in front of canine.
11. Symphysis long.	11. Symphysis short.
12. M_2 and M_3 set in ascending ramus.	12. M_2 placed nearly level with respect to tooth-row.
13. Muzzle much wider.	13. Muzzle much narrower.
14. Quaternary, probably. Asphalto, Kern Co., Calif.	14. Middle Pliocene. Near Cottonwood, East Fork of John Day River, Ore.

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[1] Merriam, J. C., The Pliocene and Quaternary Canidæ of the Great Valley of California. Univ. Calif. Pub., Bull. Dept. Geology, 3, 278 ff. with plates and figures, 1903.

example *Hyænognathus,* with *Aræocyon.* From a survey of the following lists of major characters of the comparable elements of the two genera, it is seen that there can be no close affinity between the two.

In conclusion, it is my opinion that there is nothing to preclude the possibility of *Aræocyon* being an autochthonous form, most probably having developed from the trenchant-heeled series, and belonging to this pseudocanoid line. However, both Professor Lull and the author incline very much more strongly to the theory of migration for this form and its derivation from Old World stock. If the lower jaw upon which *Aræocyon* is established had been collected in the Pliocene beds of Europe, I should have no hesitancy about referring it to the genus *Simocyon,* or at most to a subgenus under it.

If *Aræocyon* should prove to be a derivative of purely American ancestry, the possibility of which I doubt at present, it will be one of the most remarkable cases of convergence known to the science of vertebrate paleontology.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *Hydrated Oxalic Acid as an Oxidimetric Standard.*—Arthur E. Hill and Thomas M. Smith have rendered a valuable service to the art of volumetric analysis by devising a method whereby crystallized oxalic acid $H_2C_2O_4.2H_2O$ can be prepared in a state of purity in regard to its contents of water, so that it contains no excess of moisture derived from the mother-liquor, nor any deficiency of water due to efflorescence. The principle of the method is very simple and depends upon exposing the moist acid to an atmosphere in equilibrium at all ordinary temperatures with the pure hydrated acid. Such an atmosphere is obtained in the presence of mixtures of the hydrated and anhydrous acid obtained by heating the crystallized acid in a porcelain dish upon the steam-bath for a few hours. When a large excess of this mixture is placed in a desiccator with the moist acid the moisture of the latter is lost, but none of the water of crystallization can go off on account of the presence of the hydrated acid in the mixture which establishes the proper tension of aqueous vapor to prevent this change, since the system becomes univariant according to the phase rule of Gibbs. The authors have found it necessary to powder the crystallized acid sufficiently to pass a 100-mesh sieve in order to expose the mother-liquor included in the crystals to the process of drying. The time necessary for drying in a desiccator under these conditions is about two days, but the time may be shortened to about one hour by the use of a current of air which is first bubbled through a saturated solution of the acid and then is passed through U-tubes containing the desiccating agent and through a closed jar containing the substance.

The results given by the authors show that the acid prepared in this way gives results that are reliable within very small limits of error when used with potassium permanganate, and it appears probable that it might be used very satisfactorily for standardizing solutions of strong alkalies by the use of phenolphthalein in boiling solutions.—*Jour. Amer. Chem. Soc.*, **44**, 546.

H. L. W.

2. *The Atomic Weight of Beryllium (Glucinum).*—Hönigschmid and Birkenbach have made a new determination of this atomic weight, apparently with great care and skill and with satisfactorily agreeing results by the analysis of the anhydrous chloride. They started with the commercial carbonate and purified the material, particularly by crystallizing and afterwards volatilizing the basic acetate. The latter was converted into

nitrate, then into oxide, from which the chloride was prepared by ignition with sugar-charcoal in a stream of chlorine. The chloride was fused in quartz tubes for weighing.

The results gave the atomic weight 9.018 for Be or Gl, which is about 1% lower than 9.1 the value accepted in the International Table. The result obtained by Parsons, in this country, from the conversion into oxide of the acetylacetonate, $Be(C_5H_7O_2)_2$, and the basic acetate, $Be_4O(C_2H_3O_2)_6$, was 9.105; hence it appears that further work is needed to establish the correct value. There appears to be no evidence as yet that beryllium contains isotopes, and if it does not contain them the new value for the atomic weight, since it is very close to an integer, is perhaps more plausible than the old one.—*Berichte,* **55**, 4.

H. L. W.

3. *An Introduction to the Physics and Chemistry of Colloids;* by Emil Hatschek. 12mo, pp. 172. Philadelphia, 1922 (P. Blakiston's Son & Co.).—This is the fourth edition, entirely re-written and enlarged, of a little book originating in London, the first issue of which appeared in 1913. It gives an excellent account of the facts and theories of this rapidly developing and exceedingly important branch of physical chemistry, and it is to be highly recommended for the use of those who wish to obtain a clear, fundamental knowledge of this very interesting subject.

The historical part is briefly but very well presented, and mention is made of the work of the American, Carey Lea, whose papers on ''Allotropic silver'' were published in this journal in 1889 and were evidently very important in connection with the colloidal condition of the metals. No attempt will be made here to discuss the presentation of the description and theoretical topics except to say that this has been very well done. H. L. W.

4. *Distillation Principles and Processes;* by Sidney Young. 8vo, pp. 509. London, 1922 (Macmillan and Co., Limited).—This very comprehensive work is the successor to the author's excellent book on ''Fractional Distillation'' which appeared in 1903. The latter dealt chiefly with the details and principles of small-scale distillations, such as are carried out in the laboratory. A revision of this part, with the addition of a chapter on sublimation, comprises about one-half of the new book, while the remainder of it is devoted to the following sections prepared by specialists in various lines of distillation on a manufacturing scale: Acetone and *n*-Butyl Alcohol, by Joseph Reilly and F. R. Henley; Alcohol, by F. R. Henley and Dr. Reilly; Petroleum, by James Kewley; Coal Tar, by T. Howard Butler; Glycerine, by Lieut.-Col. E. Briggs; Essential Oils, by Thos. H. Durrans.

The book contains no less than 210 illustrations. Its very elaborate treatment of the principles and apparatus of laboratory distillation, together with the accounts of technical operations, make it a very complete and satisfactory one, not only for the use of chemists engaged in research, but also for technical chemists. H. L. W.

5. *Separation of Isotopes.*—The lecture by F. W. Aston before the Royal Institution as reported in *Nature* **107**, 334, 1921, contains an account of all the elements with their isotopes which have so far been examined by the positive ray spectrograph. The great interest which attaches to the sweeping simplications which have been made in our ideas of mass, by the now well established view that all atoms are built of primordial atoms of positive and negative electricity, has stimulated efforts to secure evidence as to the existence of various isotopes, by other lines of attack.

A very laborious series of operations on fractional diffusion through pipe clay has shown that neon may be separated into two components differing in density by 0.7 of one per cent.

The spectra of the three isotopes of lead have been shown to have small differences in the wave lengths of the principal lines and the same is probably true of the spectra of ordinary thallium and that extracted from pitchblende.

Following Aston's announcement of the discovery that chlorine consists of a mixture of two isotopes of atomic weights 35 and 37, Merton and Hartley suggested that as chlorine gas would probably consist of three molecules in the ratio of 9:6:1, if a beam of white light were allowed to traverse a column of chlorine the light might be differently absorbed by the different molecules, so that the emergent radiations would have different intensities in different wave lengths. It was accordingly proposed to allow the light which had traversed the filter to enter a vessel containing a mixture of hydrogen and chlorine which combine under the influence of light of these wave lengths. It was calculated that the rates of reaction for the different HCl molecules would be in the ratio $1:(10)^9:(10)^{24}$. If this were true the hydrochloric acid formed would consist almost entirely of HCl_{37} provided the reaction were allowed to proceed for a sufficient length of time. This experiment has now been carried out with great care (*Phil. Mag.* **43**, 430, 1922) but it was found impossible to say whether a real separation had been effected or not. The failure may have been due either to secondary reactions or to the fact that the difference in the absorption spectra of the two isotopes was insufficient for the purpose.

Bronsted and Hevesy have attempted the separation of mercury isotopes by methods depending upon the different molecular velocities appearing in consequence of the different masses of the isotopes. When the liquid is allowed to evaporate, the rate at which the two molecules leave the liquid should be inversely as the square roots of the masses. If a strongly cooled plate is placed just above the liquid each molecule as it reaches the plate will be condensed to a solid before it has the opportunity of meeting the other molecules and be returned to the liquid. A separation will thus be effected between the slower and the faster moving molecules. Another method proposed was to allow the molecular flow to take place through a small opening. In this case the lighter and more rapidly moving molecule should hit the opening more often than the heavier one and if it is prevented from returning by trapping it on a cooled plate a separation between the components of the vapor should be secured in this way.

Both the evaporation method and the effusion method were successfully tried by these authors who found that the quantities separated were inversely proportional to the square roots of the molecular weights of the isotopes as determined by Aston.—*Phil. Mag.* **43**, 31, 1922. F. E. B.

6. *Newcomb-Engelmann Populäre Astronomie;* Sixth Edition edited by H. LUDENDORFF. Pp. XII, 889. Leipzig, 1921 (Wilhelm Engelmann).—The favor with which this work by real authorities has been received may be judged by the increasing rapidity with which the successive editions have been exhausted. First appearing in 1881 as a translation of the Popular Astronomy of Simon Newcomb, the later issues have preserved little resemblance to the original work, so numerous and extensive have been the changes. The editors have however always sought to preserve the historical treatment which characterized the author's treatise.

Our knowledge of the structure of the universe and stellar activity has so widened since the appearance of the last edition in 1914 that the three chapters on Stellar Astronomy forming Part IV have been entirely rewritten, and two new sections on the Development of Mechanics since Newton and on the Principle of Relativity have been added to Part I. In addition all the material has been revised in the light of the newest research and the numerical data have been corrected from the most trustworthy sources. Many sections are the work of specialists as, for example, those on Meteors, the Physical Activity of the Stars, and Star Clusters and Nebulae, by Eberhard; Stellar Parallax, Proper Motion, Double Stars, and Variables, by Ludendorff; The Fundamental Laws of Mechanics, the Three-Body Problem, The Sun, and Novae, by Freundlich; the Planets, the Structure of the Universe and Cosmogony, by Kohlschütter. The unavoidable increase in the size of the book has tempted the editor to omit the appendix devoted to biographical sketches but in response to the desire of his colleagues they have been retained.

The title "popular" connotes little more than "non-mathematical." Outside of that it is a serious treatise for the student, teacher, or reader and a valuable compendium for practical work. The typography is most satisfying and the illustrations beautifully done. Their number has been increased from 228 to 240 in this edition. As a work on general astronomy it is unequalled in any language and on account of the present state of exchange its cost is but a fraction of what would be required to produce it in any other country. F. E. B.

7. *The Two Orbit Theory of Radiation;* by FRANK H. BIGELOW. Pp. VII, 37. Vienna 1921 (Austrian State Printing Office).—This brochure is designated as Supplement No. 2 to *Treatises on the Atmospheres of the Sun and the Earth.* For the purposes of atmospheric physics the author rejects the Bohr theory of stationary non-radiating orbits with electrons jumping across radial differences with a frequency ν, as too artificial for general application. In its place he proposes a two orbit theory of radiation in which it is assumed that the negative electron is revolving about the positively charged atomic nucleus while the latter is revolving about the instantaneous line of translation. Under these conditions the velocity of the electron is periodically variable and generates trains of radiation.

The paper attempts to show by thermodynamic reasoning the origin of solar radiation and the location in the solar atmosphere where the several spectrum lines originate. F. E. B.

II. GEOLOGY AND MINERALOGY.

1. *Ueber das Becken, den Schultergürtel und einige andere Teile der Londoner Archaeopteryx,* by BRANISLAV PETRONIEVICS. Pp. 31, 2 pls., Genf (Georg & Co.), 1921.—These studies are the result of further preparation of the famous British Museum specimen of *Archæopteryx* which has exposed a number of new skeletal elements. A description and dimensions are given of the pelvis, and it is compared with that of the Berlin specimen and with that of other birds and reptiles. The shoulder girdle and other elements are treated in the same manner. As a result of these comparisons, the author arrives at the following conclusions: (1) that the birds are undoubtedly derived from the reptilian stem; (2) that their ancestors are to be sought among the Lacertilia, or that at least birds and Lacertilia came from a common ancestry; (3) that the similarities between the birds on the one hand and the Dinosauria and Pterosauria on the other are due to convergence; (4) that *Archæopteryx* both in its pelvic and shoulder girdles is more primitive than *Archæornis;* (5) that *Archæopteryx* represents a generalized as well as a mixed bird-type, since it combines primitive reptilian characters with advanced bird characters; (6) that *Archæopteryx* either stands near that generalized bird-type out of which developed both the modern Carinates and Ratites, or is itself that type; (7) that as

early as the Jurassic the division of the bird-stem into the Carinate (*Archæornis*) and Ratite (*Archæopteryx*) groups had begun; and (8) that the division became still more marked in the Cretaceous, in that *Hesperornis* lies in the line toward Ratite and *Ichthyornis* in that toward Carinate, evolution.

The author gives to the Berlin specimen the new generic name *Archæornis,* leaving the London specimen under the original genus, *Archæopteryx.* He further finds sufficient distinction between them to postulate the former as the ancestor of the Carinate birds through the Cretaceous *Ichthyornis,* and the latter as the forerunner of the Ratitæ through *Hesperornis,* reviving Marsh's contention that *Hesperornis* belongs or is related to the Ratite group, a premise which has now but little acceptance.

R. S. L.

2. *Die Antike Tierwelt,* by OTTO KELLER. *Gesamtregister,* by EUGEN STAIGER, Leipzig (Wilhelm Engelmann), 1920.—This is a somewhat detailed index pertaining to the two volumes previously noticed in this Journal (Bd. I, July, 1910; Bd. II, October, 1913); it lends final completeness to a work of great interest to the student of zoology as well as to the antiquarian. R. S. L.

3. *Origin and Evolution of the Human Race;* by ALBERT CHURCHWARD. Pp. xv, 511, 78 pls., many text figs., New York (Macmillan Company), 1922.—A large and amply illustrated volume based on a considerable body of detailed and apparently accurate research, not done in the laboratory or library but largely in actual contact with the various peoples with which it deals. Doctor Churchward makes a great deal of totemism and contributes much of interest to our knowledge of this rather obscure subject. His main thesis, however, is to prove Africa to have been the primal home of mankind, the place of his original evolution and from which he migrated to all parts of the earth. He further believes that, as is the rule with other forms of life, man's evolution has also resulted in increase of stature, and he looks upon the African pygmies, not as physically degenerate, but as in a state of persistent primitiveness. These represent the stock out of which arose the other human races, through the "Masaba" negro to the Nilotic negro and thence to the diverse sorts of humanity. Churchward finds no difficulty in assigning each of the various types of European prehistoric men—Heidelberg, Neanderthal, etc.—to his own place in the scheme, the above mentioned being but Nilotic negroes which have migrated into Europe from ancient Egypt, to be replaced in time by another wave of migration from the same source. Chapter XXXII gives a tabulated summary of the assumed relationships, the standard accepted European chronology of the Recent and Pleistocene being, in the author's opinion, absurd. The book contains much of value, but the thesis is so novel that, as Churchward says, he

hardly anticipates its acceptance by the present generation of scientific men. R. S. L.

4. *The Topographic and Geological Survey of Pennsylvania;* George H. Ashley, State Geologist.—Bulletins 1 to 25 of the Survey were mentioned in the last number (pp. 305, 306). Nos. 26 to 35 are now issued (also mimeographed). These are all devoted to coal beds or coal reserves in various countries except No. 28 which discusses the magnesite of the State; it is by R. W. Stone.

5. *Geological Survey of the Union of South Africa;* Percy A. Wagner, Geologist.—Memoirs issued at Pretoria, are Nos. 16 and 17, both by Dr. Wagner, and liberally illustrated. No. 16 discusses the Mutue Fides—Stavoren Tinfields and is a valuable contribution to a subject of wide interest.

No. 17, also by Dr. Wagner, is a report on the Crocodile River iron deposits. Though at present rather inaccessible, particularly in the rainy season, being 68 miles from the nearest railway station, they promise to be of much importance in the future.

The geology of the country surrounding Johannesburg, being an explanation of the Johannesburg sheet (No. 52), is discussed by Dr. E. T. Mellor in a pamphlet of 46 pages.

6. *Carboniferous Glaciation of South Africa.*—This is the title of a paper by Alex. L. du Toit published in the Transactions of the Geological Society of South Africa (vol. **24**, 1921). A map shows clearly the radiation of the Carboniferous ice. It is stated that the Dwyka ice-sheet of the Upper Carboniferous was formed by the ice coalescing from several distinct centers, Namaqualand, Griqualand West, Transvaal and Natal. The general direction was southerly or pole-ward.

7. *South Australia Geological Report for 1920;* L. Keith Ward, Director of Mines and Government Geologist. Adelaide, 1921. Eight pages.—The report of the director recently received presents concisely the geological and economical results of the year's work.

The Department of Mines has also issued No. 34 (74 pp., illustrated) of the Mining Review for the half-year ending June 30, 1921. This has been compiled by Lionel C. E. Gee.

8. *Mineral Production in the United States and elsewhere.*—Under the general head of Mineral Resources of the United States are to be mentioned, first of all, the well-known publications of the U. S. Geological Survey, which are issued in separate chapters and kept admirably up to date.

The very varied mineral resources of the State of New York are presented by David H. Newland in the Museum Bulletin (Nos. 223, 224), John M. Clarke, Director under the University of the State of New York. Some forty separate important minerals and rocks are enumerated and their occurrence described in this publication of 315 pages (illustrated).

Bulletin No. 23 of the Geological Survey of Alabama, EUGENE A. SMITH, State geologist, giving statistics of the mineral production of ALABAMA, has been compiled from the Mineral Resources of the National Government. Further Bulletin No. 24 by GEORGE H. CLARK, assistant geologist, gives an account of the Alabama mica deposits. The state comes sixth among the states. North Carolina furnishing about one-half that of the country.

The annual report on the mineral production of CANADA in 1920 shows that the total value amounted to nearly $228,000,000, the highest on record and an increase of 29 per cent over 1919. The total value in 1886 was somewhat more than $10,000,000; this was doubled in 1896; another decade showed further increase of three and a half times, while the production now noted (1920) is about three times that of 1906. For metallic products the quantities obtained come in the following order: copper, nickel, zinc, lead, silver, gold; 600 crude ounces of platinum were produced. Among the non-metallic products coal leads by a large amount, with gypsum and asbestos prominent.

The second annual report for ALBERTA (1920, 152 pp.) has been prepared by JOHN A. ALLAN. First in importance comes coal, then rock salt and petroleum (11,718 barrels in 1920); clays, iron, etc., are also described.

9. *The Future of the Comstock Lode.*—The well-known Comstock lode in Nevada, which produced such vast wealth in silver and gold especially in the decade following 1859, has been studied anew by the U. S. Geological Survey. In a recent leaflet it is remarked that the fundamental geologic problem is the persistence of the ores with increase in depth. If the rich silver ores were deposited wholly or largely from solutions that ascended from sources far below the surface, deeper exploration is fully warranted. If they owed their richness to the action of descending surface waters on ores that originally contained relatively little gold and silver, then there is little to encourage deeper mining. The steady progress in metallurgy, by which more metal is recovered from low-grade gold and silver ores, has given large practical importance to the question of the persistence in depth of ores of this class.

E. S. Bastin has made a microscopic study of the Comstock ores. In his report (Bulletin 735-C) entitled "Bonanza ores of the Comstock Lode," he concludes that in the ores from depths greater than 500 feet, which include most of the bonanza ores of the lode, the silver is practically all in primary minerals. Descending solutions of surface origin produced a large increase in the silver content of certain ores obtained within 500 feet or less of the surface, yet even at those depths a part of the silver is contained in primary minerals, and some rich ores taken from slight depths showed no secondary silver minerals. Gold, so far as observed, is primary in all the ores. A revival of the gold and silver age of Comstock mining is not to be looked for, since the tremendous fracturing which created the channels that made ore deposition possible was more extensive near the surface than at great depths. Nevertheless, the ''roots'' of an ore deposit so immense are by no means small, and the Comstock operators have in recent years shown their confidence in the existence of deep-lying bodies of workable ore by draining a large part of the lode to and below the 2,900-foot level. Although the deeper parts of the lode probably contain no ore bodies comparable in size and richness to the great bonanzas of the past, yet the primary origin of some of the rich ores encourages deeper development.

10. *A new Meteoric Iron;* by GEORGE P. MERRILL (Communicated).—A 25-lb. mass of meteoric iron has recently come to the National Museum from Nickelsville, Scott Co., southwest Virginia. It is badly oxidized and evidently represents a very old fall. It is, however, of interest since it shows unmistakable evidence of the secondary granulation to which Berwerth has given the name metabolism.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The annual meeting of the National Academy of Sciences was held at the Natural History building, U. S. National Museum, in Washington, on April 24, 25 and 26. The scientific sessions were open to the public as usual. The number of papers offered for reading was very large, numbering about 40 in the preliminary program issued by the Home Secretary, Dr. C. G. Abbot. A particularly interesting feature of the meeting was the address by Dr. H. A. Lorentz, professor of physics of the University of Leiden and Foreign Associate of the National Academy, on ''Problems of modern physics.'' This address was given under the joint auspices of the Carnegie Institution of Washington and the National Academy of Sciences, on Monday evening, April 24. Reception to Dr. and Mrs. Lorentz followed in the Galleries of the U. S. National Museum. The subscription dinner for the members was held on the evening of April 25 at the Hotel Powhatan, and there was a ladies subscription dinner, at the same place and time.

The late date in the month of the Academy meeting makes it impossible to give here the lists of new members elected, active and associate. These will follow in the next number.

2. *A Text-book of Zoology;* by the late T. JEFFERY PARKER and WILLIAM A. HASWELL. Third edition. Two volumes; vol. I, pp. xl, 816, with 713 figures; vol. II, pp. xx, 714, with 560 fig-

ures. London, 1921 (Macmillan and Co.).—For nearly a quarter of a century this has been a standard text and reference book in all parts of the English-speaking world. The first volume includes all groups of animals except the Chordates, each of the chapters having been carefully revised from the earlier editions, and the sections on the Nemathelminthes, Molluscoidea and Annulata considerably altered and improved. Still further revision might well have been made in some of the other groups, particularly in the classes Nemertea and Arachnida, to bring them in line with the results of recent studies, but on the whole the work is of such excellence that it will continue to hold its place as the leading elementary text-book of Zoology in any language. The second volume treats of primitive chordates and the vertebrates, together with chapters on the distribution of animals, the philosophy of zoology, history of zoology, and literature.

Experience with the earlier editions has shown that the book, although sufficiently extensive to meet the needs of well advanced students of zoology, has been so written as to make it intelligible to those with no previous knowledge of the subject. The important groups are each introduced by a detailed study of a typical example, and with this as a basis the modifications of the organ systems in the other members of the group are described. The illustrations are widely known for their excellence and have been copied extensively in other works. The printing of the new edition, however, is not quite up to the high standard of the earlier volumes. W. R. C.

3. *Reptiles of the World; Tortoises and Turtles, Crocodilians, Lizards and Snakes of the Eastern and Western Hemispheres;* by RAYMOND L. DITMARS. Pp. 373, with 89 plates. New York, 1922 (The Macmillan Company).—Probably no one in America has a wider knowledge of the life and habits of the reptiles than the curator of this group of animals in the New York Zoological Park. In this popular account of his pets, Mr. Ditmars makes available to the general public as well as to the scientific world the most interesting things about the creatures to which he has devoted his life. In these days of specialization on minutiae it is pleasant to find a good old-fashioned natural history, but this is old-fashioned only in the sense that the subject is treated broadly and with a living interest, for it is strictly up to date from a scientific standpoint and thoroughly reliable. The illustrations are from photographs, most of which were taken by the author from living specimens. The book contains whatever is best worth knowing about these animals and the reader who has the good fortune of spending a few hours with it will no longer think of the reptiles as the repulsive creatures he has imagined them, but will long to make a more intimate and personal acquaintance with them. W. R. C.

4. *Monographia delle Cocciniglie italiane;* by GUSTAVO LEONARDI. Edited and supplemented by F. SILVESTRI. Pp. 555, with 375 figures. Portici, 1920 (Ernesto della Torre).—This important work summarizes the results of a lifelong study of the structure, habits and life histories of the scale insects (Coccidae) found in Italy. One hundred and forty-seven species are included, each of these being described in great detail for all stages in the complicated life history and illustrated for the most part by original drawings. Because of the great economic importance of these insects in the destruction of trees, fruits, and other crops this work will prove of service not only to science but also to agriculture, since a complete knowledge of the life of an insect is essential for devising practical measures for its control.

W. R. C.

5. *Fauna Hawaiiensis; or the Zoology of the Sandwich Isles; being Results of the Explorations instituted by the Joint Committee appointed by the Royal Society of London for Promoting Natural Knowledge and the British Association for the Advancement of Science, and carried on with the assistance of those Bodies and of the Trustees of the Bernice Pauahi Bishop Museum at Honolulu.* Three volumes, quarto; 2410 pp., with 64 plates; edited by DAVID SHARP. Cambridge, 1899-1910 (University Press).—The land fauna of the Hawaiian islands is of particular interest to zoologists because of the question concerning its origin. Determination of the closeness of its relationship with that of other islands of the Pacific or with that of the American continent will afford evidence as to the nature of the geological changes which have occurred in the more recent eras. These studies, undertaken when the zoology of the islands was almost unknown, show a land fauna consisting of more than 3,300 species of insects, 500 forms of mollusks and 50 birds, including the many new species described in these reports. There are no indigenous mammals, earthworms or ants. The introduction by R. C. L. Perkins, consisting of 228 pages, with 16 plates, reviews the salient features of all groups of the fauna and discusses the evidence as to the origin of the latter.

In Volume I, R. C. L. Perkins and Aug. Forel describe many new genera and species among the 178 species of aculeate Hymenoptera now recorded from the islands; Edward Meyrick describes 200 new Macrolepidoptera among the 292 species found; Lord Walsingham lists 441 species of Microlepidoptera, of which 420 are endemic and mostly new to science; W. H. Ashmead records 128 species of parasitic Hymenoptera, including many new forms; while the birds are discussed by R. C. L. Perkins.

The Orthoptera and Neuroptera and supplements to the Hymenoptera, and Diptera by R. C. L. Perkins are included in

Volume II, together with the Coleoptera by Perkins and Sharp, the Mollusca by E. R. Sykes, the earthworms by F. E. Beddard, the entozoa by A. E. Shipley, the Arachnida by Eugène Simon, the Isopoda by Adrien Dollfus, the Amphipoda by T. R. R. Stebbing, and a supplemental list of Hemiptera by G. W. Kirkaldy.

In volume III are the Diptera by P. H. Grinshaw and P. Speiser, Hemiptera by G. W. Kirkaldy, Coleoptera by D. Sharp, Hugh Scott and D. C. L. Perkins as well as other groups of insects, Mallophaga and Myriopods.

With the publication of these reports the Sandwich Islands may be considered as better known zoologically than most other parts of the world. But the fact that some 300 new species of insects and numerous species of other animals have been described since their publication shows that much still remains to be done. W. R. C.

6. *World Atlas of Commercial Geology.* In two parts. Part I. *Distribution of Mineral Production.* Pp. 72, 72 plates. Washington, 1921 (U. S. Geological Survey, price $2.00).—The text of this atlas consists of brief accounts of thirty of the more important mineral commodities. For each commodity is given in compact form, and stripped of all unnecessary technicalities, the salient features of the uses, possibility of employment of substitutes, geologic occurrence, geographic distribution, technology, centers of production and consumption, statistics of output, and the position of the United States in the industry of each of the mineral products. Many of the tables of world output by countries are pioneer compilations and have entailed an enormous amount of research in a dozen different languages.

The maps, as the title of the publication suggests, are the main feature. The thirty commodities are divided into nine groups, and the output of each commodity is shown by means of nine series of eight maps each. The first map of each series shows the world production and consumption of the commodities of each group; for example, one series shows the industrially related group of iron ore, manganese ore, and chromic iron ore, each commodity being indicated by a separate color. The first map of each series thus gives at a glance a world view of the distribution of mineral production, and further it serves as a key to the succeeding maps, which show the production by leading districts in the countries of the several continents, including Oceania. The production shown is that for 1913, the last normal year before the war. The final map of each series shows the production in the United States in 1918. A vast amount of information is graphically summarized and illuminatingly presented in these maps.

Part II. *Water Power of the World;* by HERMAN STABLER, B. E. JONES, O. C. MERRILL, and N. C. GROVER. Pp. 37, 10 maps (U. S. Geological Survey, price, $1.00).—This is an inventory of the world's water power, including both the developed and the potential resources. The present developed capacity of the world is 23 million horsepower and the potential water power is 440 million horsepower at ordinary low-water stage. Africa leads in undeveloped water power, with 190 million horsepower; Asia has 71 million; North America 62 million, South America 54 million, and Europe 45 million. North America has developed 12 million horsepower, more than all the rest of the world; of this amount 9,243,000 horsepower are installed in the United States. The quantitative distribution of these resources in the several continents and by States in the United States is shown graphically on an excellent series of maps (plates 2-8).

ADOLPH KNOPF.

7. *The Friendly Arctic;* by VILHJALMUR STEFANSSON. Pp. xxxi, 784. New York, 1921 (The Macmillan Co.).—This volume is the narrative of five years of Arctic exploration in the great archipelago lying north of the American continent. The author was commander-in-chief of an expedition supported most generously by the Canadian Government—"the most comprehensive polar expedition that ever sailed." It included a scientific staff of fifteen men, who were to investigate the anthropology, biology (both terrestrial and marine), geography, geology, oceanography, and terrestrial magnetism of the region explored. The expedition sailed from Nome in July, 1913, in the Karluk, accompanied by two 30-ton auxiliary gasoline vessels. Owing to the loss of the Karluk, which carried most of the equipment regarded as essential to polar exploration, the commander decided to try out the method of "living off the country," in order to carry out his geographic program. The weight of all evidence was against this bold idea—"geographers, explorers, whalers, and Eskimos alike were of the opinion that our plans were unsound and that the attempt to carry them out would be disastrous." The scientific associates felt this way about the commander-in-chief's project and thereafter, according to the author, became firmly insubordinate. In justice to them, however, it must be said that they do not present their own case in this book. The volume is largely an account of the triumphant success of the commander, accompanied by two sailor companions, in exploring great areas of frozen Polar seas north of Canada and the archipelago on the east of these seas, and it describes the important geographic discoveries that resulted from this new method of polar exploration. The lifeless Polar Sea, as it was termed by the foremost authorities, was found to be stocked abundantly with food and fuel. The book makes absorbingly interesting reading. The "friendliness" of the Arctic is much overemphasized, however, and our dissent from the overdrawn picture of its kindliness is heightened when we read the roster of the brave men who perished on the Karluk.

The scientific results of the expedition are being published by the Department of the Naval Service at Ottawa and may eventually total twenty or thirty volumes. ADOLPH KNOPF.

8. *The Evolution of Climates;* by MARSDEN MANSON. Privately printed (1922). 66 pages.—The author of this paper concludes: (1) That solar control of climates did not prevail in any period of the geologic past. Earth heat, conserved by a non-conducting crust, was liberated slowly after crustal disturbances. This heat warmed the oceans, which gave off vapor to form a permanent cloud blanket. (2) After long periods of crustal quiet the available heat decreased, the lands were cooled, and glaciation resulted. In most cases the heat conserved in the oceans prevented widespread glaciation and maintained warm climates even in polar latitudes. Liberation of additional heat from the earth, largely as a result of crustal failure under glacial loading, restored universal mildness of climate. (3) In the Pleistocene both land and ocean were greatly cooled. As a consequence, cloudiness was reduced, and the present zonal climates, under solar control, resulted.

The scientific reader must feel that the author has not been able "to explain the variations and developments of geologic and present climates without resort to assumptions or working hypotheses of any kind." For example the attempt in the paper to link climate and diastrophism in a reversible reaction, making glacial loading the chief cause of profound crustal disturbances, is in itself a "working hypothesis" which serious students of structural and historical geology will hardly accept.

CHESTER R. LONGWELL.

9. *An Essay on the Physiology of Mind;* by FRANCIS X. DERCUM. Pp. 150. Philadelphia, 1922 (W. B. Saunders Company).—This book revives a title which Maudsley used when he published his well-known volume in 1867. Dr. Dercum endeavors "to apply purely physical conceptions to the interpretation of mind." The paradoxical wording of the title may be justified by the materializing tendency of recent psychology and by the opposite tendency of recent physics. "The modern study of atom reveals it to be but an expression of energy, indestructible, persistent, unknowable. Does not this cause the difference between the old conceptions of 'material' and 'immaterial' to disappear? Does it not make unnecessary—as it is impossible—a 'dual' conception of the universe?"

We should not, according to Dercum, introduce an immaterial principle, like the *psyche* or the spiritus, to explain behavior; we should frankly apply the mechanics or physiology of the amœba and sea-anemone to higher levels. Oxidation, reduction, amœboidism, transmitted compacts, destruction of molecules, polarization, etc., account for lower forms of behavior, why not for higher? "The 10,000 million intercalary neurones of the cortex add merely to the complexity of the response; the purely physical, automatic character of the latter remains unchanged.'' Dercum holds that the cortical neurones have the property of amœboidism. ''In sleep the neurones have their processes retracted; in consciousness their processes are extended.'' Quiescent neurones occupy the unconscious field. Dr. Dercum's discussion is compact and readable. It assembles many facts in an original manner. As a broad formulation of the mechanical basis of behavior it has a suggestive value.

In an addendum on the Pathological Physiology of Mind, the author applies his formulæ to the interpretation of dementia praecox, delirium, hysteria, etc. It is here that the explanatory weakness of the formulæ is clearly revealed; and the result approaches what Adolph Meyer once called ''neurologizing tautology.'' ''Dementia praecox is essentially an affection of endogenous deterioration.'' It results in ''adynamia of the field of cortical activity.'' ''The level, the intensity of the metabolic processes, of the neurones is lowered,'' with resulting slowness of speech, poverty of thought, etc. Mental phenomena may in essence be physical, as the author holds, but their further elucidation depends upon dynamic, genetic studies of personality, by psychiatric and psychological methods. Poverty of thought, for example, may be more apparent than real, and instead of representing a quantitative reduction in the physico-chemical sense, it may have an altogether different significance when given a functional interpretation. ARNOLD GESELL, M.D.

10. *Royal Natural History Museum at Brussels.*—The fourth part of volume VIII (Memoir 31) is an extended quarto volume of 208 pages with 233 textfigures, devoted to the *Chironomides* of Belgium and especially those of the Flanders. The author is DR. M. GOETGHEBUER, who was also the author of part three on the *Ceratopogoninæ* of Belgium (1920).

OBITUARY.

M. CAMILLE JORDAN, the veteran French mathematician and a man of rare genius, died in March at the age of eighty-four years.

PROFESSOR BENJAMIN MOORE, who held (from 1918) the chair of biochemistry in the University of Oxford and earlier a member of the staff of the Yale Medical School, died on March 3 at the age of fifty-five years.

DR. AUGUSTUS DÉSIRÉ WALLER, director of the physiological laboratory and professor of physiology in the University of London, died on March 11 in his sixty-sixth year.

DR. THEODORE LIEBISCH, professor of mineralogy at the University of Berlin, died on February 9 in his seventieth year.

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[FIFTH SERIES.]

Art. XXXVII.—*A Critical Review of Chamberlin's Groundwork for the Study of Megadiastrophism;* by William F. Jones.

Summary of Thesis.

The evidence of earth rigidity and elasticity is here considered from the relative viewpoint and the conclusion is reached that while the earth may be highly rigid under tidal stress, that it is, beneath a superficial shell, in a yield state for stresses of diastrophic dimensions.

The evidence of seismic transmission apparently indicates a viscous liquid state for depths below 0.6 of the earth's radius for stresses of these dimensions, and the conclusion is reached that such a state for larger stresses will be nearer the surface.

Seismic transmission indicates an isotropically homogeneous state for the earth beneath a comparatively thin heterogeneous outer shell and this conclusion is in direct opposition to Chamberlin's postulated earth heterogeneity both in depth and laterally, and the evidence is taken as indicating a density stratification of the earth as a result of its having passed through a period of fusion.

The postulate of a continuously solid state for the earth is shown to rest on certain assumptions as to size of the earth nucleus and its rate of growth, and a solid heterogeneous earth with vulcanism a result of selective liquefaction is thought to be incompatible with the facts of occurrence of the igneous rocks.

Evidence is submitted to show that diastrophism can be readily accounted for by adjustment or lack of adjustment of a heterogeneous outer shell resting on an asthenosphere or yield zone, and does not require deep-seated variations of density or deep-seated diastrophic movements.

Introduction.

As a groundwork for the study of "megadiastrophism," a term introduced as applying to diastrophism on the large scale—continental or sub-oceanic, or even applying to the earth as a whole, T. C. Chamberlin has set forth in summary form in two recent papers[1] the salient deductions and conclusions he has drawn from his studies of the formative processes.[2] R. T. Chamberlin in a following paper[3] reviews the intimations of deep deformation derived from structural cross-section studies of two folded and deformed belts, the results of which have been previously published.[4]

It is evident that the study in megadiastrophism is to be one of the application of wedge-dynamics to continental areas. To consider continental areas as the upper surfaces of deeply pointing wedges implies, of course, that the earth lacks an asthenosphere or yield zone. This postulate is fundamental. The issue is thus sharply drawn between the two schools of thought. The basic problems of diastrophism, isostasy, and vulcanism must be attacked and interpreted in two diametrically opposite ways by the two schools. The one school, as represented by T. C. and R. T. Chamberlin, interpret these problems from the viewpoint of an earth which has maintained perfect solidity through the formative eras and down to the present; an earth, heterogeneous in its makeup both laterally and in depth, in which, as R. T. Chamberlin says,[5] "all thought of easy movement in the interior is to be scrupulously avoided." The other school, as represented by Daly and the late Barrell, interpret these problems, on the other hand, from the viewpoint of an

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[1] Groundwork for the Study of Megadiastrophism, Pt. I. Summary statement of the groundwork already laid. T. C. Chamberlin, Jour. Geology, vol. 29, pp. 391-416, 1921.

Groundwork for the Earth's Diastrophism, T. C. Chamberlin, Bull. Geol. Soc. America, vol. 32, pp. 197-210, 1921.

[2] Thirteen papers in recent volumes Journal of Geology.

[3] Groundwork for the Study of Megadiastrophism, Pt. II. The Intimation of Shell Deformation, R. T. Chamberlin, Jour. Geology, vol. 29, pp. 416-425, 1921.

[4] R. T. Chamberlin: The Appalachian Folds of Central Pennsylvania, Jour. Geology, vol. 18, pp. 228-251, 1910.

The Building of the Colorado Rockies, Jour. Geology, vol. 27, pp. 145-164; 225-251, 1919.

[5] Jour. Geology, vol. 29, p. 421, 1921.

earth which passed through a stage of fusion resulting in a coarse stratification by density and which, since crustification, has possessed a yield zone beneath a comparatively thin outer shell. This latter viewpoint is not, as Daly has pointed out,[6] incompatible with the basic postulates of the planetesimal hypothesis of geogenesis.

The purpose of the present paper is to bring together in summary form from the various sources the evidence leading to the conclusions that the earth passed through a molten stage and that there exists at no great depth a zone which yields to diastrophic differential stresses. The writer believes that this evidence, much of it direct evidence of seismic transmission and close field studies, cannot be lightly set aside.

The Rigidity and Elasticity of the Earth.

General Considerations.—The term "rigidity" has been generally loosely interpreted. Rigidity is dependent not only on the stress applied but upon the time the stress is applied. A material may be rigid for one set of stress conditions and non-rigid for another set. The earth is spoken of as having a higher rigidity than steel. Another equally good way of stating the same fact is to say that the earth yields under the same conditions that steel will yield and, as a matter of fact, steel does yield quite readily. Even Adams'[7] and Bridgman's[8] experiments besides demonstrating the high strength of rocks under cubic compression also show that these same rocks eventually yield if the pressure is great enough and if the time the pressure is applied is long enough. Rigidity, then, is merely a relative term. Nothing that we know of has absolute rigidity. And plasticity, or yielding, is not necessarily dependent on the physical state of a material. Crystals become plastic at sufficiently high

[6] R. A. Daly: The Planetesimal Hypothesis in Relation to the Earth, Sci. Monthly, May, 1920, p. 495.

[7] F. D. Adams: An Experimental Contribution of the Question of Depth of the Zone of Flow in the Earth's Crust, Jour. Geology, vol. 20, pp. 97-118, 1912.

On the Amount of Internal Friction developed in Rocks during Deformation and on the Relative Plasticity of Different Types of Rocks, Jour. Geology, vol. 25, pp. 597-637, 1917.

[8] P. W. Bridgman: The Failure of Cavities in Crystals and Rocks under Pressure, this Journal (4) vol. 45, pp. 243-268, 1918.

pressures and so crystalline aggregates must become plastic.

Temperature increase, of course, materially facilitates yielding and so, as far as yielding by flowage is concerned, and where temperature and pressure both increase, a material will yield under a lower pressure than it would if pressure were increased alone. The fact of yielding implies differential pressures. True cubic compression no longer exists when yielding takes place. Certainly any terrestrial material we know of must be in a potential yield-state under the conditions of temperature and pressure at no very great depth beneath the surface of the earth whatever its physical state as regards homogeneity or heterogeneity, crystallinity or non-crystallinity and yet such a yield-state would be one of high rigidity in the ordinarily accepted sense of that term, that is, for any short time differential stress.

The term elasticity may have the same implication. A material may rebound under one set of stress conditions and not rebound under another set of conditions. Both these terms imply simply dependent states.

A material then, under any set of conditions as regards temperature and pressure, may have properties of rigidity and elasticity of a high order in so far as short-time stress differences are concerned and yet be non-rigid and non-elastic for stress differences of long duration and large magnitude, and these latter are the types of stress conditions we are concerned with in diastrophic movements. The statement that the earth is more rigid and elastic than steel should be qualified, therefore, with the statement that it possesses these properties for certain stress conditions—for example those imposed by tidal pulsations.

Now Chamberlin's interpretation of the evidences of this rigidity—that is the rigidity shown under tidal stress and seismic vibrations, implies that this state of rigidity and elasticity holds good for stress differences of all magnitudes and of all time durations. Under this interpretation the terms rigidity and elasticity become practically absolute instead of dependent. But such an interpretation is essential if he is to postulate the non-existence of a yield-state anywhere within the earth for almost any condition of stress. Under this conception yielding can only take place by shearing or recrystallization. This is vital to deeply pointing wedge deformations.

Chamberlin deduces a holocrystalline state for the earth on the basis of its rigidity, elasticity and density. It is evident that both rigidity and elasticity are totally independent of crystallinity. Amorphous materials, like glass, or even paraffin wax, under sufficient pressure become more rigid than steel under similar pressure. Under differential stress of sufficient magnitude and duration such materials will flow because they are true liquids. While it is true that high pressure favors crystallization, since for most substances the crystalline form is the most dense, this is true for conditions of normal temperature. High pressure experiments seem to indicate that there is a limiting set of conditions as to pressure and temperature beyond which all directional molecular arrangement is destroyed. The material then becomes a highly viscous liquid. There is nothing to indicate that such limiting conditions may not exist at no very great depth within the earth and the resulting state might, and probably would, be one of ready yielding to long-imposed stresses and still be a state of high rigidity and elasticity under short-time stresses. For material to assume such fluid properties for short-time stresses required conditions of higher temperature and pressure. Seismic transmissions seem to indicate that such conditions do exist at depths below 0.6 of the earth's radius.

The great depth of deformation deduced by Chamberlin rests then upon conditions of rigidity and elasticity which are not proved by the evidence at hand. And this is vastly important, for this deduction makes it essential that all earth body deformation be deep-seated and due largely to tidal stress and its consequent kneading. The work of Michelson[9] and others does not indicate in any sense that the tidal stresses are sufficient in time duration or magnitude to overcome the rigidity or elasticity attributed to the earth. Furthermore this same evidence does not prove that stress differences of diastrophic dimensions are not competent to overcome this same rigidity and elasticity and so cause plastic yielding.

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[9] A. A. Michelson & H. G. Gale: The Rigidity of the Earth. Jour. Geology, vol. 22, pp. 97-130, 1914; vol. 27, pp. 585-601, 1919.

Now temperature increase is so very much more effective in decreasing the density of material than pressure increase is in increasing its density that it is unsafe to assume that materials within the earth are in their most dense or crystalline state, much less to assume that some unknown compressional state exists. Again, so far as high pressure experiments have extended, the density increase upon pressure increase becomes negligible. The rigidity, however, progressively increases. The increase of density in the depths of the earth, it would seem, must be independent of high pressure and so independent of rigidity.

The Evidence of Seismic Vibrations.—Since records of the transmission of seismic vibrations constitute the only direct evidence we have of the state or states of the earth's interior an analysis of this evidence becomes imperative. Seismic disturbances send out vibrations of two types, compressional and distortional. These are called the primary and secondary waves respectively. The former waves are dependent on the elasticity or compressibility of the transmitting medium, while the latter waves are dependent both on the rigidity and the elasticity of the transmitting medium, for their propagation. The two types of waves travel at different velocities but can only become distinctly separated out in a homogeneous medium; that is, homogeneous as to stress effects or, in other words, isotropic. The resultant vibrations which travel circumferentially from the shock center pass through what we know is a heterogeneous medium. The wave types are not separated in the earth's surficial shell.

At a minimum distance of 700 miles, or 10 degrees of arc, from the epicenter a three-phase record becomes decipherable. The first phase vibrations to be recorded are the compressional or primary waves; next come the second phase distortional or secondary waves, and both these phases come through the earth. Finally the third phase, undifferentiated waves, reaches the recording device via a circumferential path.

From the mere fact that the primary and secondary waves are separated at distances above 10° of arc from the epicenter "it is clear," according to Davison,[10] "that

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[10] C. Davison: A Manual of Seismology, Cambridge, 1921, p. 149.

the waves arriving there must, for part of their journey, have traversed some homogeneous material situated below a comparatively thin layer.'' In fact, the rays of these vibrations which emerge at the arc distance of 10° or 700 miles actually penetrate to a depth of only 100 kilometers. Here then is apparently direct proof of a transmitting medium which is isotropically homogeneous at a comparatively shallow depth beneath the surface.

Now Chamberlin interprets this necessary and demonstrated homogeneity as a medium possessing an average homogeneity but a minute heterogeneity.[11] Such an interpretation becomes, of course, essential under the hypothesis of deep crystallinity for the earth. If such a minutely heterogeneous medium would have the identical transmitting properties as an actually isotropic one, then one obstacle in the way of acceptance of the postulate is removed, but are there not other obstacles?

The necessary confinement of large heterogeneity to such a comparatively thin outer shell would seem to present a formidable difficulty in the way of Chamberlin's postulated process of the introduction of tongue melts from the deep interior to the more surficial portions of the earth, for certainly these introduced heterogeneities would not all insinuate themselves above such a shallow depth as the transmitted seismic waves make necessary.

The important point deserving special emphasis is that the splitting up of the two vibration phases at such shallow depths as are penetrated by rays emerging at a distance of 700 miles from the shock center indicate a profound change in physical state at a very shallow depth beneath the earth's surface. The suddenness of this change is further indicated by the apparent reflection of transmitted waves against the surface of demarkation. The most reasonable conclusion to be drawn is that this sudden change is from a heterogeneous outer shell to a non-crystalline isotropic material similar to ''under-cooled'' liquids. Chamberlin's statement[12] that ''the hot interior of the earth is not a suitable environment for under-cooled liquids,'' does not take into account that this physical state is the combined result of temperature and pressure rather than of temperature alone.

[11] T. C. Chamberlin: Jour. Geology, vol. 29, p. 395, 1921.

[12] T. C. Chamberlin: The Origin of the Earth, Chicago, 1916, p. 181.

There is some disagreement in the interpretation of the records of transmitted vibrations which penetrate depths between the surface of demarkation as between outer shell and inner homogeneous material, and a depth of about half the earth's radius. Knott[13] in his work, and Davison[14] accepts his conclusions, shows an increasing rate of velocity for both phases of waves down to depths of 1,400 kilometers (.22R. R=earth's radius) for the secondary and 1,600 kilometers (.25R) for the primary waves. Slight decreases in the rates of velocity increase are indicated at a depth of about 750 kilometers. At these greater depths the velocities reach their maximum and from these points down slowly decline. Oldham on the other hand, both in his paper of 1906[15] and in his discussion of 1918,[16] concludes that there is a steady increase of the rate of transmission, with no marked break in regularity down to a depth of about one-half the earth's radius. The interpretations by Knott and Davison would imply a breakdown of the earth's rigidity and elasticity at .22R and .25R, respectively, while Oldham's interpretation would place the breakdown of these states at greater depths.

All these authorities, however, agree that below a depth of 3.825 kilometers (.6R) the earth body is non-rigid. Below this depth the secondary waves are either blotted out or, according to Oldham[17] "......are no longer represented in their typical form, but are replaced by a record of different character, probably not due to any form of wave, which has followed the direct path from the origin, and markedly delayed from the time at which they should have arrived."

The conclusions to be drawn from these facts are obvious. On them rests the conclusion of Oldham[18] that the material in the central nucleus has a very low degree of rigidity even against stresses of only a few seconds

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[13] C. G. Knott: The Propagation of Earthquake Waves through the Earth, Proc. Royal Soc. Edinburgh, vol. 39, pp. 157-208, 1919.

[14] C. Davidson: Op. cit., p. 157.

[15] R. D. Oldham: The Constitution of the Interior of the Earth as revealed by Earthquakes, Geol. Soc. London, Quart. Jour., vol. **62**, pp. 135-174, 1906.

[16] R. D. Oldham: The Constitution of the Earth's Interior. Nature, vol. **102**, pp. 235-236, 1918.

[17] Op. cit., p. 235.

[18] Op. cit., p. 235.

duration, and Knott[19] states that: "Within this nucleus of radius .4 the material of the earth has lost its elastic-solid character and can transmit only compressional (primary) waves" and "as the nucleus is approached the material of the earth is becoming less of an elastic-solid and more of an elastic, highly compressed liquid."

The evidence of a breakdown of rigidity in the earth's central portions is difficult to reconcile with Chamberlin's statement[20] that rigidity increases "towards the center faster than density........all the way to the center." "This evidence is thus directly opposed to the conception of an earth core which is dense and rigid." The core is undoubtedly dense but its rigidity has vanished.

Now if rigidity breaks down no matter what the depth for the stress differences of such short duration and small amplitude as seismic waves impose, then the rigidity and elasticity for stress differences of diastrophic dimensions in time duration and magnitude must break down at much more superficial depths. At least no experimental evidence has yet been submitted which proves or even implies that the material within the earth cannot yield, under the long time differential stresses imposed by diastrophic movements, under the conditions of temperature and pressure which exist at not a great depth.

Earth Yielding.—An earth composed of crystalline material could apparently only yield through the dynamic influences of condensation. The adequacy of tidal stresses is questionable. In such an earth the major features of surface relief, such as continents and ocean basins, could hardly be the direct result of diastrophism but could exist only because of differences in density extending to great depths as a result in turn of selective growth with a less volume of dense material falling, during growth, per unit area on the oceanic areas than of less dense material on the continental areas.

It would seem evident that mere surficial loading or underloading of any possible dimensions could not, in a crystalline rigid earth, cause sinking or rising of the earth's surface. It is not even apparent how peneplanation would be followed by uplift and yet without excep-

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[19] Op. cit., p. 186.

[20] T. C. Chamberlin: Jour. Geology, vol. 29, p. 395, 1921, and Bull. Geol. Soc. Am., vol. 32, p. 224, 1921.

tion such areal denudation has always been followed by uplift of the denuded area. On the other hand, it is probably true that accumulations of sediments do not cause down-sagging though their weight may be additive. In a large measure sedimentation goes on because of down-sagging instead of down-sagging being the result of sedimentation. The fundamental difference in the effects of denudation and sedimentation is undoubtedly due to the relative areas they affect. Denudation is not constricted to narrow belts while sedimentation is, and in spite of the probability of greater load per unit area in depositional belts than underload per unit area in peneplaned areas, these latter areas respond to the underloading and rise. It is a question then, not of underload or overload per unit area, but of areal distribution of load. The evidence back of this is conclusive. The smaller, or narrower, the area the greater the load per unit area necessary to cause down-sinking. In a holocrystalline earth these vertical movements would be entirely controlled, in so far as surficial loading could cause movement, by load per unit area rather than areal distribution of load. If these loads are the result of greater or less density extending to great depths there is no apparent reason why a broad area so loaded should more easily sink or rise than a smaller area similarly loaded. The mere fact of the control by areal distribution rather than by unit area load implies a solid crust of some strength resting on a yield zone beneath.

Direct proof of ready yielding under not excessive load per unit area but broadly distributed is to be found in the very definite record of crustal sinking beneath the Pleistocene ice caps and the rebound following deglaciation. Furthermore, it is becoming increasingly evident that this sinking was accompanied by a corresponding upwarp[21] at some distance in front of the advancing ice. The on-moving load, in this case, was actually "sliding on thin ice."

Furthermore the universal association of down-sag and upwarp through geologic history is difficult of explana-

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[21] Joseph Barrell: Movements of the Strand-line in Pleistocene and Post-Pleistocene, this Journal (4) vol. 40, p. 13, 1914.
R. A. Daly: Oscillation of Level in Belts Peripheral to the Pleistocene Ice Caps, Bull. Geol. Soc. Am., vol. 31, pp. 303-318, 1920.

tion on any other assumption than that the earth is, in a large sense, a yielding body.

Density Arrangement Within the Earth.—It is evident that the material within the earth is more dense than the visible material and it is also evident that the density becomes greater with depth though whether this increase continues to the earth's center is problematical. If now the earth is heterogeneous in its constitution from the surface downward then increase in density would be due to increasing pressure and the consequent condensation. This state, as postulated by Chamberlin, implies a chemical constitution throughout the earth, in general, similar to the visible terranes. While he has admitted the possibility of the accumulation of more dense material near the center through the process of selective liquefaction[22] Chamberlin's final conclusion is that "the metallic theory fits only clumsily the growing evidence that the interior elasticity and rigidity rise faster than density,"[23] and again, "the tenor of accumulating evidence implies that the conditions which affected the progressive self-compression of the body were more important than those which affected the original assortment of the material."[24] The one-fifteenth volume "core" is given finally a density stratification since it was concentrated, by hypothesis, through a "gaseo-molten" line of descent and would "take on a more or less concentric structure similar to that logically assigned to the whole earth by the old-masters."[25] The final picture is then of a central core, one-fifteenth of the earth's volume, stratified by density; surrounded by a shell composed of crystalline heterogeneous material, the density of the whole mass being due to self-compression.

The large percentage of metallic alloy in meteorites, even taking into consideration the large number of stony meteorites which are unnoticed, would imply a similarly large percentage of metal in the earth, and if present, and not concentrated towards the center, the surficial earth material should contain more of it and have a

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[22] T. C. Chamberlin: Origin of the Earth, Chicago, 1916, p. 181 and p. 237.

[23] T. C. Chamberlin: The Greater Earth, Bull. Geol. Soc. Am., vol. 32, p. 224, 1921.

[24] Ibid., p. 223.

[25] Ibid., p. 224.

higher density than is actually the case. As Daly has pointed out[26] the extrusive rocks should contain conspicuous proportions of the metallic alloys of low temperature fusion. Their absence from the visible extrusive rocks implies their absence from whence these rocks come. Either then the magmas are derived from surficial depths or the metals do not constitute even a small portion of the earth. But this conclusion is not compatible with meteoritic composition nor with the earth's magnetic properties.

Furthermore high pressure experiments indicate that density increases so slowly with increased pressure that even at normal temperatures the pressures within the earth could not give to visible rocks the required density. Again transmitted seismic waves imply a concentric arrangement not only of physical state but of material.

Nor can deductions favoring increase of density by self compression be safely drawn from a consideration of the masses and densities of nearby planets. Chamberlin has stated[27] that as between the Moon, Mars, Venus, and the earth there is "an accelerated rate of increase for each increment of mass," and that "this clearly implies that their densities arise from their own massiveness." This implication would carry more weight if the densities of the Moon and of Venus were more accurately known. In so far as the densities are determined these, when plotted against masses, do not fall on an increment curve. The earth's density is too low to even fall on a straight line drawn through the Mars and Moon points, much less showing an accelerated density increase. If the Earth, Venus and Mars points are taken as points on an increment curve, then the Moon's density is too low, and if the earth, Venus and Moon points are taken then the density of Mars is too high. The density of Venus is doubtful so if the Earth, Mars and Moon points be taken as points on a curve these three bodies show a decreasing rate of increase of density for each increment of mass rather than an increasing rate.

To say that "simple pressure experiments are incompetent to determine the limit of self-compression"[28] and

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[26] R. A. Daly: Igneous Rocks and Their Origin, New York, 1914, p. 161.
[27] Jour. Geology, vol. 29, p. 401, 1921.
[28] T. C. Chamberlin: Op. cit., p. 402.

then to, on this basis, deduce a great compression reduces the conclusion to an assumption. The reverse line of reasoning was adopted when the determinations of earth rigidity for seismic and tidal stress were taken to indicate a similar rigidity under diastrophic stress conditions.

An earth coarsely stratified by density due to composition rather than compression more readily conforms to the earth's seismic and magnetic properties and can also meet any requirements of rigidity placed upon it. Such an arrangement implies a stage of fusion.

The Molten Stage.

Rate of Growth of the Earth.—If the fundamental postulates of the planetesimal hypothesis be accepted then the question as to whether or not the earth passed through a molten stage at its present size rests upon the assumed size of the original earth nucleus and its rate of growth. Now any conclusion as to the size of this nucleus is pure assumption, but whatever its size at any rate, it passed through a stage of fusion. In order then to secure and maintain solidity through the period of growth only one set of assumptions can be adopted and there are, first, a nucleus of relatively small mass and, second, an exceedingly slow rate of growth. These constitute the basic foundations of the groundwork for the study of megadiastrophism.

The question of fusion is a question of heat generation per unit time, or temperature. It hinges then not so much on the size of the nucleus but on the rate of growth, for this would largely determine the temperatures attained. Rate of growth in turn depends largely upon the orbital dynamics of the interplanetary dispersed material and the ability of the earth nucleus to gather it in.

Chamberlin pictures as the task set for the nucleus, which he assumes to have a diameter of 6,000 miles, the clearing up of a belt 55 by 58 by 592 million miles.[29] Gravitation is ignored and growth is assumed to be due entirely to orbital conjunction. Can gravity be so ignored?

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[29] Op. cit., p. 409, 410.

The earth's sphere of control is approximately 700,000 by 900,000 miles in cross-section area. For the nucleus it would be smaller but still large. It would seem evident that any smaller body passing within these limits would either be entrapped or thrown into a satellic orbit unless velocity gave to it a sufficient momentum to carry it through. But by hypothesis the planetesimals were "moving in the same general direction, at somewhat similar speeds."[30] Relative velocities were thus materially reduced. It would seem that the orbital arrangements then would favor a quite rapid entrapment. The task of the nucleus is thus materially reduced but even approximate determination of growth rate is speculative since the size of the nucleus is also speculative. There is no direct evidence, however, to show that the growth may not have been quite rapid.

Size of Planetesimals.—As Barrell has pointed out[31] the only direct evidence we have as to size of planetesimals is to be sought in the asteroids. These bodies range in size and numbers from a few over several hundred miles in diameter to many ten miles in diameter and probably many more of still smaller size. The lunar pits offer only questionable evidence, for the cause of these features is not known. But if, as Daly points out,[32] the pits are due to impact, then they constitute the record of the last infall since they are not veneered over by finer material.

If there was any great amount of interplanetary dispersed material doubtless much of it, or most of it, was finely divided, but there is no evidence to show that there were not, and there is some evidence to show that there were, numerous bodies of sizes up to some hundreds of miles in diameter. These larger bodies would avoid entrapment the longest owing to their great momentum. The infall may very possibly have been of a larger proportion of finer material at first, with only occasional larger bodies, and finally of a greater proportion of larger bodies.

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[30] T. C. Chamberlin: Ibid., p. 40.

[31] Joseph Barrell and Others: The Evolution of the Earth. Yale Univ. Press, New Haven, Ct., 1920, p. 26.

[32] R. A. Daly: The Planetesimal Hypothesis in Relation to the Earth, Scientific Monthly, May, 1920, p. 489.

Heat of Impact.—The efficacy of the heat generated by impact of planetesimals is doubted though probably the additive effect if the larger sized bodies were pelted into a molten or nearly molten surface would be greater than if pelted onto a solid surface. The heat problem is more concerned with the rate of growth rather than with size of planetesimals and their impact effect.

Résumé.—In the speculative field of geogenesis there seems to be no direct or conclusive evidence which forbids belief in a molten stage for the earth at approximately its present size. To assume that the original earth nucleus was about the same size as the present planet and was, by hypothesis, molten seems just as reasonable as to assume that the nucleus was small and grew slowly. But any conclusion in this field is rendered indefinite by some pure assumption with no evidence back of it. More direct evidence is to be sought in a consideration of the present physical state of the earth, previously discussed in its recorded diastrophic history, and in the field relationships of the igneous rocks. As Daly concludes:[33] "As critical facts are slowly accumulated, the greatly appealing planetesimal hypothesis of Chamberlin and his co-workers may well serve as a foundation for geological philosophy, though the subsidiary doctrine of essential crystallinity for the earth throughout geological time be not accepted."

The Earth's Diastrophism.

The evidence submitted by Chamberlin on the diastrophic capabilities of the earth as indicating a solid, crystalline, and heterogeneous state throughout does not seem conclusive and is susceptible of more than one interpretation.

A "gaseo-molten" earth is pictured by Chamberlin as wasting its dynamic energy in maintaining fluidity leaving "little possibility of shrinkage left except the meagre amount that could arise from further cooling."[34] But is not this "meagre amount" sufficient to have produced the visible diastrophic record? To attempt to trace a pre-Archean diastrophism far greater in amount than all

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[33] R. A. Daly: Op. cit., p. 495.

[34] T. C. Chamberlin: Bull. Geol. Soc. Am., vol. 32, p. 199, 1921.

of that recorded would seem to be unnecessary. But then with the prior assumption of a crystalline heterogeneous earth it becomes necessary, of course, to further assume a very great and deep-seated diastrophism of long duration. Daly has clearly shown[35] that simple cooling may be far less effective in volume change than that due to changes in state, both from liquid to solid and from one solid form to another as a result of static metamorphism. These changes together with contraction due to secular cooling would, it seems, be amply sufficient to cause all the lateral deformation of which we have record.

The actual total circumferential shortening of the earth since Proterozoic time, as recorded on any great circle, is not over 200 miles and is probably nearer 100 miles. If it is 150 miles the total radial shrinkage is then about 24 miles. The amount of shortening and shrinkage that can be allotted to pre-Paleozoic time is, of course, indefinite. It may not be as much as is generally supposed. Structural deformation of at least Proterozoic terranes is not generally excessive and the Archean rocks are largely igneous, bespeaking great magmatic engulfment and intrusion. Magmatic engulfment and intrusion on such a large scale may well be potent factors in themselves in lateral deformation. Where these pre-Paleozoic terranes do show isoclinal folding they have usually been involved in later deformation. At least their close association with belts of later folding is significant.

If the earth has suffered any such radial shrinkage as 700 miles, as deduced by Chamberlin by the hazardous method of density mass comparisons as between the earth and its nearby neighbors,[36] then a major part of this shrinkage was taken up during the period of growth and the resulting diastrophic record lies in depths forever hidden from view.

If now diastrophism is the expression of deep-seated inner reorganization due to condensation upon mass increase, what is to provide the diastrophic energies after the cessation of growth? Are we to conclude that this inner reorganization in favor of greater density is to continue without additional mass increase? Either way these questions are answered, it would seem that diastro-

[35] R. A. Daly: Igneous Rocks and their Origin, New York, 1914, p. 176.

[36] Jour. Geology, vol. 29, p. 400, 1921.

phism should grow progressively less after cessation of growth. But this conclusion is difficult to reconcile with Cenozoic deformation which far transcends all other post-Proterozoic orogeny.

On the other hand, with a slowly thickening crust resting on a yield zone (asthenosphere), crustal yielding, both in time and degree, is a factor of crustal strength. Periodicity of deformations in crescendoes to a high point indicate increasing crustal strength and so an increasing capacity for accumulating stresses before the breaking point is reached. Under this view the pre-Paleozoic deformations represent the rather easy yielding of a comparatively thin crust and its widespread magmatic engulfment. From the viewpoint of an earth whose diastrophic energies arise in the deep interior it is rather difficult to explain periodic deformation, for the forces must be continuously active and, since the surficial portions of such an earth would be weaker than any underlying portions, deformation could hardly result from accumulative stresses.

Even if the postulated method of very slow growth by planetesimal accretion with its consequent state of absolute solidity for the earth be accepted, the existence of any great reserve of diastrophic energy may be seriously questioned. If this growth took three or four billion years it would seem that this would give ample time for a very complete inner reorganization *pari passu,* leaving an earth practically immune to deformational stress.

The Earth's Volcanism and the Evidence of the Igneous Rocks.

Volcanism, of course, using the term in its broadest sense, finds little place in the groundwork for studies in megadiastrophism. It is considered as merely an "accessory" to a "profoundly metamorphic earth." A once molten earth would, according to Chamberlin, not only waste its dynamic energy and become diastrophically sterile but "there should have been developed and brought to the surface *all*[37] the gaseous material in the earth substance which high heat could set free," and "an earth-body formed in this way should be unsuited

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[37] The italics are mine—W. F. J.

to give rise to such a degree of gaseous volcanism as is actually manifested.''[38]

The first statement quoted needs some qualification, for the amount of gas set free is not only a question of heat but also of pressure. Very evidently under the pressure conditions existing at no great depth very material quantities of gas would remain entrapped.

The second statement quoted also requires some discussion for it is doubtful if the major manifestations of volcanism require any such great stores of gaseous material as are implied. By far the larger part of volcanism has been expressed in fissure eruptions and deep-seated intrusions. The mechanisms of both of these do not call into use any mechanical force from gaseous expansion. In fact, the greater lava floods are very often free of vesicularity. Volcanic eruptivity of the central vent type is not conspicuous in the igneous record of pre-Tertiary time. Only in late-Tertiary and recent times have the dying phases of an era of great volcanism expressed themselves in vent eruptivity on what may possibly be called a worldwide scale. Such is to be expected under the conception of a slowly thickening crust. Furthermore, volcanic vent eruptions call into use only localized concentrations of the juvenile gases in their underlying diatremes or cupolas.

The broad facts of the occurrence of igneous rock types become extremely difficult of explanation under the conception of an earth composed throughout of material similar to the visible rocks from which magmas are derived by deep-seated selective liquefaction. Chamberlin states[39] ''........if magmas consist merely of partial solutions of heterogeneous mixtures, they would quite certainly become highly diversified in the making. The primary problem would then lie in the generation of the magmas; in the ascent of magmas rather than their descent. *While differentiation in the process of solidification would still remain a factor, it would be a secondary matter, in the sense that it was necessarily conditioned by the previous generative process.*[40] Each

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[38] Bull. Geol. Soc. Am., vol. 32, p. 207, 1921.

[39] Op. cit., p. 208.

[40] The italics are mine—W. F. J.

particular case presents an *a posteriori* problem of its own. It is wholly unembarrassed by any requirements that its factors shall sum up into a speculative primitive magma.''

From this scheme of magma derivation two broad conclusions may be drawn: First, the tongue melts reaching the surface should be, at least, within continental areas, generally acidic in composition, since they are supposedly derived from the selective liquefaction of the more fusible constituents of an earth whose composition is similar to the visible rocks and this composition is that of common granite; second, the acidity should decrease towards basicity with time since the process implies the liquefaction of less and less fusible constituents as interior condensation progresses.

On the other hand the outstanding fact of the occurrence of the igneous rocks is the striking uniformity in composition of the great extrusive flows, this similarity extending in time from the most ancient extrusive masses of Archean age down to the present, and in location world wide. Diversification is absent. And the composition of these extrusives is predominantly basaltic. Acidic extrusives are conspicuous by their almost complete absence. Derivation of these great and persistent outpourings of basaltic material from an essentially acidic earth is not only difficult to explain by the process of selective liquefaction but, on the other hand, if they are considered as differentiates of a more acidic magma, then, as Daly has pointed out:[41] ''The acid pole of such a hypothetical splitting ought to be on a similarly large scale.'' Nor can the acid intrusive masses fill the need, in this case, of the acidic derivative, for then a further explanation would be necessary to account for the predominant intrusive form of the acid and the predominant extrusive form of the basic poles. Furthermore, the fact of discordancy of the batholithic contacts together with the fact that the structural delineaments of roof and wall rocks are merely truncated at the contact surfaces rather than altered implies that large masses of these rocks have been engulfed and have added their high acidity to a previously more basic magma.

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[41] R. A. Daly: Op. cit., p. 164.

Bearings on Isostasy.

It is, of course, an evident fact as Chamberlin states[42] that: "a liquid earth should be an ideal example of perfect isostasy in the highest sense—that is, isostasy in perfect horizontal as well as vertical adjustment," but is the further statement that: "the earth's crust, as it began to form, should have inherited this quality in full perfection"[43] true in its implications? This statement implies that any subsequent deformation of the crust would merely act as an upsetting influence to this perfect isostatic state. Now perfect isostatic adjustment in a "horizontal" direction does not mean, of course, perfect leveling of the surface unless, of course, in the case of a crustified earth, the crust is of uniform composition and thickness in a worldwide sense. Such an ideal state may possibly have obtained immediately after crustification. But this thin crust must have been very weak and readily subject to disruption. Fragmentation would involve engulfment, the outpouring of more basic materials and their solidification would then introduce heterogeneities of density in the crust and those portions so weighted down would seek their level of adjustment. The broader the area so weighted down, the more perfect would that adjustment be. In fact, the suggestion has been made by Willis and Barrell[44] that the ocean basins owe their origin to such a process as this.

A state of perfect isostasy is, under this view, possible only within the limitations imposed by the strength of the earth's crust and that strength becomes small for broadly distributed loads and great for more constricted loads and so an almost perfect state of isostatic adjustment must prevail as between oceanic depressions and continental areas. There is no antagonism here between isostasy and diastrophism. The strength of the earth's crust merely interposes as a barrier to perfect adjustment. Diastrophism is the expression of the final overthrow of the crustal resistive power and this overthrow

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[42] Op. cit., p. 209.

[43] Idem., p. 209.

[44] Joseph Barrell & Others: The Evolution of the Earth, 1920, pp. 39-43; Bailey Willis: The Discoidal Structure of the Lithosphere, Bull. Geol. Soc. Am., vol. 31, p. 298, 1920.

results in a more nearly perfect isostatic balance. Diastrophism is then the corrective. This is the view so ably developed by Barrell in his monumental treatise on "The Strength of the Earth's Crust."[45] Heterogeneities of load whether due to erosion, deposition, or to the introduction of intrusive or extrusive masses control, within the limits imposed by crustal strength and distribution, the degree of adjustment attained. These heterogeneities are for the most part visible and determinate. Beneath this heterogeneous layer, according to the evidence both of the igneous rocks and transmitted seismic vibrations, there lies homogeneous material which is capable of yielding under the larger differential stresses to which it is subjected. Broad scale heterogeneities of the surface shell must result in similarly broad scale and generally permanent major reliefs. This view is based upon what we can see. The opposing view—that of Chamberlin—must be built upon an assumed asymmetric earth core upon which was laid down, over a period covering several billion years and through the whims of the atmosphere, a selective rain of planetesimal dust. This constitutes the foundation for the study of "megadiastrophism." Is that foundation secure?

But the conception of an isostatic heterogeneous shell resting upon a homogeneous yield zone does not, of course, permit the application of deeply pointing wedge deformation to areas of continental dimensions.

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Cambridge, Mass.

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[45] Joseph Barrell: The Strength of the Earth's Crust: Jour. Geology, vols. 22, 23, 1914-1915.

ART. XXXVIII.—*Some Complex Chlorides containing Gold. III. A New Cesium-Auric Chloride;* by HORACE L. WELLS.

[Contribution from the Sheffield Chemical Laboratory of Yale University.]

This salt, $Cs_5Au_3Cl_{14}$, was first obtained accidentally by cooling a very concentrated solution of cesium chloride containing comparatively little auric chloride. It may be prepared from practically neutral solutions, but it is best to use strong, or even concentrated, hydrochloric acid as the solvent, since this acid makes the salt more stable, so that, in its presence, far less concentrated solutions of cesium chloride will give this red salt instead of the usual, yellow double salt $CsAuCl_4$.

The new compound forms very minute, deep red crystals, which are quickly decomposed by water, usually with the formation of the yellow double salt as a precipitate.

It appears to be the only known auric double chloride not derived from hydrochlorauric acid, $HAuCl_4$, and to be a unique type among the double halides of the trivalent metals in general. It was overlooked by Wells and Wheeler,[1] who made an investigation of the cesium and rubidium chloraurates and bromaurates, in this laboratory, and found only $CsAuCl_4$ and $2CsAuCl_4.H_2O$ as the double cesium chlorides. Evidently they did not carry their experiments to a sufficient excess and concentration of cesium chloride.

Four crops of the new salt were analyzed at first. They were prepared by cooling solutions containing in each case about 180 g. of cesium chloride and 1 g. of gold, as $HAuCl_4$, in volumes of 300, 500, 700 and 500 cc., respectively. The first three solutions contained a moderate amount of hydrochloric acid, while the last one was nearly neutral. The results of these analyses, where the crops were not washed in any way and were dried on filter-paper, in the air, and finally at 100°, were as follows:

					Calculated for	
	I.	II.	III.	IV.	$Cs_7Au_4Cl_{19}$	$Cs_5Au_3Cl_{14}$
CsCl ...	49.16	48.75	48.72	....	49.24	48.02
$AuCl_3$.	50.10	50.45	50.57	50.60	50.76	51.98

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[1] *This Journal*, 44, 157, 1892.

Although the agreement of the results with the first formula is rather close, the second one is perhaps more probable, since there is no doubt that the products were contaminated to an appreciable extent with cesium chloride, on account of the method used in preparing them for analysis, the high concentration of the mother-liquors, and also because the crystals were of exceedingly small size and thus presented very large surfaces for contamination.

Another crop of the salt was then prepared from 200 g. of cesium chloride, 1.5 g. of gold (as $HAuCl_4$) and equal volumes of concentrated hydrochloric acid and water, making a total volume of about 900 cc. After the crop had been formed by cooling in a counterpoised beaker, the whole was weighed, and then, since the amount of gold remaining in solution was comparatively very small, it was possible to calculate the amount of cesium chloride corresponding to the volatile part of the mother-liquor. The crystals were taken out, pressed with filter papers very rapidly, so as to avoid evaporation as far as possible, and, without air-drying, the loss in weight at 100° was determined. From this the amount of cesium chloride derived from the mother-liquor could be calculated. The analysis of the dried product after correcting for the cesium chloride derived from the mother-liquor is given beyond (V), while a duplicate portion of the same crop was analyzed also (VI). Analysis VII was made from a crop obtained from a solution containing 100 g. of cesium chloride and 1 g. of gold (as chloride) in a volume of 900 cc. made up of about two volumes of concentrated hydrochloric acid to one of water. The product was washed somewhat by diluting the last part of the mother-liquor with an equal volume of concentrated hydrochloric acid, without any apparent decomposition. This crop was dried at 100° without determining the loss, but it was assumed that a correction for cesium chloride about one-fourth that of the previous crops should be applied to it. The results were as follows:

	V.	VI.	VII.	Calculated for $Cs_5Au_3Cl_{14}$
$CsCl$	47.81	47.84	47.61	48.02
$AuCl_3$	50.98	50.96	51.12	51.98
Corrected for CsCl,	1.13%	1.00%	0.25%	

It is to be noticed that the summations[2] of these three analyses are about 1.2% low in each case. This is to be explained by the fact that the products when dried at 100° were in a lumpy condition, and the additional circumstance that cesium chloride when dissolved in hydrochloric acid, as experience has often shown, can be solidified and dried at 100° only with extreme slowness. Very probably a rather stable acid cesium chloride is formed, which is very hygroscopic, although cesium chloride itself is not hygroscopic to any marked extent. It is believed that the lumps of these products held a little of this liquid even after drying for an hour or two, to practically constant weight, at 100°. The possibility that the double salt contains a molecule of water of crystallization, corresponding to 1.02%, has been considered, but this seems very doubtful on account of the higher summations of the other analyses where the products were pulverulent when dried, and because of the additional circumstance that all of the crops contained small amounts of filter-paper fibers, which should give somewhat low summations in any case.

From the facts that have been presented here, there seems to be no doubt that the formula for this salt is $Cs_5Au_3Cl_{14}$. This can be written $3CsAuCl_4.2CsCl$, but it is entirely improbable that the yellow double salt retains its identity in the more complex red one, on account of the remarkable change in color.

The new salt, in view of its very minute crystals, its increased stability with hydrochloric acid, its striking color, and its very sparing solubility in the solutions from which it is deposited, appears to resemble the cesium-auric triple salts that have been described in the preceding articles of this series, and it seems possible that it may be a triple salt in the sense that the gold plays two different parts in its structure, although the gold is undoubtedly wholly in the trivalent state.

New Haven, Conn., March, 1922.

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[2] These were unchanged by the corrections for CsCl.

Art. XXXIX.—*A Chromophore Grouping of Atoms in Inorganic Triple Salts, and a General Theory for the Cause of the Colors of Substances*; by Horace L. Wells.

[Contribution from the Sheffield Chemical Laboratory of Yale University.]

The intense black color and complete opacity of the two salts

$$Cs_4Ag_2Au'''_2Cl_{12} \text{ and } Cs_4Au'_2Au'''_2Cl_{12}$$

together with the less intense blackness of

$$Cs_4CuAu'''_2Cl_{12}$$

which, although its minute crystals were very black, was distinguished from the first two salts by yielding a pale brown powder instead of a jet black one, while the salts

$$Cs_4ZnAu'''_2Cl_{12} \text{ and } Cs_4HgAu'''Cl_{12}$$[1]

were comparatively pale in color and were transparent, attracted much attention, and an explanation of these very remarkable deep colors has been sought.

In this connection attention was directed to Setterberg's very intensely colored salt[2]

$$Cs_4Sb'''Sb^{v}Cl_{12}$$

which Wells and Metzger[3] in this laboratory showed to be octahedral and isomorphous with $Cs_2Pb^{iv}Cl_6$, and which has an exceedingly deep blue color, so that even very small crystals of it appear absolutely black and opaque, although the very fine powder, or the precipitate, shows the deep color.

Upon comparing the two salts

$$Cs_4Au'_2Au'''_2Cl_{12} \text{ and } Cs_4Sb'''Sb^{v}Cl_{12}$$

it is to be observed that each of them contains *atoms of a metal in two states of valency.* This is the main feature, requiring some modification on account of the colors of the silver and cupric compounds already mentioned, of the theory, now presented, of a chromophore grouping.

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[1] All of these triple chlorides were described by the writer in the May, 1922, number of this Journal.

[2] *Öfversigt K. Vetensk. Akad. Förhandl.*, 1882, 23.

[3] *Amer. Chem. Jour.*, 26, 268.

Another instance where such a grouping may be regarded as the cause of a very deep color is in Walden's[4] two triple bromides

$$KFe''Fe'''_2Br_9.3H_2O \text{ and } RbFe''Fe'''_2Br_9.3H_2O.$$

These salts contain ferrous and ferric atoms and are described as being dark green and quite opaque. It is the writer's recollection of them, which has been confirmed by a private communication from Professor Walden, that the green color appeared to be merely a luster and that the crystals seemed to be absolutely opaque.

It appears, further, that the cuprous and cupric atoms act as a chromophore, for when a hydrochloric acid solution of cuprous chloride, which is colorless when fully reduced, for instance by heating with copper wire, is mixed with the yellow or green solution of cupric chloride in hydrochloric acid a very dark brown solution results, which if fairly concentrated is opaque and practically black. Little attention is paid to this dark colored compound in the chemical reference-books, but in one of them[5] it is stated that a triple salt, $6NaCl.Cu_2Cl_2.2CuCl_2$, has been prepared from it by Sievert. The composition of this appears to be uncertain, since it was obtained only in the form of an immiscible oil upon adding alcohol and ether to a solution of the salts, and since when a larger proportion of sodium chloride was used in its preparation a product was obtained containing twice as much of that salt as is shown by the above formula. Perhaps the dark hydrochloric acid solution that has been mentioned contains a hydrogen-cuprous-cupric triple chloride, but it may be a double salt.

Another case to which the chromophore grouping may be applied is that of Prussian blue and the similar blue products containing both ferrous and ferric atoms. The salt $KFe'''Fe''(CN)_6$ is recognized, so that the chromophore effect may be regarded as taking place in a triple salt in this case. Such formulas as $Fe'''_4Fe''_3(CN)_{18}$ and $Fe''_3Fe'''_2(CN)_{12}$ are frequently given to Prussian blue and Turnbull's blue, but that they are pure double salts

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[4] *This Journal,* 48, 283, 1894.

[5] Dammer, *Handbuch anorgan. Chem.,* II., 2, 671.

seems doubtful, since they have been found to retain potassium, etc., very tenaciously when washed.[6]

It is believed that the instances presented here, where gold, antimony and copper as chlorides, together with iron as bromides and cyanides, when present in two states of valency in triple salts produce exceedingly strong colors, are sufficient to show very conclusively that the new theory in regard to this atomic grouping as a chromophore is founded upon facts.

In regard to the very black salt $Cs_4Ag_2Au'''_2Cl_{12}$, which does not contain a metal in two states of oxidation, the theory must evidently be modified by assuming that atoms of two different metals may sometimes form this chromophore. Possibly it may be essential that the two metals should be closely related, as gold and silver are, as is shown by their positions in Mendeleéff's table. The salt $Cs_4Cu''Au'''_2Cl_{12}$ may, perhaps, be regarded in precisely the same way as the one just considered, but its color is not very intense, since it gives a pale powder, and as our chromophore group appears to be a very powerful one, it may be better to consider the color of this cupric salt to be due simply to the ordinary coloring-effects of cupric and auric chlorides.

It is to be observed that Pollard's salt[7], $(NH_4)_6Ag_2Au_3Cl_{17}$, has a silver-auric grouping in a different ratio, but that in this case the color is very dark red, without opacity.

The discussion presented here has been given particularly in connection with a chromophore grouping in triple salts, but it is not supposed that the effect of this grouping is necessarily confined to these compounds. No cases of this effect have been thought of in undoubtedly pure double salts, but the black precipitate produced by ammonia in solutions of mixed ferrous and ferric salts may be regarded as an effect of the grouping upon a double hydroxide or oxide, unless, indeed, this precipitate contains ammonium hydroxide, or some kind of basic salt, as a third constituent. At all events, it appears that the

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[6] An extension summary of what is known in regard to the complex cyanides of iron, with many references to the literature, is to be found in Beilsteins *Handbuch.*

[7] *This Journal,* 3, 257, 1922.

black color of the magnetic oxide of iron may be supposed to be due to the effect of this grouping upon the color of the combined red and so-called grey ferric and ferrous oxides.

The chromophore grouping that has been presented here is a very curious thing. In the cases of Au′-Au‴ and Sb‴-Sb^{v} there is a difference of two units of valency, while with Fe″-Fe‴ and Cu′-Cu″ there is a difference of only one unit, and, furthermore, these four pairs of valencies are all different. It is particularly remarkable that the three chlorides, CsCl, $SbCl_3$ and $SbCl_5$ which constitute one of the examples of the chromophore grouping are all of them colorless compounds.

It seems possible that the action of this chromophore may be explained by exchanges of negative electrons between the atoms that differ in valency. It is supposed that in passing from one valency to another an atom gives up or takes on one or more electrons, and if it is assumed that the atoms of a metal in two states of valency in the same molecule, instead of retaining fixed individual valencies, continually make these exchanges of electrons, it may be supposed that light, passing through such molecules, is in some way affected, so that colors or opacity are produced.

The hypothesis of spontaneous electronic activity that has been advanced to explain the behavior of the chromophore grouping may be applied as a general cause of color. It may be supposed that certain atoms, occurring in such combinations that their structures are labile, may be continually exchanging electrons with neighboring atoms even when atoms of an element in two states of valency are not present.

This supposition seems plausible, since it might be expected that unless the activity of the electrons was spontaneous it would not take place at all in bringing about chemical combinations and changes in valency.

The common occurrence between atoms of spontaneous electronic exchanges, of sufficient intensity to affect the passage of light is the theory advanced here to explain colors. A strong argument in its favor is the fact that a very large proportion of the elements that give at least one colored salt, ion, or oxide are those that occur in more than one condition of valency and whose atoms, consequently, may be regarded as particularly labile in their structures and probably capable of giving off and taking on electrons more readily than the others. There are many of these elements, particularly among the metals that form weak bases. It appears that there are a few exceptions among the metals to this connection between color and multiple valency, for cadmium gives a colored oxide, but has, perhaps, no distinct second valency, although two suboxides of it have been described, while, on the other hand, arsenic and antimony give colorless salts and oxides while showing two valencies in each case.

It is a very common occurrence that chromogenic atoms give different colors, including absence of color, under varying conditions of valency and chemical combination. For instance, the cupric ion is blue, anhydrous cupric chloride is brown, anhydrous cupric sulphate is colorless, cupric oxide is black, cuprous oxide is red, and so on.

In order to explain such variations as these on the basis of our theory it must be supposed that different chemical combinations and different conditions of valency modify the electronic behavior of the atoms in such a way that their manner of exchanging electrons varies greatly.

There is a vast amount of knowledge in regard to the molecular structures of organic coloring-matters and concerning their various chromophore groups, but it appears that the exact cause of the colors has not been satisfactorily explained. The present theory, however, if it is a reliable one, will explain these colors, as well as others, by the assumption of electronic exchanges and the resulting absorption of light. Nitrogen and carbon, under the proper conditions of chemical combination may be supposed to show electronic activity, and even oxygen may do this, if our theory is correct, as is shown by the intense blue color of liquid ozone.

According to our theory everything that is colored or opaque must possess spontaneous electronic activity, and if it is supposed that the conduction of electricity is facilitated by, or is even entirely dependent upon, this activity, we have a very satisfactory explanation of the well-recognized generalization that opacity to light is favorable to electric conductivity.

Summary.

The existence has been advocated of an inorganic chromophore grouping consisting, usually, of atoms of the same metal in different states of valency in a molecule of a triple salt.

An explanation of the behavior of this chromophore has been made by advancing the theory that there is a constant exchange of negative electrons between the atoms of different valency, and that this activity of electrons affects the passage of light, producing colors or opacity.

An attempt has been made to extend this theory to an explanation of colors of substances in general by assuming commonly occurring spontaneous exchanges of electrons, which affect the passage of light.

The author takes pleasure in expressing his thanks to his colleague, Professor John Zeleny, who has kindly read this article in its original form and has made some valuable suggestions, from a physicist's point of view, which have led to a considerable modification in the presentation of the theoretical part of it.

New Haven, Conn., March, 1922.

ART. XL.—*Some Tertiary Carnivora in the Marsh Collection, with Descriptions of New Forms;* by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTION.

The present paper is mainly descriptive of certain specimens of carnivores which furnish us with additional information regarding the geologic fauna of North America in the region between the Mississippi River and the Rocky Mountains. Moreover, it adds quite materially to our knowledge of the time and space distribution of the forms herein described. Some of the specimens form the basis of new species, while others apparently afford evidence of transitional stages between certain well defined faunal landmarks. The majority of the genera are confined either to Oligocene or Miocene strata, but it is very probable that in some instances the Lower Pliocene has contributed a small quota of forms, as will be explained below.

The John Day carnivore material in the Marsh Collection has been described separately, while nearly all of the European specimens belong to well known genera and species. The drawings were made by Rudolf Weber.

The strata of Upper Miocene, and possibly some of Lower Pliocene age along the Niobrara River in the vicinity of Valentine are herein termed the Valentine beds, a name proposed by Barbour and Cook in 1917 for this horizon near Valentine, in Cherry County, Nebraska. These beds are probably somewhat lower than those on Snake Creek (not the Snake River of western Nebraska) or in the Devil's Gulch, and a list of the fauna, which has been found in the Valentine beds, given by Barbour and Cook, shows that it comes within the Procamelus-Hipparion zone as defined by Osborn in 1918.

There are at least fifteen other names which have been applied to this formation, some of which are faunal names, while others are preoccupied. Osborn[1] designated these beds as the Fort Niobrara formation, and the type locality is on the Niobrara River, near Fort Niobrara. Doctor W. D. Matthew has also adopted this usage. However, it seems to the writer that this name is not happily chosen, for the custom in the usage of geologic formation names is to shorten them when possible. It will be recalled that the Benton, Pierre, Bridger, and other formations were originally termed Fort Benton, Fort Pierre, Fort Bridger, etc. If the "Fort" should be dropped from Fort Niobrara, then the name of this Upper Miocene formation would necessarily have to be abandoned, as Niobrara formation is the name applied to a subdivision of the Cretaceous.

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[1] H. F. Osborn, Equidæ of the Oligocene, Miocene and Pliocene of North America, Iconographic type revision. Mem. Amer. Mus. Nat. Hist., new ser., 2, pt. 1, 23-24, 1918.

OLIGOCENE CANIDÆ.

Cynodictis Bravard and Pomel.

With one exception, all of the American forms of this genus are represented in the Yale Marsh Collection. Some of these species are based on slight but usually constant variations, although there may be some question as to specific rank for them.

Cynodictis angustidens (Marsh).

FIG. 1.

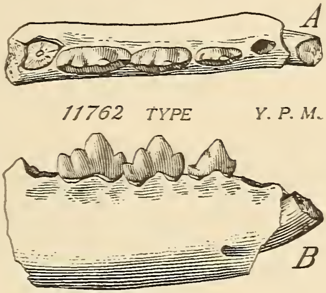

FIG. 1.—*Cynodictis angustidens* (Marsh). Holotype. × 3/2. A, occlusal view of premolars; B, external view of right ramus.

In 1871, Professor Marsh described an "anterior portion of a right lower jaw, containing the last three premolars, and the canine" (p. 124), under the new specific name *Amphicyon angustidens.* This species is identical with Cope's *Canis gregarius,* proposed in 1873, and, therefore, has precedence over the latter, since both belong within the genus *Cynodictis.*

The evidence, on which I base these conclusions, is derived from the types themselves and from the descriptions of them. Both types are lower jaws. Marsh's *C. angustidens* and Cope's *C. gregarius* are considerably smaller than the red fox; in both P_1 is one-rooted, P_4 has median and basal lobes, forming a cutting edge in line, the ramus is slender and deep, while the premolars are low and compressed, P_{2-4} have anterior basal tubercles, while P_{3-4} possess a posterior basal tubercle and cingulum.

Both the Marsh and Cope types were collected from the same geologic horizon, the former at Scott's Bluff, Nebraska, and the latter in northeastern Colorado.

The appended measurements fall well within the limits given by Cope, Scott, and Matthew for *C. gregarius.*

This species was by far the most abundant of the genus in America. It ranged from Colorado to South Dakota inclusive, and probably its habitat extended as far westward as the interior of Oregon. It is limited in time between the base of the Middle Oligocene and that of the Miocene. Scott (1898, p. 364) has described in detail the osteology of the species, his descriptions being based mainly, and probably wholly, on White River specimens. Wortman and Matthew (1899, p. 122) amplified Scott's description, so that this form is quite well known. The holotype, Cat. No. 11762, Y. P. M., was collected by Professor Marsh in 1870.

Besides the type, this species is represented by some very excellently preserved skulls and jaws, especially Cat. Nos. 10067 and 10068, Y. P. M.; by a large number of rami with dentition; and by certain skeletal elements. These are all typical and add nothing to our knowledge of this form.

Measurements.

	C. angustidens Holotype mm.	*C. gregarius* mm.
Length of premolar series	19.5	19*
Length of P_4	6	6*
Depth of ramus at sectorial	10	10*
Transverse diameter of crown of P_4	2.6	2.5
Height of crown of P_4	3.8	3.8
Width of jaw below P_4	4.3	4.5
Depth of jaw below P_4	10	9.6

* Measurements from holotype. Other measurements in this column are from Cope's drawings (1884) of specimens identified by him as *Galecynus gregarius.*

Wortman and Matthew (1899, p. 124) give the skull length as 76 mm. and the maximum width of the braincase as 29 mm. Cat. No. 12678, Y. P. M., collected by Mr. H. B. Sargent in 1870 at Scott's Bluff, is 2 mm. longer and 1 mm. wider in the same respective dimensions.

Scott (1898) shows in his table on page 373 that his specimens range in length from 86 to 92 mm. and in width of brain-case from 31 to 35 mm. Nearly all of the Yale specimens, as well as Cope's, are within the limits of Scott's table. This shows a difference of from 13 to 21 per cent in skull length, and yet the length of the superior and inferior tooth-rows, either premolar-molar series, or each individually, does not differ by more than 1 mm. in Y. P. M. Cat. No. 12678 (corresponding to Matthew's dimensions of No. 8774, A. M. N. H.) from the larger specimens which fall within the lower limits of Scott's table. I can detect no differences, other than size, between the smaller and the larger specimens, and the ratios seem to be uniform. These smaller individuals may represent a new variety, or they may be females. Y. P. M. No. 12678 is fully adult.

There are several Y. P. M. specimens in which M_3 possessed two roots, while others show but one root. Those having the two-rooted M_3 do not appear to be any more robust than the others. In fact, Y. P. M. No. 12691 has two roots on this molar and yet it is of the same slender proportions as the small skull and jaws bearing the number 12678. I fail to find any other marked distinctions between the two forms. Another specimen, No. 12687, from Scott's Bluff, Nebraska, shows very distinctly the alveolus of the double-rooted M_3. A part of a ramus, No. 12689, possesses a small posterior cusp, together with the usual posterior and anterior basal tubercles on P_2, a character possessed by *C. oregonensis* Merriam.

Cynodictis lippincottianus (Cope).

Syn.: *Canis lippincottianus* Cope 1873B, p. 9; *Galecynus lippincottianus* Cope 1884, p. 919; *Amphicyon gracilis* Leidy (non Pomel) 1856, p. 90 (nom. preoc.); *Daphænus gracilis* Roger 1896, p. 44; *C. hylactor* Hay 1899, pp. 253-254.

This species, founded by Cope, was based on several rami from Colorado found in Middle Oligocene strata. Cope stated (1884, p. 920) that the "Dimensions [were] half as large again as in *C. gregarius,* as indicated by many specimens of the latter," while Wortman and Matthew (1899, p. 130) found from the type that the teeth were one fifth greater in lineal dimensions and somewhat more robust. The Yale specimens agree with Matthew's determination and are represented by several fragments of rami, chiefly Y. P. M. Nos. 12684 and 12685, from Colorado. The skull is undescribed, unless Leidy's *Amphicyon gracilis* is considered synonymous. Matthew holds this view and I thoroughly agree with it.

Cynodictis paterculus Matthew.

This species is represented in the Marsh Collection by many specimens of rami, collected between and including Pawnee Buttes, Colorado, and Crow Buttes, South Dakota. The type, No. 9616, A. M. N. H., was collected in Montana. It apparently is not represented in the John Day fauna, but otherwise its distribution seems to be practically the same as that of *C. angustidens*. The type horizon is Lower Oligocene in the Titanotherium beds, but I consider that its vertical distribution must include a part of the Middle Oligocene (lower Brule). From the matrix and locality of the Yale specimens, it seems that the majority are from the lower Brule rather than from the Titanotherium beds.

Y. P. M. No. 12683 has a small posterior cusp on P_2 as in *C. oregonensis*. It corresponds to the type in other respects. One of the specimens has a double-rooted M_3 while the others have but the one. The specific characters, as outlined by Matthew, are constant, and thereby afford strong evidence for the validity of the species. However, I can not help feeling that this form may represent the male of *C. angustidens*. The main distinction between the two is that the former is somewhat more robust. The size of both is about the same.

Daphœnus vetus Leidy.

Various localities in Nebraska and Colorado yielded remains of this species to the collectors working under Professor Marsh's direction. An especially well preserved skull and jaws (Cat. No. 10066, Y. P. M.), from Greeley, Colorado, was figured by J. L. Wortman in 1901 in this Journal. Another specimen, collected by Doctor E. L. Troxell in Sioux County, Nebraska, was purchased by Professor Charles Schuchert and by him presented to the Peabody Museum. It consists of the major portion of the skeleton, as well as the skull, of which the basicranial area is very excellently preserved (Cat. No. 12771, Y. P. M.).

Daphœnus hartshornianus (Cope).

Mandibular rami from Pawnee Buttes, Colorado, and from White River, Nebraska, represent this species in the Marsh Collection, but add little to our knowledge of it. The Nebraska form is, however, slightly smaller than the type, while the Colorado specimens are practically identical.

Both of the above species of *Daphœnus* are Middle Oligocene (lower Brule) in age.

MIOCENE CANIDAE.

Mesocyon robustus Matthew.

A part of a lower jaw with two premolars agrees well with the type. It was collected at Gerry's ranch, Colorado, whereas the type locality is near the Rosebud reservation in South Dakota.

Nothocyon annectens Peterson.

This species is represented by rami collected at Scott's Bluff and south of Antelope Creek, both in Nebraska. That from the former locality is somewhat smaller than the type; the other locality shows specimens exceedingly close to the type. They, however, add nothing new to our knowledge of the species.

Nothocyon vulpinus Matthew.

In 1873, Professor Marsh collected specimens along the Niobrara River which are unquestionably referable to Matthew's species. The type locality is north of the Niobrara in southern South Dakota.

Nothocyon vulpinus coloradoënsis, mut. nov.

(Fig. 2.)

Holotype, Cat. No. 12812, Y. P. M. Lower Miocene, Pawnee Buttes, Colorado.

The holotype consists of part of a left ramus with P_3, P_4, M_1, and the alveolus of M_2. It differs from *N. vulpinus,* its nearest ally, in having a relatively shorter jaw, larger sectorial, relatively smaller tubercular molar, premolars crowded, but with same individual antero-posterior diameter as in *N. vulpinus,* while their anterior cingulum is nearly obsolete. The sectorial has a small cusp between the protoconid and hypoconid, which is, I think, an individual variation.

Fig. 2.

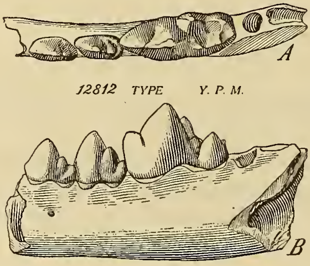

Fig. 2.—*Nothocyon vulpinus coloradoënsis,* mut nov. Holotype. Nat. size. A, occlusal view of premolars and first molar; B, external view of left ramus.

Measurements.

	N. coloradoënsis mm.	*N. vulpinus* mm.
Space occupied by P_3, P_4, and M_1	26.5	27.5*
Diameters of M_1, transverse.............	5.5	4.8
Diameters of M_1, ant.-post.	14	11.8
Maximum depth below M_1	13.5	11

* Taken from drawing.

Nothocyon latidens multicuspis, subsp. nov.

(Fig. 3.)

Holotype, Cat. No. 12801, Y. P. M. Miocene, near Antelope Creek, Nebraska. Collected in 1873 by Professor Marsh.

This specimen, consisting of part of a right ramus with M_1, M_2, alveolus of M_3 and part of that of P_4, is somewhat larger than *N. latidens,* but possesses the narrow tubercle on the external base of the protoconid which is a characteristic of that species. It, however, lacks the small tubercle just anterior to the base of the entoconid which is often present in specimens from the John Day Valley, Oregon, referred to Cope's species. The paraconid is the largest cusp of M_2, with the protoconid and hypoconid of about equal dimensions. The entoconid is small. There is a small tubercle or cusp developed on the postero-external base of the protoconid. From this it will be seen that the tooth patterns of both M_1 and M_2 are quite similar in certain respects. M_3 was one-rooted.

Fig. 3.

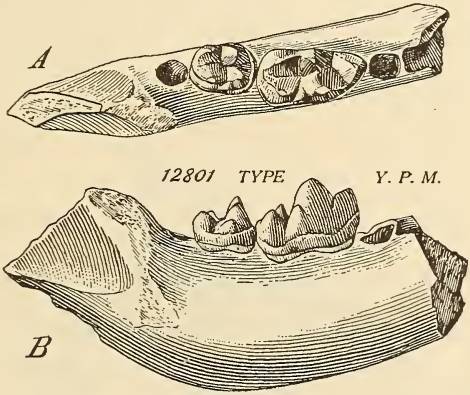

Fig. 3.—*Nothocyon latidens multicuspis,* subsp. nov. Holotype. × 3/2. A, Occlusal view of molars; B, external view of right ramus.

In 1907, Matthew called attention to a form "approaching *N. latidens* in size and characters" from the Lower Miocene of South Dakota, which he considered would prove to be a new species. The Yale specimen exceeds *N. latidens* in size, whereas I believe Matthew's specimen is smaller than the type of Cope's species.

The type locality for *N. latidens* is in the John Day Valley, Oregon, while this new subspecies is from Nebraska. Furthermore, Cope's species is Upper Oligocene (middle John Day) and the new form Lower or possibly Middle Miocene. Unfortunately we can not be positive either of its exact locality or geologic horizon. The reason for this is that the Yale College Scientific

Expedition of 1873 travelled from North Platte to Antelope Creek apparently without making any recorded collections. I am inclined to believe that whatever material was collected during the course of this long traverse was boxed at Antelope Creek, where the first collecting camp was established, and shipped east. Hence material from lower horizons came from the Antelope Creek camp, but was collected somewhere between there and North Platte (city), Nebraska.

Measurements of Holotypes.

	N. multicuspis mm.	*N. latidens* mm.
M_1, ant.-post. diameter	9.3	8
M_1, ant.-post. diameter of heel...........	4	3.5
M_2, ant.-post. diameter	5.2	
Depth below middle of sectorial	12	10.5

Nothocyon sp.

Cat. No. 12791, Y. P. M. Lower Miocene, near Scott's Bluff, Nebraska.

Both rami and part of a maxilla indicate a form of *Nothocyon* which does not readily fall within any of the known species. The length of the tooth-row is very close to that of *N. vulpinus,* but the depth of ramus below the alveolar parapet is nearly equal to that of *Mesocyon robustus,* that is, the mandible is considerably heavier and deeper than that of any other species of this genus. The depth below M_1 is 16 mm., the same as shown in the figure of *M. robustus,* although in the table of measurements for that species the depth is given as 6 mm., which is undoubtedly a typographical error. The antero-posterior diameter of M_2 is 1 mm. greater than that of *N. vulpinus.*

Harold Cook (1909) records a large form of *Nothocyon* discovered near the Agate Spring quarries in lower Harrison beds. His specimen is "somewhat larger and heavier than *N. geismarianus* Cope," and has a faint cingulum encompassing the anterior part of the sectorial. The Yale specimen also shows a slight cingulum in this position.

Measurements.

	mm.
Length of lower molar-premolar series	53
Length of lower premolar series	29
Breadth of skull at M^1	52.5

Cynodesmus cuspidatus, sp. nov.

(Figs. 4-5.)

Holotype, Cat. No. 12788, Y. P. M. Upper Miocene (Valentine beds), Niobrara River below Rapid (now Minnechaduza) Creek, Nebraska.

The holotype consists of parts of both maxillæ with molars, P^3 and P^4, the other premolars being represented by parts of the crowns or alveoli. A fragment of a jaw without teeth is provisionally referred to this species. These specimens were collected by O. Harger in 1873.

Fig. 4.

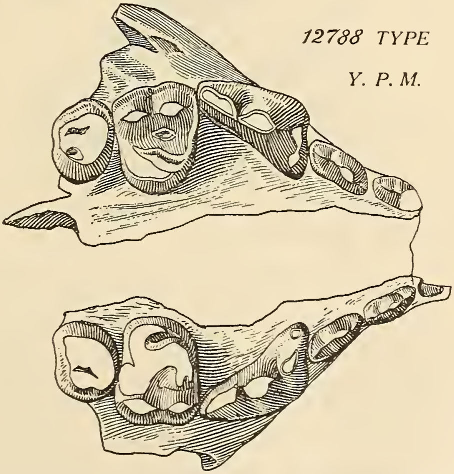

Fig. 4.—*Cynodesmus cuspidatus,* sp. nov. Holotype. Nat. size. Palatal view.

The species is intermediate in size between *C. thoöides* Scott and *C. thomsoni* Matthew, more closely resembling the former in size and the latter in dental characters, while the convexity above the anterior root of P^4 is very much more prominent than in either of the described species, and that above M¹ is weaker. The infra-orbital foramen is above the posterior part of P³ as in *C. thoöides,* the type of the genus.

This form differs from the two species previously described in possessing an anterior tubercle on P⁴, as in *Ælurodon.* However, it does not appear to invalidate the generic reference, for *Canis familiaris* possesses a well defined anterior tubercle on P⁴, while *C. latrans* has not the least suggestion of one. P² possesses a posterior tubercle similar to that of *C. thomsoni,* and unlike the corresponding tooth in *C. thoöides.* The shear of the carnassial is not so transverse as in *C. thomsoni,* but approximately the same as in the genoholotype. The inner half of the superior molars is much broader than that shown in the type.

FIG. 5.

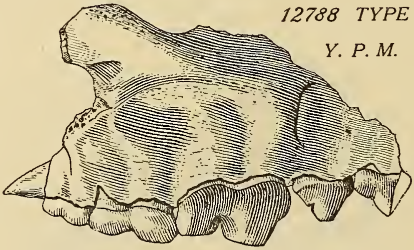

FIG. 5.—*Cynodesmus cuspidatus,* sp. nov. Holotype. Nat. size. Lateral view of right maxillary with teeth.

This new species is from a horizon higher than that of the others. From the similarity of tooth structure and the individual peculiarities of the teeth exhibited by both *C. thomsoni* and *C. cuspidatus,* sp. nov., I regard the latter as a derivative of the former. The type of the genus shows variations, which may be due to regional isolation, but whatever the cause, these seem to indicate an aberrant tendency on the part of the type. The South American canid, *C. cancrivorus,* probably shows the nearest approach, among modern Canidæ, to the genus *Cynodesmus.*

Measurements.

	C. cuspidatus Holotype mm.	*C. thomsoni** mm.	*C. thoöides*† mm.
Upper molar series, length	19	16	18.2
Upper premolar series, length	38	31	40.5
P¹, ant.-post. diameter	3.5	4	4
P¹, transverse diameter	3	3	3
P², ant.-post. diameter	8	7.5	9
P², transverse diameter	4	4	4
P³, ant.-post. diameter	9	8	9.5
P³, transverse diameter	4.5	4.5	5.1
P⁴, ant.-post. diameter	16.5	16	15
P⁴, transverse diameter	9	10	11
M¹, ant.-post. diameter	11.8	10.5	11
M¹, transverse diameter	15	13.7	16
M², ant.-post. diameter	8	5	7
M², transverse diameter	11	6.4	10

* From Matthew 1907.
† From Scott 1894.

Tephrocyon hippophagus Matthew and Cook.

Typical specimens of this species were collected in Nebraska and Colorado. The skull is, however, not known, although it must possess characters very similar to that of *T. rurestris*. On this basis an individual M¹, Cat. No. 12789, Y. P. M., has been referred to this genus and species, as it is nearly the same size and shows the same characters as the John Day type of the genus. This superior molar was collected on the Niobrara River, between Antelope Creek and the mouth of Minnechaduza Creek, Nebraska, by Capt. (later Brig.-Gen.) Mills, in 1873. Specimen No. 12833, Y. P. M., collected by Professor Lull, in "Quarry D," Ft. Niobrara Bird Reservation, on the Niobrara River, Nebraska, in 1914, has parts of both maxillæ. The axial length of P⁴, M¹, and M² is 33 mm. There is also, among other bones, a scapholunar which most probably belongs with the other parts. It is very similar in size and characters to *Canis latrans*.

Tephrocyon marshi, sp. nov.

(Fig. 6.)

Holotype, Cat. No. 12787, Y. P. M. Upper Miocene (Valentine beds), Cherry Co., Nebraska, along the Niobrara River, not far west of the mouth of Minnechaduza Creek. Collected by Professor Marsh in 1873.

This species is represented by a nearly complete left ramus with P_2, P_3, M_1, and M_2. It is nearly one half larger lineally than *T. hippophagus* and in its analogous parts seems to correspond most closely to the specimen recorded by Matthew and Cook (1909, p. 376) from the Snake Creek Pliocene. It differs, however, from all the other species of the genus in that it shows the beginning of a shortening of the ramus with a concomitant crowding, but not reduction, of the premolars, which overlap in each case. P_2 is placed obliquely with the anterior part outward, while P_1 was probably small, with a single root. M_3 was set in the ascending ramus of the jaw, and in this specimen is absent, with the alveolus partially closed, resembling a specimen of *Ælurodon haydeni* in the American Museum (No. 9744, Upper Miocene, Montana).

Fig. 6.

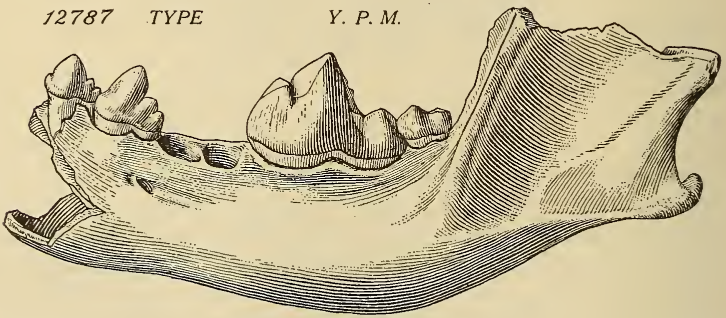

Fig. 6.—*Tephrocyon marshi*, sp. nov. Holotype. × 2/3. External view of left ramus.

From *T. mortifer* this new species differs in being about one quarter smaller lineally, less robust, and in the crowding of the premolars.

If, as we are disposed to believe, *Tephrocyon* is approximately ancestral to *Canis* and *Ælurodon*, then this new species seems to be in the line from which *Ælurodon* developed, for here we have the robust sectorial showing a slight increase in length and robustness with a jaw shortening. The premolar reduction might well result from this form in a few generations.

Measurements of Holotype.

	mm.
Lower dentition, P_1-M_2	81.5
Lower premolars, P_1-P_4	43.
Lower molars, M_1-M_2	41.
P_2, ant.-post. diameter 11. ; transverse diameter	7.
P_3, ant.-post. diameter 13.2 ; transverse diameter	8.5
P_4, ant.-post. diameter 19. ; transverse diameter	10.
M_1, ant.-post. diameter 30.3 ; transverse diameter	12.1
M_2, ant.-post. diameter 11.2 ; transverse diameter	8.5
Depth of jaw beneath M_2	30.7
Depth of jaw beneath P_2	29.1

This species may be referable to the genus *Tomarctus* Cope 1873, and in fact it is possible that *Tephrocyon* may be synonymous with Cope's genus. The holotype of the type species, *Tomarctus brevirostris* Cope, was collected near Pawnee Buttes, Colorado, in the Middle Miocene Pawnee Creek beds. It consists of "an immature jaw, the carnassial about half emerged, and the anterior part of the jaw so broken that it is not at all certain that the premolars were, as Cope considered them, reduced in number" (Cope-Matthew 1915, pl. CXIXc).

This type retains only the carnassial, but if the drawing of this be correct, then it apparently bears a strong resemblance to the analogous tooth in *Tephrocyon.*

Leptocyon vafer (Leidy).

Several lower jaws, with teeth, in the Marsh Collection are referred to this slender-jawed genus. The premolars are compressed and not crowded, and the heel of M_1 shows the low entoconid crest obscurely divided into two cusps as stated by Matthew.

Amphicyon americanus Wortman.

The type of this species, Cat. No. 10061, Y. P. M., consists of a palatal portion of a skull with the teeth, except the incisors and first premolar. It was very fully described by J. L. Wortman in 1901.

Amphicyon sinapius Matthew.

(Figs. 7, 8.)

In the collection there is a part of a right ramus with the base of P_3, nearly complete P_4, and complete M_1 and M_2, a detached crown of a lower canine and a practically complete left superior canine. These bear the catalogue number 10010, Y. P. M., and were collected on the Niobrara River in 1875. The superior canine has the same characters as that of the type of *A. americanus*.

Fig. 7.

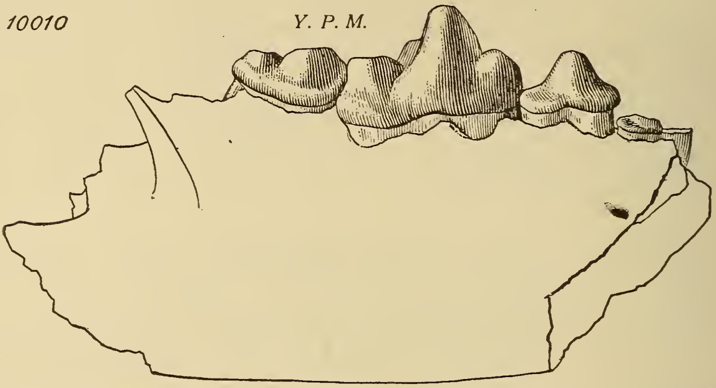

Fig. 7.—*Amphicyon sinapius* Matthew. × 2/3. External view of part of right ramus.

There are three molars in the lower jaw, the first two of which are very robust, while the premolars are relatively considerably reduced as in the superior dentition. The paraconid of M_1 is reduced, while the protoconid and metaconid are robust and prominent. Of the heel, the hypoconid is by far the more prominent element, for the entoconid is marginal and much reduced. The robust M_2 is composed of a large protoconid, a smaller paraconid

Fig. 8.

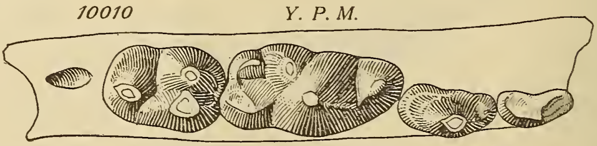

Fig. 8.—*Amphicyon sinapius* Matthew. × 2/3. Occlusal view of molars and premolar.

and hypoconid. The entoconid is represented simply by a ridge.

An unworn M_1, Cat. No. 12841, Y. P. M., collected on the Niobrara River, near the mouth of Minnechaduza Creek, exhibits nearly the same characters, except that the entoconid is composed of two small marginal cusps as in *Leptocyon* and the metaconid is a little smaller.

In size this species is probably about the same as the grizzly bear *(Ursus horribilis)*.

Measurements.

	10010 Y. P. M. mm.	18258* A. M. N. H. mm.
P_3, ant. post. diameter	15	
P_4, ant.-post. diameter	19.5	
P_4, transverse diameter	10	
M_1, ant.-post. diameter	35.5	35
M_1, transverse diameter	17	17.3
M_2, ant.-post. diameter	23	25.1
M_2, transverse diameter	16	17.6
Depth of ramus below middle of M_1	52	57.3
Length of inferior tooth row, P_3-M_2, incl.	91	92.8

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* The author is indebted to Doctor W. D. Matthew for his kindness in sending these measurements to him.

Ælurodon sævus (Leidy).

A left lower jaw with milk premolars, Cat. No. 12817, Y. P. M., is identified with this species. The first true molar was not erupted, but the external mandibular wall has been removed, thus exposing this tooth. The three deciduous premolars are similar in the main characters to those of *Canis*. The details of the crown of the fourth premolar closely resemble that of the permanent first lower molar, except in regard to size. All of the premolars are two-rooted.

Ælurodon near *wheelerianus* (Cope).

Cat. No. 10060, Y. P. M., consists of part of a left ramus with P_2 and P_3 and part of M_1 and M_2 with the canine, the alveolus of P_1 and part of that of I_3, together with a part of the maxilla bearing P^4 and M^1, and two loose teeth. It was collected on the Niobrara River, Nebraska.

The upper carnassial possesses a stout anterior tubercle and the lower jaw corresponds most closely with the type of *A. wheelerianus,* except that both P_2 and P_3 are set obliquely, anterior end internal, in the mandible, and the two premolars preserved do not possess anterior basal cusps, as seen in No. 8307 (Cope Collection), A. M. N. H. The crowns of all teeth in the specimen (supposedly the type) figured by Cope in 1877 were broken away, so that the presence or absence of anterior basal cusps on the premolars can not be determined. Matthew and Gidley (1904) have definitely said that all of the superior and inferior premolars of this species had anterior basal cusps. Both the type and the Yale specimen are of Upper Miocene (Valentine beds) age.

Ælurodon taxoides lacks the anterior basal cusp on P_2 and P_3, but differs in its much larger size, in which it approaches *A. haydeni.*

Another lower jaw, Cat. No. 12785, Y. P. M., was also collected on the Niobrara River. This right ramus is somewhat smaller and much more slender, possibly being that of a female. The differences, however, are not sufficiently great to invalidate the identification, in my opinion.

Ælurodon taxoides magnus, mut. nov.

(Figs. 9-11.)

Holotype, Cat. No. 10057, Y. P. M. Upper Miocene (Valentine beds), Niobrara River, a few miles east of the mouth of Antelope Creek, Nebraska. Collected by E. S. Lane in 1873.

The type material consists of both rami, with part of the right side of the face, with complete superior dental parapet, containing P^1, P^2, P^4, and M^1, all others being represented by alveoli, together with the distal half of the tibia and part of a cervical vertebra.

This new mutation is the nearest in size to *A. taxoides* Hatcher, but differs from it in possessing prominent anterior basal cusps on all of the premolars, both superior and inferior, with the possible exception of P^1, the anterior part of which is broken away. The presence of these anterior basal cusps would seem to refer it to *A. wheelerianus,* but such is apparently not the case. Both *A. taxoides* and this new form are approximately 25 per cent larger. Moreover, in the latter the alveolar parapet of the mandible rapidly ascends posterior to M_1, so that a line from the posterior edge of the alveolus of M_3 to the base of the canine passes through the tip of the protoconid of the sectorial; in *A. taxoides* and *A. wheelerianus,* through the anterior base of the paraconid of M_1.

FIG. 9.

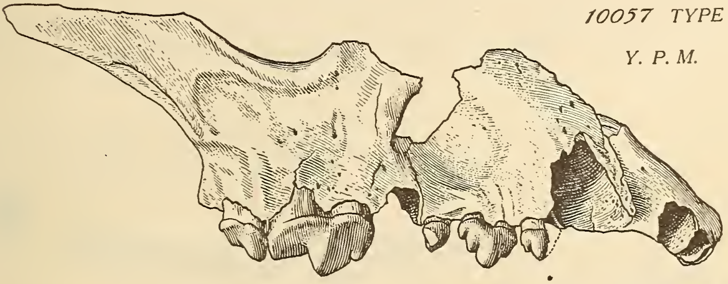

FIG. 9.—*Ælurodon taxoides magnus,* mut. nov. Holotype. × 1/2. Right lateral view of part of maxillary and premaxillary with teeth.

This upward trend of the parapet is analogous to that in *A. ursinus,* which species has been referred to the Amphicyonine group. In other respects, however, this new individual is not like *Amphicyon.* Another differentiation lies in the fact that the length of the inferior premolar series of *A. wheelerianus* is less than that of the

FIG. 10.

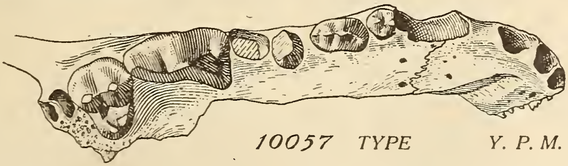

FIG. 10.—*Ælurodon taxoides magnus,* mut. nov. Holotype. × 1/2. Right palatal view.

molar series, while in both *A. taxoides* and the Yale specimen the premolar length exceeds the molar by one fifth.

The superior canine was large and, in cross-section, oval-shaped, and separated from the external incisor by a considerable diastema, while on the other side it was in contact with P¹. From the external incisor the incisive alveoli show a progressive reduction in transverse diameter. M^2 is considerably reduced in size. The parastyle on the upper carnassial is well developed.

The large infra-orbital foramen lies above the posterior part of P^3. The anterior zygomatic pedicle is very heavy, measuring 41 mm. from the infra-orbital border to the alveolar parapet, directly beneath.

In some respects this new mutation is similar to *A. platyrhinus* Barbour and Cook, but the former differs in the following respects: (1) somewhat larger, (2) no crowding of the premolars except that there is no diastema between the first and the canine, (3) larger canine, (4) carnassial over one fifth greater in transverse diameter and M^1 smaller and of relatively less transverse diameter, and in still others, the number of which would undoubtedly be increased if we had more of the skull of the Yale specimen or the mandible of the Nebraska individual.

Fig. 11.

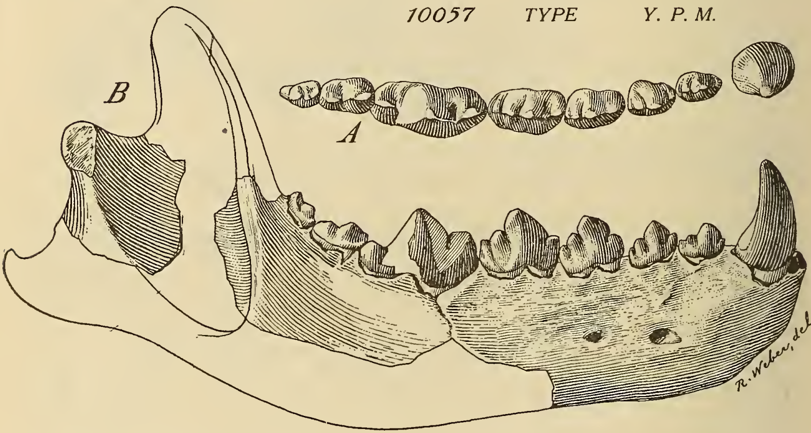

Fig. 11.—*Ælurodon taxoides magnus,* mut. nov. Holotype. × 1/2. A, occlusal view of inferior dentition; B, external view of right ramus.

Measurements of Holotypes.

	A. taxoides mm.	*A. magnus* mm.	*A. wheelerianus* mm.
Length of inf. premolar series	62	63	46
Length of inf. molar series	53	53	49
Ant.-post. diameter of sectorial	34	32	28
Ant.-post. diameter of P_4	22	21	15
Ant.-post. diameter of M_2	12	14.5	12
Ant.-post. diameter of M_3	8	9	6
Depth of ramus below P_4	37	36	29.5
Length of sup. dental series, C-M^2 inc.		113	
Length of sup. premolar series		74	
Length of sup. molar series		24	
Ant.-post. diameter of carnassial ..		27.3	

MUSTELIDÆ.

Brachypsalis pachycephalus Cope.

This genus and species is represented by the posterior part of a right ramus, except the coronoid process, possessing M_1 and M_2, somewhat damaged. It is Cat. No. 12780, Y. P. M., and it was collected near the mouth of Minnechaduza Creek on the Niobrara River, Nebraska. It is somewhat more slender than the type, in this respect approaching *B. modicus* Matthew, although in other essentials it is identifiable with Cope's species, representing a possible variety of the latter form.

Another specimen, a right ramus, Cat. No. 12803, Y. P. M., is more typical than No. 12780. Professor B. F. Mudge collected the jaw near Ellis, Kansas, in the Ogalalla formation, which is not later in age than Lower Pliocene and may well be of late Upper Miocene. This ramus shows characters intermediate between that of *B. modicus* and *B. obliquidens* Sinclair, although its modifications are much less extreme than those shown by Sinclair's species. The length of the tooth-row and of the individual teeth is a little greater than in the type of the genus.

Measurements.

	Cat. No. 12803 Y. P. M. mm.	Holotype mm.
Molar-premolar series, length	58	55
Premolar series, length	32	31
P_2, ant.-post. diameter	7	
P_3, ant.-post. diameter	9.5	
P_4, ant.-post. diameter	13*	
M_1, ant.-post. diameter	17.5*	14.5
M_2, ant.-post. diameter	9	
Depth of ramus at sectorial	25	25

*Alveolar measurements.

Potamotherium lycopotamicum (Cope).

The type of this species, from the Mascall beds of Oregon, has unfortunately been lost. It was based on a jaw broken away immediately behind the carnassial, and belonged to an animal about the size of a mink. The type was figured in 1915 (Cope-Matthew).

Two lower jaws, collected on the Niobrara River, are referred to this species. One, from "Quarry D," Ft. Niobrara Bird Reservation, Nebraska, Cat. No. 12834, Y. P. M., found by Professor Lull in 1914, has the carnassial unworn and intact, as well as the premolar alveolar parapet, with the ramus below intact. It also possesses the alveolus of M_2, the presence or absence of which in this species has not before been determined. All of the premolars are two-rooted except the first. The other

Measurements.

	Cat. No. 12834 Y. P. M. mm.	Cat. No. 12825 Y. P. M. mm.	Holotype mm.
Molar-premolar series, exclusive of M_2	22		22
M_1, ant.-post. diameter	7.1		6.6
M_1, transverse diameter	3.8		4
M_1, length of heel	2.4		2.4
P_4, ant.-post. diameter		4.2	4.5
P_3, ant.-post. diameter		3.8	
P_2, ant.-post. diameter		3.4	
Depth of ramus below sectorial		7	

specimen, Cat. No. 12825, Y. P. M., is one of the results of the Yale College Scientific Expedition of 1873, under the direction of Professor Marsh. It is a portion of the left ramus with P_2, P_3 and P_4, with the alveolus of P_1 and the canine. The fourth premolar has a low posterior cusp and prominent cingulum posteriorly. There is an alveolus for one incisor.

FELIDÆ.

Material referable to the cat family is extremely meagre in the Upper Miocene and Lower Pliocene, and it is with this in view that I desire to call attention to some of this material in the Yale collections.

Felis augustus Leidy.

The distal end of the humerus of a large felid was collected by Professor Lull on the Niobrara River, in Cherry County, Nebraska. It is a well preserved fragment, somewhat over 5 inches in length, bearing catalogue number 12809. The humerus exceeds in size that of *Felis leo* and is considerably more robust. *Felis augustus* must have been very close in size and probably in proportions to the Bengal tiger, which in turn is larger than the average male lion.

The lower half of another humerus, better preserved and 9 inches in its present length, was collected by F. W. Darby in Sheridan County, Nebraska, also near the Niobrara River. This humerus, Cat. No. 12810, Y. P. M., has practically the same dimensions as that of the type, while No. 12809 is about one twelfth smaller.

Felis sp.

A scapholunar and a median phalanx, from the Upper Miocene on the Niobrara River, near Fort Niobrara, Nebraska, indicate the presence of a felid or machærodont of about the size of *Daphænodon superbus* (Peterson). The scapholunar, Cat. No. 12838, is flatter and less oblong than that of *Felis leo* and the articular surfaces are in some cases slightly divergent. The resemblance, at any rate, is much closer to the cats, than to any of the other carnivores.

Pseudælurus intrepidus Leidy.

Two specimens of this genus and species, found on the Niobrara River in Cherry County, Nebraska, exceed the type in size. The difference is not of specific value, but worthy of notice, as heretofore the type of the species has been regarded as representing the maximum size to which this genus attained in America. The posterior half of a left ramus, Cat. No. 12830, Y. P. M., was collected by Professor Lull in 1914. The other specimen, Cat. No. 12816, Y. P. M., consists of a third lower premolar, which is 2 mm. higher, 1.5 mm. wider, and 2 mm. greater in antero-posterior diameter than Leidy's type.

Pseudælurus marshi, sp. nov.

(Fig. 12.)

Holotype, Cat. No. 12865, Y. P. M. Upper Miocene (Valentine beds), Niobrara River, near mouth of Minnechaduza Creek, Cherry Co., Nebraska. Collected by Professor O. C. Marsh in 1873. Paratype, Cat. No. 12815, Y. P. M. Middle or Upper Miocene, northwestern Colorado.

The holotype consists of both lower jaws, partially restored, and the paratype of a left ramus with the alveolar parapet complete, as well as P_3 and P_4. The new species is about the size of *Hoplophoneus primævus,* or one fourth smaller than *P. intrepidus* and hence considerably smaller than *P. intrepidus sinclairi* Matthew. The mandible is very much more slender than either of the above forms and does not exhibit so great depth below the tooth-row, although both the holo- and paratype are fully adult. The teeth are not crowded as in the above mentioned variety. Both types of the new species possessed a very diminutive P_2, the antero-posterior diameter of which is not over 2 mm. The position of this premolar is inward from the true line of the tooth-row, as in Matthew's variety. The posterior basal tubercle of P_3 in the paratype is exceedingly small and that of the holotype is much reduced. The fourth premolar, in its component parts, most closely resembles the analogous tooth in *P. intrepidus sinclairi,* while the metaconid of M_1 has not suffered so great a reduction as in the latter variety. The paratype alone shows a distinct, but very small alveolus for M_2, its antero-posterior diameter being 3 mm.

The mental foramina have approximately the same position as in Matthew's felid.

The European species *P. quadridentatus* (Blainville) is slightly longer than *P. intrepidus*, but is of approximately the same depth below the tooth-row. *Pseudælurus marshi*, sp. nov., in size corresponds more closely to *P. edwardsii* Filhol, although the latter is somewhat smaller. *Pseudælurus intermedius* Filhol possesses a minute inner cusp on M_1 which is not found on any American form, so far as I am aware.

FIG. 12.

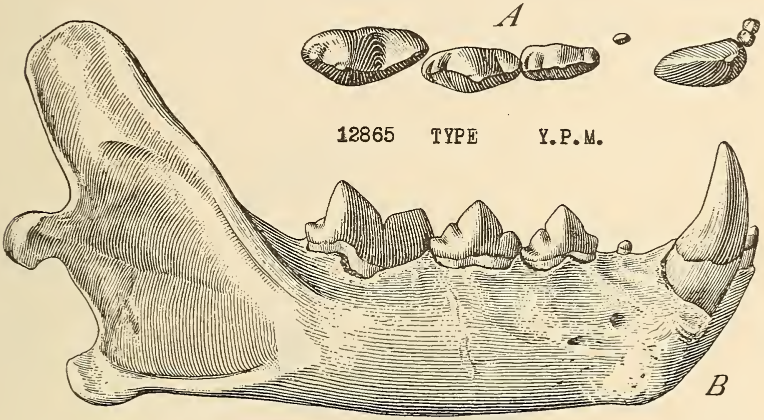

FIG. 12.—*Pseudælurus marshi,* sp. nov. Holotype. Nat. size. A, occlusal view of inferior dentition; B, external view of right ramus.

Measurements of Holotypes.

	P. marshi mm.	*P. intrepidus* mm.
Length, condyle to median incisor	97	122.7
Length of tooth series (M_1, P_4 and P_3)	36	44.5
Length of diastema between C and P_3	8.6	14.8
Ant.-post. diameter of M_1	16	19.6
Ant.-post diameter of P_4	12.5	14.8
Ant.-post. diameter of P_3	9.5	11.6
Width of jaw at sectorial	9	
Depth of jaw at P_4	17	23.2

Machærodus niobrarensis, sp. nov.

(FIG. 13.)

Holotype, Cat. No. 12829, Y. P. M. Upper Miocene (Valentine beds), Niobrara River, Cherry Co., Nebraska.

The portion of a skull, anterior to P³, collected in 1873, is tentatively referred to *Machærodus,* in spite of the fact that no undoubted specimen of this genus has been hitherto found in North America. This specimen does not by any means dispel doubt as to the presence of this genus in the New World, but it does show that there were forms present here which were more nearly allied to *Machærodus* than to any other genus of felids.

FIG. 13.

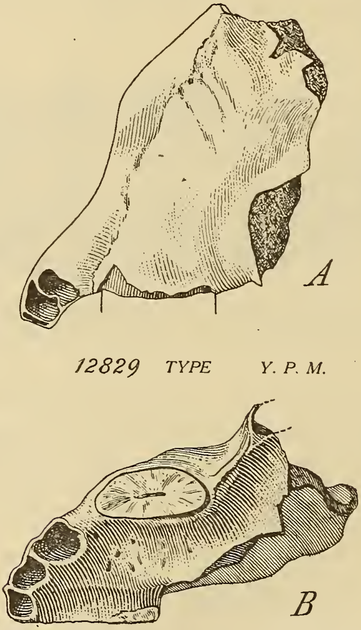

FIG. 13.—*Machærodus niobrarensis*, sp. nov. Holotype. × 3/4. A, left lateral view of part of maxillary and premaxillary; B, palatal view of same.

One of the outstanding and diagnostic characters of the specimen is seen in a cross-section of the canine, this tooth being very much compressed, and having an antero-posterior diameter of 21.5 mm. and a maximum transverse diameter of 8.8 mm., measured at the alveolar parapet. The ratio between the transverse and anteroposterior diameters, measured at the base of the crown, is as follows in the forms listed below: *Felis leo,* 1 to 1.4, *Pseudælurus,* 1 to 1.7, in the true *Felis* line; while in the machærodont series, *M. necator* (based on Cope's figure), 1 to 2.2, *M. palmidens* (Blainville), 1 to 2.6, *M. niobrarensis,* sp. nov., 1 to 2.4, and *Smilodon neogæus* Lund (from Burmeister's measurements), 1 to 2.33. *M. crassidens* may be nearer to the felines as indicated by the ratio of 1 to 1.65. Hence it is seen at once that the proportions of the canine in the felid and machærodont series are very different, and that this new machærodont is much closer to *Machærodus* than to any form in the feline series of equivalent or later geologic age.

Machærodus is very brachycephalic and this new species shows the same character. The anterior part of the alveolus of P^3 is external to a plane, parallel to the sagittal plane, passing through the outermost part of the canine. In the Yale specimen the anterior part of this premolar is offset approximately 6 mm.; in *M. palmidens,* about 4 mm.

This new species differs from the typical *Machærodus,* in so far as we have comparable parts from which to judge, in that the incisors are a little more anterior to the canines, thereby making the muzzle slightly more pointed. Another divergence is seen in the incisor proportions, the external being larger and the amount of reduction from this one greater than in *M. palmidens.*

The skull of *M. palmidens* is a trifle greater than one half that of *Felis leo,* while this new species is probably about two thirds the size of the lion and hence smaller than any of the specimens hitherto referred to this genus from North America.

Measurements.

	M. palmidens mm.	Cat. No. 12829 Y. P. M. mm.
Width of palate at and including canines . .	47	54
Width of palate at anterior part of P^3	60	73
Length of diastema between C and P^3	7	11.5
Length (axial) from prosthion to line through post. of canines	27	38

Felid, gen. et sp. indet.

Another specimen, Cat. No. 12839, Y. P. M., is that of an undoubted felid, but whether a member of the *Machærodus* or *Felis* line is not determined. As cat material from this horizon is so very scanty, in fact, largely unknown, it will not be out of place to give a brief description of certain bones of this skeleton. No skull is present, but several vertebræ, part of the pelvis, ribs, and the major part of the left femur are extant. It was discovered in 1914 by Professor Lull and collected by him, with the assistance of F. W. Darby, 5 miles east of Valentine, Nebraska. For comparison, an average-sized skeleton (Cat. No. 01050, Y. P. M.) of a male *Felis leo* was used. The geologic horizon is either Upper Miocene or possibly Lower Pliocene, as the specimen was found at approximately the same level as a 4-tusked mastodon, genus not yet determined, collected by the same party. The fossil skeleton, in the anterior portion of its anatomy, is apparently lighter than the lion, but in the posterior region it is fully as heavy, or possibly a little stouter and more robust.

The transverse processes of the atlas are slightly thicker, of less width, but greater posterior extent; the width of the dorsal surface is considerably greater; and the posterior opening of the passage for the vertebral artery is absolutely smaller than in the lion. The hypapophysial tubercle is apparently reduced, while the neural spine is very rudimentary. The alar canal is bridged over, and is not in the form of a notch as in *Felis leo*.

Measurements of Atlas.

	Cat. No. 12839 Y. P. M. mm.	Cat. No. 01050 Y. P. M. mm.
Max. width across wings	132	137.5
Ant.-post. diameter across articular surfaces	59	64
Ant.-post. diameter of neural arch, dorsal side	43	29
Ant.-post. diameter of neural arch, ventral side	17	24

The fifth and sixth cervicals, transversely, have a more nearly square outline to the neural canal; the walls of the neural arch are heavier; the vertebral canal is more elongate; the anterior and posterior faces of the centra are much more concave; the postzygapophyses stand at a slightly greater vertical angle than in the lion. The transverse processes are directed downward and outward; in *F. leo* outward and downward. The sixth lacks the upper transverse process of the lion. The seventh closely resembles that of the lion except that the costal facets are large and well defined in the fossil and the ends of the centrum are more concave.

Measurements of Cervicals.

	5th		6th		7th	
	12839	01050	12839	01050	12839	01050
	mm.		mm.		mm.	
Length of centrum	33	31	33	30	30	30
Width across prezygapophyses	43	74	52	66	52.3	66
Width across postzygapophyses	51	60	48	61		

Dorsals.—The first is very similar to that of *F. leo* except that it is slightly smaller and less robust; the fourth has a more oval (flattened from above downward) neural canal, less robust mammillary processes and is in general smaller and lighter than that of the lion. Its posterior articular surfaces extend but slightly beyond the centrum, while in *F. leo* they extend quite prominently. In the eleventh dorsal, the posterior articular surfaces are more vertical, with the superior section vertical, while in the lion the upper part bends outward, that is, has a more horizontal position. In the lion this vertebra has a vestigial spine, while the fossil possesses a relatively enormous one. The spine is wider, heavier, and longer in the twelfth; the centrum narrower, while the metapophyses of the prezygapophyses extend outward, are heavier and more robust, and the anapophyses extend to a line through the posterior margin of the postzygapophyses in the fossil. In the thirteenth, the metapophyses extend upward and outward; the anapophyses extend slightly beyond the posterior margin of the postzygapophyses; and the facets for the rib heads are deeper in this and the twelfth than in *Felis leo*.

Measurements of Dorsals.

	12839 mm.	01050 mm.
Length of centrum		
1st	28	30
4th	26.5	31
11th	30.5	37.5
12th	33	40
13th	35	43
Length of spine		
1st	65	76
4th	70	90
11th	55	16
12th	47.5	35
13th	46	34
Max. width across transverse processes		
1st	79	90
4th	68	67
Width across postzygapophyses		
11th	24	26
Width across anapophyses		
12th	44	51
13th	46.2	50
Width across metapophyses		
12th	51	44
13th	50	50

The first and second lumbars have heavier spines, their anapophyses extend slightly farther back and are situated a little farther down than in the lion.

Measurements of Lumbars.

	1st		2d	
	12839 mm.	01050 mm.	12839 mm.	01050 mm.
Length of centrum	39	46	40	48.5
Length of spine	46.1	38	50.5	43
Width across anapophyses	43	46	41*	45
Width across metapophyses	46	52	55	52

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* Approximate.

The sacrum is but slightly smaller, while the spines are higher and a great deal more robust. The anterior articular facets lie in two planes, one outward and upward, and the second directly upward, while in *F. leo* they only have one—outward and upward. The rudiments of the zyga- and metapophyses are larger between the first and second segments and smaller between the second and third than in the lion. In *F. leo* the articular surfaces for the pelvis and the last lumbar are solidly united with each other and the centrum, but in the fossil they are widely separated and have no connection with each other. This fossil sacrum shows a pathological condition on the left side where there has been much exostosis, and the lateral mass is much closer to the centrum. The right side is normal. The maximum width across the lateral masses is 86 mm. in the fossil and 85 mm. in *F. leo,* while the combined length of the first two sacrals is the same in both, 62 mm.

The remaining part of the pelvis shows close similarity to *F. leo* in size and character. The tubercle for attachment of the rectus femoris muscle, in advance of the acetabulum, is slightly larger and more elevated, while the concavity above is smaller in the fossil, the ischiatic spine is a little less prominent, the ileo-pectineal eminence is more robust and less elevated, and situated a little more posteriorly. The maximum diameter of the acetabulum in both is 40 mm.

Of the femur, the great trochanter is not quite so heavy at the top, but extends a little farther down the shaft. The lesser trochanter is larger, the linea aspera more prominent, the trochanteric fossa deeper, and the bone somewhat heavier than in the lion.

Measurements of Femur.

	12839 mm.	01050 mm.
Max. transverse diam. at middle of lesser trochanter	50	49
Max. distance from inf. part of lesser trochanter to top of greater trochanter	76	69
Transverse diameter at middle of shaft	28.1	29

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Art. XLI.—*The Dilemma of the Paleoclimatologists;* by Robert W. Sayles, Harvard University.

The so-called Glacial Theory was promulgated about 1835 by Agassiz and Carpentier. Since that time geologists have sought diligently to discover the cause or causes of periods of glaciation, and one theory after another has been propounded to account for them, but up to the present time no one of the many explanations has proved wholly adequate.

In 1855 A. C. Ramsey advocated the glacial origin of certain breccias of Permian age in the Midland district of England, but there were very few who accepted his view. In 1856 the Blandford Brothers discovered the Talchir glacial conglomerate or tillite in the Cuttack district of India. Discoveries of tillites of the same age as those of India were soon made in South Australia and South Africa, then in South America, North America at Boston, then in Alaska. There are a number of conglomerates in other parts of the world of late Carboniferous or early Permian age which may be glacial in origin.

Tillites that occur at other points in the time scale have now been made known. Thus, in 1908, Coleman found glacial striæ on pebbles and bowlders in the Cobalt conglomerate of Huronian age at Cobalt, Ontario. Although geologists had accepted the Permo-Carboniferous glaciation and the late Proterozoic or early Cambrian evidence of glaciation, it was more or less of a strain on their faith to believe that the earth was cool enough to permit of a period of glaciation in the Huronian. But the gradually increasing confidence in the planetesimal hypothesis of Chamberlin and Moulton would do away with presumption of a hot globe growing progressively cooler and cooler, which was the prevailing belief of the geologists of the 19th century—this, of course, based on the nebular hypothesis of La Place.

More evidence of glaciation from all parts of the geological column has come in. In addition to the Huronian and Permo-Carboniferous glaciations, evidence of glaciation in the Late Proterozoic, Lower Cambrian, Lower Ordovician, Silurian, Late Silurian or Early Devonian, Triassic, Cretaceous, Eocene, and Miocene, has been found.[1]

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[1] For references, arranged alphabetically, see the close of this paper.

The Lower Ordovician glaciation mentioned above was found by the writer in the presence of T. H. Clark on September 21st, 1921, at Levis, Quebec, in shales of Beekmantown age. The evidence of it is a tillite of the submarine or sublacustrine variety, varying in thickness from about four to eight feet. The shale below and above it is very regularly banded suggesting seasonal deposition.

NOTE—Since making this discovery Professor Coleman has called the attention of the writer to his Presidential Address before the Royal Society of Canada, in April, 1921, in which he states his belief in the glacial origin of the Levis conglomerates.

Three papers of great importance to paleoclimatologists have appeared in America in the last three years The first by Knowlton[2] in 1919, the second and the third respectively by Coleman[3] and Schuchert[4] in 1921. Knowlton claims on paleobotanical evidence, that before the Pleistocene there was a non-zonal arrangement of earth temperature, and that the surface temperature was warm-humid from poles to equator, for the most part, throughout the entire geological record. He explains this by the hypothesis of Marsden Manson[5] which calls for a cloud sphere that shut out the greater part of sunlight and heat rays, and thus surface temperatures were kept up by the heat of the earth itself through the ocean waters. Knowlton claims that glacial periods were often accidents in the history of the earth, and that many of the tillites indicate glaciation of a local nature only. He also claims that Manson's theory explains the almost tropical distribution of Permo-Carboniferous glaciation better than any other, this notwithstanding the fact that tillites of this age have been found in Alaska.

Knowlton's evidence for the general mild climates for the earth during many periods cannot be doubted, but when he totally eliminates seasons during these times of warmth the geologists demand explanations of many things. Coleman and Schuchert have shown many excellent reasons for believing that the sun held sway and seasons existed in the warm periods as now, although seasons were less marked during the warm episodes than our seasons today.

The writer has asked Dr. Knowlton to explain many things which seemed incompatible with his ideas of a universal warm climate without sunlight. For example, it is difficult to explain the evolution of our flowering plants and insects, and the feathers on birds and hair on mammals, and the desert apparatus with which the camel is furnished, without sunlight. Dr. Knowlton cites many cases of annual rings of growth in fossil trees from Carboniferous to present time. Dr. Winifred Goldring[6] has recently described Cordaites of Alleghany age from Oklahoma which show pronounced growth rings, indicating seasons in 35° N. latitude at that time. The seasons need not necessarily have been cold and warm but may have been wet and dry. How can such occurrences be explained except by seasons? The Dead Sea is today making seasonal deposits of mud with salt and gypsum alternating regularly. In the past the same process went on as evidenced by the seasonal deposits of the Stassfurt salts, of upper Permian age in Germany, and by the Alsace salts, of Miocene age described by Gale[7] and believed by him to be of seasonal origin. In Arizona Shimer[8] described beds of gypsum and shale of Triassic age, which alternate in a regular manner, and although he did not say so, they are possibly of seasonal origin. Blackwelder has recently made a study of oil shales from the Green River region. This shale has very regularly alternating brown and black bands. Blackwelder took the specific gravity of the material of these brown and black layers and found the former had an average specific gravity of about 1.9 and the latter about 1.3. This, in the opinion of Blackwelder and the writer, is a case which strongly suggests seasonal deposition. As time goes on and the attention of geologists is called to such occurrences many more cases will doubtless be noted and studied. Seasonal layers in glacial clays of Pleistocene age have been known for many years, as described in the works of DeGeer[9] and a number of other geologists.[10] In 1915 the writer gave a paper before the Geological Society of America describing seasonal banding in the slate which occurs above the Squantum tillite in Boston harbor. A paper comparing some Pleistocene clays in the Connecticut Valley with the Squantum Permo-Carboniferous banded slates was published in 1919. As noted by Coleman[3] and Barrell[11] and others, this comparison leaves little doubt as to the same origin of the seasonally banded Pleistocene clays and the banded Squantum slate. Banded argillites with other tillites in various parts of the world were also noted in this paper. Sederholm[12] and Halle[13] of Sweden expressed their belief in the seasonal nature of certain banded slates in 1913. David and Süssmilch[14] published a paper in 1919-20 in which they counted the years by means of banded slate in an upper Carboniferous glacial lake in Australia. At the present time the writer is engaged in a study of banding in various argillites. From the progress so far made, it is difficult to escape the conviction that seasonal deposition existed in many places and periods. That all this banding is of a glacial nature, it is not necessary to conclude, for seasonal deposition is going on now far from glaciers. Shaw[15] believes that seasonal deposition is going on at present in the delta of the Mississippi. It will be necessary to compare this banding with the bandings in slates and shales of which there are many examples. Coleman cites the case of the middle member of the Sudbury Series called the McKim Graywacks consisting of "thin layers of interbanded graywacks and slate."

From a study of a metamorphosed slate, given to the writer by N. E. A. Hinds, which shows regular bandings of coarse and fine materials, it is not impossible to believe that some of the banded schists and possibly some of the regularly banded gneisses were originally seasonally deposited sediments. This is a matter for future investigation.

The Dual Heating System of the Earth.

With the tremendously long lease of life given to the earth by the discovery of a very much greater number of unconformities and disconformities than we had any idea of a few years ago, as pointed out by Barrell, and Chamberlin, and the new method of estimating the age of the earth through the study of the transformations of radium, it is evident that during the hundreds of millions of years estimated, there is time for all kinds of climates. In fact, the monotonous, non-zonal arrangement advocated by Manson would not, as noted by Coleman, appear to have been favorable in the least to evolution as it is recorded in the rocks. That there were many more changes of climate than we had any idea of 20 years ago, is becoming evident from the discoveries of tillites all over the world, to say nothing of the mass of evidence for arid conditions. Is it necessary to conclude that there were no seasons during all this tremendous lapse of time, or to say that there were times when seasons were not pronounced enough to make their mark, and at other times sufficiently pronounced to manifest themselves with or without glaciation? If they were not marked enough to show themselves in any manner who can say that Manson is not right for such periods?

In spite of all the accumulating evidence for seasons in the immediate and distant past, Knowlton and Manson have stimulated an inquiry about earth heat which, let us hope, will not cease until the matter is settled beyond all question. They have courageously stated their views and brought a new viewpoint in this field of past climates. Under the false idea that this earth started hot and has ever since been growing cold, geologists have tried to explain the reason, or reasons, for the glacial periods. Now that the evidence points to the idea that the earth is a self-heating body mainly under the influence of pressure and radioactive substances, and that there is no evidence in the rocks that the first stages of the earth were very hot, is it not just as important to explain such surface temperatures as must have existed when warm weather plants and corals thrived near the poles, as to try to find a cause or causes for glacial periods? No efforts have been put forth in this direction commensurable with the efforts expended on the glacial periods. It is about time that geologists face about and overcome a great difficulty that has not been fully recognized as a difficulty, so crystallized has become our opinion that the surface temperatures of the earth during the warm periods were explained by the Nebular Hypothesis and the heat of the sun. Such is not the case if the Nebular Hypothesis be rejected, and the more thought given to this subject, the more difficult does it become to explain the conditions of those times. Before the solution of the glacial climates is accomplished, the conditions of the heat supply of the warm periods must be understood, and perhaps the glacial question will then settle itself.

What part of our surface temperature is due to the sun and what part is due to our own heat? This question has been settled by the physicists of the past with a confident answer that the heat from the earth's interior is a negligible quantity. What would our surface temperatures be if by some magic the ice from the poles should suddenly be melted away? It would appear that both of these questions must be answered satisfactorily before we can make progress with the glacial period riddle, and the warm period riddle.

If the earth receives at the surface more heat from the interior than we are aware of, the place to look for it is evidently in the oceans rather than on the continents. When we consider the tremendous mass of ocean water, all of which is supplied with heat in excess of 493 degrees F. in temperature above absolute zero, it is difficult to conceive of the sun as the sole agent of the heating. There is no zonal arrangement of temperature along the ocean bottoms, where the temperature rarely goes below the freezing point, and it looks very much as though the earth must prevent any lowering of the heat below that point. There are several things which point to the earth as the heating agent for at least part of the heat of the waters. For a long time such heat has been suspected. The geothermal gradients along the coasts, as shown by the records of deep borings, are not as much depressed as they should be if the oceans have cooled off the upper part of the crust close to the oceans. At a depth of two miles below the surface of the continents and with a thermal gradient of 60 feet to a degree rise, there should be a temperature of about 680 degrees F. above absolute zero in middle latitudes. We do not know what the temperatures of the rocks are in the ocean bottoms at a depth of two miles from the bottom of the waters. Is it possible that they have lost 187 degrees in heating the waters? Murray[16] records some observations on this point. He says:

> "Some such increase of temperature towards the bottom has long been suspected as an effect of the internal heat of the earth; as early as about 1840 Aimé looked for it, but his methods were not sufficiently accurate. More recently, several indications of a rise of temperature towards the bottom have been observed. The pressure and the internal heat having the same effect, it is difficult—at our present stage—to determine how much is due to the internal heat of the earth. In any case the bottom water temperatures would be considerably lower but for the effect of pressure on the sinking waters."

Then again we are not sure just how much heat the radioactive oozes on the ocean floor generate. Joly[17] found that the red clay and radiolarian ooze exhibit much radioactive substance, this in the case of the red clay being over ten times as much as in average continental rocks. Murray says again in regard to a rise in temperature of the bottom waters:

> "This rise of temperature has also been attributed to decomposing organic matter and to radioactive matter in the deposits at the bottom. Whatever may have been the cause we certainly found a similar slight rise in the temperature of the deepest layer on several subsequent occasions during our cruise."

We do not know how thick the red clay is, but we do know its great extent and its great radioactive content. All the bottom oozes have high radioactivity. Is it not possible that these self-heating deposits prevent so great a loss of heat from the underlying rocks and thus conserve considerable heat which would otherwise be lost to the waters? If such a conservation of heat were possible, instead of a greatly depressed thermal gradient, due to the cooling of the waters, might we not have a temperature of about 680 degrees F. in absolute units under the oozes? Possibly the temperature might be higher than 680 degrees F., for according to recent observations in many deep borings the thermal gradient often increases markedly after passing the 5,000-foot level, although in some cases the reverse of this is true.

Now as to the second question. What would the temperatures of our earth be without the polar ice? If it is true that the oceans, with a constant supply of ice water from the polar regions, receive a negligible amount of heat from the earth—and this has not been proved—the cold water would cool off the earth under the oceans to a considerable extent and thus lower the geotherms. Perhaps this is the case, but there is little evidence for such a conclusion. If the polar ice was melted away the heat from the ocean bottoms might warm up the ocean waters considerably. What would be the result of this combination of earth heat and sun heat on our climates?

At the present time the oceans and the seas cover about 139,686,000 square miles and the lands are estimated at about 67,254,000 square miles. In comparison with some of the former periods when epicontinental seas covered much more of the present continents than today, we are living during a period of high relief and land emergence and of accelerated geological processes. When the epicontinental seas covered so much of the continents much more heat was stored in their waters and not permitted to radiate back into space as rapidly as is the case today on the continents, and especially in the polar regions, where so great a part of the insolation is reflected away by the ice and snow surfaces. There was a warm water heating system which carried warmth to every quarter of the globe. The seas of those periods of warmth and low relief are not even imitated to-day, except imperfectly perhaps in one case, the Red Sea. Here the cold bottom waters of the Indian Ocean kept out by the sill at the straits of Bab-El-Mandeb, do not enter, and the result is a sea with warm waters from top to bottom, that approximates the mean annual temperature of the Red Sea region. It is possible that the Red Sea today approaches the conditions of the deep oceans during the warm periods. With a depth of 1,200 fathoms the bottom waters have never been known to fall below 532 degrees F., absolute degrees. This is about 40 degrees F. warmer than water at similar depths in the adjacent Indian Ocean. Is this 40 degrees F. due to the stored heat of the sun or to heat imparted by the lithosphere under the Red Sea, or to a combination of both?

The close agreement of our air temperatures and the temperatures of the regolith presents an interesting case. At the equator the mean annual temperature can be found one yard below the surface. Ground temperatures in middle and high latitudes several yards from the surface are usually one or two degrees F. higher than the mean annual air temperature of the places. Lane[18] believes that the snow cover in the northern states causes the ground temperature about 6 feet below the surface to be 1 or 2 degrees above the mean annual temperature of the place. In fact, observations of underground temperatures several hundred feet below the surface would show that they are in large measure controlled by latitude. The writer finds[19] that the temperature of the earth between 400 and 500 feet from the surface, is higher in the southern states than in the northern states by about 16.5

Wells between 400–500 feet.

								Averages
	Depth	400	400	420	454	420		
		417	400	400	400	425		413
Nebraska	Temp.	60	58.5	59	58.5	60.5		
		58	59	54	62	61		59
	Air Temp.	46.5	46.5	46 5	46.5	46.5		
		46.5	46.5	48.3	48.1	48.1		47
	Depth	396	509	450	460	500	500	469
Iowa	Temp.	52	56	60	60	58	53	56.5
	Air Temp.	47	50.5	50.5	50.5	49.3	46.8	49.1
	Depth	530	447					488
Indiana	Temp.	56	54					55
	Air Temp.	53	50.9					51·9
	Depth	535						535
Ohio	Temp.	54						54
	Air Temp.	49.3						49.3
	Depth	540	497	415				478
Pennsylvania	Temp.	53	63.5	53				56.5
	Air Temp.	49.3	49.8	49.3				49.4
	Depth	448	420	408				425
New Jersey	Temp.	60	60	60				60
	Air Temp.	51.9	51.9	52.1				51.9
	Depth	403	548	500				483
Texas	Temp.	76	73	74				74
	Air Temp.	62.9	68.9	65.4				65.7
	Depth	427	385	480	520	526		467
Louisiana	Temp.	75	71	72	72	74		72.8
	Air Temp.	68	65.6	66.8	66.8	66.8		66.8
	Depth	500	400					450
Mississippi	Temp.	79.5	70					74.7
	Air Temp.	68	63·4					65.7
	Depth	487	470	409	415	495		
		450	456	440	495	415		453
Alabama	Temp.	68	72	67	68	71		
		71	72.5	71	72.5	68		70.7
	Air Temp.	64.8	64.8	64.8	63.7	63.5		
		63.5	63.5	63.5	63.5	63.6		63.9
	Depth	465	455	490				470
Georgia	Temp.	70	70	71				70.3
	Air Temp.	67	66 1	62.4				65.1
	Depth	400?	500?	500	450	498		
		496	403	400				460
Florida	Temp.	77	78	80	78	71		
		80	80	80				78.3
	Air Temp.	72.6	72.6	68.3	68.3	68.2		
		73.1	73.1	71.7				70.9

South Average Earth Temperature	73.4
North " " "	56.9
	16.5
South Average Air Temperature	66
North " " "	49.7
	16.3

Wells between 900–1200 feet.

							Averages
	Depth	1125	1000	1050	900	1150	1053
Iowa	Temp. Well	62	65.4	60.5	59	62	61.8
	Air Temp.	50.2	49.3	49.4	46.8	49.3	49
	Depth	1050	1121	950			1040
Illinois	Temp.	61.5	61	70			64.1
	Air Temp.	49.4	49.4	49.9			49.5
	Depth	1040					1040
Indiana	Temp.	62					62
	Air Temp.	50.7					50.7
	Depth	1165					1165
Ohio	Temp.	67					67
	Air Temy.	50.4					50.4
	Depth	960	1200	1030	1090	1125	1081
Pennsylvania	Temp.	59.5	61	61.5	59.5	56.3	59.5
	Air Temp.	49.3	49.8	50	48.3	48.3	49.1
	Depth	1244					1244
New Jersey	Temp.	67					67
	Air Temp.	53.6					53.6
	Depth	1020	1010	1100	1170		1075
Oklahoma	Temp.	84	78	86	98		86.5
	Air Temp.	60.4	60.3	59.2	60.3		60
	Depth	975	1011	996	900		970
Louisiana	Temp.	82	75	84	79		80
	Air Temp.	68.7	66	65.1	68.2		67
	Depth	900	1021	1100			1007
Mississippi	Temp.	82.5	74	70			75.5
	Air Temp.	68	64.7	64.8			65.8
	Depth	1200	930				1065
Alabama	Temp.	73	79				76
	Air Temp.	65.2	63.7				64.4
	Depth	1020	1031	900			984
Florida	Temp.	81	74	74			76
	Air Temp.	68.2	68.2	68 2			68.2

South Average Earth Temperature	78.8
North " " "	63.5
	15.3
South Average Air Temperature	65
North " " "	50.4
	14.6

degrees F. The average difference between the mean annual air temperature of the stations in the northern states (Nebraska, Iowa, Indiana, Ohio, Pennsylvania and New Jersey) and the southern states (Texas, Louisiana, Mississippi, Alabama, Georgia and Florida) is 16.3 degrees F. The average temperature at a depth between 400 and 500 feet for the southern states for 31 wells was 73.4 degrees F. and for 25 wells in the northern states 56.9 degrees F. All boring records were taken at random. For temperatures at depths between 900 and 1,200 feet it was found that in the northern states with sixteen records, the average temperature was 63.5 degrees F., and in the southern states between the same depths with sixteen records, the average temperature was 78.8 degrees F. Oklahoma was substituted for Georgia and Illinois for Nebraska as there were no records between 900-1,200 feet available in Georgia and only one in Nebraska, and Texas was omitted. The average mean annual air temperature for the northern states was 50.4 degrees F. and 65 degrees F. for the southern states. The difference between the average ground temperatures in northern and southern states this time was 15.3 degrees and between the air temperatures 14.6 degrees F. In Nebraska and westward, and in Texas and westward, the thermal gradients are on the whole higher than in the Appalachian states. On this account the states in the above list east of the Mississippi River only were used in an additional test, and the difference between the average earth temperatures of the north and south between depths of 400 and 500 feet was found to be 14.9 degrees and the difference of the average air temperatures of the stations 15.8. At depths between 900 and 1,200 feet there was a difference between the average earth temperatures of only 11.9 degrees, and between the average air temperatures of 15.5 degrees. A map of the United States with thermal gradients plotted, resembling the isostatic map recently published by Bowie, is much needed.

In Alaska and Siberia the regolith is often frozen solid for many feet. From there southward the temperature of the upper crust grows warmer until at the equator the warmest temperatures, for a large average, are obtained. Has this always been the case?

It is probable that during the Pleistocene this condition of the temperature gradients was accentuated. With a removal of the polar ice and prevalence of warmer conditions would the underground conditions of the north approach the conditions found in low latitudes today? If so, would not the earth give much more heat to the waters in a warm period than at such a time as the present when the earth is evidently still cooled by glacial conditions and has not yet gained back its warm period heat?

Now let us again consider the rocks under the bottoms of the oceans. If the temperatures of the outermost crust are controlled to the extent indicated above by the temperatures of the air, the temperatures of the rocks below the oceans should also be controlled by the bottom waters of the oceans. In other words, these rocks should be cooled to a temperature of about 32° F., for an unknown depth below the bottom. The evidence gathered from geothermal gradients along the coasts does not point to such a conclusion, nor does the evidence of a rise in the temperature near ocean bottoms, as discovered by Murray, indicate such cold sub-oceanic rocks.

It has been said that a drop in the mean annual temperature of 10-15 degrees F. would bring on a glacial period. This would not apply to one of the warm periods. To change one of the warm periods into a glacial period a drop of something between 30-40 degrees F. might be necessary. It would almost seem that nothing but land emergence could cool off the earth enough to prepare the way for glacial conditions, and furthermore, large continental areas are necessary for large continental glaciers, such as are recorded in some of the tillites of the past. If the sun should change its heat or if volcanic ash filled the upper air during a period of great ocean transgression no glaciers of great extent could form, so it is only during periods of land emergence that great continental glaciers could register their existence in the rocks. Croll[20] mentioned many strata barren of organic remains and inferred from this cold periods intercalated between warm periods. These cases may be doubtful, but the inference has not been proved wrong. To change the temperature of the earth from what it was during the warm periods to a condition cold enough for a great ice sheet would mean a very great change.

If the waters and lands of the past were universally warm over the earth without very marked zonal arrangements of temperature, as most of the paleontologists and paleobotanists would have it, the waters no doubt contributed largely to this condition. According to Murray,[16] who states the case graphically and in few words, the influence of the ocean waters on our temperatures is as follows:

> "It is thus not only the surface-water that may give off heat to the air, but a great body of water extending to several hundred metres in depth, and hence the great influence of the sea on winter climates. The capacity of water for heat is very great compared with that of the air. Supposing that we have 1 cubic metre of water giving off enough heat to the air to lower the temperature of the water one degree, this heat would be sufficient to raise the temperature of more than 3,000 cubic metres of air by one degree. An example will show the importance of this. Suppose a body of water, 700,000 square kilometres in extent and 200 metres deep, to give off enough heat to the air in winter to lower the water-temperature one degree, then the heat given off would be sufficient to raise the temperature of a stratum of air covering the whole of Europe to a height of 4,000 metres on an average ten degrees. This explains how the Gulf Stream renders the climate of northern Europe so much milder in winter than would be expected from its northerly latitude. We shall see later on that the oceanographical researches of the last few years give reason to hope that it will even be possible to predict the winter temperature of northern Europe from the temperature of the sea some time in advance."

It is seen from this account that the transfer of a few degrees of heat from a large body of water means a great increase of heat in the atmosphere.

It is certain that cooler climatic conditions accompany and follow mountain building and vulcanism, although not all of these diastrophic periods had world-wide continental ice sheets. There would appear to be some causal connection between diastrophism and cooler climates, and to many that connection would seem to be the emergence of the continents and thus the breaking up to a large extent of the warm water heating system of the earth. Did the emergent continents really effect the cooling?

In the case of the Pleistocene ice age the cooling effect was a very slow one. All through the warm Eocene the continents were emergent and yet there was no great cooling, except local glaciation in the early Eocene, until the Miocene and Pliocene. It is true that no great mountains existed in the Eocene comparable with those of the Pliocene. Mountain building and vulcanism went on for millions of years before the cool Pliocene and cold Pleistocene. There is a lagging effect here which points to a gradual cooling off of the earth. In this slow cooling, mainly during the Pliocene but to some extent also during the Miocene, the oceans cooled before the lands, as proved by the migration of northern marine species southward and the less rapid migration of the land flora and fauna during the same time.[21] This cooling of the waters could have been produced by the cooling of the lithosphere under the oceans or by the cooling of the atmosphere and formation of winter ice at the poles. To cool off the oceans to the extent indicated would take a very long time. The process was fairly steady. The effects of water vapor in carrying heat can hardly be emphasized too much. With the emergence of continents and the emergence of barriers in the seas, during periods of mountain building, the scope of the heating effects of water vapor would be much restricted, with a cooler earth as the result. However the cooling was accomplished, when the glacial conditions finally did set in they came on rapidly. The earth had cooled off enough for some cause, other than its gradual cooling off, to act abruptly. The cooling and heating, if accomplished by secular cooling, as Manson would have it, is much too slow a process to account for the interglacial episodes of the Pleistocene and Permo-Carboniferous. Changes in the carbon dioxide content of the atmosphere is also much too slow a process to explain these same interglacial episodes.

A great many theories for ice ages have come and gone. No theory can stand long which does not satisfactorily account for interglacial episodes. Only two hypotheses so far advanced would appear to the writer to have any chance: changes in the heat of the sun, and periods of vulcanism with great amounts of volcanic dust. If it could be proved that a change in the heat of the sun would bring on glaciation, when the earth had been cooled off enough by continental emergence, affected somewhat by loss of heat through large volcanic extrusions, then a reverse change would explain an interglacial episode. That such a change in the heat of the sun should come just at the time when the earth was sufficiently cooled off, would appear to be a coincidence. How can we understand it, unless we say that continental emergence cooled off the earth a little, and that the major changes were due to great changes in sun's heat; or that the sun changed gradually through the Pliocene and then more abruptly to bring in the glaciers, and then changed just as abruptly in the reverse direction to bring on more heat again? It is conceivable that the sun has a regular period of change of great length, of an oscillative nature, compared to which the sunspot period would be the merest ripple on a great wave. With the greater length of geological time now becoming evident, such a change in the sun might very well come during a time when the lands were highly emergent and the earth cool. At other times when the continents were submerged such changes in the sun could not bring on great glaciation, but might cool the earth considerably and produce local glaciation. As noted above, Croll thought the barren strata indicated periods of cold.

The volcanic dust hypothesis advocated by Humphreys[22] has an advantage over the solar hypothesis in that we need not go beyond the earth itself for an explanation of interglacial phases. Periods of vulcanism followed by times of quiet clear air would explain glacial and interglacial episodes. There have been many periods of great vulcanism without accompanying glacial periods, but in these cases it is most probable that the earth was either too warm to be brought to a condition of glaciation, or that vulcanism was too spasmodic in its action to have a prolonged cooling effect, or it is possible that evidence exists or existed for such cooled periods but that it remains undiscovered or lost. It would not be remarkable if such evidence were lost. Suppose, for example, that we have at present reached the end of the Pleistocene and are now at the beginning of a new warmer period of earth history. Unless the glaciated areas sink relatively soon there will be very little to preserve as evidence of Pleistocene glaciations. The marine Pleistocene glacial deposits are very limited. The chances that these will be uplifted are very uncertain. Such thoughts as these lead one to conclude either that the Pleistocene glaciation was very limited or that there is much more to come, and that we are now living in an interglacial time. If a small remnant of till should be preserved, would the Pleistocene be regarded as just a local glaciation? There ought to be some evidence of the climate of the Pleistocene in the deposits which formed outside the glaciated areas and on these, if there were no tillites or glacial slates, the conclusions would be based.

If the geologists can make out four episodes of great explosive vulcanicity during the Pleistocene to correlate with the four glacial episodes now recognized, the most important cause for ice ages may have been found. The occurrence of an interglacial ash bed at Des Moines, Iowa, reported by Keyes, is interesting in this connection. In any event any cause within the earth itself, which could cause glacial periods, should be investigated to the uttermost before we venture beyond the earth. If the sun is responsible for glacial and interglacial episodes it will be well-nigh impossible with our present knowledge to prove it, however strong any solar theory may be.

The finding of tillites in formations which originated during times of great land emergence have led geologists to infer that only at such times could the earth be cool enough for glacial conditions, and that there was a causal connection between mountain building and glaciation. From recent discoveries of tillites deposited during times of great ocean transgression it is now greatly to be questioned whether a large land surface is necessary for at least a logical glaciation. As already pointed out, a world-wide glaciation could not be registered without great land masses, but local glaciation appears to have occurred during the Silurian, about Niagara time, as discovered by Kirk[23] in Alaska in 1917, and in the Beekmantown at Levis, Quebec, as discovered more recently. Kirk found a thick bed of tillite between what would appear to be warm water limestones. In the Beekmantown the waters were supposed to be warm by some and cold by others. In both cases the extent of land was comparatively small and the extent of marine waters was great. If there had been extensive continental areas during these times it is probable that great continental glaciers would have formed. It is to be noted that the latitude of the Silurian case is between 55°-60° north and of the Beekmantown case at Levis about 47° north. Very regularly banded shales of Lower Ordovician age with marked seasonal characters, collected by Mr. A. C. Swinnerton in the summer of 1920 in Georgia and Tennessee, would indicate that seasons existed in the Ordovician in latitude 35° north. It would seem necessary to invoke some cooling agent if the glaciers went some distance into the sea, as they evidently did. Blackwelder[24] and Kirk[23] both believe that there were seasons in Alaska during these times. During the Beekmantown time great vulcanism, mostly of the explosive kind, was going on in the British Isles. Twelve thousand feet of volcanics, mostly of an explosive nature, were deposited in the Lake District alone. Vulcanism was also going on in other parts of the world. In the case of the Niagara tillite of Kirk, volcanic activity went on contemporaneously in what is now the Penobscot Bay region of Maine. Kirk speaks of vast thicknesses of volcanic materials in this Paleozoic section of southeastern Alaska. In the case of the Beekmantown, splendid banding with seasonal characters occurs in the section. Whether or not a great land emergence is causally connected with wide-spread glacial conditions is still an open question.

In this paper the writer does not advocate Humphrey's volcanic theory to the exclusion of any solar theory, or any other theory that will explain interglacial episodes, but to say with Schuchert that Humphrey's theory will not answer, because periods of glaciation or cooling are not found to accompany every period of vulcanism, is not enough to disprove it. The criteria for the determination of cool periods has increased in the last few years and many formations must be examined again. Periodic changes in our present climate due, according to Brückner and Huntington, to changes in solar heat, have been observed, and the solar theories must be weighed carefully. If Manson's theory, or some modification of it, can explain interglacial episodes satisfactorily, Manson may be nearer the truth for parts of earth history than has been supposed.

This paper has been written in a spirit of inquiry rather than of affirmation. The theory of seasonal banding is on trial and as an advocate of that theory the writer would ask geologists to suspend judgment until the evidence for periods other than the Pleistocene and Permo-Carboniferous has been presented.

Note: Since writing this paper Dr. Knowlton has published a reply to the papers of Coleman and Schuchert, but it is not possible to discuss it here.

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SCIENTIFIC INTELLIGENCE

I CHEMISTRY AND PHYSICS.

1. *The Heats of Neutralization of Potassium, Sodium and Lithium Hydroxides with Hydrochloric, Hydrobromic, Hydriodic and Nitric Acids, at Various Dilutions.*—THEODORE W. RICHARDS and ALLAN W. ROWE have made a very elaborate study of the heats of neutralization of each of these bases with each of the acids; the adiabatic calorimeter, which was devised in Professor Richards' laboratory was employed, while the refinements in the precautions employed to secure the greatest accuracy and the remarkable agreements obtained in the various series of determinations command the highest praise. The authors had previously determined with great care the heats of dilution of solutions of these bases and acids as well as of their salts, in order that the heats of neutralization at various concentrations might be calculated.

Solutions of uniform molecular concentration, corresponding to a dilution with 100 molecules of water, of the four acids and the three bases were neutralized calorimetrically in all possible pairs at two temperatures not far apart, and the results were interpolated to exactly 20°. The values ranged from 13,750 to 14,085 calories, sodium hydroxide giving the lowest values among the bases, and hydriodic acid among the acids. By means of calculations to other dilutions, and extrapolations to infinite dilution, it was concluded that the heat of formation of water from its ions at 20° is probably not over 13.69 Cal. (20°) or 57.22 kilojoules, and possibly not under 13.62 Cal. or 56.93 kilojoules.

H. L. W.

2. *A Rapid Iodometric Estimation of Copper and Iron in Mixtures of their Salts.*—IAN WILLIAM WARK has worked out a method for making these determinations successively in a single solution. The process appears to be fairly accurate and very convenient, so that it should find extensive application, particularly in technical work. The solution, in which the iron should be in the ferric condition and which should be as concentrated as possible, is neutralized with ammonia. Moderate amounts of ammonium salts do not seriously affect the end-point. Then 2 g. of disodium phosphate, or twice as much if there is little copper, are added for each 0.1 g. of iron, together with 5 g. of KI and 5 cc. of acetic acid (80%) for each 0.1 g. of total metal present. The titration with tenth normal thiosulphate for copper is then made after waiting for 5 or 10 minutes, and the mixture is warmed to 50° and titrated further, if necessary, after 5 minutes. This method for the determination of copper in the presence of iron was described in its essential features by Moser in

1904. To the titrated solution mentioned above 10 cc. of 6 *N* sulphuric acid is added for each 0.1 g. of total metal, and after 5 or 10 minutes the iron is titrated with the thiosulphate solution. No indicator except the free iodine is needed in either titration. It was found that the method gave satisfactory results except in cases where the amounts, either of copper or iron present, were very small.—*J. Chem. Soc.*, **121**, 358. H. L. W.

3. *Introduction to Physical Chemistry;* by SIR JAMES WALKER. 8vo, pp. 440. London, 1922 (Macmillan and Co., Limited).—This text book appears to have been very favorably received and extensively used, for this is the ninth edition that has appeared since its first publication in 1899.

The book contains 36 chapters, each of which discusses an important topic of physical chemistry very clearly and ably, with particular attention to the practical applications of the theories. The use of any but the most elementary mathematics has been avoided, except in the last chapter which deals with the thermodynamical proofs, where a rudimentary knowledge of the calculus is needed. The recent developments, such as those relating to atomic number and isotopy, and also in regard to the structure of atoms, including the theoretical work of the Americans G. N. Lewis and Irving Langmuir, are well presented in this book.

It may be mentioned that the author regards a recent ionization theory by Ghosh as a satisfactory one having a theoretical basis, whereas this theory is severely criticized by James Kendall of Columbia University in the April, 1922, number of the Journal of the American Chemical Society. Further discussion of this matter is to be awaited with interest, and even if too much credit has been given to this theory in the book, it is a very small matter in connection with its general reliability and excellence.

H. L. W.

4. *Colloid Chemistry of the Proteins;* by WOLFGANG PAULI. Translated by P. C. L. THORNE. Part I. 8vo, pp. 140. Philadelphia, 1922 (P. Blakiston's Son & Co.).—This little book has been developed from lectures delivered in Vienna a number of years ago, and the English translation was made in England. It deals with quantitative methods of physical and colloid chemistry as applied to proteins, a field in which the author and his associates have made extensive and important investigations. It is to be observed that the book does not deal with the ordinary chemistry of the proteins, but considers the physical behavior of a few of them in connection with their ionization, particularly in the presence of acids and bases. The second part will include the relations of the proteins to neutral salts and to the salts of the heavy metals, to colloids and to ampholytes, the properties of the albumin gels, and, finally, the physical chemistry of the purest albumin so far prepared. H. L. W.

5. *The Aurora Line of the Night Sky.*—A green line of unknown origin corresponding to the wave length 5578, in the spectrum of the aurora, has been reported by several observers as present in the sky on ordinary nights, and in comparatively low latitudes. Various questions suggested by this occurrence have been systematically investigated by Lord Rayleigh. If the phenomenon is directly connected with the polar aurora it might be expected that a gradation of intensity between the usually very faint effect and a bright auroral display would be observed and that this would become more pronounced at higher latitudes. A series of spectral photographs was made at Terling (near London), every night from Feb. 26 to July 3. From this systematic series estimates of the intensities of the line were prepared and comparisons made with the amount of magnetic disturbance and the transit of spots over the sun's central meridian. No obvious connection between the intensity of this green line and the terrestrial or solar phenomena was found.

Comparisons between photographs made in the neighborhood of Newcastle with those taken near London, showed that the intensity appeared to be greater at the more southerly station, which would indicate that the cause must be different from that of the polar aurora. This conclusion is further supported by the fact that the aurora line is visually observable by California observers, 15° further south, while Rayleigh has been unable to see it at all under ordinary conditions.

Some authors have identified this aurora line with krypton 5770, but the more recent measurements clearly prove that it does not originate with this element. Rayleigh also tested the suggestion that the green line might be the fluorescent spectrum of ozone excited by the ultra-violet light of negative oxygen bands but nothing corresponding to it was indicated by his experiments.—*Proc. Roy. Soc.* **100**, 367, 1922. F. E. B.

6. *The Color of the Sea.*—The early theories of the color of the sky assigned its blue color to the scattering of light by particles of water or dust in the air. It is now known from the work of Cabannes and of Rayleigh on the scattering of light by dust free gases, and from the measurements on the light from the atmosphere, that the sky owes its colors to diffraction by the molecules of the air itself.

In regard to the color of large masses of clear water considerable divergence of opinion has existed. The late Lord Rayleigh was inclined to the view that the blue color of the deep sea was simply the blue of the sky seen by reflection. Judged by the literature of the subject, the trend of opinion appears to have been that in so far as there is any real effect apart from reflected skylight, the color is to be explained by absorption in the water, the return of light from the depths of the liquid being due to matter suspended in it.

A recent investigation by R. V. RAMAN has led him to the conclusion that the color of the sea is due to the scattering of light by the water molecules alone. The Rayleigh law of scattering for gas molescules cannot be applied directly to the case of a liquid where the spacing of the molecules is so close and the freedom of movement must be small. A method of attack has however been found in the "theory of fluctuations" proposed by EINSTEIN and SMOLUCHOWSKI who consider that a liquid medium may be regarded as undergoing small local variations of density due to the irregular movements of the molecules and that as a result of these fluctuations of density, light is scattered. Raman's calculations from this theory show good agreement with the observed intensity of light scattered by pure water. It is not far from 160 times that in dust free air.

Other observations which confirm the author's new view are that: (a) the coefficient of extinction agrees well with the theoretical value in the parts of the spectrum where there is no selective absorption; (b) a sufficiently deep layer of water is shown to exhibit by molecular scattering a deep blue color independent of reflected sky light; (c) apart from the fact that the bluest waters are highly transparent and markedly free from colloidal matter, a discussion of the effects of suspended matter shows that the observed results are hardly consistent with the assumption of its presence; (d) a number of interesting phenomena of polarization and scattering are satisfactorily explained.—*Proc. Roy. Soc.* **101**, 64, 1922. F. E. B.

7. *Proportionality of Mass and Weight.*—In the *Proceedings Am. Phil. Soc.* **60**, 1921, CHARLES F. BRUSH published a kinetic theory of gravitation and the results of certain experiments which were thought to corroborate it. The author's view was that gravitation was due to an energy flux in the ether and on this hypothesis it was thought that the very minute negative permeability (*sic*) of diamagnetic substances might offer some appreciable obstacle to this flux and thus affect the gravitational field behind them.

To test it three sets of experiments were tried. (1) A repetition of the Cavendish experiment with the apparatus of Boys comparing the attraction of masses of aluminium, zinc, tin, lead, silver and bismuth on a small silver ball. (2) Comparison of the periods of two similar gravity pendulums, one having a zinc bob and the other a bismuth bob. (3) Comparison of two similar torsion pendulums each loaded with equal masses of zinc and bismuth. In (1) the attraction of bismuth was reported to be less than that of zinc in the ratio of 72 to 100. In (2) the bismuth pendulum was said to show a gain of about one oscillation in 35,000 over the zinc. In (3) the bismuth period was found to be the shorter by 1 part in 1333.

The experiment on the gravitational pendulum has recently been repeated by H. H. POTTER and O. W. RICHARSON at the Research Laboratory of King's College, London, and they cannot confirm Brush's result. The gravitational acceleration of bismuth was found to be same as that for brass to at least one part in 50,000.—*Phys. Rev.* **19**, 188, 1922. F. E. B.

8. *The Teaching of General Science;* by W. L. EIKENBERRY, pp. xiii, 169, Chicago, 1922 (University of Chicago Press).—The publishers have projected a number of volumes entitled the *Nature Study Series* under the editorship of ELLIOT R. DOWNING of which the present work is the first to appear. It is a work upon the theory of teaching, i. e. the aims, the principles of organization, and methods of instruction in high and secondary schools. Under the term general science are gathered such branches as Astronomy, Agriculture, Physiology, Biology, Commercial Geography, Chemistry, Meteorology, Physiography, and Physics. As might be expected from a work on pedagogy the author is apologetic rather than dogmatic toward the student, as though the study of science needed to be justified. Taken from this angle the reader will find in the book a forceful statement as to the economic-vocational values of usable facts and their bearing on science-education, conduct-controls, tastes, ideals, and sociological aims. F. E. B.

II. GEOLOGY AND MINERALOGY.

1. *Hesperopithecus, the first anthropoid primate found in America.*—It is thus fittingly that Professor HENRY F. OSBORN announces in *Science* for May 5 what may prove to be one of the most remarkable discoveries in the history of vertebrate paleontology. The type is a single water-worn tooth found by Mr. Harold Cook, consulting geologist, of Agate, Neb., in the upper or Hipparion phase of the Snake Creek beds of western Nebraska. These beds are conceded to be of Pliocene age, and the opinion is expressed that the tooth is certainly a contemporary fossil.

In the judgment of Professor Osborn and Doctor W. D. Matthew, to whom the specimen was referred, it represents the second or third upper molar of a new genus and species of anthropoid. Doctors W. K. Gregory and Milo Hellman are perhaps more specific in their statement, when they say: "On the whole we think its nearest resemblances are with '*Pithecanthropus*' and with men rather than with apes." Since 1908 there has been in the American Museum collection another tooth from this same horizon. It was so water-worn and from so aged an animal that it has lain thus far undescribed, but comparison with the new form seems to show genetic if not specific affinity.

The horizon is that of the Thousand Creek (Nevada) and Rattlesnake (Oregon), of which the fauna contains not only *Plio-*

hippus in abundance, but *Illingoceras* and other twisted-horn antelopes of Asiatic affinity, which suggest for *Hesperopithecus* or its ancestors a possible migration from the great primate center of the Old World.

Further corroborative evidence would be greatly welcomed to establish beyond doubt this most unique occurrence. R. S. L.

2. *Shallow-water Foraminifera of the Tortugas Region;* by J. A. CUSHMAN. Dept. Marine Biology, Carnegie Inst. Wash., vol. **17**, 85 pp., 14 pls., 1922.—An interesting description of the 145 forms of foraminifers found about the extreme western end of the Florida Keys. There are also new observations on living specimens, relating to their movements, colors, commensals, development, and variation. The plates are from drawings by J. Henry Blake. C. S.

3. *Fossil Echini of the West Indies;* by ROBERT T. JACKSON. *Stratigraphic Significance of the Species of West Indian Fossil Echini;* by T. W. VAUGHAN. Carnegie Inst. Wash., Pub. No. **306**, 122 pp., 18 pls., 5 text figs., 1922.—In this excellent memoir, Jackson treats of all the known fossil echini of the West Indies, 89 species. Of these 8 are Cretaceous, the remainder Cenozoic from Eocene to Pliocene. Of the known forms the author describes 57, and of these 16 are new; the 32 forms not seen by the author are listed. There are 12 regular or endocyclic echini, and the remainder are of the irregular or exocyclic type of structure. Vaughan describes the stratigraphic significance of the group. C. S.

4. *Triassic Fishes from Spitzbergen;* by ERIK A:SON STENSIÖ. Pt. I, Introduction, Some Remarks on the Geology of the Triassic of Spitzbergen, and Descriptions of the Families Cestracionidæ, Cœlacanthidæ, Palæoniscidæ, and Catopteridæ. Pp. 307, 35 pls., 90 text figs. Vienna (Adolf Holzhausen), 1921.—In this monograph are described and illustrated in great detail about 40 forms of fishes that occur in the Lower Triassic of the Ice Fjord of Spitzbergen. Of elasmobranchs there are 4 genera and 11 species; of *Ceratodus,* 1 species; of crossopterygians, 5 genera and 10 species; and of actinopterygians, 8 genera and 18 species. There is also a detailed statement of the stratigraphy of the Triassic of Spitzbergen, having a total thickness of 594 meters, of which 315 meters are essentially black shales, the remainder mainly yellow sandstones. C. S.

5. *The Miocene of Northern Costa Rica;* by A. A. OLSSON. Part 1, Bull. Amer. Paleontology, No. **39**, 168 pp., 15 pls., 1922 (Harris Co., Ithaca, N. Y., $2.50).—A valuable report, of which the first thirty-four pages are devoted to a general description of the stratigraphy and correlation. The remainder contains descriptions of the gastropods, of which there are 208 forms (110 new). C. S.

6. *The Geology of the Corocoro Copper District of Bolivia;* by Joseph T. Singewald, Jr., and E. W. Berry. Johns Hopkins Univ. Studies in Geology, No. **1**, 117 pp., 15 pls., 1922 ($1.25).—Here is described the geology of the Corocoro district from the standpoint of the stratigrapher, paleobotanist, and economic geologist. The district stands at an altitude of over 13,000 feet, but in Pliocene time, when these muds and sands of fresh water origin were being deposited, with a measured thickness of more than 17,000 feet, the elevation was at or below 6,500 feet. The entombed flora consists of one fern, one gymnosperm, and twenty dicotyledons, all of genera "which still survive at lower levels east of the Andes, where they are represented by closely allied species." Overlying the plant beds is another series (Desaguadero), which may be of Pleistocene age. In 1919 the district yielded about nine million pounds of copper.

This paper is the first one of a new series to be issued by the Johns Hopkins University. Four other parts on the geology of South America are announced. This serial deserves support because of the good geologic and paleontologic results which have long been emanating from the Department of Geology at the Baltimore institution. C. S.

7. *A Guide to the Fossil Remains of Man in the Department of Geology and Palæontology in the British Museum of Natural History.* Third edition, 34 pp. with 6 plates and 14 text-figures. London, 1922.—Recent interest in the remains of fossil man has been much stimulated by Mr. Charles Davison's discovery of the Piltdown skull, by that of the Rhodesia remains (this Journal, **4**, p. 96) and finally by Harold Cook's discovery of a tooth at Agate, Nebraska, interpreted by the authorities in the American Museum as the first anthropoid primate found in America (see page 478 in this number). Hence the unusual value of this small volume in which the whole subject (except as to the Nebraska *Hesperopithecus*) is clearly but concisely presented in all its relations.

8. *Illinois Geological Survey;* Frank W. DeWolf, Chief.—Bulletin 42 (322 pp., reclamation map of Illinois in pocket), is devoted to the engineering and legal aspects of law drainage in Illinois. Of the two authors, G. W. Pickels has prepared part I on the status of drainage in September, 1920; also part II on engineering problems, and part IV on State aid. Part III, dealing with legal problems, is by F. B. Leonard, Jr. The discussion of the whole subject is enlightening as showing the difficulties in the organization of districts under existing laws and the obstacles met with in the effort toward the reclamation of large areas of fertile lands in the river bottoms. The investigation begun in July, 1919, was completed in September, 1920, most of the field work being done in the spring and summer of 1920.

The large map (28 x 49 inches, scale about 8 miles to 1 inch) presents clearly the physical data obtained.

Another publication of the Survey is BULLETIN 26 of the Co-operative Mining Series, being investigations prepared by the co-operation of the Illinois Survey, the Engineering Experiment Station of the University of Illinois and the U. S. Bureau of Mines. This bulletin (247 pp., with 8 plates, 31 figures and 7 tables) is by GILBERT H. CADY and gives data as to the coal resources of district IV. The district named is the part of the central portion of the State yielding coal of the No. 5, or Springfield, bed. All of Peoria county is here included, a large part of Fulton county, the part of Sangamon county north of Chatham; also smaller areas in ten other counties some of which are underlain by this coal. The No. 5 bed yielded over 11 million tons from this district in the year ending June 30, 1920. Among the districts of the Co-operative Investigations, this one ranks second in area, third in order of production, and possibly first in the amount of workable coal.

9. *Illinois State Water Survey.*—Bulletin No. **16**, EDWARD BARTOW, Chief, gives a report (280 pp., 36 figures) for the years 1918, 1919, of the State waters, both chemical and biological.

Bulletin No. **17**, A. M. BUSWELL, Chief, is an index (17 pp.) to Bulletins **1** to **16**.

10. *Geological Survey of Western Australia;* A. GIBB MAITLAND, Government Geologist.—Publications received include the Annual Progress Report for the year 1920, pp. 31. This is accompanied by a map of Western Australia showing the series of geological sketch maps (four miles to the inch) and other geological maps issued since 1896. Points of special interest are the development of water power for the generation of electricity in the Kimberley division; petroleum prospects of the Busselton region, in general favorable in outlook; deep borings at several points, for example revealing the presence of coal at various depths in the township of Collie. All of these are by Dr. Maitland. Other members of the staff also note works of important character.

Four Bulletins have been issued, as follows:

No. 78. The mining geology of Kookynie Niagara and Tampa, North Coolgardie Goldfield, J. T. JUTSON, field geologist; with petrology by R. A. FARQUHARSON. Pp. 98 with 5 plates and six figures.

No. 79. Mining geology of Comet Vale and Goongarrie, North Coolgardie Goldfield, by J. T. JUTSON. Mineralogy by E. S. SIMPSON and petrology by R. A. FARQUHARSON. Pp. 52, with 8 plates and 8 figures.

No. 80. The Mining Centres of Quinn's and Jasper Hill, Murchison Gold Field, by F. R. FELDTMANN. Pp. 92, with 3 plates and 18 figures.

Nos. 81, 83. Geology and Mineral Resources. No. 81. The Yalgoo Goldfield, Part I, the Warriedar goldmining centre, by F. R. Feldtmann. Pp. 40, with 3 plates and 5 figures. No. 83. The Northwest, Central and Eastern Divisions (E. Long. 119° and 122°, S. Lat. 22°and 28°), by H. W. B. Talbot; petrology by R. A. Farquharson.

III. Miscellaneous Scientific Intelligence.

1. *Washington meeting of the National Academy of Sciences.*—At the recent meeting of the National Academy (see p. 386) the following gentlemen were elected to membership: Edward W. Berry, Johns Hopkins University; George K. Burgess, U. S. Bureau of Standards; Rufus Cole, Rockefeller Hospital, New York; Luther P. Eisenhart, Princeton University; Herbert Hoover, Secretary of Commerce; George A. Hulett, Princeton University; Charles A. Kofoid, University of California; George P. Merrill, U. S. National Museum; Carl E. Seashore, State University of Iowa; Charles R. Stockard, Cornell Medical School; Ambrose Swasey, Cleveland, Ohio; William H. Wright, Lick Observatory.

Further, Dr. Albert Einstein, of the University of Berlin, was elected foreign associate.

The presentation of medals was as follows: The J. Lawrence Smith Medal for important contributions to knowledge concerning meteorites to Dr. George P. Merrill, of the U. S. National Museum. Also the Daniel Giraud Elliot Medal was awarded with an honorarium to Dr. O. Abel of Vienna, for his book, "Methoden der parläobiclogischen Forshung;

Delegates were appointed to a number of University and Scientific meetings at home and abroad; notable among these was the recent (May 14-17) seventh centenary of Padua, and the one hundred and fiftieth anniversary of the Académic Royale des Sciences de Belgique at Brussels, May 24.

The Academy voted to accept the invitation of the members in New York City to hold its Autumn meeting there, the details to be arranged by the President and Home Secretary in conjunction with the Local Committee.

2. *Considérations sur l'Etre vivant:* II, *L'Individu, la Sexualité, la Parthénogénèse et la Mort, au point de vue orthobiontique;* pp. 193. 2. *Note préliminaire sur l'Orthobionte des Characées;* pp. 18; par Charles Janet. Beauvais, 1921 (Dumontier et Hagué).—In an earlier paper the author has postulated his theory of the orthobionte as a series of reproductive cell aggregates (merisms) which lead from the fertilized egg, or zygote, of one generation to the same stage in the subsequent gen-

eration. Since these reproductive bodies may be homologized in all groups of plants and animals they are evidently of phylogenetic significance. In many of the groups of plants these merisms are associated with a complex alternation of generations. In these later papers it is shown how the orthobionte is related to the individual of the various generations and how sexuality, parthenogenetic reproduction and somatic death have become established in the different groups of organisms. W. R. C.

3. *Fünf Reden von Ewald Hering;* published by H. E. Hering. Pp. 140, with portrait of Ewald Hering. Leipzig, 1921 (Wilhelm Englemann).—These lectures, although delivered many years ago by the distinguished physiologist Hering, were so much in advance of the time in their general conceptions that they prove of real interest at the present day. They treat of memory as a general function of organic matter, specific energies of the nervous system, and theories of the vital processes, including nervous activity. W. R. C.

4. *Board of Scientific Advice for India. Annual Report for the Year 1919-20.* Pp. 111, Calcutta.—The thirty-eighth meeting of the Board was held at Simla on May 17, 1920; the thirty-ninth at Delhi in December 20, 1920. The president of the Board is the Hon. J. Hullah, Secretary to the Government of India; associated with him are eleven gentlemen in the different departments. Numerous brief statements of matters, of importance, in any case locally, are given in this publication. Worthy of note are the researches in solar physics carried on at Kodaikanal under the direction of J. Evershed. Measurements of the displacement of cyanogen bands and also of iron lines were found to be of the same sign and magnitude as that predicted by the Einstein hypothesis. This displacement differs for different substances and is not proportional to the wave-length, suggesting the existence of some modifying influence outside of that due to the gravitational field. Displacements in the Venus spectrum were unfavorable to the Einstein hypothesis.

OBITUARY.

PROFESSOR PHILIPPE A. GUYE, the eminent Swiss organic chemist, died on March 27, in his sixtieth year.

DR. HENRY NEWTON DICKSON, the Scotch geographer whose special work was in meteorology and oceanography, died recently, at the age of fifty-six years.

DR. GEORGE BALLARD MATHEWS, professor of mathematics in the University of North Wales at Bangor, died on March 19, at the age of sixty-one years.

INDEX TO VOLUME III.*

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*This Index contains the general heads, Chemistry, Geology, Minerals, Obituary; under each the title of Articles referring thereto are included.

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