CENSUS OF THE PHILIPPINE ISLANDS : 1903

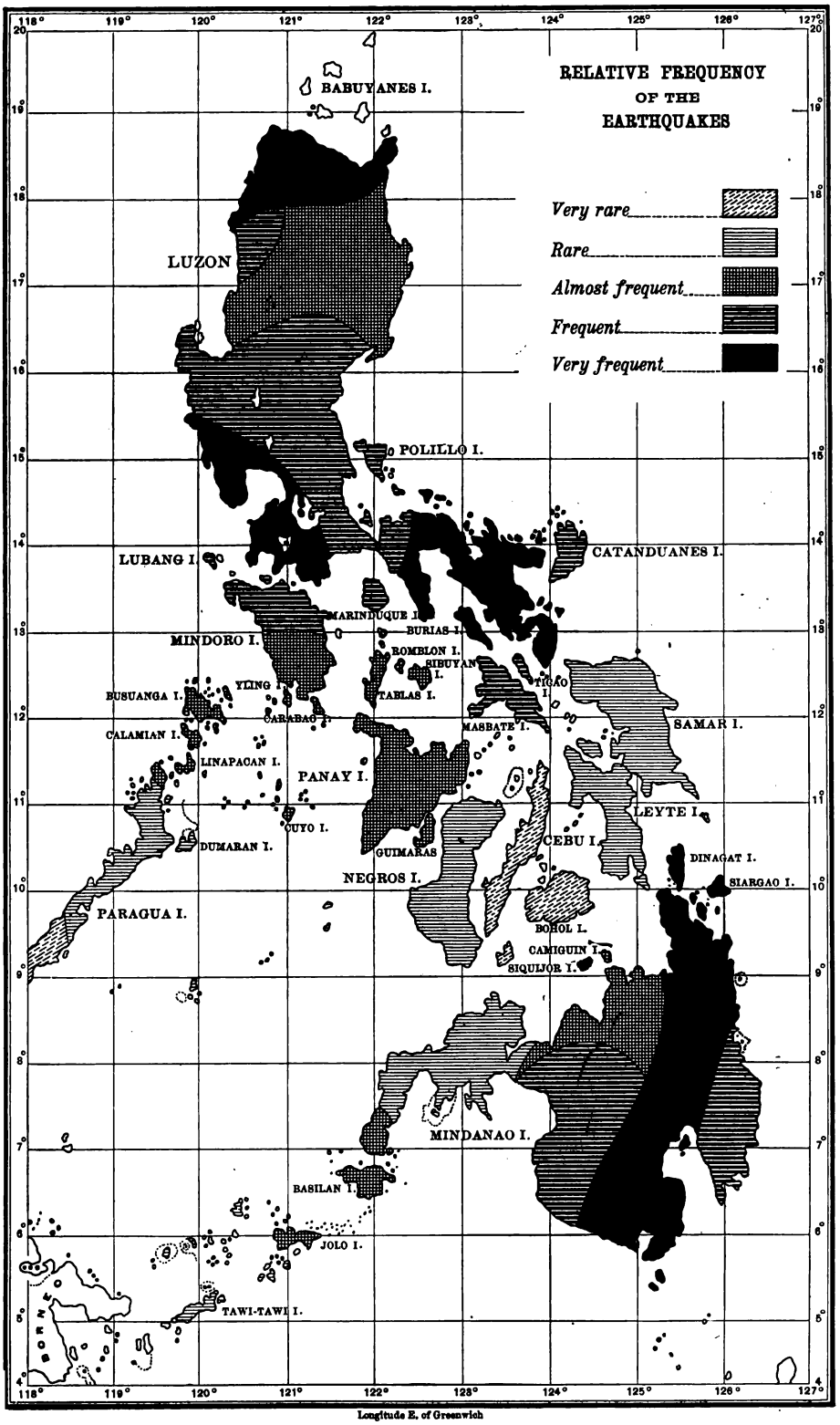
BULLETIN 3

# VOLCANOES AND SEISMIC CENTERS

OF THE

# PHILIPPINE ARCHIPELAGO

DEPARTMENT OF COMMERCE AND LABOR
BUREAU OF THE CENSUS : 1904


RELATIVE FREQUENCY
OF THE
EARTHQUAKES
Very rare
Rare
Almost frequent
Frequent
Very frequent
BABUYANES I.
LUZON
POLILLO I.
LUBANG I.
CATANDUANES I.
MARINDUQUE I.
BURIAS I.
MINDORO I.
ROMBLON I.
SIBUYAN I.
BUSUANGA I.
YLING I.
TABLAS I.
TICAO I.
CARABAO I.
MASBATE I.
SAMAR I.
CALAMIAN I.
LINAPACAN I.
PANAY I.
LEYTE I.
CUYO I.
DUMARAN I.
GUIMARAS
CEBU I.
DINAGAT I.
NEGROS I.
SIARGAO I.
PARAGUA I.
BOHOL I.
CAMIGUIN I.
SIQUIJOR I.
MINDANAO I.
BASILAN I.
JOLO I.
TAWI-TAWI I.
BORNEO
118°
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Longitude E. of Greenwich

With the Author's Compliments

CENSUS OF THE PHILIPPINE ISLANDS

DIRECTOR

GEN. J. P. SANGER, U. S. A.

ASSISTANT DIRECTORS

HENRY GANNETT, VICTOR H. OLMSTED

BULLETIN 3

# VOLCANOES AND SEISMIC CENTERS

OF THE

# PHILIPPINE ARCHIPELAGO



BY

REV. M. SADERRA MASÓ, S. J.

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DEPARTMENT OF COMMERCE AND LABOR

BUREAU OF THE CENSUS: 1904

# MAPS AND OUTLINES.

# CENSUS OF THE PHILIPPINES: 1903.

The Philippine Islands lie in a volcanic belt, which stretches from northeastern Asia southwestwardly nearly to Australia, and includes the volcanic peninsula, Kamchatka, the Japanese Islands, and the East India archipelago. This belt is composed in the main of volcanic rocks, and there are in the Philippine Islands several volcanoes which have been in active eruption in recent years, and scores which are extinct or dormant. In recent geologic periods the islands have been subject to extensive movements in uplift and depression, and probably such movements are now in progress, accompanied by earthquakes and tremors, which are very frequent and in some cases severe.

It is therefore especially fortunate that there has been maintained for many years at Manila one of the best equipped seismic observatories in the world. It contains the finest and most modern instruments for recording the force and direction of earthquake shocks, and is manned with the most skilled observers who keep careful records of all volcanic and seismic phenomena occurring in the archipelago.

In the following pages is set forth a historical account of volcanoes and seismic centers in the Philippine Islands, written for the Philippine Census report by the leading authority upon the subject, Rev. M. Saderra Masó, S. J. Father Masó has been connected with the Manila observatory for the past fifteen years, and in 1894 published the first work on Philippine seismology. He has made a careful personal examination of the active and dormant volcanoes of the Philippines and is the author of some very valuable papers on the subject.

J. P. SANGER, *Director.*

WASHINGTON, *May 14, 1904.*

# VOLCANOES AND SEISMIC CENTERS OF THE PHILIPPINE ARCHIPELAGO.

By Rev. M. Saderra Masó, S. J.

## SITUATION AND BOUNDARIES OF THE ARCHIPELAGO.

The number of islands which compose the Philippine archipelago is not less than 3,141, although up to the present time no one can state the exact number. All these islands are comprised within the north Torrid zone, between 4° 40′ and 21° 10′ north latitude and longitude 116° 40′ and 126° 34′ east of Greenwich. They are surrounded on the north and west by the China sea, on the east by the Pacific ocean, and on the south by the sea of Celebes. From the extreme point of land on the northwest to the China coast is a distance of 230 kilometers. The nearest land on the north is the island of Formosa, on the east the Palos Islands, on the southeast the Molucca archipelago, on the south the island of Celebes, on the southwest the island of Borneo, and on the west Cochin China.

The waters which surround the archipelago are very deep, not far from the east coast the Pacific being from 4,000 to 6,000 meters in depth. The Joló sea between Mindanao and Joló reaches a depth of 4,069 meters, off the Celebes 3,750 to 4,755, and not far from the south coast of Mindanao the depth reaches 5,000 meters; nevertheless, the Philippines are united to the Asiatic archipelago at three points where the straits filled with islands reach but little depth, namely, north of Borneo by the islands of Balábac and Paragua, on the northeast of Borneo by the Joló group, and on the northeast of Celebes by the islands of Sanguir and Tulur. Without doubt, therefore, the whole of the Philippine archipelago belongs to the same geographic region as Borneo, Sumatra, Java, and the rest of the islands of the great Asiatic archipelago, and in consequence to Asia rather than to Oceania. Considering, therefore, only geographic reasons, it is sufficient to note the analogy which the situation of the Sunda Islands, the Celebes, the Moluccas, and the Philippines, with relation to Asia, bears to the situation of the Antilles with relation to America. The former bound the

interior China and Sunda seas, the latter, the Mexican and Caribbean seas, which bathe, respectively, the Asiatic and American coasts. According to this analogy, therefore, if the latter belong to America the former belong to Asia.

"On the other hand," says G. F. Becker,[1] "a glance at such a map as Stieler's physical map of Asia is sufficient to show that Borneo, Celebes, Gilolo, and the Philippines are very nearly related from a structural point of view. The southwestern ranges seem to gather in toward the eastern edge of the Philippines as do the branches of a tree to its trunk. The eastern coast range of Mindanao is continued southward by the Tulur Islands and others to Gilolo, in the Moluccas. Near the center of our own island of Leyte there is a fork in the mountain system, and the westerly branch is seemingly continued southward through Mt. Apo and the southernmost point of Mindanao, by way of Sanguir Island, to Celebes. In the Visayas, at Masbate, it would seem that a second branch is thrown off, extending through Negros and western Mindanao, Basilan, and the Joló group, to the Bornean coasts. More obscure is a line which starts apparently in Panay and is marked in the Jolo sea by the Cagayanes, including Cagayán de Joló. A very important line is represented by the Calamianes and Palawan, continued in Borneo by the range, one point of which is the lofty Kina Balu, which is not volcanic. This range extends through Borneo to its southwest coast and, in the opinion of some geologists, not including Mr. Verbeck, there connects with Bangka. In northern Luzón the coast range, or Sierra Madre, is clearly continued by the Babuyanes and Batanes to the neighborhood of Formosa, but the relations of the Zambales range and the Caraballo Norte are not evident on mere inspection."

But if we turn our consideration from the apparent ridges indicated by the lined islands to the submarine features, then we shall find that the whole archipelago, excepting western Paragua, lies out of the shallow sea area, connecting the great islands of Borneo, Java, and Sumatra with the Asiatic continent. The deep sea in which our archipelago lies, runs through the Celebes and the Moluccas, between the Borneo shallow sea just spoken of and the eastern one connecting New Guinea with Australia.[2] Therefore, it would seem that our archipelago is really connected with the Celebes and the Moluccas, all of which lie in this sort of channel dividing Asia from Australia. It may be that further investigations will show a closer similarity between our archipelago and the Celebes and the Moluccas. Recently A. Wichman has rejected the supposed homologies between Celebes and Borneo. "The mountain ranges of Borneo are ancient, while

[1] Report on the Geology of the Philippine Islands, 1901.
[2] Malay Archipelago, Wallace, page 7.

Celebes, instead of being the remaining skeleton of an immerged land, got its actual relief from the Tertiary and post-Tertiary eruptions."[1] We shall see further on that the Philippines had the same origin.

The chief mountain ranges run, generally speaking, along the greater axis of each island, with several arms branching therefrom. Thus the orographic system follows the striking features of the whole archipelago pointed out in the foregoing quotation. In Luzón, the largest island of the archipelago, there are three clearly distinct mountain ranges, running from north to south, as far as 14° north latitude. Below this latitude the mountain ranges of Luzón, as well as those of the Visayas and Mindanao, invariably deflect more or less either to the southeast or to the southwest. We have to except only the mountain system of Mindoro and Bohol. In the island of Mindanao, besides the central range, running southward, there are many groups without any very apparent direction, in the Dapitan, Misamis, Lanao, and Cottabato districts.

### VOLCANIC NATURE.

The archipelago is clearly comprised in the Pacific volcanic belt, one of the chief volcanic belts of the globe. The volcanic line of our archipelago certainly serves to connect the Celebes, Moluccas, and Sunda volcanic lines with those of Formosa and Japan. The Satsuma, Sakurajima or Formosa line seems to continue along the Philippines southward, through Sanguir and Gilolo. The volcanic belt of the Pacific is too well known for us to dwell on it here. Great efforts have been made by many authors to classify the volcanoes of the archipelago into distinct lines or parallel systems. It will suffice to mention some of them:[2]

Perry proposed to classify the volcanoes of Luzón into three lines nearly parallel to one another. The three trend northwesterly. One includes Mariveles and Taal, a second Aráyat and Banájao, the third Mayón. The Mariveles-Taal system, in Perry's opinion, passed southward through Siquijor and Mindanao, including the volcanoes Macaturín and Sanguil; it took in Ternate, and probably reached the Banda group. Mr. von Drasche called attention to the fan-shaped disposition of the islands and to the forking of Masbate, one prong of which is parallel to southern Luzón and the other to Negros and Cebú. Mr. Centeno, in his Memoria, distinguished two systems, one passing through Aráyat, Taal, central Mindoro, Canlaón, and Macaturín; the other through Mayón, Burauen (in Leyte), Camiguín de Mindanao, Apo, and Butulan. He regards the two systems as uniting to the south of Mindanao, their prolongation passing through Sanguir and to the Moluccas. He also refers to the northerly continuation of the volcanic system of the Philippine Islands toward Formosa, but without specifying the relations of the northern portion to the more southerly lines. Mr. Abella called attention to the continuity of the volcanic phenomena in Leyte northward through Biliran, Maripipí, etc., to the volcano Bulusan, and to Mayón, in southern Luzón, as well as southward to the eastern coast

[1] Dic. Binnenseen von Celebes, Petermann's Mitteil. XXXIX, 1893, page 225.
[2] Report on the Geology of the Philippine Islands, Becker, 1901, page 59.

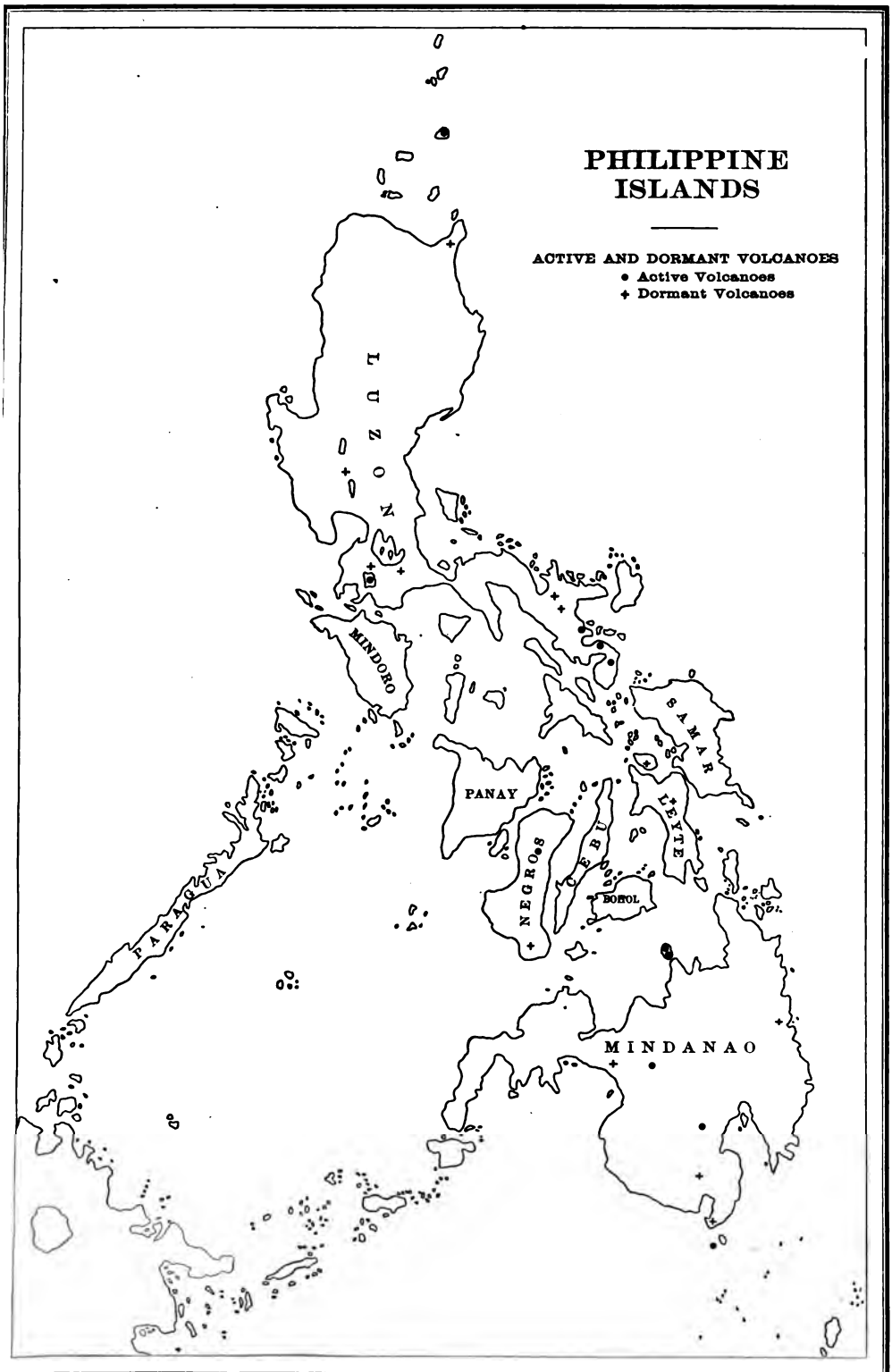
range of Mindanao. Mr. Koto gives the Philippines a single belt of active volcanoes. From the Babuyanes and Cape Engaño it passes out to sea, reaching land again in Camarines Norte, and including Biliran and Camiguín de Mindanao in its course. In the Gulf of Dávao it forks, one branch reaching Sanguir and Celebes and the other Talaut and Gilolo. This scheme omits the active volcanoes Macaturín, Magasó, Canlaón, and Taal. Mr. Koto, however, adds tectonic lines. Two of these diverge from Masbate; the eastern branch crosses the volcanic belt in Leyte and follows the eastern coast range of Mindanao; the other branch follows Negros and western Mindanao to Joló. A third tectonic line follows the Sierra de Zambales. Leaving the shore at Mariveles, it intersects Ambil and follows Palawan (Paragua) to Kina Balu, in Borneo, reaching the center of that great island.

It may be that further study concerning the structure and lithology of the whole volcanic country will lead to a knowledge of their age, and consequently to a more satisfactory elucidation of the volcanic and tectonic systems.

There are at least twenty well-known and recent volcanic cones in the archipelago, twelve of which are more or less active. The active and solfataric volcanoes are given in the following list:

TABLE 1.—*Active and solfataric volcanoes, with location, height, and date of eruption.*

| NAME. | Province. | APPROXIMATE— Latitude. | APPROXIMATE— Longitude east of Greenwich. | Height (feet). | Rock. | Date of eruption. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | | |
| Babuyán Claro | Cagayán | 19 30 | 121 56 | ..... | ..... | 1831, 1860. |
| Camiguín de Babuyanes. | Cagayán | 18 55 | 121 52 | ..... | ..... | Solfataric. |
| Didica | Cagayán | 19 2 | 122 9 | 700 | ..... | 1856 to 1860. |
| Cagua, or Caua | Cagayán | 18 13 | 122 4 | 3,920 | ..... | Solfataric in 1860. |
| Taal | Batangas | 14 2 | 120 57 | 1,050 | Andesite | 1709, 1715, 1716, 1731, 1749, 1754, 1808, 1873. |
| Mayón | Albay | 13 16 | 123 39 | 7,916 | Andesite | 1616, 1766, 1800, 1814, 1827, 1835, 1845, 1846, 1851, 1853, 1855, 1858, 1868, 1871, 1872, 1873, 1881, 1885, 1886, 1887, 1888, 1890, 1891, 1892, 1893, 1895, 1897, 1900. |
| Bulusan | Sorsogón | 12 47 | 124 1 | ..... | ..... | 1852.solfataric. |
| Canlaón | Negros Oriental | 10 25 | 123 6 | 8,192 | Andesite | 1886, 1893. |
| Magasó | Negros Oriental | 9 15 | 123 9 | ..... | Andesite | Solfataric. |
| Camiguín de Mindanao. | Misamis | 9 12 | 124 42 | 1,960 | Andesite | 1871, 1875. |
| Apo | Dávao | 7 3 | 125 17 | 10,311 | Andesite | Solfataric. |
| Calayo | Cottabato | 7 50 | 124 40 | ..... | ..... | Solfataric; eruption in 1886. |


PHILIPPINE ISLANDS
ACTIVE AND DORMANT VOLCANOES
• Active Volcanoes
+ Dormant Volcanoes
LUZON
MINDORO
PANAY
NEGROS
CEBU
BOHOL
LEYTE
SAMAR
PALAWAN
MINDANAO

The first three are in the Babuyanes Islands; Cagua, Taal, Mayón, and Bulusan lie in Luzón; Canlaón and Magasó in the island of Negros; Camiguín in the island of Camiguín, just off the north of Mindanao; and finally Apo and Calayo in Mindanao. The volcanoes considered as extinct are as follows: Aráyat, Maquíling, Banájao, San Cristóbal, Isarog, and Malínao, in Luzón; Macaturín and Matútum, in Mindanao. Their approximate geographic positions are given in the following table:

TABLE 2.—*Extinct volcanoes, with location and height.*

| NAME. | Province. | APPROXIMATE— | | | | Height (feet). | Rock. |
|---|---|---|---|---|---|---|---|
| | | Latitude. | | Longitude east of Greenwich. | | | |
| | | ° | ′ | ° | ′ | | |
| Aráyat | Pampanga | 15 | 13 | 120 | 42 | 2,880 | Andesite. |
| Banájao | Laguna | 14 | 2 | 121 | 27 | 7,382 | Andesite. |
| San Cristóbal | Laguna | 14 | 3 | 121 | 24 | 5,288 | Basalt. |
| Maquíling | Laguna | 14 | 8 | 121 | 10 | 3,724 | Basalt. |
| Isarog | Ambos Camarines | 13 | 41 | 123 | 21 | 6,450 | Andesite. |
| Malínao | Albay | 13 | 26 | 123 | 34 | ..... | Basalt. |
| Macaturín | Cottabato | 7 | 36 | 124 | 26 | ..... | |
| Matútum | Dávao | 6 | 11 | 125 | 10 | ..... | |

The above paragraphs refer only to the distribution of the best-shaped cones of the active and the extinct volcanoes in the archipelago. Concerning the general distribution of the volcanic rocks we take the following from G. F. Becker's report:

The interior of northern Luzón is little known, but is supposed to consist mainly of crystalline schists, broken through at some points by intrusives and volcanics; and a similar statement is true of the eastern range of Luzón, the Sierra Madre, as far south as the province of Príncipe. The southern portion of the Zambales range and the greater part of the territory between the Bay of Manila and the Strait of San Bernardino are occupied by volcanic rock. In the Visayas volcanic rocks are not rare, but Negros only is remarkable in this respect. Nearly the whole of the range, which extends from one end to the other of that exquisite island, is volcanic. According to Semper, all the larger Visayas show extinct volcanic cones, except Cebú and Bohol. Of Mindanao, it is known that there are crystalline schists along the eastern coast and Macajalar bay on the north coast, but the island contains at least three active volcanoes, not to speak of the more numerous extinct ones. Finally, much of the Joló group is volcanic, and Palawan (Paragua) is known to contain volcanic peaks. Thus, while it is by no means true, as has sometimes been alleged, that the archipelago is of volcanic origin, volcanic areas are distributed at short distances from the Batanes to Tawi Tawi.

The rocks which have been more or less inadequately determined as trachyte are of limited distribution. One doubtful specimen comes from Panay, at Barbaza, in the province of Antique; the remainder are all from Luzón. In that island, near the southern end, in Camarines Sur, between the villages Iriga and Buhi, a pumice-like tuff was considered trachytic by Roth. Mr. von Drasche found the rock base of Maquíling, not far to the southward of the town of Calamba, on Laguna de Bay, which he regarded as trachyte. Baron von Richthofen discovered trachyte on the peninsula of Binangonan, on the north side of the same lake; and Mr. von Drasche, on his map, colors the western half of the peninsula as trachyte. The trachytes recur

on the San Mateo river, near the caves, about five miles above the town of San Mateo, in Manila province. Mr. von Drasche found a large area of trachyte farther north. He encountered this rock at Pórac, in Pampanga, and to the westward of that town in the foothills of the Cordillera de Mabañgâ; again close to O'Donnell in Tárlac, and once more in the province of Pangasinán, among the foothills of the Sierra de Zambales, not far from the town of Aguilar. He summarizes his observations thus: "On the eastern slope of the southern half of the Sierra there are superposed on these rocks (gabbros and diorites) thick masses of trachytic tuff, which include numerous fragments of trachyte. These tuffs can be followed to the watershed at an altitude of 3,000 feet, and on the east stand in close relationship with the plain of Pampanga, the surface of which consists principally of their decomposition products. The crystalline rocks must be pierced by numerous intrusions of trachyte, for one finds great quantities of such rock species in all accumulations of pebbles derived from the Sierra."

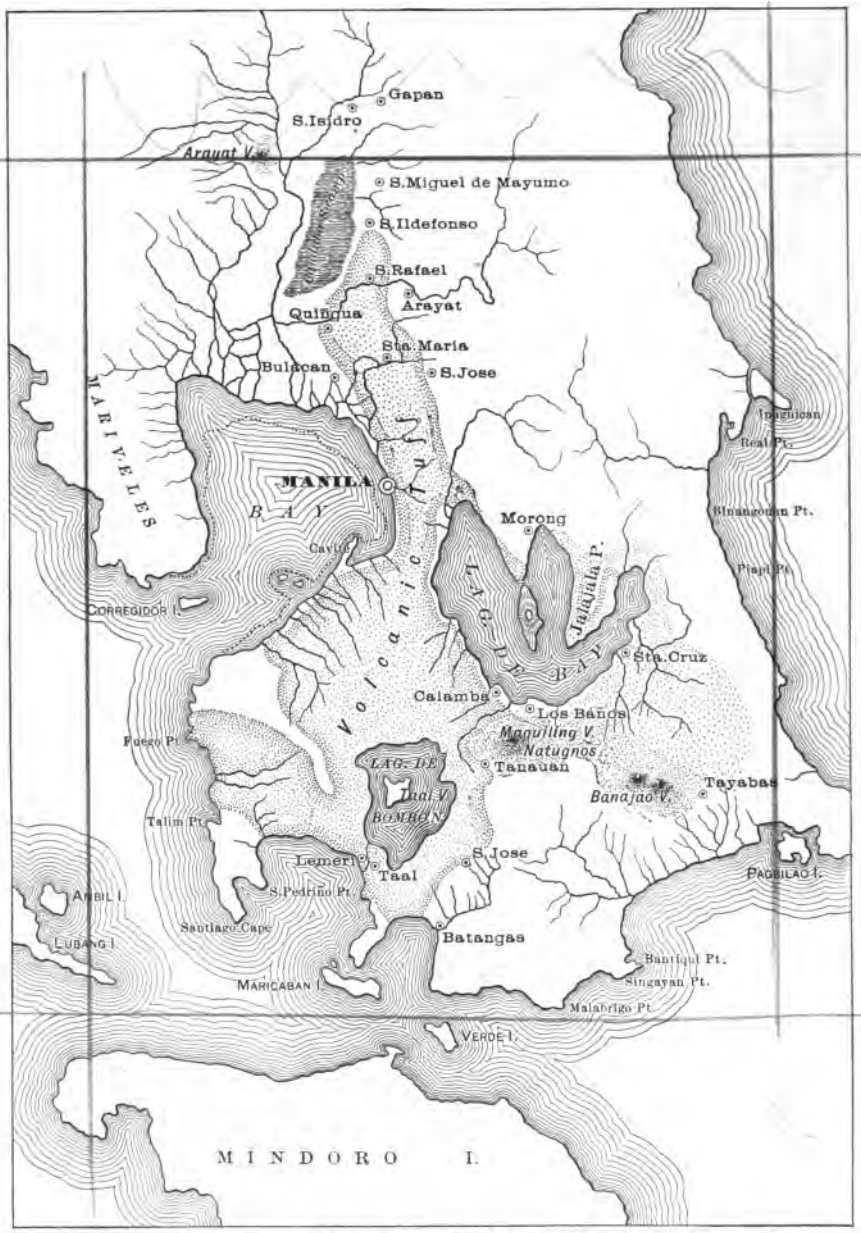
In the province of Lepanto-Bontoc also Mr. von Drasche found trachytes abundant, but closely associated with andesitic rocks. The important copper deposits of Mancayán occur, he says, in a quartz lens embedded in sanidine-trachyte.

Mr. Abella recognizes the very general distribution of trachytes in the Cordillera Central and the mountains east of the great plain of Luzón, but the only precise locality I find mentioned is at Canan, on a tributary of the Patlín river, about two miles to the westward of O'Donnell, in Tárlac province. Here dikes of porphyritic sanidine-trachyte make their appearance, "on the one side in the slopes of the hills Marangla and Cospien, and on the other between the town and the river Capatian, forming the volcanic line of the hills Dayagdag, Taoagan, and Patlín." I am not in possession of maps showing these hills by name, but they will doubtless be identified with ease from O'Donnell.

Basalts and andesites seem to be closely associated in the Philippines, as they so frequently are elsewhere, but the quantity of pyroxene-andesite probably far exceeds that of any other volcanic rock in the archipelago. The island of Talim, in Laguna de Bay, is basalt, and much of the shores of the lake is also basaltic. The Mariveles district, forming the north headland of Manila bay, was pronounced basalt by Roth on the strength of Jägor's specimens, and this determination was accepted by Mr. von Drasche, who did not visit the locality. I suspect that some of Jägor's labels were displaced, for my personal examinations and Mr. Semper's specimens show that the region is andesitic, the pyroxenic variety predominating.

The chain of extinct and active volcanoes which stretches from Laguna de Bay to the extreme southeastern point of Luzón appears to be mainly andesitic, but not devoid of basalts. In his interesting study of Panay, Mr. Abella finds that the mountain system, the skeleton of the island, is composed largely of massive rocks of two eras. The older is characterized by diorites and diabases, the younger by andesites and basalts. This latter period may be regarded lithologically as a repetition of the earlier one. In the Samaraquil peak of Anini-y, at the southwestern extremity of the island, Mr. Abella found nepheline-leucite-basalts. He considers the basalts as generally younger than the andesites.

In Negros a magnificent range extends from near the northern end of the island to the active peak of Canlaón. At the first glance this range resolves itself into three mountains of most unusual similarity, and there can be no substantial doubt that the two more northern masses are extinct volcanoes of the same type as Canlaón. I was unable to reach the main range but the streams on both coasts bring down such a mass of pyroxene and hornblende-andesite as to indicate that these are the principal rocks. In the eastern foothills, on the Talabe river, I found basalt in place which seemed to be older than a portion of the coral reefs, and is certainly older than the later ejecta of Canlaón. To the southward of the volcano the range is lower and less striking than to the northward, but at the southern end of the island the Dumaguete




**SKETCH SHOWING THE TUFF AREA OF CENTRAL LUZÓN**

Peaks, or Cuernos de Negros, again rise to an altitude of several thousand feet. In this region, near Dumaguete and Valencia, Tanjay, and Bais, I saw only andesite rocks.

In Cebú most of the country is covered with a blanket of coral, but where the streams have cut through this Mr. Abella found some decomposed andesites. I, too, found on the river above Naga, about two miles from the town, a considerable sheet of hornblende-pyroxene-andesite.

In the island of Leyte, at Mt. Dagami, according to Roth, Jägor collected fresh hornblende-andesite. Dagami is the name of a town in northeastern Leyte which Jägor visited, but he probably collected his specimen on Mt. Manacagan, as he calls it, a few miles south of Burauen. He speaks of the rock of this mountain as "a very hornblendic trachyte." On the island of Limasaua, just south of Leyte, Mr. Semper found hornblende-andesite, and Mr. Renard has determined the rocks of Camiguín de Mindanao as pyroxene and hornblende-andesites.

In Mindanao, the great Apo volcano, according to Mr. Joseph Montano, is andesite. He also found andesite north of Lake Dagun on Mt. Bunauan. This locality is in the valley of the Agusan, in eastern Mindanao. In much the same region he found andesites at the western foot of the coast range, on the river Miaga. A few miles upstream from Butúan, at the mouth of the Agusan, he found decomposed dolerite. Mr. Semper also collected augite-andesites from several points along the Agusan, as well as close to Zamboanga at the southwest extremity of Mindanao. Basalts, this naturalist found near Isabela, on Basilan, and on the neighboring islet of Lampinigan. Mr. J. Itier states that from Mt. Pico, in the center of Basilan, basaltic ridges, not over 500 meters in height, run east and west-northwest.

Near Joló, on the island of the same name, I found basalt. This island is mentioned by Mr. Koto also as basaltic, as are the Calamianes.

Vast quantities of pyroclastic tuffs and volcanic sediments accompany the more solid flows almost everywhere in the Philippines. They are especially abundant in the great central plain of Luzón, and seemed to stretch in an almost unbroken, nearly flat area from near Lingayén gulf southward past Manila and Taal to the seacoast of Batangas. Mr. von Drasche regards these tuffs as trachytic from the north coast of Manila bay northward, and as doleritic to the southward, but Mr. Oebbeke shows that some of the northern tuff is andesitic. In the more southerly area, along the Pásig, I am confident that andesitic tuff is abundant. Unfortunately my specimens are lost. On the other hand, much of the basaltic rock of the Laguna de Bay region is tuffaceous. In a large proportion of cases the tuff is so decomposed that a determination of its original lithological character would be very difficult. There can be no question that this tuff area has been laid down in water. So uniform a distribution and such flat surfaces could not have been attained under subaerial conditions. Evidence of aqueous rearrangement of material is frequently visible, and plant remains, or even traces of lignite in minute seams, are not rare. The light scoriaceous material of which the tuffs are composed may, as is well known, be carried to almost indefinite distances by river or oceanic currents. There is no doubt that since the close of the Tertiary the sea has flowed freely from Tayabas gulf to Lingayén gulf, and such a channel must have been traversed by currents sufficiently strong to account for the wide distribution of the tuff. Father Zúñiga seems to have been the first to see in ancient eruptions of Taal the origin of the greater part of the material forming the southerly tuff area. He has been substantially followed by all who have expressed their opinion on this subject; but Mr. Abella points out that all the volcanic vents from Aráyat to Banájao must have contributed material to this accumulation, in which opinion I entirely agree with him.

The great number of mineral or hot springs in many places accords very well with the wide distribution of volcanic rocks throughout the

whole of the archipelago. Many of these springs are clearly due to volcanic action. In his introduction to the Descriptive Study of some Mineral Springs of the Philippines, Abella writes:

In the central plain of Luzón, notwithstanding its rather limited area, the mineral springs are only found at the foot of the cordilleras which limit it, or in the neighborhoods of the volcanic foci which rise in its center, and they constitute two independent and well-defined groups, the eastern related to the cordillera which here is the division from the Pacific and the western to the Zambales range.

The eastern group sometimes outcrops from the heart of the early diorites and diabases within the cordillera, and sometimes from the post-Tertiary beds which lie upon and are elevated by the trachytes and andesites.

It is believed that these modern rocks of a volcanic character, upon lifting the strata of the post-Tertiary formation and crossing them in many places, have produced in them foldings, faults, and other geological displacements which have been able to facilitate the hydrothermal mineral emissions and those of the gases which occasionally accompany them; so that certainly an a priori argument can be announced that the mineral springs thus originated should be found in lines approximately parallel to the direction of the anticlinal and synclinal axes of these beds and to the trend of the cordillera upon which they lie. Thus it is, as a matter of fact, that the springs of Sápang-Maínit in Pantabañgan, of Sibul in San Miguel de Mayumo, and of Sibul in Norzagaray, occur in a right line running north and south, approximately parallel to the direction of the cordillera and to that followed by the outcropping of the beds of conglomerates, sandstones, slates, and limestones which constitute the said post-Tertiary formation of the center of Luzón.

Mr. Centeno, in his Memoria Geológico Minera, says with reference to the regions of Batangas and Albay where the volcanic action is yet more active:

The province of Batangas is also very rich in mineral waters, for, besides the sulphuric waters of the volcano of Taal, of which we shall speak further on, there are several important springs in it. In the township of San Luis, at a place called Maínit (hot), some jets of hot water gush from the ground, which leave an abundant ferruginous sediment. The waters of the brook Panipil, near the town of Lemery, are very sulphurous and are used with good results by the natives for cutaneous diseases. In the territory of the same town, on the road which leads to Calacâ, at a place called Mataasnabayan, there are also some springs which are little known and used. In the mountains of Taysán also there are hot springs whose composition is unknown to us, but which are used by the natives with good results for diseases of the bladder and cutaneous diseases. Besides, the water is used as an efficacious purgative in many cases. Finally, to the southwest of Bauan, near Point Cazador, there is another small spring, to which all afflicted with rheumatism and paralysis resort in search of relief from their sufferings, and which they usually find.

In the province of Albay, near the town of Tiuí, and at a place called Jigabó, there are several thermic springs of different temperatures, some containing a large quantity of sulphur, which is precipitated when the sulphureted hydrogen decomposes, and others have a gelatinous silica in solution, which the waters on cooling deposit on objects dipped into them, incrusting them in a short time with remarkable perfection.

The sulphurous springs appear at several points along the channel of a small stream, whose waters, of the ordinary temperature, conveniently mixed with the water from the hot springs, make baths of any temperature that may be desired. Underneath the round stones which make the bed of the brook there are found

small deposits of sulphur sublimate, and at certain places in a pasty state and colored by metallic oxides, which are used in that locality for paint. The second—that is to say, the siliceous springs—appear some 200 meters from the first, and are much more remarkable, not only on account of the greater space they occupy, but also on account of their very high temperature (108° C.) and the very beautiful siliceous concretions they produce, sometimes consisting of flattened cones with cylindrical terminations, perfectly joined and with bands of different colors, sometimes forming small cylindrical and semispherical hollow crystals, wholly filled with quiet and transparent hot waters. In these waters, with a little care, the purest siliceous incrustations can be obtained by simply putting the molds in them for a few days.

There are many other important centers of volcanic action shown also by hot springs, which we will make mention of when speaking of the different volcano-seismic centers.

## HISTORICAL GEOLOGY.

The geology of the Philippine Islands is summarized by G. F. Becker as follows:

From early Paleozoic times onward an archipelago has usually marked the position of these islands. Prior to the Eocene nothing definite is known of them, but further investigation will very likely disclose Paleozoic and Mesozoic strata there, as in the Sunda and the Banda islands. During the Eocene it is probable that the lignitic series of Cebú was deposited, and the contorted indurated strata, which in other localities also carry black lignite relatively free from water, should be referred provisionally to this period. Whether the nummulitic limestone found at Binañgonan is Eocene seems to me to be an unsolved question. After the Cebuan lignitic epoch a great uplift and folding took place, and this may have been a detail of the late Eocene movement which so profoundly modified Asia and Europe. It must have brought about temporary continuity of land area between Borneo and Luzón. Somewhere about the middle of the Miocene the country sank to a low level. Many of the present islands must then have been far below water, while Luzón and Mindanao were represented by groups of islets. Observations appear to suggest that the Agno beds represent the basal conglómerate formed at this subsidence. A slow rise began again during the later Miocene, and may have continued to the present day without inversion, yet the actual distribution of living forms is such as to give some grounds for believing that at some intermediate period the islands were a little higher than they now are, but sank again only to rise afresh. The diorites and associated massive rocks, including their tuffs, may have made their appearance about the close of the Paleozoic. The less siliceous of these rocks seem to have followed the more siliceous intrusions as a whole. The gold deposits, and perhaps other ores, are so associated with these massive rocks as to indicate a genetic relation. The neo-volcanic period began as early as the highest Miocene horizon, and very probably at the post-Eocene upheaval. If the semiplastic marls of Cebú are all Miocene, the earlier andesitic rocks, at least, date back nearly to the great upheaval. Among these rocks also there is sometimes a tendency for the basalts to follow the andesites, but the one dacite found at Corregidor is later than the andesites of that island. The relation of the trachytes to the andesites is not certain, but the sanidine rock is probably the earlier. A very large part of the neo-volcanic ejecta has fallen into water and been rearranged as tuffaceous plains. The volcano vents appear to me to occur rather on a network of fissures than on a single system of parallel diaclases, and the volcanic activity is to be regarded as a thermal manifestation of the energy of upheaval.

In another report the same author says:

When the elevation was at its minimum the archipelago was reduced to a group of small, hilly islets, four of which existed within the area now occupied by the island of Luzón. Cebú was almost completely submerged.

At or before the period of maximum subsidence began a series of eruptions which has not yet closed. Mayón volcano, in southern Luzón, had a violent eruption in 1897. It is probably the most beautifully symmetrical volcanic cone in the world, and the truncation at the top, due to the crater, is scarcely sensible.[1] The work done in fusing lavas and ejecting ash is probably a manifestation of the energy involved in the mighty earth throes which bring about regional upheavals with incidental subsidences. The earlier of the eruptions under discussion were largely submarine and vast additions were made to the superficial material of the archipelago by these outflows, especially in the central and southern portions of Luzón. The ejecta include andesites, rhyolites, basalts, and probably other less common rock species.

The period of upheaval, once initiated, does not seem to have been interrupted by any era of subsidence, and the modern coral reefs give evidence that it is still in progress. It is said that uplifts accompanying earthquakes have actually been observed by the Spaniards, and the earthquakes themselves are spasmodic jars in the process of elevation. The elevation has not been, properly speaking, catastrophic, however, for the tremors which may wreck a cathedral are insignificant from a terrestrial standpoint. On the whole, the uplift has been very gradual, so that even the coral polyp has been able to adjust himself to the changing conditions, building outward into deeper water as his old home was raised too high for his welfare. In this way nearly the whole of Cebú, to a height of over 2,000 feet, has been covered with a nearly continuous sheet of coral, which can be followed seaward into living reefs. Much of Négros has been clothed with a similar mantle. On a small scale, also, off the coasts of these islands, and particularly about Mactán, reefs can still be studied in every stage of upheaval, all those portions being dead which are exposed to the air even at the lowest tides. In southern Luzón and to the northward of Lingayén bay similar phenomena can be observed.

Although upheaval does not appear at any time since the close of the Tertiary to have given way to subsidence, there have been repeated pauses in the uplifting process. On exposed coasts these pauses are marked by benches eaten into the land by the action of the waves. Thus the southern ends of Cebú and Bohol are terraced from top to bottom, each terrace being an old bench cut out of the rock mass by stormy seas. Pauses in the uplifting process are also marked by a rude stratification of the corals. Even in the interior of the islands terraces indicative of uplifts are frequently visible. Some of them represent base level of erosion, others are ancient coral reefs which have been checked in their upward growth by reaching the surface of the water. In short, terraces constitute one of the most prominent topographical features of the archipelago.

## EARTHQUAKES.

We may truly say, speaking of the Philippine archipelago, what Mr. A. R. Wallace says of the Malay archipelago:

In the whole region occupied by this vast line of volcanoes, and for a considerable breadth on each side of it, earthquakes are of continual occurrence, slight shocks being felt at intervals of every few days or weeks; while more severe ones, shaking

[1] The radius of any horizontal section is the hyperbolic sine of the distance from this section to the summit.

down whole villages and doing more or less injury to life and property, are sure to happen in one part or another of this archipelago almost every year.

It is an elementary principle that the earthquakes as well as the volcanoes occur along the lines of relief shown either by ridges or mountain ranges or by sea deeps or depressions, and especially when there rises a high ridge not far from a sea deep, thus forming a steep slope, as, for instance, along the Japanese and Kurile islands, south of Sunda Islands, and in the West Indies. The Philippine archipelago on this account may be considered as a clastic country. Owing to the small breadth of the islands and the depth of the seas it is almost formed by ridges. Here occurs also what Milne says of the southern regions or the Java district. In this district the suboceanic irregularities are as irregularly distributed as the islands between which they occur. Many of these islands are but mountain ranges or peaks emerging from the sea.

The recent observations of Dr. E. von Rebeur Paschwitz, Milne, and other seismologists about earth tremors, with the invention of the extremely sensitive microseismographs, have thrown much light on the character and extent of the seismic movements, or earthquakes, and open a new field for research.

We may divide closely the earthquakes into rockfall, volcanic, and tectonic.

The rockfall earthquakes are due to the falling in of the roofs and sides of subterranean hollows or caves. They are feeble, of very small extent, and may often be noticeable only as sounds and not as sensible shocks.

The volcanic earthquakes are those due to the activity of volcanoes, with which may be included earthquakes due to the rending open of fissures by the sudden development of steam under high pressure.[1]

This last cause has been inferred in the case of some earthquakes, but its reality has never been proved; volcanic activity is well known, however, to be associated with earthquakes, and these may sometimes be of very great severity, though always local in their extent. Within a very moderate distance of a town which has been laid in ruins the shock may be quite insensible.

To the class of tectonic earthquakes belongs by far the majority of earthquakes and all those which can be classed as really great, on account of their violence or extent. They may be regarded as invariably due to the sudden relief of strain, as opposed to the volcanic earthquakes, properly so called, which may be regarded as due to the sudden development of strain.

[1] Probably the earthquakes which preceded the eruption of the Camiguín volcano may be referred to this cause. They ceased suddenly with the outburst of the volcano. (See Camiguín volcano, page 33.)

The investigations just mentioned led Mr. Milne to propose a wider division:[1]

The earthquakes may be divided into two groups: First, those which disturb continental areas and frequently the world as a whole; and, secondly, local earthquakes, which usually only disturb an area of a few miles' radius, and seldom extend over an area with a radius of 100 or 200 miles.

The former are very probably the result of sudden accelerations in the process of rock folding, accompanied by faulting and molar displacements of considerable magnitude; whilst the latter are for the most part settlements and adjustments along the lines of their primary fractures. The relationship between these two groups of earthquakes is therefore that of parents and children.

The former, which represent a disturbance, not only of the crust of the world, but also of the homogeneous nucleus it covers, will be referred to as macroseismic disturbances or large earthquakes; and the latter, which appear to be the shiverings within the crust, will be referred to as microseismic disturbances or small earthquakes. To avoid confusion it must be mentioned that several observers refer to the world shaking disturbances as microseismic, the reason, no doubt, being that they are usually recorded at such a great distance from their origins that their vibrations have so far died in amplitude, and increased in period, that they can not be felt or be seen in the traces of an ordinary seismograph. It also must not be overlooked that the term microseismic has been used to describe disturbances evidenced by minute and long continued swingings of pendulums and other apparatus, the cause of which is, in many instances at least, attributable to movements in the atmosphere rather than in the earth.

According to the recent investigations of the same Prof. J. Milne, the Philippine archipelago is included in that region of the globe in which the greatest number of macroseismic earthquakes has occurred since 1899. This region of maximum macroseismic activity takes in the Philippine archipelago, the whole of the Dutch East Indies, Celebes, Borneo, the Moluccas, New Guinea, and several other islands in the Pacific. Forty-one large earthquakes, which were registered all over the world, have had their origin in this region during the last four years. Of these earthquakes at least four had their origin in the Philippine archipelago, or very close to it, viz, that of the 15th of December, 1901,[2] felt in Luzón, which was not destructive; that of the 21st of August, 1902, which took place in Mindanao, close to the Lanao Laguna and Illana bay; that of the 26th of August, 1902, which was felt in the province of Iloílo; and finally that which occurred in Guam on the 21st of September, 1902. What happened in the earthquakes of December 15, 1901, and August 26, 1902, proves that some earthquakes, nondestructive at their origin or epicenter, may send their waves around and across the globe.

The seat of origin of both the Mindanao and the Guam earthquakes appears to be submarine, while that of the Luzón and Panay earthquakes seems to be terrestrial. The seat of origin of the Mindanao

[1] Seismological Observations and Earth Physics, 1903.

[2] A report on the propagation of the seismic waves around the earth in this earthquake, by Fr. Marcial Solá, S. J., may be seen in the Bulletin for December, 1902.

earthquake must be quite close to the coast, because, according to reports, it caused ground displacements not only on the sea but also on land. Further on we shall have occasion to speak again of this center which is situated between Zamboanga and Cottabato. There are other important submarine centers in the archipelago; one being in the Joló sea, another not far from the island of Masbate, and probably another in the Pacific opposite the coast of Binañgonan, nearly east of Manila.

We shall treat of these as well as of the terrestrial centers more at length later on. At present we have not sufficient data to say precisely how many of the different volcano-seismic centers in the archipelago give rise to macroseismic movements; because it is only within recent years that, with the aid of apparatus of Milne, von Rebeur, and Vicentini, the existence of these macroseismic centers has been manifested, and even in the Philippine archipelago not enough occasions have presented themselves for us to distinguish the nature of each center. The Vicentini microseismograph has only been in operation in the Manila observatory for a little over a year and a half, and yet already many earthquakes of a distant origin have been registered, as for example, the Guatemala and the Andijian. There have also been registered in Manila almost all of those earthquakes called by Milne microseismic, the origin of which was within the archipelago. When a fair number of observations of these latter earthquakes shall have been collected it will be possible to say which of the numerous foci in the archipelago which appear to give out microseismic earthquakes are really volcanic, which rockfall, and which tectonic. In the short description of the principal ones something will be said on this particular.

Before finishing we will add a word or two on the movements called microseismic, the cause of which is, according to Milne, in many instances at least, attributable to movements in the atmosphere rather than in the earth.

An hourly register of these movements has been taken at the Manila observatory since the year 1881 by means of the Bertelli tromometer. A careful examination of these observations, in conjunction with those of the ordinary movements of the atmosphere, has led to the following conclusions:

First, the greater part of these movements in Manila are due to endogenous causes; second, when the movements of the atmosphere cause these microseismic movements they do so indirectly, now by the movement produced on the sea, at other times by the pressure on the mountains. The first movement has greater effect than the second; so much so that it may be said that as soon as there are waves in the Pacific, the microseismic movements are observed in Manila. The movements of the other seas have much less influence than those in

the Pacific. When there are any extraordinary movements in the atmosphere, or cyclones, the tromometer gives indications which may serve as indirect signs of a cyclone. The Rev. Father Algué, in his book "The Cyclones of the Far East," after having studied the registers of the tromometer during the passage of several cyclones over the archipelago, comes to the following conclusions:

First. The tromometrical oscillations and the distance of the center of the cyclone vary inversely, but the proportion is not a mathematical one.

Second. The force of the wind in the locality has a certain relation with the movements of the tromometer, but it can not be considered as their cause. It would appear that the direction of the wind had a slight influence on the oscillation of the tromometer. This is doubtless because the direction of the wind depends upon the orientation of the center of the cyclone.

Third. The gradual perturbation of the tromometer constitutes an indirect sign of the existence and approach of a cyclone, but a sign which has only a relative scientific value depending upon the experience of the microseismic movements proper to each locality and also on the frequency of microseismic movements produced by endogenous causes.

We notice three important points in this conclusion. The first is that the microseismic oscillation is an indirect sign of a cyclone; the second, that the scientific value of this sign is purely relative and depends upon the experimental knowledge of the movements in each locality, for the geographical position, the topographical, and even the geological constitution of the soil play a great part in facilitating or hindering the transmission of the mechanical movements produced by cyclone forces. All these factors have to be taken into account and their influence on microseismic movements determined by experiment.

Finally, the scientific value of these microseismic movements as a sign of a cyclone depends upon the frequency of the movements produced by endogenous causes. This is the principal cause why the microseismic movements can not have an absolute value.

SEISMIC SERVICE IN THE PHILIPPINE ISLANDS.

During the old meteorological service only those stations of the island of Luzón connected by telegraph with the central observatory were properly meteorologico-seismic, although all the stations in the register of meteorological observations usually noted the principal earthquakes which they had felt. In the new service all the stations in the archipelago are at the same time meteorological and seismic, as almost all of them are provided with a seismological apparatus with which they can analyze much better the earthquakes which occur with such frequency in almost the whole of the archipelago.

To extend the network of seismic stations to all the islands it was determined to erect a seismograph of exactly the same pattern at each station, so that the curves obtained from the different points for any one earthquake could be compared without the inconvenience of having to reduce them, as would be the case if different patterns of instruments were employed. It was, moreover, agreed upon that this pendulum should only be sensitive enough to record those movements of the earth which are perceptible to persons moving about.

By this we do not exclude the more perfect instruments; indeed, so far from this being our purpose, we intend to place in some of what we might call the classic points of seismic activity, instruments of a much greater sensitiveness.

The central observatory is at present furnished with the following instruments, most of them being placed on the solid pier rising through the floors in the left tower of the main building:

INSTRUMENTS FOR DIRECT OBSERVATION.

Bertelli's horizontal microseismometer or tromometer.
One vertical microseismometer.
Three ordinary seismometers—two for horizontal and one for vertical motion.
One pendulum for the direction of initial motion.
Two cryptophones—one of which has the surface of a paraboloid mathematically traced by Father Rankin, assistant director of the Manila observatory in 1886.

REGISTERING SEISMIC INSTRUMENTS.

Cecchi's microseismograph.
Cecchi's seismograph.
Rossi's microseismograph.
Gray-Milne's improved triple pendulum seismograph.
Vicentini's improved microseismograph.
Necoman's improved self-recording tide gauge.

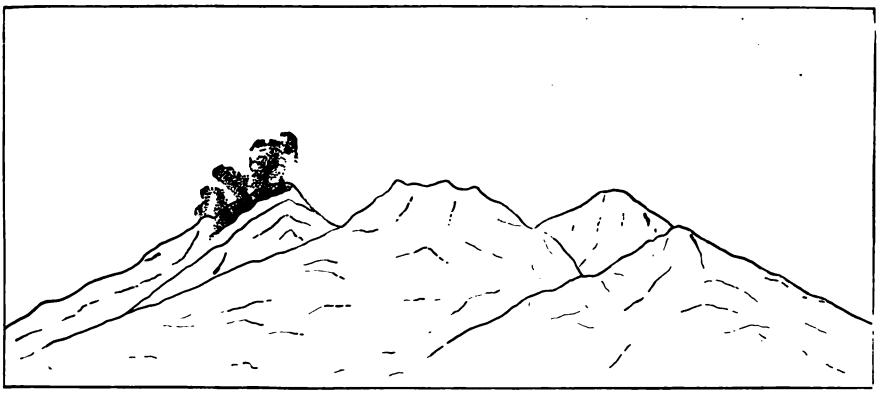
There are also several microseismographs in the astronomical building adjusted to the solid bases of the equatorial and transit telescopes.

For the purposes of the new seismo-meteorological service the archipelago is divided into four districts or sections; this division we shall adopt in this report, setting aside the one used heretofore in other pamphlets.

## EASTERN MINDANAO AND THE VISAYAS.

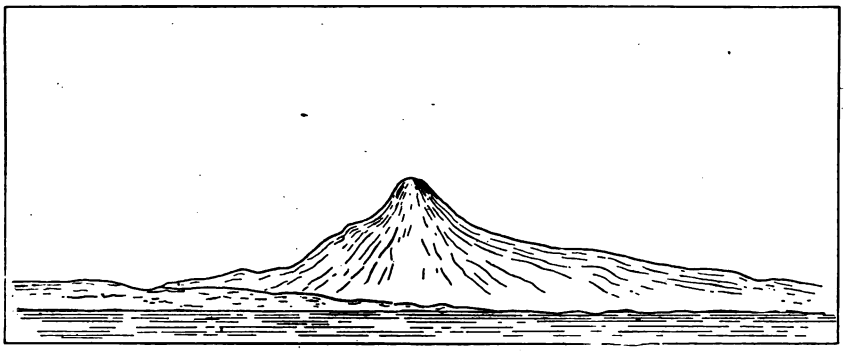
This southeastern region, or the first meteorological district, is situated east of the meridian 123° 30′ east of Greenwich, and south of 12° north latitude. It comprises the greater part of Mindanao, the islands of Leyte, Bohol, and Camiguín, and the southern part of Sámar and of Cebú. It includes the active volcanoes of Camiguín, Apo, and Calayo, and some of the most active volcano-seismic centers of the archipelago.

APO VOLCANO LOOKING WEST FROM DÁVAO RIVER.



OUTLINE OF THE APO VOLCANO.

The seismic region of this focus probably comprises not only the southeast of Mindanao but also the southern part of Misamis, the whole district of Cottabato, and the sources of the Agusan river. Besides the solfataric volcano Apo, the giant of the archipelago, there are some other volcanic cones lying in this region. The extinct volcano Matútum, at the farther end of the Sarangani bay, is very striking, owing to its clear conic shape; there also rises, at the most southern edge of the island, Mt. Butulan, generally considered as a volcanic cone as well as the highest peak of the Sarangani Islands.



MATÚTUM VOLCANO, LOOKING S.

The Apo volcano (7° 03′ north latitude and longitude 125° 17′ east of Greenwich), the summit of which rises 10,311 feet above the sea level, gives evidence of its activity by numerous solfataras, or jets of sulphurous vapors, which escape with a sharp, hissing sound and hover, cloudlike, over the summit of the mountain. The principal solfataras break out from a nearly southern crevasse which starts from the top, or the ancient crater, down the side of the mountain. The first man who tried to ascend this volcano was D. José Oyanguren, in 1859, but he failed. In 1870 Mr. Real, governor of Dávao, attempted it, but he succeeded no better. At last it was ascended, in 1880, by Mr. Montano, Mr. Joaquin Rajal, governor of Dávao, and the Jesuit missionary, Father Mateo Gisbert; in 1882 by Messrs. Schadenberg and O. Kock; and in 1888 by the Jesuits, Martin Juan and John Doyle. These two Jesuits were taking magnetic measurements in Mindanao in order to draw a magnetic chart; after obtaining the absolute magnetic values of declination, dip, and horizontal force at Dávao, Sámal, Malálag, and at the mouth of the Tágum river, they ascended the volcano in order to determine on its top the magnetic values and to take photographs, but, as happened in all the ascents, the stormy weather stopped the work, and thus they were only able to determine a fair value of the horizontal force at 3,000 meters altitude.[1]

[1] The magnetic values obtained by these fathers may be seen in the Monthly Bulletin for October, 1902, of the Manila observatory, and in the Report of the Philippine Commission for the year ended August 31, 1902. Appendix P, page 678.

The reports of the different parties show that there is not a single regular and deep crater in the summit. According to the Guía Oficial the summit consists of three peaks, of which the present crater forms the most southwesterly. Mr. Montano says that this extinct crater measures 500 meters in diameter; its interior slopes, like the exterior ones, are covered with stunted vegetation. It seems probable, therefore, that the present activity does not exist on the very summit, but a little below, where the enormous crevasse running downward opens and which is reported by all the visitors as the active crater of this volcano. It opens on the southern side of the mountain, the northern side being covered with vegetation up to the top. Around this crevasse, which is about 50 meters wide and 20 to 60 meters deep, there runs the space reported by Montano as denuded of all vegetation and covered with a mantle of sulphur, ashes, and andesitic blocks. The crevasse seems to run up from the height of 2,400 meters to near the top of the crater. Mr. Rajal, who made the ascent with Doctor Montano, describes the summit as follows:

Being on the top (they ascended following eastern ridge) we saw to the west an enormous crater, the walls of which were formed of andesitic edges and ashes, in the bottom of which there was a lake. Stunted vegetation covered the lower part of the interior slopes. Some 400 meters below we distinguished a second lake in another similar but smaller crater. To the north, but separated by a deep crevasse where the Siriban river has its origin, rises a lower mountain cut near its summit by a deep and ridged cavity, probably some other ancient crater.

We take from Otto Kock's report the following description:

At the height of 1,320 meters we forded the river Vaigmainit (warm water) which river, according to the natives, is very hot at its source. A little higher up we came across the channel of a river with running water, but which was not drinkable on account of the amount of sulphurous acid and sulphohydrate which was held in solution. The atmosphere also contained a large amount of sulphurous acid. On reaching a height of 2,700 meters the first large solfatara was met with. It was in the form of a very wide crevice, with several others not so large. All of them gave out sulphurous vapors in great quantities and the ground around was very hot, and at times there were heard loud subterranean noises like those given by a powerful steam engine. At that height a brick was found having the following inscription which recorded the former expedition: "Apo, única expedición Rajal 1880." From the region of the solfataras the ascent was easier till the most northerly of the three peaks was reached. It is the most northerly peak which contains the volcano. The southwest peak, which is higher than the other two, was also very difficult of ascent because the ground was very soft, and in some places undermined so that if one put his foot carelessly on it the ground shook and sank. The large crater is in the highest peak and is covered by a lake of moderate dimensions, situated to the southeast, with a large pyramid formed of enormous blocks, which are completely covered with sulphur which had been deposited on them. The third peak is to the westsouthwest of the principal one.

On descending Mt. Apo we came across two new solfataras below the northeast peak. These two solfataras did not exist on the ascent of the first expedition. About 100 meters lower down there was a hole from which came a great deal of steam but which had absolutely no smell.

Looking at the volcano from Dávao or Sámal on a cloudless morning there may be distinctly seen a wide space, narrowing to the lower part, covered with small cones of sulphur, from which burst forth intermittent eruptions of white sulphurous vapors. This is a magnificent spectacle when at sunrise the sulphur mantle and cones are shining and there then appears a sudden jet of vapors, sometimes growing and growing until the white, fine cloud covers the whole spot and even the summit of the volcano. Though Apo is well known to be active there is no record of its eruptions.

The Apo volcano-seismic center is one of the most active of the archipelago; small seismic shocks are felt weekly, if not daily; very often a rumbling sound precedes the stronger shocks; such a rumbling sound, invariably attributed to the volcano, has been reported also without any perceptible shocks.

The most violent earthquakes felt in this region may be seen in the following list:

TABLE 3.—*Earthquakes of the Apo region.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1836.... | January .... | 3 | ..... | General earthquake accompanied, according to some, by volcanic eruption. |
| 1870.... | November.. | 4 | 3.00 a. m. | This earthquake was felt over almost the whole island of Mindanao. Its violence in Dávao is not known; it was destructive in the northern provinces toward Misamis. |
| 1871.... | June ..... | 28 | 3.30 p. m. | Very violent earthquake. |
| 1871.... | December.. | 19 | 10.30 p. m. | Earthquake felt in this region more than in western regions. |
| 1872.... | August ..... | 24 | 9.01 p. m. | Several shocks distinctly felt; destructive principally in the southeast of the island. |
| 1878.... | September.. | 17 | 0.50 a. m. | Destructive effects inconsiderable. |
| 1894.... | February... | 10 | 1.05 a. m. | Earthquake destructive principally in the southeast of Mindanao. |

SEISMIC CENTER OF THE AGUSAN RIVER.

Independent of the above-mentioned Apo center there is another seismic center in the southern part of the Agusan river valley, about longitude 125° 50′ east of Greenwich and 7° 40′ north latitude, not far from the source of the river. This focus is possessed of great seismic activity, as is evidenced by the long series of earthquakes observed and carefully recorded by the Jesuit missionaries of that region since the year 1890. In June, 1891, a violent earthquake was the beginning of a long and fearful seismic period. This earthquake produced the most awful havoc to the houses and ground; fortunately, owing to the wildness of the country, there was little loss of life or of property. The falling banks of the river dammed it in many spots. Long and wide fissures were opened everywhere, especially on the hills separating the Agusan valley from the Hijo and Sálug rivers, which empty themselves into the Dávao gulf. The earthquake lasted several minutes, and during this time, says an eyewitness, the ground was moving

as the troubled sea. During the following months, or during more than a year, the earth trembled with more or less force every day. In June, 1892, there was a second violent earthquake, shaking the same region and renewing the havoc of the preceding year. These two earthquakes shook the island of Mindanao nearly from end to end, and were fairly perceptible in the eastern Visayas. From these dates small shocks have been more frequent in this region than in any other part of Mindanao. Their cause is probably geomorphic rather than volcanic. There are unmistakable signs that the southern coast of Mindanao comprised between Cottabato and Panguián point, the most southern one of the island, is at present undergoing subsidence, while, on the other hand, an upheaval seems to be going on in the northeastern and Pacific coast of the island. The southwestern part of the epicentral region, especially the hills or low ranges where the widest fissures were opened, may be considered as the junction between the eastern ranges of Mindanao, running from Surigao to the San Agustín cape, and the central one, stretching from the Diuata and Sipaca points in the north to Panguián point in the south. All the rocks in this range, through which run the Sálug and the Tubúan rivers, are of madrepore and polypus of recent formation, alternating with clay beds and limestone strata. "On going up the Sálug river," says Mr. Montano, "I came across frequent rapids and waterfalls. The rocks which form these falls are of white limestone mixed with enormous blocks of coral polypus, doubtless Astraea, very similar to those still growing in the Dávao gulf. This is another proof of the recent upheaval of this part of Mindanao." The eastern range is andesitic, as also are some hills northeast of the epicentral region and probably also the central range. Owing to the fact that this epicentral region until the year 1880 was quite unexplored and only inhabited by wild tribes, there are no reports concerning earthquakes possibly radiated from this center in earlier years.

VOLCANO-SEISMIC CENTER OF MACATURÍN.

The region most affected by the earthquakes from this center, or centers, which are located west of the foregoing ones, is comprised between the parallels 8° 38′ and 6° north latitude and the meridians 123° 38′ and 124° 45′ east of Greenwich. In it lies the famous but almost unknown volcano Macaturín. From the time of the arrival of the Spaniards in these islands, in the sixteenth century, three eruptions are reported—one on the 20th of January, 1840; another on the 1st of November, 1856; and the third, according to various accounts, occurred a little before the earthquake of the 8th of December, 1871. This last earthquake was very destructive in Cottabato, Polloc, and westward along the Illana bay coast. The actual state of this volcano, which is supposed to lie at about 7° 40′ north latitude and longitude

124° 03′ east of Greenwich, is not known. Various authors say that the volcanic bombs thrown up by this volcano may be seen near the port of Polloc, which is at a distance of 7 leagues from the volcano. Many volcanic rocks may be seen lying on the coral banks which extend along the coast from Polloc to Malabang. In this military post, which is famous for the springs which issue from cellular basalt mixed with clay beds, there may be seen a kind of porous or scoriaceous detritus, probably due to some relatively recent eruption.

Northeast of the Macaturín, at the southern part of the Misamis district, somewhere about 7° 50′ north latitude and longitude 124° 40′ east of Greenwich, and close to the Río Grande, otherwise known as Pulangui river, there is a small volcano called Calayo, or Volcán. The first report of it comes from the Jesuit Father Eusebio Barrado, perhaps the first white man who traveled across the island of Mindanao from the Misamis district to Cottabato, in 1891. His report of this volcano is as follows:

> The river Pulangui (Río Grande) flows from Linabo through different kinds of land with a very swift current, and at a spot called Salagalpón there is a wonderful waterfall. Not far from it and close to the same river is a volcano, which burst into eruption some four years ago and constantly emits vapors which burn everything about. The banks of the river are here so steep, high, and close together that they form a very narrow canyon. On the left of this bank stands an active volcano. There is no flow of lava, but it emits a column of vapors so sulphurous as to prevent any approach.

Down the same river, or near Cottabato, Mr. Centeno in his chart marks the Cottabato hill as a volcano, and he observed many other conical hills along the river which he did not examine. On the slope of the Cottabato hill looking toward this town there is a sulphurous hot spring.

In past times the region bordering the Illana bay has doubtless been frequently devastated by violent earthquakes, but history records only the following: December, 1636, 1858; January, 1864; December, 1871; March, 1882; February, 1889; and August, 1902. The earthquakes of 1858, according to some reports, were the effect of an eruption of the Macaturín volcano. Great molar displacements on the surface of the ground and under the sea were caused along the Illana bay coast by the earthquake of 1636, when the Flechas point was badly cracked. In the last earthquake large displacements were produced not only on the seashore but also in the whole of the tract separating it from Lake Lanao. Some idea may be gathered of the violence of this earthquake from the following note published in the newspapers of Manila on the 27th of August:

> The island of Mindanao is receiving a general shaking up these days, and from the number of the earthquake shocks and tremors that are occurring there it is evident that there are mammoth disturbances in the earth at the present time. The earthquakes continue unabated, and since the first shock, on the 21st instant, there

have been about four hundred slight tremors, with perhaps twelve or thirteen shocks, many of them severe enough to overturn stacks of quartermaster and commissary supplies. Captain Pershing wires the division commander that it has been reliably reported that twelve Moros were killed near Tubaron on the 21st by falling houses, and that since that date shocks have been alarmingly frequent; that the stores piled up for the troops are frequently overturned, and that the barns have been wrecked. The work of reconstructing the storehouses is progressing as rapidly as possible, but the frequency of the shocks and the tremors make it extremely difficult to rebuild. The Moro forts at Bayán and Bacólod are reported to have been seriously damaged during the first shock on the 21st. General Sumner also wires from Zamboanga that a severe shock was felt at that place on the morning of the 21st.

The submarine cable was broken in several places and it was so buried in other places that it would seem that the sea had changed its depth considerably.

These facts and the directions of the shocks observed at Zamboanga and Cottabato, especially in those of 1871, 1882, and 1889, induce us to believe that there is a submarine center of great activity near Illana bay. Certainly the southern sea of Mindanao, as well as the Joló sea, constitutes one of the most irregular and consequently most unstable regions of the archipelago.

### SEISMIC CENTER OF SURIGAO.

The seismic region of this very active center extends not only throughout the peninsula of Surigao, but also to the islands of Siargao, Dinágat, and the southern part of Sámar and Leyte. In this region no active volcanic centers exist, excepting the Maínit Lake, situated south of Surigao at 9° 28′ north latitude and longitude 125° 33′ east of Greenwich, and supposed to be the crater of an extinct volcano. Doctor Montano, who visited this lake, says: "It is situated in the crater of an ancient volcano. It is circular in form and has steep banks. Near the shore the ordinary depth is 60 feet and more than 600 near the center. The amount of the water in it sometimes increases very suddenly. But the most certain sign that there is a volcanic center is the sulphurous thermic springs issuing from and around the lake." According to the same Doctor Montano some recent volcanic rocks are to be found in the neighborhood of this lake, but he states also that on the eastern shore there is a compact limestone formation through which there are many open caves. Many of the most violent earthquakes felt in this region have been referred to the supposed volcanic center, and certainly in many cases they were most severe in the villages close to it. Doctor Montano records that in all the abovementioned limestone caves there are many fissures and overthrown bowlders, probably due to the earthquakes. The earthquake felt in July, 1879, probably the most violent recorded in the last few centuries, had certainly, according to Centeno's report, its epicenter in

Maínit Lake. It propagated northward mainly through the mountain range, ending in Bilán Point, the northern extremity of Mindanao. This earthquake caused many important displacements. Mr. Centeno, who visited the place some days later, reports two visible subsidences; a submarine one in the Bilan-bilan port, east of Surigao, and the bodily sinking of a valley measuring some 5,000 feet in length and 1,000 in width. This valley, which is situated to the southwest of Bilán Point, sank some two feet.

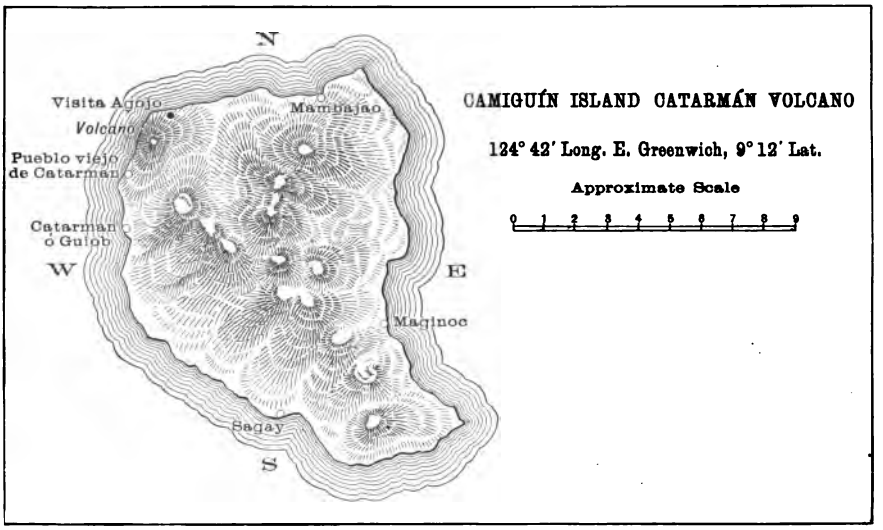
At the north end of the range near Bilán Point wide fissures were produced in the rocks; a little south, but not far from Surigao, many landslides took place in the alluvial banks and sandstone hills in the direction of the Cansuran river. This earthquake was the beginning of a long seismic period lasting until the end of the year 1881. The seismic records at hand, which since the year 1870 are accurate, show that the years 1878, 1879, 1880, and 1881 may be considered as a period of great seismic activity in this region. The stronger earthquakes are usually preceded by a strange rumbling sound. We will mention in the following list a few of the more violent earthquakes felt in this region:

TABLE 4.—*Earthquakes of the Surigao region.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1836.... | January.... | 3 | ..... | Felt almost throughout the whole island. |
| 1871.... | November.. | 5 | 9.00 a. m. | The shock felt over a wide area, comprising Mindanao and the eastern Visayas, although it was destructive only in the district of Surigao. |
| 1871.... | December .. | 19 | 10.30 p. m. | Felt along the Pacific coast of Mindanao from north to south. |
| 1878.... | September.. | 14 | 1.00 p. m. | |
| 1879.... | July ..... | 1 | 2.38 a. m. | Caused great havoc throughout the country, and was the commencement of a long and very active seismic period, lasting for more than a month. |
| 1885.... | February... | 22 | 3.30 p. m. | This also affected all the coast of Mindanao along the Pacific mountain range from Surigao to Cape San Agustin. |
| 1889.... | October .... | 6 | 11.06 a. m. | The destructive force extended more toward the south than toward the north. |

## VOLCANO OF CAMIGUÍN.

The small island of Camiguín lies near the north coast of Mindanao, between 9° 42′ and 9° 14′ .7 north latitude and longitude 124° 39′ .7 and 124° 47′ .4 east of Greenwich. It consists of a single range of mountains, apparently a prolongation of the central range of Mindanao, its northern extremity forks, forming the two ridges of Catarmán and Mambájao. The island is Y-shaped, with the base lying southeast. Three principal peaks rise rather sharply, and are supposed to be extinct volcanoes. The whole island is famous for its great fertility, shown in the exuberant vegetation which covers even its steepest hillsides. Plantations of abaca are seen everywhere, even on the


N
Visita Agojo
Mambajao
Volcano
Pueblo viejo
de Catarman
Catarman
ó Guiob
W
E
Maqinoc
Sagay
S
CAMIGUÍN ISLAND CATARMÁN VOLCANO
124° 42′ Long. E. Greenwich, 9° 12′ Lat.
Approximate Scale
0 1 2 3 4 5 6 7 8 9

almost inaccessible slopes. Close to the foot of Mt. Catarmán, to the west and near the seashore, rises the active volcano, which was in eruption from 1871, when it first broke forth, until the year 1876. Adhering, as it were, to the side of the mountain, and in a spot that was formerly an extensive depression, it rises to the height of 1,499 feet above the sea, with a base measuring more than 3,000 feet in diameter. This small volcano, known abroad as the Catarmán volcano, is merely a recent mouth or crater of the gigantic and much older one that has been dormant for many centuries, but which now seems to be waking up.

*Condition of the Camiguín volcano previous to 1871.*—Besides the solfataras that have made their appearance in recent years, its conical form and the nature of its rocks give sufficient data for classing Mt. Catarmán, which rises 6,000 feet above sea level, as an ancient volcano. The conic shape, the massive blocks of basalt, claystone, and andesite, many of them resembling the volcanic bombs thrown out by the volcano Mayón, afford solid foundation for such an opinion. These blocks are found scattered throughout the fields, almost down to the madreporic formation of the coast. The soil, blackish in color, also shows a mixture of the above materials, together with other fragmental ejecta. No eruption of this mountain is reported in the history of the islands, nor is there any previous mention of any signs of activity in the mountains of Camiguín Island. There are in the library of the Manila observatory some old documents of unknown origin, probably consulted by Mr. Jägor before he published his book in 1873, wherein it is stated that on top of Mt. Catarmán, occupying an old crater, there existed a lake of some 600 meters in circumference, the water level in which was subject to such fluctuations that at times the lake became practically dry, while at other times the water overflowed the containing walls. The crater, moreover, was sometimes seen in a violent state of ebullition caused by the escape of gases from the bottom of the lake. It is also reported that at Catarmán, Mambájao, and other towns confused rumbling sounds and detonations were at times heard, which were usually referred to some of the neighboring volcanoes of Mindanao. Thus all reports of this volcano previous to the year 1871 are vague and uncertain, though there can be no doubt that in past ages it must have been one of the most active and powerful volcanoes in the archipelago.

*The Camiguín eruption of 1871.*—In the first months of this year, about February 16, earthquakes became very frequent; shortly after the inhabitants of Mambájao and Catarmán became convinced that the radiating center of the seismic disturbance was located in their little island, and not very far distant in the same mountain, whose fertile side, covered with verdure, had never been suspected of harboring a

dangerous enemy. An eyewitness of the events, the presidente, or capitan, of Catarmán, thus describes the beginning of these disturbances:

On February 16 at 1 o'clock p. m. a slight shock was felt, which was repeated at 7.30 p. m. of the same day. On the 17th at 9.30 a. m. another and stronger shock was experienced, after which moment there began a series of tremors that continued throughout the day and the following night. Great alarm spread among the inhabitants. On the 18th, shocks were felt at shorter intervals than on the preceding days, so that the earth seemed to be in continuous vibration. At 6 p. m. a very strong shock came. During the night there was no change, except that at 11 p. m. another very strong shock was felt, and that each distinct shock was preceded by rumbling noises, which seemed to come from the mountain to the east of the town. This last fact, together with the rumor that on the northern slope of this hill a wide fissure had been opened, which had produced heavy landslides, gave rise in the minds of the people to the idea that an eruption might take place from any of the mountains of this island. On the 19th the shocks became stronger, and during the stillness of the following night the noise produced by the heavy stones rolling down the slopes of the mountain after the shocks could be heard at great distances. On the 21st at 4 o'clock a. m. a violent earthquake shook the island, causing considerable damage to the stone buildings. On the flank of the mountain the sight was dreadful. The rolling masses of stone were destroying trees and plantations, while the opening of fissures caused a noise like that of a great storm. The inhabitants of the town were terrified and from this moment began to escape in their boats to the neighboring coasts of Mindanao and Bohol in search of safety.

From the above the reader may form an idea of the events which announced the eruption of 1871. During the months of March and April earthquakes succeeded one another with the same frequency and were accompanied by effects identical with those just described. The active area of some of these earthquakes was very extensive, for they were felt strongly throughout northern Mindanao and in the islands of Bohol, Cebú, and Negros. The inhabitants of the towns in the neighborhood of Mt. Catarmán, with the exception of a few of the bolder spirits and some of the very poor, fled from their houses. Hence it is that when the eruption actually took place it found very few victims.

At last the shocks suddenly ceased. When day broke on April 30, at the foot of Mt. Catarmán, which had been so shaken by the preceding earthquakes that it exposed its skeleton through the landslides and fissures, a column of thick vapor was seen rising up into the sky near the sea and about 400 yards distant from the town of Catarmán. This column of vapor disappeared completely some hours afterwards.

At about 7 p. m. of the same day a tremendous explosion was heard in the direction of the above-mentioned spot, accompanied by a dense cloud of smoke, which came from the same place. Everything roundabout was set on fire. At the same time a shower of stones, earth, and ashes was vomited forth from the recently made openings. The ashes rose to a considerable height, spreading out and reaching Cebú and

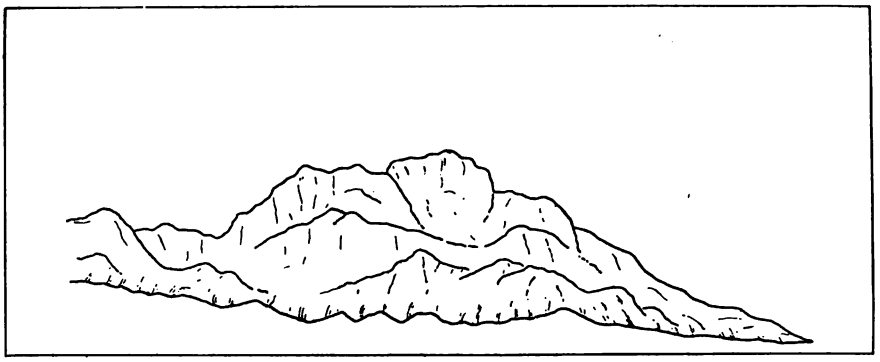
other islands 110 miles away. Within a radius of 2 miles from the new crater the destruction caused by the shower of fire, stones, earth, and ashes was almost complete; but fortunately there is no report of many human victims, evidently because the inhabitants of Catarmán, which the destruction reached, had fled in due time to safer quarters. The eruption continued for six or seven days, after which the paroxysm died down, but the silent flowing of the semifluid lava continued, building up a rough cone, which in two or three weeks' time measured some eight feet in height. Some travelers who visited the place a few weeks after the eruption gave us the following details:

> The base of the volcano lies close to the shore and about 35 feet above sea level. The cone is becoming round and looks like a large burning limekiln. It consists of black stones stuck together by means of pasty incandescent lava. At present the base measures 1,500 feet in diameter. It is smoking, but there does not seem to be any stream of lava. The crater is simply throwing out a kind of paste or cement mixed with earth and heavy stones, which latter, rolling down the sides, cause explosions and emit gases in large quantities, so as to resemble so many small vents.

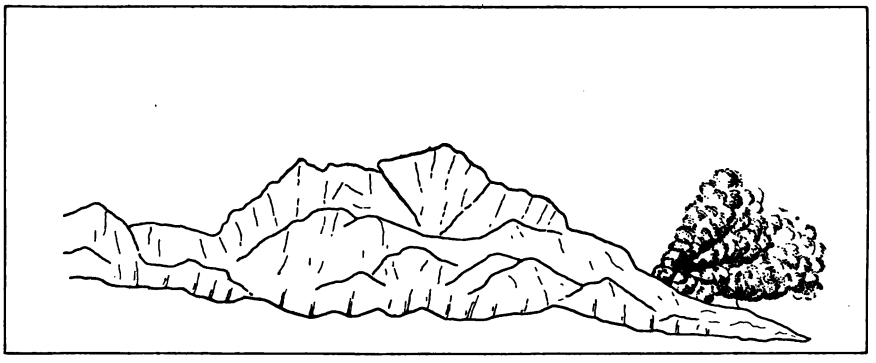
The crater continued in this quiet eruptive state during three years, constantly pouring out solid material. This material kept building up the sides of the cone, not only by being forced over the rim of the crater, but owing to the feeble emissive force from the interior, by accumulating on the interior surface and pushing outward the preceding ejecta that had not yet become hardened. The effects of this outward thrust were frequent landslides and fissures occurring on the sides, thus forming new escapes for the gases. Owing to the character of this eruption, which we might well call laborious, the cone gradually took on the form of a rough dome, which gained daily in height and in extent. Thus, four years after its birth, when it had become to all appearances perfectly extinct, it had reached a height of 1,900 feet, with a base nearly a mile in diameter.

Camiguín was visited by the *Challenger* expedition in 1875. It was then described as a dome 1,900 feet in height, without any crater, but still smoking and incandescent at the top.

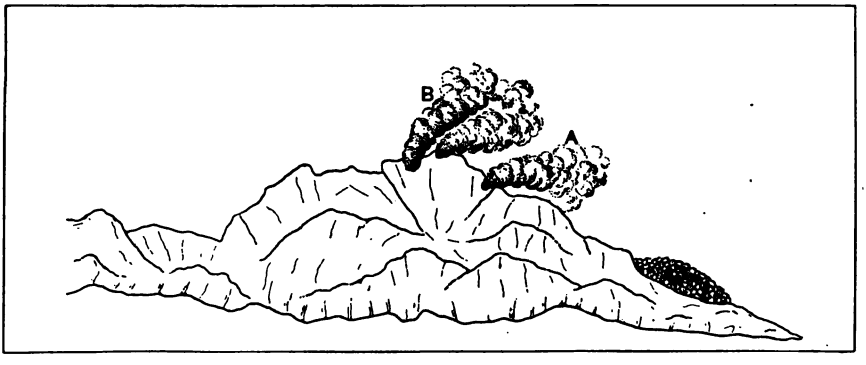
With the same form, but completely extinct, it can be seen to-day rising out of the western slope of the steep green hill of Catarmán, appearing like a rough appendage to the mountain, scarred with fissures and covered with sharp rugged stones. From the above it may be seen that the true eruption, or actual throwing out of the ejecta, which forms the existing cone, lasted for a period of about four years. For some time afterwards gases and vapors were emitted continuously; later on only at intervals, until at last such action ceased altogether and the volcano lost all signs of activity and heat. Such has been its condition for the last twenty years, and thus it stands to-day, exposed to the destructive influences of the atmospheric elements, which in this climate have a powerful effect.



OUTLINE TAKEN FROM SEA LOOKING SOUTHWEST.
PREVIOUS TO APRIL 30th 1871.



AFTER APRIL 1871.




A - SOLFATARA APPEARED, 1897.
B - " " ON JULY 27th, 1902.

*Appearance of new solfataras in 1897 and 1902.*—After centuries of inaction (just how long is uncertain) the main cone or hill of Catarmán, upon which the above-described crater leans, began in 1897 to show signs of awakening. From the previously mentioned crater lake, at the top of the mountain, there began to issue a constant column of white sulphurous vapor that killed the neighboring vegetation, and even destroyed the plantations that existed on the northeastern and southwestern slopes of the hill. I have been told by some gentlemen of Mambájao that when the winds are from the northeast and the vapors are blown down the southwestern slopes of the mountain, the leaves of the trees fade and drop, the earth is made bare of vegetation, and the branches become covered with a kind of sulphurous powder. But when the wind changes, and a little rain has washed the powder away, the trees and earth again don their green dress. The accompanying sketch was made in the month of July, while the southeast wind prevailed. Thus a view of the northeast side is presented, which was then of a brownish color. According to the gentlemen above referred to, no earthquakes nor other unusual events preceded the appearance of the new solfataras of 1897. But it must be remembered that this year was noted as one of extraordinary volcano-seismic activity in the archipelago. It was this occasion that called forth from Father Coronas, S. J., the two valuable pamphlets, La Erupción del Volcán Mayón el 25 y 26 de Junio de 1897 and La Actividad Séismica en el Archipiélago Filipino durante el Año 1897. In the latter he points out the radiating centers of the different seismic periods reported up to the end of the year: That of Zamboanga, September 21; that of Sámar, October 19 and 20; and another lasting till March, 1898. The appearance of the new fumaroles of Camiguín must probably be referred to one of these seismic periods, although this volcano has apparently never been the radiating center of any of the more important earthquakes of this year. Probably some of the feeble shocks felt at Cebú, Negros, and Iloílo were connected also with this volcanic center.

Up to July, 1902, no further change had been observed in the mountain. A cloud of white vapor, more or less thick according to the degree of humidity of the atmosphere, was continually rising from the summit, and that was all. The inhabitants of the neighboring towns looked at it without the least anxiety or fear. However, on the 9th of said month, between 2 and 3 o'clock in the morning, hollow sounds were heard which seemed to proceed from the mountain. But when day broke no change was noted in the appearance of the volcano. During the night of the 27th, at about 1 o'clock a thunderstorm was heard rumbling about the mountain and when day broke the people were surprised by the sight of a new solfatara that was seen issuing from a fissure near the summit, on the opposite side

from the old one and separated from it by the large crest that forms the eastern ridge of the ancient crater. It is not known whether any rumbling sounds preceded the bursting out of the new solfatara, or if these were confounded with the rolling thunder of the storm. I happened to reach the port of Mambájao on board the steamer *Aldecoa* at 7 o'clock on the morning of the 27th, and was astonished at being shown the new solfatara and being told that it had appeared only the night before, during the thunderstorm. I can certify to the fact that when I arrived the vapor was issuing in a thin white column from only one fissure extending downward from the top; but three or four hours later vapors were also rising from a little depression that ran horizontally farther to the right; later on during that day, and during the next, when I left Mambájao, no further change could be observed. We received a letter from Mambájao, dated September 8, in which we were told that the fumaroles that appeared on July 27 disappeared within eight or ten days; but that on the other hand, since their disappearance, frequent subterraneous sounds had issued from the volcano.

### ISLAND OF CEBÚ.

In this island, where the most important coal region of the Philippines is located, there is no seismic center. The few earthquakes that have been felt there have probably radiated from seismic centers situated in other islands. The most violent were those which came from the volcano of Camiguín. An earthquake occurred on the 6th of December, 1882, causing damage to the buildings of Bantayán, a village situated in the north of Cebú. Another violent earthquake occurred on the 23d of July, 1885, at 10.55 p. m., its center being near Dapitan (Mindanao).

### SÁMAR AND LEYTE.

From the scant data obtained from these two islands it is difficult to ascertain whether the radiating center of the earthquakes felt there is situated within or without the islands; whether, for instance, the shocks come from Mayón in the north, or from Surigao in the south. There is no doubt that the Mayón earthquakes more frequently exert their influence in the direction of these islands than in that of the Camarines. A certain repetition or extension of the seismic action of the Mayón earthquakes has also been observed in the islands of Leyte and Sámar, and even in Surigao. The only signs of the volcanic activity found on these islands are certain solfataras or sulphuric emanations. Mr. Becker summarizes the volcanic vents of Leyte and those of Biliran and Maripipí, lying north of it, as follows:

> In the island of Leyte there are two volcanic vents in the solfataric phase from which much sulphur has been gathered. They lie to the southward of Burauen, in the northeastern portion of the island, and were visited by Jägor. The more south-

erly is called Mt. Danán. The other is called the crater of Kasiboi, and lies, according to Jägor, on a mountain named Manacagan. This mountain, on Mr. d'Almonte's map, is called Himaiacagan. Jägor describes the rock as "very hornblendic trachyte." It is probably the rock determined by Roth as hornblende-andesite. Roth probably refers to Kasiboi when he states that the outflow of the solfatara at Dagami (some miles north of Burauen) forms a brook with a temperature of 50° Réaum. = 145° F. The Guía Oficial mentions a volcano at Burauen called Caolangojan, which, I suppose, is another name for one of those just referred to.

The island of Biliran is well known for its sulphur deposits, the best in the archipelago. The sulphur occurs in solfataras, some of which are extremely hot, Mr. Abella getting temperatures of no less than 115° C., which would show that the water is a strong solution of some salts. These hot springs contain pyrite of recent formation "produced by the reducing action either of an excess of sulphur or of vegetable remains, brought by water or wind, on the iron sulphate which had previously formed." Mr. Abella says nothing of craters, but refers the solfataras to still existing volcanic action. He compares the phenomena on Biliran to those near Burauen in Leyte, and calls attention to the fact that the volcanic range continues southward through Panaón to Surigao, Mindanao, while to the northward it is connected through Maripipí and other small volcanic islands with Bulusan on Luzón. Maripipí, by the way, is represented by Mr. d'Almonte as a conical island, almost round, about 3.5 miles in diameter and 3,000 feet high. Its plan is very much like that of a volcanic cone. The chief rock of Biliran is described by Mr. Abella as containing greenish and black hornblende and phenocrystic feldspars in a feldspathic ground-mass, while augite and magnetic iron are sometimes visible. This description makes it substantially certain that the rock is hornblende-andesite.

Not far from Maasin there are some sulphurous springs and it is stated also that near Cabalían lies an active solfatara.

The destructive earthquakes which shook these islands during the past years are the following:

TABLE 5.—*Earthquakes in the islands of Sámar and Leyte.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1868.... | April ..... | 4 | ..... | Violent in Leyte. What occurred in Sámar is unknown. |
| 1869.... | August ..... | 16 | 3.00 p. m. | Long seismic period commenced. The only destructive earthquake was that of the 16th of August; its greater violence was felt in Masbate, where, in addition to the ruin caused to buildings, the earth was rent with long, deep crevices, and small islands even are recorded to have disappeared in the region north of Ticao. Information is lacking from Albay, where the shock was probably still more violently felt. |
| 1870.... | March..... | 2 | 3.00 a. m. | Not destructive, and felt more in Sámar than in Leyte. |
| 1873.... | March..... | 19 | 1.00 p. m. | Area of action small, and the only damage caused thereby was in the pueblo of Mercedes (Sámar). |
| 1877.... | July ..... | 23 | 4.24 p. m. | Violent, especially so in Leyte. |
| 1890.... | February... | 7 | 0.40 a. m. | More violent in the north of Sámar than in the island of Leyte. |
| 1897.... | October..... | 19 | 8.05 a. m. | Destructive in the northeast of Sámar. |

## WESTERN MINDANAO AND THE VISAYAS.

This southwestern district lies south of 12° north latitude and west of the meridian 123° 30′ east of Greenwich, and comprises the western portion of Mindanao, the Joló and Mindoro seas, and the islands of Negros, Panay, and Paragua. There are few important seismic foci in this district.

SEISMIC CENTER OF ZAMBOANGA AND JOLÓ.

The seismic area of this center comprises the most westerly part of Mindanao or the southwestern region of the peninsula united to the rest of the island by a narrow neck of land between Panguil and Illana bays. The Zamboanga and Joló earthquakes rarely extend their influence beyond the said western peninsula, owing partly to the configuration of land and perhaps more especially to the distance of the center which is situated in the sea north of Joló archipelago. Consequently Zamboanga is located between two submarine centers, viz, that very probably situated in Illana bay and the center in the Joló sea. The existence of this latter volcano-seismic center was determined with certainty, in the year 1897. In the old chronicles there is mention of an eruption which took place in some island of the Joló group; there is a report of an earthquake and eruption in the land of the Igorot, northern Luzón; and of two others, which occurred at the same time, one at the Sanguil volcano and the third at Joló. The record says:

> And although at the time the darkness and atmospheric disturbances were so great that the people of Joló could not perceive whence came the stuff which fell from heaven upon them, yet when it became light it was observed that at the same time when the volcano burst forth at Sanguil, Mindanao, the elements there also had become excited, and that a second volcano had opened on a small island which lies opposite the bar of the chief river of Joló, where is our military station. The crater of this volcano is still open. Semper and Jägor, says Mr. Becker, are of the opinion that such an eruption really took place, but no further outbreak is known to have occurred there, and the remains of the crater have not been described of late years, so far as I know.
>
> The charts show crater-like depressions at the southern end of Cagayán Joló, one of them broken down at the edge and admitting the sea. Capt. Charles S. Perry, U. S. Navy, who landed there to raise the American flag, informs me that these are unquestionably craters, but that they are to some extent covered with vegetation and can not therefore have been active very recently. They seem first to have been recognized as craters by Mr. F. H. H. Guillemard.

The origin of the earthquakes of 1897 must be placed in the sea of Joló not far north of this island; the damage to buildings, the displacements and fissures produced on land, and the waves on the sea were tremendous. Father Coronas, S. J., gave all the details of this great disturbance in a pamphlet published soon after the event.[1] Omitting the description of the damage done to buildings and the fissures opened, especially those near the seashore at Zamboanga, Basilan, and Joló, we will deal with the tremendous movements of the sea. The memorable sea waves observed after the earthquakes of Lisbon, Calabria, Chile, and Peru, as well as those which occurred after the eruption of Krakatoa, were renewed in this district. The destructive

[1] La Actividad Seísmica en el Archipiélago Filipino durante el Año 1897.

shocks occurred on the 21st of September at 1.17 p. m.; two hours later another lighter earthquake was felt and immediately afterwards came the sea tides and waves. At Zamboanga the swell occurred two full hours after the big earthquake; many times the awful waves advanced rapidly into the town and even swept some places which were 20 feet above the sea level. Small crafts lying near the shore were thrown out and even some ships at anchor were carried to and fro. All the inhabitants began to flee to look for a safer place inland. All along the coast, west of Zamboanga, the waves invaded the shores with the same fury and on retreating swept away many native houses, not a few of which, unfortunately, were occupied at the time.

The island of Basilan experienced the same disturbance but sooner than at Zamboanga. The waves were higher than at Zamboanga, probably because the latter was protected by the flat island of Santa Cruz lying in front of its harbor. The waves began to rush against the island some thirty minutes after the earthquake, and swept away some Moro villages on the western coast, and the market and other houses situated near the wharf in the town of Isabela. The gunboat *Lezo*, at anchor in the harbor, was carried by the waves or flood and had a narrow escape. The waves advanced against the coast and retreated many yards beyond the tide line, with the same rapidity, at least thirty times. There were many victims. At Joló, the seismic tide began some fifteen minutes after the earthquake shocks. The first movement was an ebb, the water retreating farther than the low tide limit, then it rose again with tremendous fury, repeating the process six or seven times. No damage was caused at Joló by the waves, because their velocity and height was less than at Basilan and on the west coast of Mindanao. Extraordinary sea movements were noticed all along the southwestern coast of Negros, the western coast of Panay, the southern coast of Paragua, the eastern coast of Borneo, and one might say on all the islands and lands facing the Joló sea. Certainly there must have occurred some great submarine displacements or eruptions to cause such a wide perturbation. There is an event which is fully proved, namely, the sudden rising of a mud bank or island at Labuan, near the northwest coast of Borneo, on the same day and hour of the destructive earthquake. Mr. Van den Brock, a resident of Labuan, in a letter kindly sent to the observatory, gives the following details:

The dimensions of the island are as follows: Length, 750 feet; breadth, 450 feet; height, 45 feet.

As to the general aspect of this island which appeared from the depths of the sea, I may say that it is flat; still in the middle of it there is an elevation in form cone-shaped and in general appearance very much like a crater; and from it mud and clay come forth. The diameter of the lower part of the crater is some 180 feet. Inflammable gases are emitted from many cracks or crevices.

Another new island also appeared the same day, near Kudat, to the southeast of the island of Malundangan. It is rectangular in form, measures 360 feet in length,

300 feet in breadth, and but 3 feet in height. This island according to what the natives say, rose from the sea during the morning of the same day, the 21st. They saw the waves approach; they felt a strong and violent wind; they heard a loud noise; and in an instant the island rose on the spot where before the sea had been more than 20 feet deep.

In this letter there is not the least indication of any sea movement; the seismic shocks were felt there but lightly, so that the rise of these islands does not seem to be the cause of the perturbation experienced in the Joló sea and, therefore, there must have occurred some faults or displacements which produced it. Some days later the newspapers of the Visayas published a letter from Joló in which it was stated that some Moro mother-of-pearl shell fishers reported that the island Dammi, lying between Siassi and Tawi Tawi, disappeared during the earthquake and in the island of Tubigon, near Pañgutáran, a crevasse or channel was opened dividing it into two parts. Although these data are not entirely trustworthy, still big displacements must undoubtedly have taken place in the Joló sea north of the Joló group and west of Zamboanga and Basilan. At Zamboanga, owing to the fact that the highest wave came almost simultaneously with the second violent earthquake, it was believed that some displacement or fault had occurred very near. Not only through the plains but also on the northern mountain slopes the ground remained badly fissured and great landslides were produced.

The disturbance which occurred on the 21st of September was a very macroseismic one, since the vibrations produced were registered all over the world by the microseismographs. Afterwards this region remained in a very unsettled condition as is shown by more than 500 very perceptible shocks felt during the following eighteen months; weaker shocks during this long period were countless. As has been indicated in the introduction, these south seas are considered an unstable region, the suboceanic disturbances being very irregularly distributed; but the history of the islands does not show any disturbance similar to that just described. Further details and conclusions may be seen in the pamphlet of Father Coronas. The most violent earthquakes recorded for this region are the following:

TABLE 6.—*Earthquakes in the seismic center of Zamboanga and Joló.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1871.... | November.. | 29 | 4.30 p. m. | Caused slight damage to buildings. |
| 1874.... | August ..... | 25 | 6.30 a. m. | Damaged buildings, and the ground was cracked on all sides. |
| 1885.... | July ..... | 23 | 10.45 a. m. | Very violent. |
| 1889.... | February... | 2 | 4.30 a. m. | Apparently radiated from a submarine center toward the east. |
| 1897.... | September.. | 21 | 1.17 p. m. | This earthquake was a very remarkable one. |

## SEISMIC CENTER OF PANAY.

Although many earthquake shocks felt in this island can be referred to the volcano seismic centers of the neighboring island of Negros, nevertheless there exists in the southeastern part of Panay a well-known seismic center. Many violent earthquakes, which were mainly felt in the Iloílo province, had their origin in this center. The last one occurred on the 26th of August, 1902. We will transcribe here the report written on that occasion referring to the location and conditions of this center. It seems to belong to those called by Milne macroseismic centers.

From the data at hand, then, we would locate the epicenter at the foot of the abrupt and rugged abutments of the eastern side of Mt. Tuaman or Duyan, and Mt. Tiguran, which are found deeply scarred by any number of streamlets and torrents that rise in the mountains, flowing thence into the Tigón and Aganan, which in turn pour their waters into the Sálog, which empties finally into the sea at Nagtacán.

The surface of this region is very wild and rugged and is composed of Tertiary formations; conglomerates and calcareous or limestone formations predominate, with underlying arenaceous and argillaceous beds. These latter beds contain considerable amounts of lignitic and carbonaceous matter in many places. Inflammable gases arise from these beds at various points, the best known being those at Igpalang creek, and at the spring or well at the barrio of Binalod. At other points there are outcrops of salt and numerous salt springs, the water of which, being more or less saturated with sodium chloride, the poor people utilize by evaporating it and obtaining the salt for domestic purposes. Such a constitution of the soil under the circumstances indicates that the soil there is not of the firmest consistency and is liable to cave in at times and to be subject to other disturbances.

There are at present very few manifestations of volcanic action in the island of Panay, and these are confined to a number of thermal mineral springs that are situated at great distances from the region of which we have been speaking.

## OTHER EARTHQUAKES OF PANAY.

If we look backward through the years we notice that there are very few important earthquakes on record as having been felt in this island. The first and most disastrous one recorded occurred July 13, 1787. All the houses in the province of Iloílo were almost completely destroyed; nothing was heard from the other provinces. In these later years there were some very violent ones; for example, the one of July 11, 1881. Those living at the time had never experienced one of equal intensity. Others occurred on February 12, 1885, April 10 and October 29, 1886, January 25 and February 2; 1887; this last one did some damage to the buildings. Another took place on July 20, 1889. It should be noticed that, with the exception of the earthquake of February, 1887, which was felt with great violence all over the island of Panay and in the neighboring island of Guimarás, all these earthquakes seem to have been felt more violently in the province of Iloílo. Secondly, in nearly every case, even in the case of those that would scarcely be denominated violent earthquakes, they were either preceded or accompanied by subterraneous sounds.

The volcanic vents of the island of Negros are thus described by Dr. Becker:

On the island of Negros there are two volcanic vents. One of these is a very small affair at the southern end of the island, some 10 miles from Dumaguete, on the southeastern slope of the Cuernos de Negro. It is called Magasó. I was told in Dumaguete that vapors arise from a small crater-like vent, and that there are cracks in the hot rock in which a stick will inflame. There are sulphur deposits and strong sulphur springs at its base. The Cuernos are largely, so far as I know, wholly andesitic. The volcano of Canlaón is in the central range of the island, of which it forms a culminating point. It lies in latitude 10° 24′ 35″. The upper part of the mountain has the typical form of a volcanic cone, but this portion rests upon a more irregular mass, which forms a portion of the range stretching northward for some 30 miles. The Spanish hydrographic office gives the elevation at 8,192 feet, so that it would rank with Datá and be exceeded only by Halcón, Apo, and Mayón. It is visible from near Iloílo and can be seen even from vessels cruising on the eastern side of Cebú. From the sea on the western side of this island, called Tañón Passage, Canlaón is a very impressive spectacle, for, in addition to the picturesque form of the cone, steam is always pouring out from at least two vents at the summit. No violent eruptions are remembered, but ash has been ejected from time to time. The last considerable ash fall occurred, as I was informed at San Carlos, in July, 1893. There was also an eruption in 1866. Andesite is the prevailing rock of this region, as shown by the stream pebbles, and I suppose Canlaón andesitic. On some Spanish maps and in Jägor's Travels this mountain appears under the name Malaspina.

In May and June, 1894, ashes fell on many towns around, and more recently, on the 31st of January, 1902, the volcano was throwing out fluid lava during the night in the midst of a display of light. An earthquake, not very violent but perceptible at a distance of many leagues, coincided with the outflow of lava. In May, 1902, in the region of the solfataric volcano Magasó, there was a seismic period which lasted some days, with frequent earth movements of no great intensity, while at the same time an extraordinary increase in the amount of gases emitted by the volcano was noticed. Owing to the scarcity of records of earthquakes felt in the island of Negros, it is impossible to know the seismic activity of these centers. In the year 1896 Mr. Mencarini, a well-known publicist in the Far East, ascended the volcano of Canlaón, reaching the wide terrace where the lowest solfataras issue. He took, also, some photographs, but a coming storm prevented further examination.

## SOUTHEASTERN LUZÓN.

This region forms the third meteorological district, and extends northward from parallel 12° north latitude, and eastward from the meridian 122° east of Greenwich. It comprises the southeastern part of Luzón, including the Camarines, Albay, and Sorsogón, and the islands of Catanduanes, Ticao, Masbate, and Burias, and the northern part of Sámar. In this district is situated the most active volcano and one of the main seismic centers of the archipelago.

VOLCANO OF MAYÓN.

We think it best to repeat the description of this volcano made by Doctor Becker in summarizing those of Mr. Abella and other authors:

Mayón, or the volcano of Albay, is, next to Taal, the most famous Philippine volcano. It is possibly the most symmetrically beautiful volcanic cone in the world, and at times its crater is almost infinitesimal, so that the meridional curve of the cone is continuous almost to the axis. The height has been variously determined, and appears to change with each eruption. Since the crater always remains small, the height should tend to increase, but the determinations are probably not sharp enough to develop this tendency. Jägor's barometrical measurement in 1859 was 2,374 meters. The Spanish Hydrographic Commission, according to Mr. Abella, gives 2,522 meters. Mr. d'Almonte's map of 1883 gives 2,527 meters. Mr. Abella himself gives 2,734 meters, but he did not reach the summit, because his visit was made during the eruption of 1881–82, and does not state his means of determining the height. Mr. d'Almonte, however, made a sketch map of the mountain for Mr. Abella's memoir, and I fancy that he measured the height by triangulation. In English measure Mr. Abella's elevation would be 8,970 feet. The rock of Albay is described by Roth and von Drasche as dolerite, but Mr. Oebbeke regards it as an olivinitic augite-andesite.

Albay has had a vast number of eruptions. Father Coronas gives some details as to eruptions in 1616, 1766, 1800, 1814, 1827, 1835, 1845, 1846, 1851, 1853, 1855, 1858, 1868, 1871, 1872, 1873, 1881, 1885, 1886–87, 1888, 1890, 1891, 1892, 1893, 1895, and 1896, and he describes the eruption of 1897. According to the newspapers, there was an eruption early in 1900. Some of these eruptions have been very serious. In 1814 about 1,200 lives were lost (Jägor, by error of transcription, says 12,000), and the country was covered with ash. Many picturesque details may be read in Perry or elsewhere. Of more permanent interest than the destruction of life and property is the character of the emanations. Mr. von Drasche, adopting Stöhr's hypothesis of three periods in the life of a volcano (first, that of lava flows; second, that of agglomerate flows; third, eruptions of ash), considers Mayón in the second stage, and says that the ash eruptions are seldom interrupted by small lava flows from the summit. Mr. Abella states from observation that the ash ejections are small and preliminary to extensive flows, and Father Coronas gives a map of the flows of 1897, when lava from the summit poured down in various directions, even reaching the sea at a horizontal distance of about 6 miles from the crater. In 1897, however, there was much ash as well as flowing lava. An area of about 4 square degrees was covered with ash, which, nevertheless, formed an orogenically insignificant layer at points considerably removed from the foot of the mountains. At Tabaco, less than 10 miles from the crater, the inhabitants were reasonably in fear of smothering, but the ash which fell was only 3 or 4 centimeters in depth. Per contra, on the mountain side, the fall was heavy; the village of San Antonio, more than 4 miles from the crater, was so buried under lava and ash that the ridgepoles of the houses were hidden. It would appear from the descriptions that a very considerable part of Mayón consists of a solid framework of lava flows, which alternate more or less irregularly with ash eruptions, but that the external form of the mountain is determined by showers of ash and coarser fragmental ejecta. I can hardly believe that there is ordinarily any such regularity in the life-history of a volcano as is implied in Stöhr's hypothesis. Study of the history of Mayón and comparison with other volcanoes show that the form of the vertical cross section is a definite one (depending on the resistance of the material to crushing), and it follows that the material ejected during any considerable eruption is so distributed that the vertical depth of the added layer is substantially uniform from the summit to the base. Of course, more material

falls near the top than near the bottom, but more rolls down from the steeper slopes of higher portions than from the gentler slopes near the foot. If each particle were to remain where it fell the slope would become steeper at each eruption and the mountain would tend toward the shape of a cylindrical column.

Some months after the eruption of 1766, in October, havoc was produced by a typhoon. It is reported in a letter of the alcalde of Albay as a new, awful eruption, but all probabilities induce us to believe that there was no eruption at all. "Although in this letter and in other old accounts," says Father Coronas, "all the damage is attributed to a terrible eruption, nevertheless it seems certain that it was due to the extraordinary violence of one of these giratory storms known in these regions by the name of 'baguios,' which, with the fury peculiar to them when near the vortex, threw down from the sides of the mountain immense quantities of lava and loose stones, which fell upon the plain and over the neighboring towns and completely covered them." A similar storm is reported to have taken place on the 31st of October, 1875, in which, according to Mr. Abella, the effects of a strong baguio were felt, which caused the death of 1,500 people and enormous damage, greater, indeed, than any of the volcanic eruptions.

The eruption of 1814 is reported by the parish priest of Guinobatan as follows:

Repeated earthquakes took place the night before, and they continued during the morning of the 1st. There was then a stronger shock, and at the same moment a cloud of smoke rose from the mouth of the volcano. The cloud rose in the form of a pyramid and then assumed a feathery appearance which was very beautiful. As the sun was shining the phenomenon presented varied colors. The top was black, the center took on various colors, while the sides and lower part appeared of an ashy tint. While we were watching this, we felt a strong earthquake, which was followed by loud noises and rumblings. The volcano then continued to vomit forth lava, and the cloud extended till it darkened the whole district, and then sparks and flashes seemed to come from the ground and from the cloud, so that the whole presented the aspect of a most terrible storm. There followed almost immediately a rain of large, hot stones, which broke and burnt whatever they fell upon. A little later smaller stones, sand, and ashes were thrown out for more than three hours. The towns of Camálig, Cagsaua, and Budiao were entirely destroyed and burnt, and the towns of Albay, Guinobatan, and Bulusan but partly destroyed, because the eruption was not on that side of the mountain, and also because the wind was from the south. The darkness caused by the eruption was noticeable as far as Manila and Iloílo, and, according to some, the ashes erupted passed as far as China.

An account of what happened during other eruptions, which caused much loss of life, may be seen in the list of the eruptions which we give a little further on. We reproduce the notice of the last eruption only, which occurred in March, 1900. This notice was kindly sent to the observatory by Col. Walter Howe, of the U. S. Vol. Infantry:

I have the honor to report an eruption of the volcano Mayón (8 miles from Legaspi), commencing on March 1, in the afternoon about 2.30. At this time the ction of large stones could be seen with the naked eye.

The eruption fluctuated from time to time, but gradually grew worse, until large streams of red-hot lava could be seen at night flowing down the mountain. One of these streams apparently has reached the sea about 6 miles from here. For one day and night the eruption was accompanied by a rumbling noise, at times increasing to a roar, which was very terrifying. All the houses in Legaspi shook, windows and doors rattling. On the morning of March 3, this vibration and noise was very trying; there was no wind, and the clouds of smoke only could be seen, reaching far into the heavens, perhaps 5 miles or more above the top of the volcano. This spread out and covered the town; the sun became obscured, and a thin cloud of ashes fell constantly. It cleared in the afternoon sufficiently to show about one-half the crater at sunset, but the rumbling and roaring, with the flow of lava, continued all night.

This morning (March 4) the eruption seems to be practically over, although smoke obscures the mountain, and steam is still rising from the hot lava.

The volcano of Mayón has been ascended and examined many times since the Conquest. Early in 1592 two Franciscans made the first ascent, but they did not reach the summit being prevented by two mouths or small craters, so turned back, after gathering some samples of sulphur. In May, 1823, Capt. D. Antonio Linguienza reached the summit. He wrote a report of this ascent for a scientific society of Spain, by which he was rewarded with a silver coin or medal. Later on, two Scotchmen made another ascent. Mr. Jägor, in 1859, and Mr. von Drasche, in 1876, ascended and examined the summit, being the first who gave a full description and some views of the crater.

Mr. Abella says in his report that there were many Spaniards and natives in the towns about the volcano who had made the ascent. There was one among the guides of Mr. von Drasche who had reached the summit on three different occasions.

Quite recently (in 1902), a party of Americans made the ascent and took many photographs of the crater.

Concerning the form and state of the crater, Mr. Abella writes as follows:

From the descriptions of those who have written on the subject, it would appear there was not a true hollow crater, or that, if there had been one, it has been filled up with the material from the interior.

What can be seen at the present day, either from the two towns or the slopes of the volcano, or from the sides when we saw it, is a sort of enormous sieve, formed by the fragments of large stones piled on top of one another, through the crevices of which many little jets of vapor are rising. When these jets of vapor unite they form the immense feather-like cloud on the top of the volcano. It would appear, however, the only mouths which emit lava are the secondary ones on the south of the mountain, especially if we fix our attention on the vegetation on the sides of the volcano. Toward the south the vegetation stops at a height of 700 meters above the level of the sea, while on the north and west sides it grows up to the very crater.

This would seem to indicate that the products of the volcano have not been thrown out in these directions for a long time past. Moreover, on the north side the ground is much firmer and more solid, and is not fissured as the south side.

TABLE 7.—*Eruptions of the volcano of Mayón.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1616.... | ..... | ..... | ..... | The most ancient eruption reported, but without precise date or any remark. |
| 1766.... | July ..... | 20 | ..... | It lasted six days, during which an immense column of ashes and smoke rose in the air and a stream of lava poured down the east side of the volcano. It is reported that some months after this eruption, in October, the heavy rainfall accompanying a violent typhoon carried down disintegrated fragmental ejecta, burying plantations and whole villages. A similar storm is reported to have occurred in October, 1825, which destroyed the lives of about 1,500 persons. |
| 1800.... | ..... | ..... | ..... | Many, but not very destructive, eruptions. |
| 1814.... | February... | 1 | ..... | Dreadful eruption, which well-nigh buried under its streams of lava and ashes the whole country around the towns of Budiao, Camálig, and partially destroyed Guinobatan and Albay. About 1,200 lives were lost. The ashes were carried through the air as far as the coast of China, and the darkness produced by the clouds of ashes extended even over north Luzón. Since the year 1814 many slight eruptions have occurred, such as those of July, 1827, March, 1835, January, 1845. |
| 1853.... | July ..... | 13 | ..... | Eruption of very short duration. During three or four hours the crater belched forth smoke, ashes, and heavy stones, which, rolling down the steep slopes of the mountain side demolished many houses and killed 35 persons. |
| 1855.... | March ..... | ..... | ..... | Not violent. |
| 1858.... | ..... | ..... | ..... | Lava flowed quietly from the summit during the greater part of this year. |
| 1868.... | December .. | 17 | ..... | Small eruptions. |
| 1871.... | .....do ..... | 8 | ..... | Moderate eruption; some lava streams flowed eastward. |
| 1872.... | September.. | ..... | ..... | This one lasted four days, accompanied by strong rumbling sounds. No loss of life or property. |
| 1873.... | June ..... | 20 | ..... | Longer than the preceding one, but of the same peaceful character. |
| 1881.... | June ..... | 6 | ..... | Very long, but weak; it began on the 6th of June and ended in August, 1882. The lava flowed from many crevices near the summit and was accompanied by rumbling sounds. |
| 1885.... | November.. | 21 | ..... | Flows of lava on the south, southeast, and southwest sides of the volcano. |
| 1886.... | February... | 8 | ..... | Long eruptive period; lava flowed quietly, except on the 8th, the 22d, and 27th of February, 1886, and the 1st and 9th of March, 1887, when the manifestations increased, the crater hurling forth ashes, stones, and igneous vapors, with an accompaniment of rumbling sounds. |
| 1888.... | December .. | 15 | ..... | Small and short eruption. |
| 1890.... | September.. | 10–30 | ..... | Small and short eruption. |
| 1891.... | October .... | 3 | ..... | Small and short eruption. |
| 1892.... | February... | 20 | ..... | A very noisy eruption, but not destructive; the flow of lava was very abundant and the summit of the crater was greatly deformed, the thin edges of which completely disappeared. |
| 1893.... | October .... | 4 | ..... | Similar to the preceding one. |
| 1895.... | July ..... | 20 | ..... | Very weak. |
| 1896.... | August ..... | 31 | ..... | Very weak. |
| 1897.... | June ..... | 25 | ..... | Very strong eruption, lasting twenty-four hours. Great loss of life (350 victims) and property. |
| 1900.... | March..... | 1 | ..... | Strong eruption, lasting four days. |

Around the beautiful cone rise many small ones, described by Mr. Abella as follows:

The hill to the northeast, which dominates the town of Malilípot, has two or three tops, which are in a straight line. They are rounded, which might indicate that they were secondary cones which have been modified by the eruptions of Mayón. The same hill, Tancolao, situated to the southwest of San Antonio, has the form of a pointed cliff between the old and actual course of the river Quinali.

Toward the north it is an abrupt cliff, at the foot of which is the road from Tabaco to Ligao.

Very much like Tancolao, though much larger, is Linĝión, to the north of Albay. It is at the foot of the Mayón, though its formation is difficult to explain, as is also Tancolao; for even supposing them to be subordinate volcanic cones, it is very difficult to see how atmospheric action could modify them so much.

Northwest of Mayón rise the extinct cones, Isarog, Iriga, and Malínao. Isarog was ascended in the year 1903 by two American teachers, who, in their report to Hon. James Ross, governor of the Camarines, describe the crater as follows:

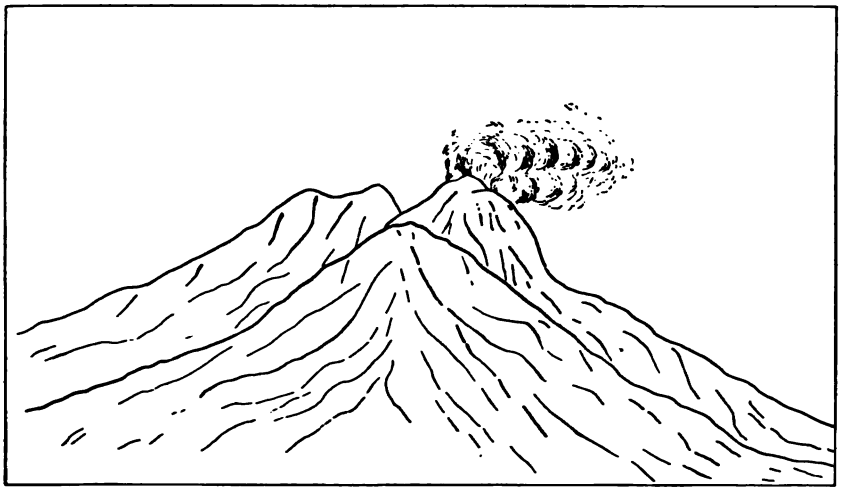
The crater rim is nothing but a knife-edge, but even on the very summit are large shrubs and small trees up to 25 feet in height. So dense is the vegetation that it was impossible to get an outlook in any direction without climbing into the trees and cutting away the smaller branches.

The crater was perfectly clear, though it was cloudy in every direction outside. The bottom of the crater is a comparatively level, wooded plain, almost circular, and about half a mile in diameter. I judge it to be about 2,000 feet below the general level of the rim. To get a better idea of the distances I fired two shots from a Krag carbine at a white spot on the upper part of the great landslide on the southwest side of the crater. With the sight raised to 2,000 yards, the ball fell below the mark. I then aimed over the top of the sight frame, and the ball still fell below, so the distance must be well up toward a mile and a half. A north-and-south line from rim to rim must be good two miles.

Contrary to the usual opinion, there is no such thing in the crater as a lake. From the foot of each of the two great landslides which fell from the rim to the bottom in March, 1902, runs a little stream. A third one appears to come from the cleft which, on the outside of the mountains, forms the canyon of the Maalsom river.

Mt. Iriga has not been examined, as far as we know. The Estado Geográfico also alleges that Iriga, in the province of Ambos Camarines, was in eruption in 1641; but Jägor gives seemingly good reason for believing that this statement, not to be found in earlier works, is a mistake. Many of the extinct cones retain traces of solfataric action, or at least give vent to hot springs.

Mt. Malínao is doubtless an extinct volcano; its crater is broken or opened to the north probably by the erosion of the waters which found their outlet in that direction. At the foot of the north side of this volcano the most remarkable solfataras and hot springs in Luzón are to be found; some of the springs here deposit siliceous sinter in various fantastic forms, and pyritous deposits of recent date are also found.



BULUSAN VOLCANO, LOOKING NE.

## VOLCANO OF BULUSAN.

In the most southern part of Luzón, on the Strait of San Bernardino, lies the volcano Bulusan. Jagor calls attention to the striking similarity of its shape to that of Vesuvius. According to the Guía Oficial, its height seems comparable with that of Mayón. "At present it is nearly extinct, but sometimes emits aqueous and sulphurous vapors." The Estado Geográfico, page 314, states that it began steaming in 1852, after long seeming extinct. Around the foot of this volcano are many hot and mineral springs, especially on the eastern and southern sides.

Its crater is open to the southwest. Among the people there is the belief that this volcano shows greater solfataric activity when the Mayón volcano is in eruption. During the eruption which occurred in 1892, the Bulusan was steaming. Between this volcano and that of Albay there are many spots where the volcanic activity springs out. The hot spring called Manito near Pocdol mountain is a remarkable one. "The reddish hot waters," says Mr. Montero, "issue, forming a waterfall from an elliptic crater, the diameters of which measure some 400 and 200 feet, respectively. This spring is an intermittent one, the waters being pushed out by the vapors at very short intervals; their temperature is almost constantly 70° C."

This volcanic region, the most remarkable of the archipelago, is where the earthquakes also are very frequent. Many of the most violent ones have been of a clearly volcanic character, for they have either preceded or followed volcanic eruptions of the volcano of Mayón.

It has been observed on many occasions that within a few days after earthquake shocks have been felt in the Albay region, shocks are noticed in Sámar, Leyte, and Surigao, as if the disturbing force were spreading to the southeast along the volcanic belt, running to Surigao.

Besides the volcano-seismic center of Albay, there seems to exist a seismic center near the island of Masbate, or between this island and the coast of Sorsogón and Albay provinces. The last outburst of this center occurred in May, 1897, a month before the great eruption of the volcano of Mayón, which took place on the 25th of June. In the following table we mention some of the most violent earthquakes felt in the southeastern region of Luzón:

TABLE 8.—*Earthquakes of southeastern Luzón.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1628.... | ..... | ..... | ..... | The precise date of the occurrence of this earthquake is unknown; it was destructive chiefly in Camarines. |
| 1766.... | July ..... | 20 | ..... | Eruption accompanied by violent shocks during several months. |
| 1811.... | October..... | 5 | ..... | Long seismic period; the shocks felt on the 5th of October damaged many churches and other buildings in Albay and Camarines. |
| 1855.... | March ..... | 22 | ..... | Small eruption, accompanied by a violent earthquake, felt with force throughout Luzón. |
| 1875.... | May ..... | 19 | 11.30 a. m... | Felt more strongly in Camarines than in Albay. |
| 1877.... | July ..... | 5 | 0.07 p. m... | Very violent in Albay and in the islands of Masbate and Ticao. |
| 897.... | May ..... | 13 | 7.44 p. m... | Destructive in the island of Masbate and in some villages in the province of Albay. |

## CENTRAL AND NORTHERN LUZÓN.

This region, which forms the fourth meteorological district, extends from parallel 12° north latitude northward, and to the west of the meridian 122° east of Greenwich, thus comprising the whole of the main part of Luzón and the island of Mindoro. In the southern part of this district lie the active volcano Taal and the extinct ones Banájao, Maquíling, and Aráyat.

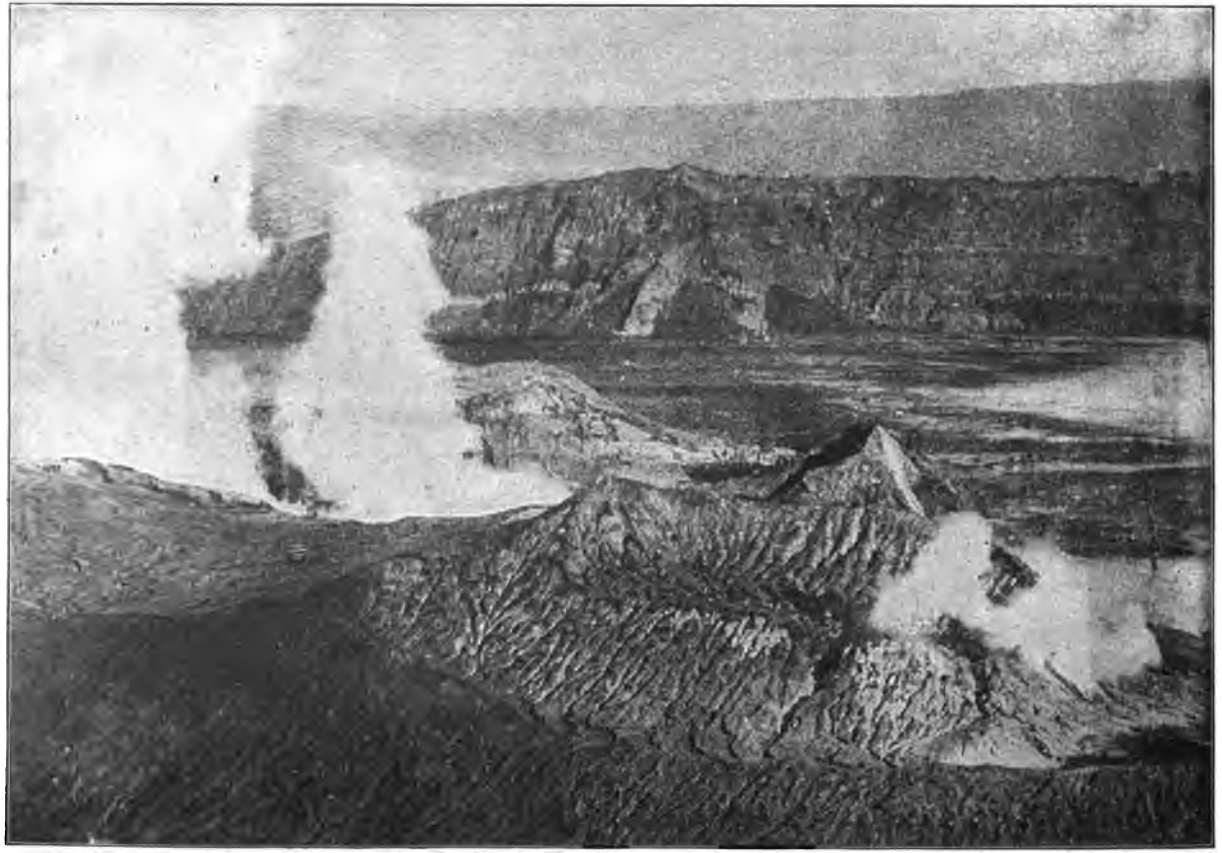
### VOLCANO OF TAAL.

The volcano of Taal (14° 02′ north latitude and longitude 120° 57′ east of Greenwich) is a very remarkable one, and is readily accessible from Manila; it lies in the middle of Lake Bombón. One comparatively large crater and several other small extinct ones virtually form the island of Volcán.

The most important of the secondary cones are the Binintian and Malaquí, forming the northwest corner of the island; it is a well-shaped but truncated cone, and is cut through the western side by a crevasse, which serves as an outlet; on its interior and exterior slopes many layers of volcanic ejecta can be distinguished, corresponding to different eruptions. Not only in the bottom of the crater but also at the western foot of the cone near the lake there is still some activity, manifested by ejections of sulphurous vapors. The flat bottom of the crater is only some 500 feet above the waters of the lake, while the remaining ring or ridge reaches in the southwest to a height of 860 feet, or some 300 feet from the bottom. The diameter of the bottom is some 660 feet.

The Balantoc crater, southeast of the last one, has an elliptic form, the longest diameter measuring more than 1,400 feet; the highest point of its borders rises to some 450 feet. This crater is also broken on the west. There is not the least sign of volcanic activity, and the mingled volcanic ejecta, disintegrated from the bordering ridges, is filling the bottom, and vegetation is growing well. Close to this crater to the south, in a space of not more than one square mile, there are the numerous craters known by the name of Canas; all are of circular form, some 450 feet in diameter. Many of them have been almost filled up with the disintegrated volcanic ejecta, in which the cogon (Saccharum Koenigii, Rets.) is growing. They lie on a slope, the highest being at some 140 feet above the lake and the lowest at the water level.

In the southwest end of the island there rises the old crater Binintian Munti. It is completely extinct, and filled up with disintegrated materials of the falling borders or ridges of the ancient rim; there remain only two edges, situated in the northeast and southwest. The summit stands at 60 feet above the level of the lake, and its diameter or longest axis measures about 1,200 feet. On the denuded slopes of this cone Mr. Centeno distinguished nine different and very distinct layers of volcanic ejecta. Just northeast of Binintian Munti rise



PRINCIPAL CRATER LAKE OF TAAL VOLCANO.

Tabaro, a well-shaped cone, and Tabaro-Munti, of similar form. Along the eastern shore there rises the Pinagulbuan, a fine crater formed on the shore line; only the western part on the shore remains, for the eastern, if it was formed by the ejecta fallen into the water, has been washed away.

The central or main crater is nearly round, its diameter on a north-south line being 1,900 meters (6,233 feet) and the east-west diameter 2,300 meters (7,546 feet). The edge of this crater is somewhat irregular, but is nowhere broken through, its highest point standing at only 320 meters (1,050 feet) above sea level and its lowest at 130 meters (426 feet). It is said that Coshima, in Japan, is the only other volcano of similarly low altitude. Within the rim are two hot pools, known, respectively, as the yellow and the green lake, and a little active cone about 50 feet in height, from which escape steam and sulphurous gas in varying quantities. The level of the interior pools, according to Centeno, is approximately that of Lake Bombón itself.

In the smaller lake, every few minutes, the water in the center is blown up like an immense bubble, which, rising above the surface, finally bursts, revealing a black orifice and causing the boiling and very turbulent water to assume all imaginable colors. The quantity of aqueous and sulphurous vapor escaping from the lakes, from the active cone, and from the opened crevices on all sides, is sufficient to form a broad, smoke-like column of vapor, which is visible especially during the night and in the early morning. At some distance, and before reaching the edge of the crater, where a view of the bottom can be obtained, the rumbling sound produced by the escaping vapor, under the influence of the mysterious subterranean forces, can be heard, like that of an immense boiling kettle.

The changes which this volcano has undergone and the disasters which it has caused since historic times are very remarkable. According to the chronicles of the time of the Conquest, the crater was then on the northwestern point of the island, having a cone which exists to-day, and is called Binintian Malaqui. A few years after the Conquest that crater ceased acting and another appeared on the eastern side of the island, which in 1716 was submerged, leaving above the surface the two islands Nabuin and Napayon. Then a new crater appeared on the eastern side of Pulo Volcán, which was gradually enlarged toward the west until the present crater was formed, which has not changed much since 1754. Among the various eruptions since the Conquest, the most notable are that of 1749, when the village of Lala disappeared, and that of 1754—the greatest of all—when the villages of Taal, Lipâ, and Tanauan, which were then on the shores of Lake Bombón, all disappeared. All the eruptions have consisted of showers of burning ashes and scoriae, between which showers, great blocks of basalt were thrown out, covering the whole region to a depth varying from a few centimeters to two or three meters and

THE GREEN AND YELLOW CRATER LAKES OF TAAL VOLCANO.

causing the different strata of volcanic material which can be seen throughout the province.

The earliest known published reference is by Father Gaspar de San Agustin, written in 1680. This account is given in full by Centeno for the light it throws on the condition of the volcanoes prior to the more recent eruptions, and I have examined the original work. Father Gaspar says: "In this Lake of Bombón there is a small island upon which is a fiery volcano, wont at times to eject numerous and very large burning stones, which destroy and lay waste many cultivated fields which the natives of Taal possess on the slopes of the said volcano." Father Alburquerque, priest of the town of Taal, which lay on the shore of Bombón, but is now destroyed, examined the volcano. He had himself let down into the crater which had two openings, one of sulphur and one of green water which is always boiling. To this place now come many deer, which are attracted by the saline deposits (*salitrales*) existing about the lake of the volcano. The opening which lies toward the town of Lipá (east-southeast) is a quarter of a league in width.

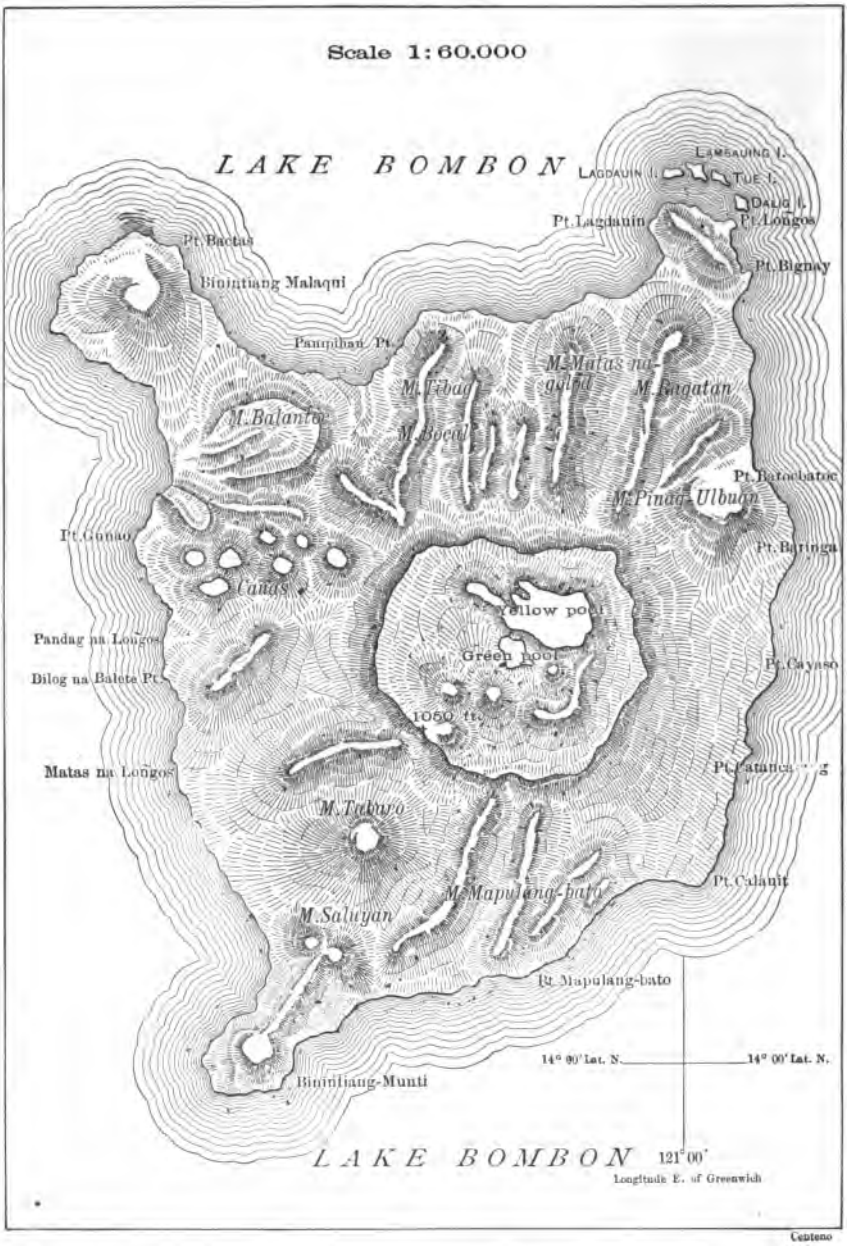
Father Alburquerque was prior of Taal during the period 1572–1575, so that the first historic eruption can be placed a little earlier than the former date. Father Rada mentions it as having occurred in the year 1572.

Again about the year 1591, the volcano began to smoke, when Father Bartolomé de Alcántara was priest of Taal. After this outburst it remained quiet; but during the period 1605–1611, when Father Abreu was priest at Taal, frequent rumblings were heard. Mr. Semper thus summarizes the early history prior to the year 1749, the date of a more serious eruption:

> Two doubtful eruptions are mentioned in the years 1634 and 1645, without statement of the name of the craters. From 1707 to 1733 the two Binintians alternated with one another till at length, in 1749, the middle crater burst out, silencing the other two.

Of the eruption which occurred on the 24th of September, 1716, Father Francisco Pingarron, rector of Taal, wrote a detailed report. In 1731 a new eruption took place, which was described by Father Buencuchillo, priest of Taal. Mr. Becker summarizes both reports as follows:

> September, 1716, after sounds mistaken for discharges of artillery had been heard, fire was described bursting from the volcano on the island at the side toward Lipâ, on a point called Calavite. This point is now called Caláuit and is in the southeastern corner of the island. The fire then shifted into the lake in the direction of Mt. Macolod, throwing up water and ashes in immense bubbling masses, rising like towers into the air. The water grew hot and black, fishes were strewn on the beaches as if they had been cooked, and the air was so full of sulphurous smells and the odor of dead fish that the inhabitants sickened. This state of things lasted three days. In 1731, so Father Buencuchillo writes, "fire broke out in the lake in front of




**SKETCH OF THE TAAL VOLCANO.**

the point which looks to the east, obelisks of earth and sand so large and high raising themselves from the water that in a few days an islet was formed with a quarter of a league of coast line."

Centeno thinks the Father referred to the northeastern point of the island, and that the islets which now exist there were formed at this eruption. Possibly, however, an island of pumice may have been formed at Caláuit and have been washed away at a later date. It would be interesting to examine the existing islets with a view to estimating their age.

After eighteen years of relative calm, a great eruption occurred in August, 1749. From the long report of Father Buencuchillo we take only the following:

On the evening of the 11th of August a glare was seen on the summit of the volcano, and at 3 o'clock of the following morning strong detonations began to be heard, and immediately a column of black smoke issued forth, not only from the main crater, but also from many other small craters opening in the island. From the very bottom of the lake there also arose awful pyramids of water, sand, and smoke, towering to the clouds. These immerged craters opened to the north and east of the island, or toward the towns of Sala and Lipâ. About 9 o'clock in the morning violent shocks were felt, coinciding with the opening of new immerged craters close to the northern and eastern shores. Near Sala a great extension of the coast of the lake sank down into the lake, only the heads of the tallest trees emerging above the surface. The land as far as the town of Calamba and the bank of Laguna de Bay was divided with tremendous noise. The land all around was considerably shaken, so that Tanauan as well as Sala were almost destroyed; the rivers changed their courses, streams broke out from new springs, and the ground in several places sank. While this was taking place I saw several coco and bonga trees, which trees, as everyone knows, are very high, yet I could touch the branches with my hands without any difficulty; and I also saw several houses which before, on account of their height above the ground, it was necessary to make use of a ladder to enter, but that after the sinking of the ground it was necessary to go down to enter them. But what struck me most of all was that the Indians kept in their houses, quite happy, although they saw that they were being buried alive.

This eruption lasted for three weeks and darkness was produced by the dust and ashes suspended in the air, so that for some days it was necessary to light candles at noon. After three weeks the eruption terminated, as well as the frequent shocks of earthquake which accompanied it, but a thick column of smoke and vapors continued to rise quietly for some years.

The greatest eruption of Taal took place in 1754. It consisted of only fragmental ejecta, but these were sufficient to destroy four villages lying about the lake. "This ash," Semper says, "has now indurated and a new growth of bamboo and palms has sprung up around the projecting ruins." Father Buencuchillo wrote also a pathetic description of this eruption, from which we take the following:

It began on May 13 and did not end till the 1st of December. During this time the intensity and aspect of the eruption were continually changing. It was two hundred days of devastation and ruin for the inhabitants, to whom the time must have appeared an eternity. During this terrible time the four principal towns of the laguna of Bombón disappeared, viz, Sala, Lipâ, Tanauan, and Taal, with the numerous villages around them.

Other towns of the same province at a great distance, as well as towns of the neighboring provinces of Balayán, Batangas, and Bauan, also suffered great damage. Rosario, Santo Tomás, and San Pablo also felt the effect of the rain of ashes and scoriae, as also did almost all the provinces below the center of Luzón. The quantity of ashes and scoriae which was sent up by the volcano was so great that a great quantity of pumice stone appeared on the surface of the water of the laguna; and several villages around Tanauan and others around Taal being near the volcano and because the wind was east were totally destroyed by this rain.

The eruption continued thus with greater or less intensity, but continuous, till the 10th of July, when the nature of the volcanic rains changed, as may be gathered from the following words:

There was not a single night throughout the whole of this month of June till July 10 in which flames were wanting on the volcano or in which there were not rumbling noises. This went on till July 10, when it rained mud over the town of Taal, and the mud was of so black a character that ink would not have stained so blackly, and when the wind changed, the mud covered a village called Balele, which is near Sala, which village was the most fertile of the whole of that district.

The volcano continued to throw out, with more or less intensity, flames and black smoke during July and August and part of September, till on the 25th of this last month it appeared as if the volcano wished to parade all its forces against us, because, on that date, to the horrible rumblings and the tremendous flames was joined a tempest which originated in the cloud of smoke. The lightnings which accompanied the storm continued without interruption till December 4. It is truly marvelous that the cloud lasted for more than two months. Over and above this, there was from this same 25th of September till the morning of the 26th such a copious rain of pumice stones that we were obliged to abandon our homes for fear the stones would break through the roof, as indeed happened in some houses. We were thus compelled to flee through this rain of stone and several were wounded by the stones falling on their heads. During that one night the ground was covered with scoriae and ashes to the depth of a foot and a half, thus destroying and drying up the trees and plants as if a fire had passed over them.

The activity of the volcano continued, with short intervals of quiet, during the months of October and November. On the evening of the feast of All Saints the volcano again began to vomit forth fire, stones, sand, mud, and ashes in a greater quantity than ever. This went on till November 15, on which date, after vespers, there commenced a succession of rumblings, so loud as to deafen one, and the volcano began to vomit forth smoke so dense and black as to darken the atmosphere, and at the same time such a great quantity of large stones fell into the lake as to cause big waves. The earth trembled, the houses shook, and yet this was but the preparation for a fresh rain of scoriae and ashes, which lasted the whole of the afternoon and part of the night.

On the 27th of November another eruption occurred, which the chronicler describes thus:

Notwithstanding the disaster that had overtaken us, I still remained in the said town, together with the chief justice of the province, till, on the night of the 27th, the volcano began once again to vomit such a quantity of flames that it seemed as if all that had been erupted during the preceding months together did not equal that which was thrown forth during that hour.

Every moment the violence of the eruption increased, so that the whole of the island was covered with fire. This increasing volcanic activity, accompanied as it was by frightful subterranean rumblings and earthquakes, caused the unfortunate inhabitants to abandon their town and at any risk to gain the heights which rise between it and Santuario de Caysasay.

Thus passed the 28th, but on the morning of the 29th smoke was observed rising in various points of the island from Caláuit to the crater in a straight line just as if a fissure had been opened all along the line. Between 4 and 6 o'clock of the same evening (November 29) the horizon darkened leaving us in complete darkness, and at the same time it began to rain mud, ashes, and sand, and though not in such quantities as before, yet it kept on without interruption the whole of that night and the morning of the 30th.

The rain of mud ceased somewhat at 4 o'clock in the afternoon. It then measured a meter in depth in Santuario de Caysasay, which is distant about four leagues from the volcano. In some places nearer the island the depth of the mud, etc., reached more than three yards.

The rain of ashes completely ceased on the 1st of December, and then a hurricane, which lasted two days, came to put the finishing touch to so many disasters by tearing up the little that had been left standing.

No great eruption has occurred since 1754. In 1808, 1873, and recently, in 1903, there were outbreaks, but the damage done, if any, and the outbursts themselves, seem to have been confined to the island itself and to the main crater.

"In spite of the terrible lessons of the last century," comments Centeno, "all of these localities have been repopulated. Their fertility, their surpassingly beautiful topographical situation, and their healthfulness charm the people into a prompt forgetfulness of past disasters."

We have given a somewhat full account of the greatest eruptions which have occurred during the past three centuries, which must be kept in mind to see the probability of the following theories concerning the past history of this volcano. The Zúñiga theory supposes that Lake Bombón, actually surrounding the craters, was originated by the collapse of a volcanic cone. It is probable that the primitive cone was blown out by successive explosions rather than by a collapse. We will not deal longer with this theory, discussed at length by Mr. Centeno. It will be enough to repeat what Mr. Becker has written concerning it:

Lake Bombón has a rudely oval form, with a mean diameter of about twelve miles. I have not been able to ascertain its level, but the surface can not stand many feet above the sea, for the Río Pansípit, which connects the lake with the Gulf of Balayán, is only about six miles long and has no cataracts, and it was formerly navigable. It cuts through a low mass of tuff. The other portions of the lake are encompassed by a crest considerably higher than the surrounding country. At some points this crest comes close to the shore of the lake, while at others a narrow strip of lowland intervenes, but, as Mr. von Drasche pointed out, the watershed is everywhere so near the shore that the lake has not a single affluent. The entire surrounding region is composed of volcanic materials, almost altogether tuff. Father Zúñiga regarded the lake as originating in the collapse of a volcanic cone, and to this theory von Hochstetter, von Drasche, and Centeno assent. The theory of volcanic collapse seems to imply that an empty space beneath the earth's surface is formed by the eruption of lava and that the intervening rock is too weak to bear the load put upon it, as the country over a mine sometimes subsides. I doubt this theory as applied to volcanic cones, excepting when invoked to account for local details of structure. It seems to

me very improbable that a considerable cavernous subterranean space is left when lava is extruded, nor can I think the foci of volcanic activity so close to the surface that such a cavern, if formed, could be filled by means of mere subsidence of the cone. If the focal distance from the surface is many miles, such a cavern would be filled in immediately by molded or fractured rock from its own sides, and even this would most likely only partially relieve the tendency to upheaval which so usually accompanies active volcanism. On the other hand it is well known that craters of vast size have been formed by explosions, and I can see no reason to doubt that Bombón may have been, probably has been, formed in this way in spite of its large dimensions.

From the southern edge of Bombón to the Gulf of Batangas, and, again, from the northern edge of the lake to the northern end of Manila bay, stretches a great area of tuff, to which reference has been made in discussing the distribution of volcanic rocks. The area to the north of the lake slopes with extreme gentleness toward the bay, decreasing in elevation only 500 to 600 meters in 30 kilometers on a wonderfully steady slope. All observers seem to be forced to the conclusion that most, at least, of this tuff comes from Taal. Under subaerial conditions, I should say that this would be impossible. Such masses could not be projected to distances so great or distributed in such a manner along so flat a country. Nothing is more certain, however, than that Luzón stood at a considerably lower level than it now does in recent times. Taal and Bombón must have been immersed, and a channel then passed from Batangas gulf to the eastward of Zambales range into the Gulf of Lingayén. In such circumstances the actual distribution of tuff from the Taal vent would be intelligible.

The conditions, then, seem to point to the hypothesis that at the locality of Lake Bombón there existed a volcano, at least the lower portion of which was below water level. By ordinary eruptions and Krakatoan cataclysms vast quantities of scoriaceous ejecta were expelled, and such of these as fell into the Batangas-Lingayén channel, or its drainage area, were distributed as the more or less stratified tuffs now so widely spread along this course. Finally, Taal itself is the small inner cone of a great crater of explosion. This hypothesis appears to account for all the facts at present known to me, such as the rim about the lake, the contour of its bed, the steady slope of the northern tuff plain, the distribution and character of the tuff. I am by no means of the opinion, however, that all the tuff of Manila province came from Bombón.

Mr. H. D. McCaskey, B. S., has also recently written on the same point:

My own notes and observations in these provinces tend to the belief that Taal was unquestionably, at a prehistoric period, very high and of tremendous activity; that it stood partly surrounded, if not wholly, by a stretch of the sea extending from the Gulf of Batangas to the Lingayén gulf; that during its activity large quantities of volcanic ejecta fell into this inland sea, forming the more or less stratified deposits of tuff now furnishing much of the rich soils of the provinces of Batangas, Laguna, Cavite, Rizal, and Bulacán; that an explosion, or a series of them, blew out the entire upper cone, leaving the rim of the present boundaries of the lake of Taal; and that subsequently minor cones were formed and this region was gradually raised to its present level.

A number of points of similarity between the volcano of Taal and that constituting Barren Island, in the Indian ocean, present themselves, and it does not seem at all unlikely that these two exceptionally low volcanoes, that are now but most unsightly remnants of their former cones, may have passed through similar mighty cataclysms to result in their present similar forms.

Prof. J. W. Judd, F. R. S.,[1] believes also that the actual cones forming the Krakatoa group represent small cones which have grown inside the great crater originated by the blowing out of a previous great volcano.

At the southern limits of this tuff area there are many sulphurous springs.

A summary of the historic eruptions of Taal may be seen in the following table:

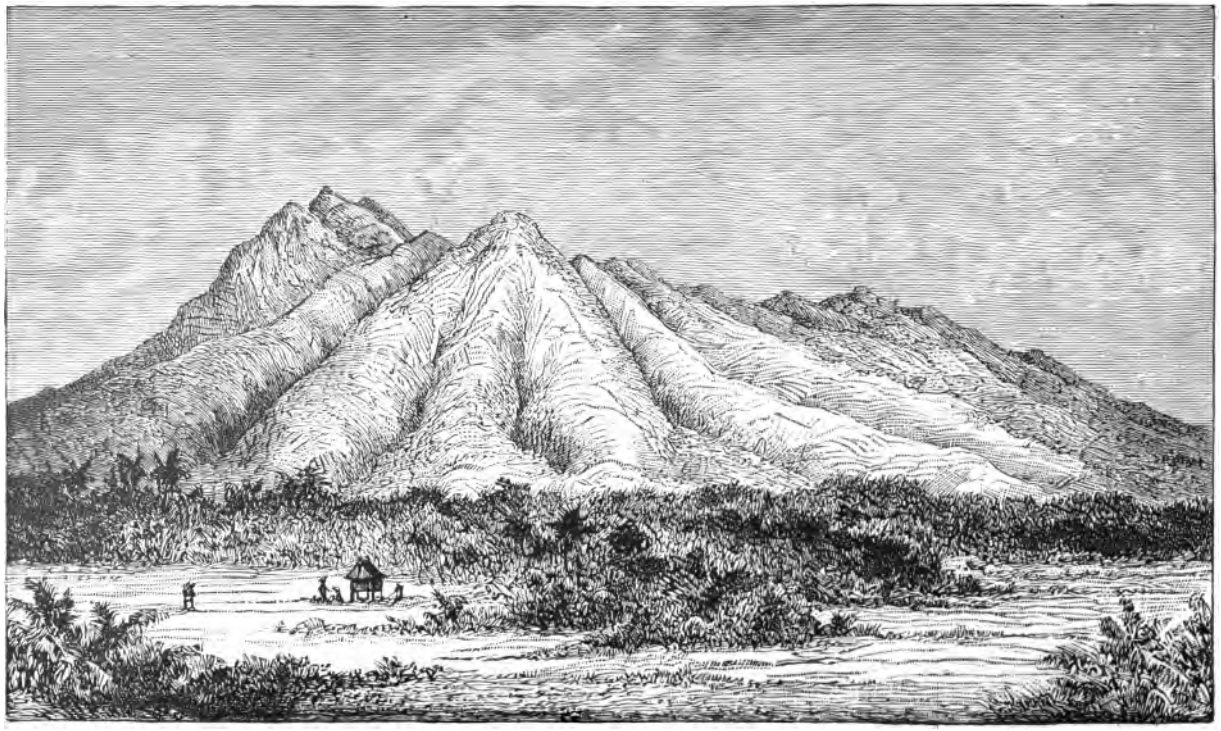
TABLE 9.—*Eruptions of the volcano of Taal.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1572.... | ..... | ..... | ..... | Vaguely reported by Fathers Rada and Zúñiga. |
| 1709.... | ..... | ..... | ..... | Eruption without loss of life or property. |
| 1716.... | September.. | 24 | 6.00 p. m..... | Violent eruption accompanied by strong earthquakes which shook the neighboring regions. |
| 1749.... | August ..... | 12 | 9.00 a. m..... | Two violent eruptions, the first on the evening of the 11th, the second at 9 a. m. on the 12th, the latter accompanied by a violent earthquake. Numerous witnesses report that many explosions took place in a line running from Taal to the Maquíling cone on the banks of Laguna de Bay. |
| 1754.... | May ..... | 15 | 9.00 p. m..... | The greatest eruption reported of this volcano; it continued with intervals till December 1. Four villages lying around the lake were completely destroyed. |
| 1874.... | May ..... | 17 | ..... | Eruption of black smoke and ashes. |
| 1874.... | July ..... | 19 | ..... | Eruption of gases which were so sulphurous that the characteristic odor was perceptible as far as the town of Talisay. A large herd of cattle died on the island of Volcán, on whose western shore the abundant vegetation was almost completely burned. |
| 1878.... | November.. | 13 | ..... | From the end of October until the 12th of November subterranean noises were heard frequently in the direction of the volcano. On the day mentioned the eruption began and lasted until the 15th, covering the whole island of Volcán with a light layer of volcanic ashes. |
| 1880.... | June..... | 8 | ..... | From the 8th of June the volcano was observed to be more active than usual, and sometimes at night the crater was covered with a glare. On the 17th, 18th, 19th, 20th, and 21st of July subterranean noises were heard, and many witnesses at Talisay, some six miles distant, report that from time to time a small ball of fire (apparently about 2½ feet in diameter) appeared above the crater. This ball, after reaching a considerable height, burst into small fragments, some of which fell back into the crater and the remainder upon the exterior slopes. |
| 1903.... | April ..... | ..... | ..... | The eruptions occurred at intervals, an immense column of vapor, stones, and ashes shooting up at each explosion, which, on account of the calm state of the atmosphere, returned to the earth almost in the same spot around the crater. |

## THE VOLCANO OF MAQUÍLING.

Just a few miles to the northeast of the volcano of Taal rises the Maquíling, a rough basaltic or doleritic cone some 3,800 feet high. It presents many ridges and cliffs on the summit and sides. The crater is open to the southwest and east-southeast, and the rest of the standing rim rises to a height of 1,600 feet above the ancient bottom. The northern slopes leading into the Laguna de Bay are so steep that the whole of the mountain seems to be inclined to the lake, as its name Maquíling signifies. Around the main cone there rise some subordinate hills—all of them secondary craters related to the principal one by

[1] The Eruption of the Krakatoan and Subsequent Phenomena.



MOUNT MAQUÍLING LOOKING SOUTH.

low lava and tuff ridges. There is a more remarkable one on the shore of the lake called the pool of the Caimanes. A layer of rather soft tuff covers the lower part of the mountain slopes. This tuff is very similar to that employed in the buildings in Manila, which is obtained from the left bank of the river Pásig, and outcrops at Guadalupe.

*Present volcanic activity of Maquíling.*—Among the most remarkable evidences of activity are the mud-pools called Natugnos, situated on the eastern side of the volcano at a height of some 900 feet. Mr. Abella describes these volcanic pools as follows:

> There is a small lake about 20 meters in diameter around which an odor of sulphur is noticeable. The lake is composed of boiling mud of a dark grayish color. When the bubbles of mud burst, a peculiar sound is produced and particles of the semiliquid mud are splashed on the borders of the lake. The temperature of these splashes of mud is 84° C.
>
> The ebullition must have had periods of increase, because there is a broad track of matter very similar to the lava or currents seen in active volcanoes, from the border of the lake as far as the river Molauin. It would seem as if the lake had overflowed and the mud had run down the incline.
>
> Close to the principal lake there are others much smaller, some being merely little pits and others simply smoke vents, but all are filled with mud; and vapor comes from them with great force, while the boiling mud presents different colors—red, yellow, gray, and sometimes completely white.
>
> There are, not far from the pool just described, some places where the solfataric action has almost ceased. The mud has dried up and the white clay which remains is used now by the natives as paint. In one of them the sulphurous vapors are still issuing forth; wherever the ground was touched it showed a high temperature, and near the smoke vents it reached as high as 100° C. The ground also presented the variegated colors of sulphur, of which white, red, and yellow predominated. There are also found fine sulphur concretions.
>
> Besides this, there are fumaroles all around the volcano at different heights from its base; in almost all of them there is some production of the white clay or kaolin going on, owing to the alteration of the doleritic rocks by the sulphurous vapors.
>
> As another sign of the remaining activity of this volcano we must mention the numerous thermal springs which exist on the slopes of Maquíling; which springs, we can and ought to consider as a result of the existence in the interior of fumaroles, which, instead of coming to the surface, employ their activity in raising the temperature and dissolving substances in the waters of the subterranean currents which they come across. They are, we might say, the last traces left after the extinction of the volcanic foci.
>
> The most important and at the same time the best known springs for their medicinal properties are those which rise in the town of Los Baños. These springs were known by the natives from the time of the Conquest. They were then known by the name of Maínit, that is to say, "hot."

The existence of Mt. Maquíling, of Pansol, and especially of the Caimanes Lake, together with the lava rock of which they are formed, also indicate that after the commencement of the activity of the principal focus of Maquíling, and perhaps even after its partial or total extinction, other foci of activity broke out. The activity of

these latter was of less intensity as being subordinate to the principal focus. The last of these was undoubtedly the annular or crater-like hill in the Caimanes Lake. This hill, which is one of the typical ones formed of lava, still preserves the rapilli and peperines which are characteristic of recent activity. Probably there was also a gradual rising of the land in the interval between the two eruptions, and at the same time the volcano itself was raised; for it seems very natural that the band of tuff which surrounds it is not of subaerial formation, but that it was deposited in water not very deep and perhaps disturbed and agitated, for there are large and small pieces without any apparent order, but all of them perfectly superposed and sedimentary. The peperines and conglomerates of the mountain are all composed in this way, and exist not only at the foot of Maquíling, but also all along the south shore of Laguna de Bay, and the left bank of the Pásig, till close to Manila.

### THE VOLCANO OF BANÁJAO.

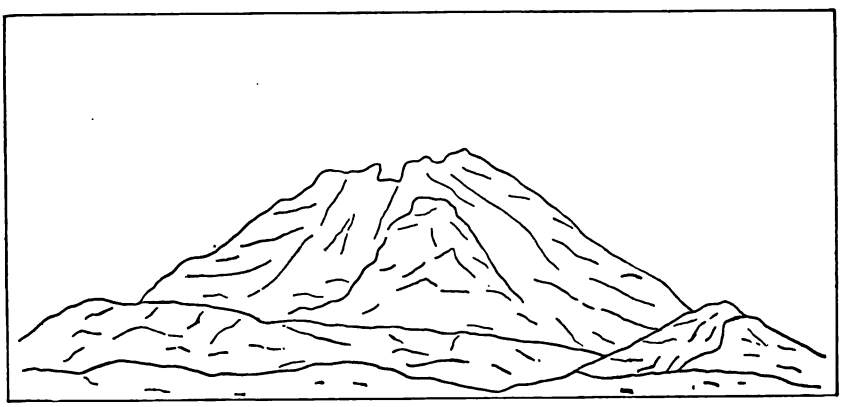
Not far from Maquíling, to the southeast, rises the magnificent cone of Banájao 7,382 feet in height. Its crater, now 700 feet deep, was occupied by a lake till 1730 when, according to Father Huerta, in his Estado Geográfico, a violent eruption occurred bursting the southern side of the crater and pouring out water, incandescent lava, and big rocks which can be seen near Sariaya town. The crater now, as seen from the south, seems an elliptical deep hole looking to the south. Since 1730 it has been dormant. There are other subordinate cones about it, two of them, Mt. San Cristóbal to the northwest and Masalacot to the southwest, being very well shaped. There are also near Dolores at the foot of Mt. San Cristóbal and elsewhere some deep circular ponds which are probably extinct craters, to which the natives of the country attribute a rather mysterious origin. This volcanic country has not yet been examined. The volcanic formations of Banájao and Maquíling very probably extend to Talim Island and Jalajala peninsula. In this, besides the volcanic rocks and layers of tuff, there exists a hill known as the sulphur hill at the foot of which are thermic sulphurous springs.

Northward from Manila there is the striking conical Aráyat looming up over the extensive plain between Pampanga and Nueva Écija. The Zambales range bordering the western part of Luzón was spoken of when treating of the distribution of volcanic rocks.

### SEISMIC CENTERS OF PANGASINÁN AND NUEVA VIZCAYA.

It is not easy to determine whether the seismic center disturbing the provinces of Pangasinán and Nueva Vizcaya forms but one center or system situated near the connecting point of the two ranges of

BANÁJAO VOLCANO, LOOKING NW.



BANÁJAO VOLCANO, LOOKING E.

mountains, namely, the central and the eastern one, called the South Caraballo. The volcanic vents and the many fissures found in the Benguet district show that there once existed at this place a very important volcanic center, the relics of whose activity are still to be found in the form of hot sulphurous springs. Thus the true center, radiating sometimes southwestward and at others northeastward, seems to be situated near this district, although the shocks were more frequently felt with force in the alluvial plains of Pangasinán and Nueva Vizcaya than in the highlands of Benguet.

To this region probably must be referred the eruption or displacements which occurred in 1641; but the report of this event is so confused that it is quite impossible to locate the place pointed out in it. Mr. Becker summarizes and comments on the report as follows:

> The third eruption on the same January 4, took place from what was called "a water volcano" by the archbishop's agent. The description makes it clear that by this term he had no intention of indicating thermal phenomena, but merely an outburst of water accompanying what he himself called a frightful earthquake. It took place in Luzón among the Igorot, "who, relatively to the Ilocos, live five days' journey eastward and inland." Three hills and several villages are said to have been thrown into the air in fragments and utterly annihilated. This locality has been regarded as Mt. Santo Tomás or Tonglón, some 15 miles from Arínday, in Unión province. This identification does not appear accordant with the original description, and how it was reached I have not succeeded in ascertaining.

In the seismic center of Pangasinán and Benguet there was a violent disturbance in March, 1892. All the stone buildings in the north of Pangasinán and south of Unión and Benguet provinces were greatly damaged by the earthquakes which were repeated with more or less force during nearly three months; wide fissures were produced everywhere, especially through the low alluvial plains, and big crevasses were opened and landslides occurred on the southern mountains of Benguet.

> The epicenter of these earthquakes, says Mr. Abella, must be placed between the towns where the force of the earthquakes was more intense, and noticing their positions on a map, we may say that the epicenter appears to be very elongated or almost linear. In the south it follows the mean direction of the river which is known under the names of Bued, Abilulen, and Angalacan and in the north it spreads out in two directions, one passing to the north-northwest by Santo Tomás and Agoó, the other to the north-northeast by Baguío in the district of Benguet.
>
> This north bifurcation must be more apparent than real and is owing both to the few points of observation in which the effects of the earthquakes could be studied, and to the fact that when the great mass of Mt. Tonglón was violently agitated, the direct transmission of the force thus produced to the alluvial land of Santo Tomás and Agoó, necessarily caused in these towns the greatest effects. It does not follow, however, from this that the direct action of the earthquakes takes place precisely under these towns.
>
> Moreover the configuration of the ground along the inaccessible defile of the Bued; the great number of thermal springs which are at the bottom of the canyon; the recent volcanic rocks in Álava, Baguío, and La Trinidad in the same direction as

the defile; all this, together with the relations which exist between the situations of the places of maximum seismic effect, make one suspect that they were produced by volcanic action.

The center of Nueva Vizcaya seems to be more active than that of Benguet and Pangasinán. The central and northern part of the Benguet district seems really more stable than its southern part and the neighboring provinces of Pangasinán and Nueva Vizcaya. The most violent seismic disturbance on record, which occurred in this last province, was that of 1881. It was described as follows by Mr. Abella:

Ever since the month of July of the preceding year 1880, in which the great earthquakes of the island of Luzón happened, the province of Nueva Vizcaya has not been without shocks from time to time, but some of these were so slight that the majority of the inhabitants did not notice them. In the month of July of this year, however, these movements began to become more sensible. On the 27th of that month, at 5 p. m., a strong shock was felt, damaging several of the few masonry buildings. This was the forerunner of the seismical activity now to be described. From that time began a decided and seldom interrupted series of slight and strong shocks, the maximum intervals between which did not exceed three days. Without any interruption of the series of shocks, on September 1, at 12.20 p. m., a sudden, strong, quiet trembling motion was felt, similar to all the shocks which have agitated and still continue to agitate the district. From that moment a considerable increase of seismical activity was developed, on such a scale that the shocks were felt at intervals of an hour or a minute, and sometimes continuously with palpitation of the ground, only interrupted by the interpolation of more serious shocks. This of course could not fail to produce upon the terrified inhabitants of that splendid province a painful and nervous tension.

During the month of September thirteen very strong earthquakes were felt, besides numerous slight shocks. We must observe here that only the most important shocks were recorded, the remainder, although quite sensible, being too numerous to mention.

I have been able to establish the probable centrum of the agitated region, my observations on which I will now summarize.

The thunder, which always precedes the shock by a few seconds, is heard most distinctly toward the middle of the province in the neighborhood of Bambang. The most important circumstance is that the interval between the sound and the movement is always shorter the nearer the observer is to that town, and especially when on the surrounding heights clear of the deadening effects of the valley's alluvium. The sound of the shock and the movement, although sensibly successive in these places, become very often mingled together. On the other hand, toward the frontiers of the province there are observed: First, a sound of subterranean thunder; second, an interval of rest and quiet sometimes of five or six seconds; and third, a vertical shock accompanied by a noise which we may call the "squall" of the seismical waves, followed without interruption by a horizontal movement of oscillation. When we observe the cracks produced in the masonry buildings of Bambang we also come to an analogous but more certain conclusion.

It is also very important to remember that while cracks produced in the buildings of villages at a distance from Bambang show more or less visibly an inclination to the horizon, in this town they are perfectly horizontal; so that, for instance, two complete cracks in its church tower divide the tower into three complete distinct blocks, which have not yet fallen, partly, doubtless, on account of the excellent material, but principally from the circumstance that the shocks sustained by the tower were purely vertical movements; while it is most probable that if a horizontal shock had occurred the upper portions of the tower would have fallen.

This town has also suffered much other damage in its masonry buildings. All these peculiarities lead us to conclude with sufficient certainty that the seismical vertex of movement which agitates the district lies at or about Bambang; that is to say, the active center of subterranean vibrations must be a point in a vertical line below the vicinity of Bambang. Which is that point, or at what depth is this active center of seismical disturbance situated?

It is believed that it is not far from the surface, and I adduce for your excellency's consideration two principal reasons for maintaining this deduction; namely, the almost simultaneous occurrence of sound and movement at Bambang, and the comparative intensity and localization of the shocks.

In this report Mr. Abella is inclined to give a volcanic origin to the earthquakes of Nueva Vizcaya. He did the same some years later to those of Pangasinán, considering them as due to the remaining but probably dying activity that brought to light the rather volcanic rocks found in Benguet, and also pointed out that there was probably some possible subterranean communication between the active Mayón volcanic group and the volcanic vents of these regions. It may be so, but considering the structure both of south Benguet and the valley of Nueva Vizcaya one is led rather to consider these shocks as rockfall or tectonic. Certainly the region lying between Benguet and Pangasinán, through which the Bued river runs, can not be a very stable one, being, as Mr. Abella reports, formed principally of coralline, abrupt, and fissured banks lying on clay, alluvium, and sandstone formations. On the other hand, the thermic manifestations and increase of temperature in some springs occurred when the earthquakes of 1892 were very doubtful. Mr. Centeno visited Nueva Vizcaya some three years after Mr. Abella, and threw much light on the origin of the earthquakes felt there in 1881. In his report on the salt springs, which appeared on Monte Blanco in 1884 or at the end of 1883, he insists upon the necessary instability of the region west of Bambang.

To the west of the town of Bambang there appeared during last March some large thermal springs. They are at a height of 490 meters above the level of the sea, and 170 above the town of Bambang. The force of the water is such that a large quantity of clay and stones has been thrown up from the underground passages, and the water and clay thus sent out forms a stream which when it joins the river Abáot, discolors the water considerably.

When we visited them, on the 3d of May, the springs consisted of 10 or 12 holes, all of them within the compass of 900 square meters. Within this space there were also signs of other springs which had been destroyed by the blocking up of the channel, probably by the falling in of the sides. Of the 10 or 12 springs which were still in activity only two were of any importance for the amount of water sent out, for in the rest the amount of water was so small that they would be considered simply as vapor vents.

The temperature of the water differed considerably in the different springs, although they were all quite close to one another. In some the temperature was 30° C.; in others, which were only distant some 20 meters, it rose to 60° C., which was the greatest.

The taste of the water was distinctly salty, and in some springs it had a bitter taste, something like that of bicarbonate of soda.

After visiting these springs we went on to see Las Salinas of Monte Blanco, which are about 4 kilometers to the southeast of the springs and 250 meters above the level of the sea. These "salt pits" consist of several small springs with water at the ordinary temperature, which appears on the surface of a mass of white chalk, on which common salt and carbonate of lime were being deposited. Many stalactites were always being formed by the carbonate of lime.

The diminution or almost total extinction of the springs on Monte Blanco is very recent, because von Drasche, in his expedition of 1876, found them in full activity, and I myself have noticed that the sediment in many places where the water does not now flow is of very recent formation. The existence of several salt pits in different points of the Cordillera Central leads me to suppose that there are large deposits of salt, which are traversed by subterranean currents of water, more or less hot, and thus give rise to the salt springs or pits.

We believe neither direct nor indirect volcanic action was the cause of the earthquakes of Nueva Vizcaya in 1881; rather we found a certain relation between the existence of the salt springs and the phenomena not only in Bambang, but also in several other points of the Cordillera Central; for these springs, which appeared at such a great height above the level of the sea and with water so charged with salt, would seem to indicate that under the ground of that district there are currents of water, passing over salt deposits, which consequently grow less and less thus leaving large caverns under the ground.

These caverns are continually on the increase, owing to the dissolving action of the water, till the moment when they give way and sink, causing at the same time shocks or earthquakes. These shocks are transmitted to the surface with more or less intensity and duration according to the nearness and size of the cavern, which has fallen in. This class of earthquakes, which I have named purely mechanical ones, always presents some special characteristics: for example, they are almost always preceded by subterranean noises; the largest component is the vertical one, and the zone affected is very small. If any support is required to establish my theory I would call attention to several analogous earthquakes which took place in Europe and were carefully studied.

There are no records of destructive earthquakes felt in those regions in the past centuries. The most violent experienced there, excepting those mentioned above of 1881 in Nueva Vizcaya and 1892 in Pangasinán and Benguet, had their epicenter to the south of Luzón, because they were stronger in Manila and the neighboring provinces. Besides the havoc of 1641 mentioned in the beginning there is another story concerning the Benguet district. It is found in an old chronicle of the order of the Augustinians. According to this story, at the beginning of the eighteenth century quite a large number of cottages, situated to the east of Aríñgay and occupied by the natives, disappeared in a great earthquake which produced the submersion of an extensive tract of land.

Mr. Centeno says, commenting on the story:

Doubtless the topography of the beautiful plain in which La Trinidad is situated might give some reason for conjectures on the subject. A level circular plain about 4 kilometers in diameter is surrounded on all sides by hills whose height does not exceed 130 meters. In the interior of this plain is a lake, whose only outlet is through a fissure toward the northeast, and this outlet, perhaps, gives rise to the river which empties at Báuang (Unión). Looking down on this circular depression from the last heights (1,550 meters altitude) which are passed in reaching La Trinidad, the valley presents all the appearance of an old crater and it was our first impression that it was one.

There is no doubt that such a circular plain is an ancient atoll.

The few known violent earthquakes felt in these regions are the following:

TABLE 10.—*Earthquakes of the Pangasinán and Nueva Vizcaya centers.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1627.... | August ..... | ..... | ..... | Chronicles report large landslides on the Caraballo peaks. |
| 1645.... | December .. | 1 | 8.00 p. m. | This is the earthquake which laid Manila in ruins; it was also destructive in the northern provinces. |
| 1728.... | November .. | 28 | ..... | Was destructive in the fourth district. |
| 1880.... | July ..... | 18 | 12.00 noon. | At Benguet it was accompanied with great subterranean noise. |
| 1881.... | January .... | 3 | 8.30 a. m. | On this date there commenced in Nueva Vizcaya one of the longest and most dreadful seismic periods on record; during the months of January, May, July, August, and September the shocks were almost continuous. The seismic center was probably near Dúpax. The strongest seismic waves extended over all the provinces of Luzón. |
| 1892.... | March ..... | 16 | 9.01 p. m. | Spread ruin throughout almost the whole province of Pangasinán, not a single stone building escaping without serious damage. |

SEISMIC CENTERS OF THE NORTH OF LUZÓN.

In this northern region there probably exist two seismic centers, one to the east and the other to the west of the central range of mountains. In fact, many earthquakes felt with great force in North and South Ilocos and Abra are almost imperceptible in the eastern provinces of Cagayán and Isabela. On the other hand, many others have been known to be very powerful in the latter provinces throughout the Cagayán valley and very feeble in the former. This tends to show that the two centers are almost independent. Nevertheless, they probably belong to one general seismic system, like the one in Nueva Vizcaya and Pangasinán. Neither in the eastern nor in the western region are there well-known and important volcanic centers.

Not far from the northwestern point of Luzón or Cape Bojeador there exists a lake which the natives attribute to a submersion of land and of a town during an earthquake. In the central and western regions of Luzón there are also to be found many hydrosulphuric and sulphurous springs, as well as some salt ones similar to those of Nueva Vizcaya. Mr. Centeno describes some of Lepanto and Abra districts:

We have slightly touched on the existence of thermal sulphurous waters on the ranches of Magañgan and Buguiás when speaking of the volcanoes. There are a great number of pools of water which smell strongly of sulphureted hydrogen between the hamlet of Magañgan and Acnal. The temperature of the water varies from 16° C. to 50° C. From one of the pools a large quantity of black mud, having the same smell as the water, is being constantly given forth. We do not know the composition of the mud. About these pools there are numerous sulphur deposits.

In the eastern provinces not far from Cape Engaño there is a volcanic cone known as Caua or Cagua (18° 13′ north latitude and longitude 122° 04′ east of Greenwich), which is now at the solfataric stage, and which was seen smoking in the year 1860; it is commonly known among the natives as a "fire mountain." It was discovered by Mr. Claudio Montero, of the Spanish Hydrographic Commission. In 1860 Mr. Semper, from Aparri, saw smoke ascending from this mountain, and his servant, who went to its base, assured him that it was well known among the natives as a "fire mountain."

There are two active volcanoes, one on the island of Babuyán Claro (19° 40′ north latitude and longitude 121° 56′ east of Greenwich) and the other in the Dedica Reefs (19° 02′ north latitude and longitude 122° 09′ east of Greenwich). It appeared in September or October, 1856, between two rocks well known to the natives, at first as a column of smoke. No earthquake attended its first appearance, but in 1857 it underwent a violent eruption, attended by earthquakes. From that time to 1860 the volcano was constantly active, and in four years it reached a height of 700 feet. They are known as "smoking mountains." The well-known volcano of Camiguín (18° 55′ north latitude and longitude 121° 52′ east of Greenwich) is now in the solfataric stage. Mr. Cavada reports that in 1857 there was open on its southwestern side at the sea level a hole or vent from which hot water issued and sometimes solid ejecta, which formed a small island in front of it. In the "Derrotero" we read that near the point Escarpada, west of the volcano, there is a salt boiling spring close to the sea level.

The earthquakes recorded in the Batanes Islands during the last few years show that these islands form a seismic region with the northeast of Luzón rather than with the northwest. In the following list we mention the stronger earthquakes felt in northern Luzón:

TABLE 11.—*Earthquakes in northern Luzón.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1627.... | August ..... | ..... | ..... | Chroniclers exaggerate the extensive landslides which occurred on the Caraballo peaks. The shocks were very violently felt in all the northern provinces. |
| 1645.... | December .. | 1 | 8.00 p. m. | This earthquake was very destructive in Manila. It was felt with great force in the north; at Lal-ló large fissures were opened in the earth and many large landslides occurred on the hills. |
| 1728.... | November.. | 28 | ..... | Very destructive in the whole fourth district. |
| 1862.... | September.. | 9 | 3.00 a. m. | Destructive chiefly in Ilocos Norte. |
| 1856.... | December .. | 29 | 3.00 a. m. | Destructive chiefly in Ilocos Norte. |
| 1870.... | May ..... | 23 | 11.55 p. m. | Destructive chiefly in Ilocos Norte. |
| 1874.... | August ..... | 3 | ..... | It was destructive only in the Lepanto district. |
| 1879.... | October .... | 14 | 9.00 p. m. | These two earthquakes were felt more violently in the northern than in the northeastern provinces. |
| 1879.... | December .. | 19 | ..... | |
| 1896.... | September.. | 13 | 1.02 p. m. | This earthquake was destructive only at the northwestern edge of Luzón. |
| 1897.... | August ..... | 15 | 8.22 p. m. | Destructive chiefly in Abra and Ilocos Sur. |

## SEISMIC CENTERS ESPECIALLY AFFECTING MANILA.

*Position of Manila.*—Manila is most advantageously situated for experiencing almost all the shocks radiating from the different centers of Luzón; it is no more than thirty-five miles north of the active volcano Taal and a little more from the extinct ones, Maquíling, Banájao, and Aráyat. It stands on alluvial soil, probably covering the great tuff area stretching from the Gulf of Batangas northward through Cavite, Rizal, and Bulacán provinces, and which has been considered as originally coming from the southern volcanoes. This deep layer of tuff appears as an outcrop east and northeast of Manila. The surface ground of the capital is low and soft and traversed in all directions by many creeks or streams called "esteros," and from east to west by the Pásig river, which flows into the bay after a sinuous course of some eighteen miles. This river flows from the Laguna de Bay and forms its outlet. The observatory is situated about a mile southeast of the Walled City.

*Number of earthquakes.*—The total number of perceptible earthquakes registered at the observatory by the standard seismograph during the eighteen years between 1880 and 1897, inclusive, is 221, as may be seen in the following table:

TABLE 12.—*Earthquakes in Manila, by months: 1880–1897.*

| YEAR. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1880 | ..... | ..... | ..... | 1 | ..... | ..... | 6 | 2 | 1 | 1 | 2 | ..... | 13 |
| 1881 | ..... | 1 | ..... | ..... | 2 | ..... | 2 | 2 | 3 | 4 | 1 | 2 | 17 |
| 1882 | 1 | ..... | 2 | 3 | 2 | 2 | 6 | ..... | 5 | 2 | 3 | ..... | 26 |
| 1883 | ..... | 4 | ..... | 1 | 1 | 1 | 3 | 2 | ..... | ..... | ..... | ..... | 12 |
| 1884 | 1 | ..... | 1 | 1 | 1 | ..... | ..... | ..... | ..... | 3 | 1 | 2 | 10 |
| 1885 | ..... | ..... | 1 | 2 | 3 | ..... | 1 | 1 | ..... | 1 | 6 | ..... | 15 |
| 1886 | 2 | ..... | ..... | ..... | 1 | 3 | 1 | 1 | 1 | ..... | ..... | ..... | 9 |
| 1887 | ..... | ..... | 2 | 1 | ..... | 1 | 1 | ..... | ..... | 1 | ..... | 1 | 7 |
| 1888 | ..... | 2 | ..... | ..... | 1 | ..... | ..... | 2 | ..... | ..... | ..... | 3 | 8 |
| 1889 | ..... | ..... | ..... | 1 | 3 | 1 | ..... | ..... | ..... | ..... | ..... | 1 | 6 |
| 1890 | 1 | 1 | 1 | 2 | 3 | 3 | ..... | 1 | ..... | ..... | ..... | 1 | 13 |
| 1891 | ..... | ..... | 1 | 1 | 2 | 1 | ..... | ..... | 3 | 2 | ..... | 1 | 11 |
| 1892 | ..... | 1 | 8 | 3 | 2 | 1 | 2 | 1 | ..... | 1 | 2 | 2 | 23 |
| 1893 | 2 | 1 | 1 | 3 | ..... | ..... | ..... | ..... | 1 | 1 | 1 | ..... | 10 |
| 1894 | ..... | ..... | ..... | 3 | ..... | ..... | ..... | 2 | ..... | ..... | 1 | ..... | 6 |
| 1895 | 1 | 3 | ..... | 1 | 3 | ..... | 2 | 2 | ..... | 3 | 1 | ..... | 16 |
| 1896 | 3 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | 1 | ..... | ..... | ..... | 5 |
| 1897 | 2 | ..... | 1 | 1 | 2 | ..... | ..... | 3 | 2 | 1 | 1 | 1 | 14 |
| Total | 13 | 13 | 18 | 24 | 26 | 14 | 24 | 19 | 17 | 20 | 19 | 14 | 221 |
| Average | 0.72 | 0.72 | 1.00 | 1.33 | 1.44 | 0.78 | 1.33 | 1.05 | 0.94 | 1.11 | 1.05 | 0.78 | 12.30 |

From the above table we see that the average annual number of earthquakes at Manila is twelve. In the first six years, with the exception of 1884, the number was equal to or greater than the average, while in the four following years it was constantly below the average. After the year 1890 the number varies, the minimum being in 1896.

The average monthly number of perceptible earthquakes at Manila is one. The number in each of the six months of the spring and summer, or hot dry and rainy seasons, with the single exception of

June, is greater, while that in each of the six autumn and winter months, or the end of the rainy and during the cool dry season, is ordinarily less. The maximum number occurs in May and the minimum in January and February, the former being just double that of the latter.

The following list contains the most violent earthquakes felt in Manila and the neighboring provinces since the sixteenth century:

TABLE 13.—*Notable earthquakes in the vicinity of Manila.*

| YEAR. | Month. | Day. | Hour. | Remarks. |
|---|---|---|---|---|
| 1599.... | June..... | ..... | ..... | Took place after a long dry period. |
| 1600.... | January .... | 2 | 12.00 a. m. | Its duration of seven minutes was very extraordinary; many buildings fell and many people were injured. |
| 1610.... | November.. | 30 | ..... | Very violent shocks appeared to proceed from east-southeast. |
| 1645.... | December .. | 1 | 8.00 p. m. | Almost the whole city was laid in ruins; destruction to property was immense and much loss of life. |
| 1646.... | March..... | ..... | ..... | Long series of shocks lasting sixty days; many of these shocks were violent. |
| 1658.... | August ..... | 20 | 5.00 p. m. | Very violent, of short duration; destroyed the buildings which the earthquake of 1645 had left. |
| 1665.... | June ..... | 19 | ..... | Reports of this earthquake are very few; many buildings were ruined and 19 people killed. |
| 1675.... | January or February. | ..... | ..... | Destructive in the neighborhood of the Taal volcano and in the island of Mindoro, where many fissures were opened in the ground and many landslides occurred. |
| 1683.... | August ..... | 24 | ..... | Damaged some buildings. |
| 1699.... | ..... | ..... | ..... | The exact date of this earthquake is unknown. It is reported by Mr. Perry, who quotes Mr. Le Gentil. |
| 1716.... | September.. | 24 | ..... | It accompanied an eruption of Taal. |
| 1728.... | November.. | 28 | ..... | Caused great loss of property in Manila. |
| 1749.... | August ..... | 12 | 9.00 a. m. | It accompanied an eruption of Taal. |
| 1754.... | May ..... | ..... | ..... | Long period of violent shocks felt in the southern provinces of Luzón during an eruptive period of Taal. |
| 1767.... | November.. | 13 | 3.25 p. m. | Caused cracks in stone walls and the falling of tiles. |
| 1771.... | February... | 1 | ..... | Threw down the church of Ermita. |
| 1796.... | ..... | ..... | ..... | Many chroniclers report during this year a great number of violent shocks felt in Manila, but the exact date of these earthquakes is unknown. |
| 1797.... | February or March. | ..... | ..... | Caused but slight damage to buildings. |
| 1824.... | October .... | 16 | ..... | Damaged many buildings in Manila and in the provinces of the south. |
| 1852.... | September.. | 16 | 6.45 p. m. | The center of this destructive earthquake appears to have been in the Taal volcano. Many fissures were opened in the earth around the volcano. Damages to buildings were very great in the provinces of Manila, Cavite, Bulacán, Laguna, Tayabas, and in the island of Mindoro. The hill Ubamba near Súbic (Zambales) was reported to have been almost leveled to the ground. |
| 1852.... | December .. | 24 | ..... | Was destructive only in the vicinity of Taal. |
| 1855.... | March..... | 22 | ..... | It accompanied an eruption of Mayón, in Albay. |
| 1862.... | March..... | 4 | 5.30 p. m. | The damage it caused was very slight. |
| 1862.... | July ..... | 13 | 4.25 p. m. | These two earthquakes were destructive only in the district of Principe and along the eastern coast of Luzón. |
| | | 16 | 7.30 p. m. | |
| 1863.... | June ..... | 3 | 3.20 p. m. | Threw down the Manila cathedral and in the town and neighborhood destroyed 25 public and 570 private buildings. Many people were buried in the ruins of the cathedral. The destructive force was felt chiefly in the southern and eastern provinces. |
| 1869.... | October .... | 1 | 11.35 a. m. | Exercised its most destructive force in the province of Batangas around the volcano of Taal. Violent only northward; strong in the island of Mindoro. |
| 1872.... | December .. | 29 | 11.48 a. m. | Its epicentric area ran from Taal volcano to Zambales. |
| 1873.... | November.. | 14 | 5.30 p. m. | Most violently felt from Taal volcano eastward and southward in the island of Mindoro and in the provinces of Tayabas and Laguna. |
| 1875.... | May ..... | 19 | 11.30 a. m. | Destructive in the provinces of Tayabas and Ambos Camarines. |
| 1877.... | June ..... | 24 | 5.00 a. m. | Felt violently about the volcano of Taal. |
| 1880.... | July ..... | 18 | 0.40 p. m. | The last destructive earthquake felt in Manila; it laid in ruins the town and the neighboring provinces. |
| 1889.... | May ..... | 29 | 2.23 a. m. | Its destructive force was restricted to the vicinity of Taal volcano. |

It is an undoubted fact that most of the more violent shocks experienced in Manila seem to radiate from about the Taal center, and the epicentric area of many of them appears to proceed now northeastward, now northward, from the volcano. These facts suggest that the volcanoes of Taal, Maquíling, and Banájao belong to a single volcanic system. The seismic waves coming from this center travel more easily northward along the western ranges of mountains, the Sierras of Mariveles and Zambales, the central hills of Mórong, and throughout the great tuff area stretching to Bulacán, and even southward to the island of Mindoro, than along the mountains of the Camarines.

Among the shocks affecting Manila very frequently there can be distinguished two very different and distinct types, distinguishable by the difference of the area shaken and by the force and character of the movement. Those of the first type move an area much more extensive and prolonged in a north and south direction. The oscillations are slow, but of great amplitude, reaching, in the neighborhood of the volcano, a violent or destructive force. Since the year 1880 there have been many instances—for example, those of May 29, 1889, and December 15, 1901—of earthquakes quite violent or destructive southward in Batangas and the island of Mindoro. These were felt at Manila in the form of large, slow waves, inclined either to the southeast or to the southwest.

Earthquakes of the second type have an ellipsoidal area prolonged also in a nearly north and south direction; the movements, which seem to have the same direction everywhere, are rapid, with the vertical component predominating, though they rarely attain great force. They are felt strongly in the direction of the Zambales and the Mariveles, where a secondary center seems to exist. It frequently happens, as it did this year, that subterranean sounds are heard in the region. Apparently the two foci of the ellipsoid when shaken act like two simultaneously active centers. This proves that the volcano of Taal and the Zambales cordillera, supposing them to be of volcanic origin, form one identical system. Among many others which we might cite we shall mention as examples of the same type the earthquakes of September 16, 1852; January 26 and December 29, 1872; May 1 and June 24, 1877; April 27, 1878; and July 25, 1882. Of these, only the first was really destructive. Throughout the Taal region and the cordilleras of Zambales and Mariveles great upheavals and displacements took place, and in Manila many buildings were laid in ruins.

The seismic center most dangerous for Manila seems to be situated in the east or east-northeast rather than in the southern and southeastern volcanic region. The waves radiated from this center are the most irregular, both in direction and force.

*Direction of the seismic waves at Manila.*—Since the year 1880, 278 greater waves have been registered, distributed among 221 perceptible earthquakes. The directions of the waves correspond to the sixteen main directions of the compass and are summarized in the following table. The number of the oscillations registered is expressed after the corresponding direction.

| FIRST QUADRANT. | Number. | SECOND QUADRANT. | Number. | THIRD QUADRANT. | Number. | FOURTH QUADRANT. | Number. |
|---|---|---|---|---|---|---|---|
| N-S | 19 | E-W | 20 | S-N | 16 | W-E | 2 |
| NNE-SSW | 38 | ESE-WNW | 16 | SSW-NNE | 9 | WNW-ESE | 4 |
| NE-SW | 23 | SE-NW | 24 | SW-NE | 14 | NW-SE | 25 |
| ENE-WSW | 19 | SSE-NNW | 22 | WSW-ENE | 10 | NNW-SSE | 17 |
| Total | 99 | Total | 82 | Total | 49 | Total | 48 |

The above table shows that the smallest number of waves are those from the west and west-northwest. This seems to suggest that there is no seismic center westward under the sea, such as is very probably the case at the western edge of Mindanao. Besides no tidal wave has ever been mentioned in connection with the destructive earthquakes of Manila.

The direction in which the shocks are more frequently felt at Manila are southeast, northwest, and north-northeast, the maximum number corresponding to the last direction. All the most important seismic and volcanic centers of Luzón, Taal, Maquíling, Banájao, and the volcanoes of Mayón and Bulusan lie to the south and southeast.

The two latter volcanoes do not represent any danger for Manila; their seismic waves hardly retain any force after passing through the mountain ranges of the Camarines.

The great number of southeastern waves seem to be partly due to the fact that those radiating from the southern centers reach Manila a little inclined to that direction.

The investigations of the causes to which we can attribute these deviations of the seismic waves would carry us too far from our present purpose, so we postpone the question to a more opportune occasion.

The great number of waves proceeding from the northwest might urge us to consider the centers of Pangasinán and the Iloco provinces as independent of those of Nueva Vizcaya and Cagayán were it not for the fact that such a direction has sometimes been registered even in earthquakes which evidently have their epicentric area in the north.

In the first quadrant, whence the greatest number of registered waves came, we find not only the center of Nueva Vizcaya and the one in the northeast end of the island, but there also exist two closer ones in the east-northeast and east. These last can be called the Manila centers, for their shaken area comprises ordinarily the city of Manila, the provinces of Rizal and Bulacán, and the former district of Infanta.

All the centers mentioned are very active, but only the last, those lying in the east-northeast and east, seem, as far as our present knowledge goes, to be dangerous to Manila. The destructive waves experienced in July, 1880, can be very probably ascribed to these centers. The shocks felt on the 14th and 20th radiated from the eastern center, while those felt on the 18th of July radiated from the more distant east-northeastern one. There very probably exists in that direction a partly submarine macroseismic center. Concerning the northwestern part of the epicentric region Mr. H. D. McCaskey, B. S., has recently written:

> In my observations in the field I found numerous instances of violent twisting, fracture, and faulting, due in part, at least, to volcanic action and to these andesites and trachytes that form the modern eruptives. Along the Bayabas river, for instance, in several places the stream is choked with tumbled masses of great limestone bowlders, fallen into it, and broken from the strata on the hillsides above; the strata themselves are violently fractured and displaced, the shales farther up the stream are twisted and faulted, and between La Mesa and Bayabas the streams flow at various angles over the synclinal and anticlinal axes of the strata; there are frequent evidences of marked extrusions of andesite and trachyte, and, finally, the escarpments of such cliffs as are seen at Mt. Balite, and at points above Bayabas, tend to the belief in extensive displacements, faulting, and slipping of the entire strata, leaving more or less gradual and regular slopes upon the west and abrupt faces to the east and northeast, certainly not to be ascribed entirely to the effects of erosion.

## RELATIVE FREQUENCY OF EARTHQUAKES IN THE ARCHIPELAGO.

The frontispiece shows the relative activity of the different centers, or the relative frequency with which the earthquakes have been felt in every region of the archipelago. This plate is chiefly based on the lists gathered during the eighteen years which immediately preceded the war. This is the most complete record at our disposal. The scarcity of data from some provinces has obliged us in some cases to calculate the frequency of the shocks by that of the neighboring provinces, and thus the value of the result is but approximate. The regions referred to are the central districts of Luzón, inhabited by wild tribes, and the islands of Mindoro, Negros, Cebú, Leyte, and Sámar. The reports received from these islands came generally from only one place in each island, namely, the chief town. The values found for Manila are relatively too great, even if we take account of the very perceptible earthquakes alone; and the reason for this is too clear to need explanation. The more active centers are those of Surigao, Albay or Mayón, and Taal. But neither in these nor in other centers is the intensity of the shocks proportional to the frequency of the earthquakes, as is shown in the foregoing chapters.

The mean frequency of earthquakes in the whole archipelago in the eighteen years, 1880–1897, is given in the following table, in which the unit taken is the earthquake day as it is considered by many seismologists—that is, omitting the after shocks which are sometimes very

numerous during the day of the earthquake itself, and often for many consecutive days.

TABLE 14.—*Earthquakes in the Philippine archipelago, by months, 1880 to 1897, with the mean annual frequency.*

| YEAR. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. | Aver age. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1880 | 1 | 4 | 2 | 4 | ..... | 2 | 7 | 13 | 8 | 5 | 6 | 4 | 56 | 4.7 |
| 1881 | 7 | 8 | 8 | 6 | 7 | 4 | 6 | 7 | 13 | 6 | 2 | 6 | 80 | 6.7 |
| 1882 | 4 | 4 | 4 | 2 | 5 | 7 | 6 | 2 | 9 | 4 | 5 | 3 | 55 | 4.6 |
| 1883 | 1 | 6 | 4 | 3 | 1 | 2 | 3 | 4 | 3 | 3 | 1 | 1 | 32 | 2.7 |
| 1884 | 4 | 3 | 4 | 1 | 3 | 5 | 2 | 4 | 4 | 2 | 2 | 7 | 41 | 3.4 |
| 1885 | 1 | 5 | 3 | 3 | 4 | 1 | 7 | 3 | 3 | 9 | 8 | 3 | 50 | 4.2 |
| 1886 | 5 | 2 | 2 | 2 | 5 | 3 | 1 | 2 | 1 | 2 | 3 | 1 | 29 | 2.4 |
| 1887 | 1 | 5 | 6 | 8 | 2 | 3 | 2 | 2 | 4 | 5 | 3 | 2 | 43 | 3.6 |
| 1888 | 4 | 3 | 2 | 1 | 7 | 2 | 2 | 3 | 3 | 6 | 2 | 6 | 41 | 3.4 |
| 1889 | 6 | 3 | 1 | 5 | 5 | 2 | 2 | 3 | 4 | 1 | 3 | 3 | 38 | 3.2 |
| 1890 | 3 | 3 | 2 | 3 | 5 | 4 | 6 | 1 | 1 | 3 | ..... | 4 | 35 | 2.9 |
| 1891 | 3 | 1 | 4 | 3 | 4 | 6 | 3 | 7 | 8 | 3 | 5 | 4 | 51 | 4.3 |
| 1892 | 5 | 7 | 4 | 6 | 4 | 3 | 6 | 4 | 8 | 3 | 3 | 3 | 56 | 4.7 |
| 1893 | 5 | 3 | 3 | 5 | 4 | 10 | 5 | 6 | 5 | 2 | 7 | 5 | 60 | 5.0 |
| 1894 | 4 | 8 | 2 | 9 | 1 | 6 | 8 | 5 | 7 | 4 | 2 | 4 | 60 | 5.0 |
| 1895 | 7 | 7 | ..... | 2 | 7 | 3 | 7 | 6 | 6 | 4 | 9 | 4 | 62 | 5.2 |
| 1896 | 7 | 6 | 7 | 3 | 8 | 5 | 8 | 10 | 4 | 3 | 3 | 2 | 66 | 5.5 |
| 1897 | 10 | 9 | 9 | 9 | 10 | 9 | 7 | 8 | 7 | 7 | 15 | 7 | 107 | 8.9 |
| Total | 78 | 87 | 67 | 75 | 82 | 77 | 88 | 90 | 98 | 72 | 79 | 69 | 962 | 80.4 |
| Average. | 4.3 | 4.8 | 3.7 | 4.2 | 4.6 | 4.3 | 4.9 | 5.0 | 5.4 | 4.0 | 4.4 | 3.8 | 53.4 | 4.5 |

From this table we find an average of 53.4 earthquake days for the year, or 4.5 per month; no small number indeed, when we remember that the unit is the earthquake day and that it does not include the subsequent shocks.

The same table also shows a maximum frequency in 1881 and 1897, and a minimum in 1886. Since the year 1893 the numbers show an increase, probably due to the fact that during this period there have been more private observers of such phenomena throughout the islands. Hence we may reasonably expect that when our new meteorological service is established and in working order, the table of the frequency of earthquakes will show a still further increase over that previously given, based on somewhat deficient data.

If, following the method of Mr. Montessus de Ballore, applied by him not only to many European regions, but also to our archipelago, we study the earthquake frequency itself, taking the above period of eighteen years, we shall find the following numbers for the principal provinces of the archipelago:

| PROVINCES. | i | s (miles.) | PROVINCES. | i | s (miles.) |
|---|---|---|---|---|---|
| Ilocos Norte | 3.7 | 18.3 | Batangas | 4.2 | 17.0 |
| Cagayán | 3.6 | 38.6 | Tayabas | 3.2 | 26.5 |
| Abra | 3.0 | 19.0 | Ambos Camarines | 3.9 | 27.4 |
| Ilocos Sur | 3.4 | 12.7 | Albay | 4.6 | 18.1 |
| Nueva Vizcaya | 3.4 | 22.3 | Island of Panay | 2.0 | 51.0 |
| Benguet | 2.0 | 21.6 | Island of Negros | 1.4 | 30.7 |
| Unión | 2.0 | 19.7 | Island of Sámar | 1.1 | 72.0 |
| Pangasinán | 3.0 | 19.0 | Island of Leyte | 0.7 | 61.9 |
| Nueva Ecija | 3.0 | 29.1 | Zamboanga | 1.4 | 52.0 |
| Zambales | 3.4 | 12.0 | Surigao | 9.8 | 21.5 |
| Mórong | 3.1 | 14.3 | Cottabato | 2.0 | 73.7 |
| Laguna | 3.6 | 16.7 | Dapitan | 1.8 | 15.1 |
| Manila | 12.3 | 4.6 | | | |

Archipelago: i=53.5, s=47.7 miles.

There is some difference between our numbers and those found by Mr. Montessus de Ballore in his recent pamphlet, Die Seismen der Philippjnen, Amsterdam, 1901, because he took a very different period, and sometimes the single shock as unity, while we consider only the period running from the year 1880 to 1897, and take the earthquake day as our unit.

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