# REPORT ON THE GEOLOGY OF THE PHILIPPINE ISLANDS

BY

GEORGE F. BECKER

FOLLOWED BY A VERSION OF

# UEBER TERTIÄRE FOSSILIEN VON DEN PHILIPPINEN (1895)

BY

K. MARTIN

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MAYÓN VOLCANO.

# REPORT ON THE GEOLOGY OF THE PHILIPPINE ISLANDS.

By GEORGE F. BECKER.

## SOURCES OF INFORMATION.

An attempt will be made in the following paper to bring together, so far as is practicable, all that is known of the geology of the Philippine Islands. The report is intended as a vade mecum for geologists in the field and a guide to the literature in the office. Doubtless something has escaped which should have been included, especially among the shrewd remarks of early Spanish travelers, but research in that direction is curious rather than profitable. If here and there they caught a glimpse of truth, with which it would be pleasant to credit them, most of their views on geological matters were of a grotesque falsity, with which it would be unkind to reproach them.

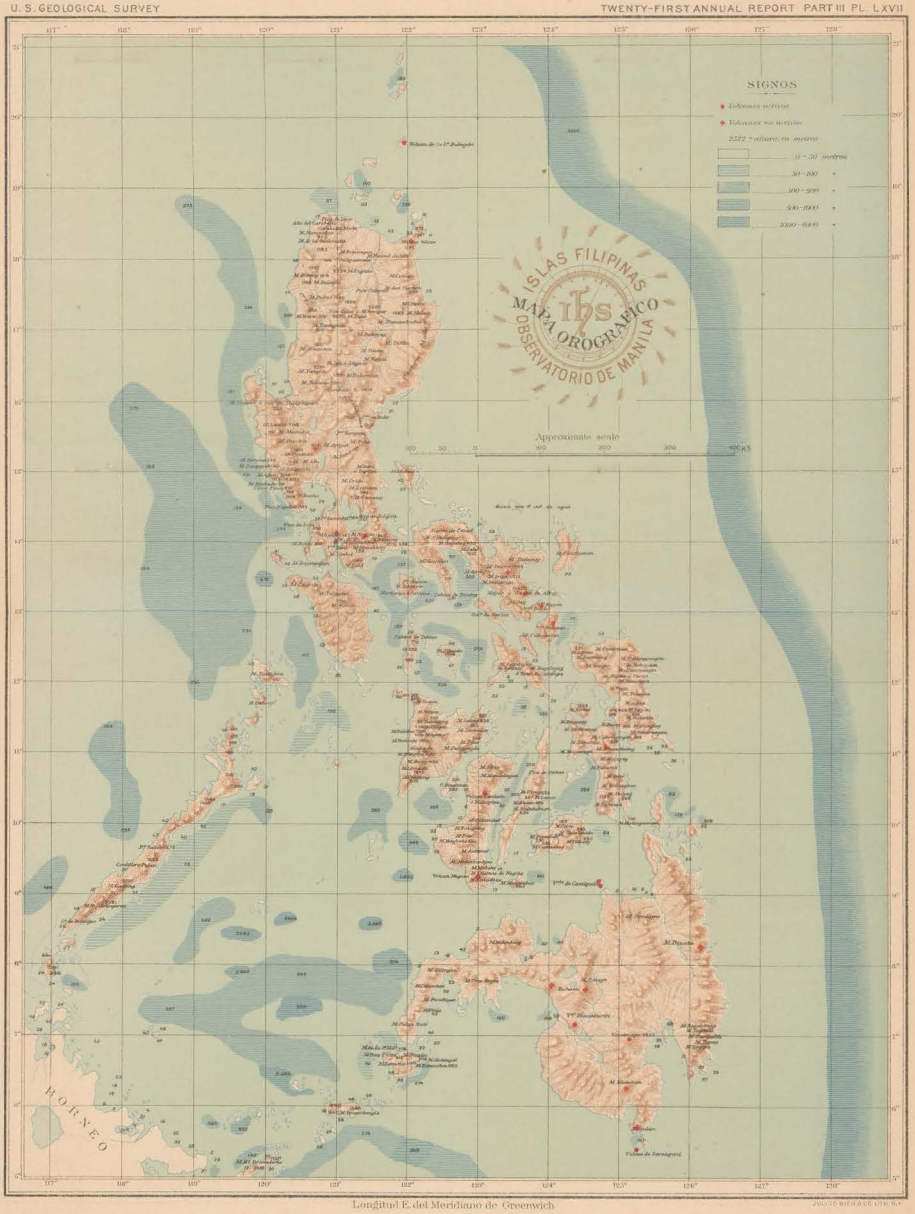
In the bibliography will be found references to about 100 papers touching on the Philippines. The greater number of them are of very subordinate value, containing only casual observations, or compilations which sometimes show careless preparation. Some errors I have noted; many more I have simply ignored.

Serious work began late in the fifties, with a group of German and Austrian geologists and explorers. Ritter von Hochstetter spent a few days in the Philippines, but his chief work was done elsewhere in the Far East. Baron von Richthofen, though but a short time in Luzón, was fortunate enough to discover nummulites at Binangonan. Carl Semper spent years in toilsome travel in the archipelago, almost completely cut off from civilized intercourse. His labors were zoological, but his studies of coral reefs are of great geological importance, and his geological collections are most valuable. They enabled Mr. Oebbeke, in 1881, to make his important study of massive rocks, and they furnished the material for Mr. K. Martin's paper on the Tertiary fossils of the Philippines (1895). Mr. Martin's paper seems to me so exactly suited to the end here aimed at that I have translated it as a complement to this report. Jagor was in the Philippines at the same time with Semper. He was not a specialist, but a very intelligent traveler, and he made many geographical observations. His collection of rocks was worked up by Roth, who took occasion to compile

everything then known of the geology of the Philippines. Jagor's human skulls were studied by Virchow, and both these important papers appeared in 1873 as appendices to Jagor's travels. Mr. R. von Drasche spent a few months in the islands, and explored new ground in 1875–76. His Foraminifera were studied by Mr. Felix Karrer, and threw new light on the stratigraphy. Mr. J. Montano also made some studies in Mindanao in 1879 to 1881, which, however, were mainly ethnological.

The Spanish engineers Sainz de Baranda, Antonio Hernandez, José Maria Santos, and José Centeno have contributed many details to the sum of knowledge. Much more has been done by Mr. Abella, who, under conditions which seem to have been very discouraging, spent many years in geological research. Much the best maps of the islands have been prepared by Mr. Enrique d'Almonte, whose work was largely performed in connection with Mr. Abella. Where Mr. d'Almonte was able to make surveys himself the execution was admirable, as I have reason to know. In much of the area of his maps he was compelled to rely on insufficient information. Besides other favors, I have to thank him for a table of areas of some of the islands, given on pages 10–11. The best map of Mindanao and the Joló Archipelago is that prepared by the Jesuit missionaries. The two maps accompanying this report, Pls. XLVII and XLVIII, are borrowed from the Atlas of the Philippine Islands prepared by the Jesuit Fathers and printed by the Coast and Geodetic Survey, 1901. While they are not wholly satisfactory, I know of none so good on a similar scale. Mr. Luis Espina compiled for me from the archives of the Inspección de Minas a sketch of the mineral resources and the geology of the islands which has been very useful.

In July, 1898, I was ordered to report to the military governor of the Philippines for duty as a geologist, and I accompanied Gen. E. S. Otis to Manila. I remained in the Philippines fourteen months, but could accomplish little geological work because of the attitude of the natives. When the cessation of the rains made it practicable to travel, Mr. Aguinaldo's associates had assumed a threatening attitude and soon afterwards became "war rebels." I was able to do something about Manila Bay as far north as San Fernando, and a little at Laguna de Bai. I had somewhat more success at Negros and Cebú, but geologizing under arms with a military escort is more exciting than profitable. I visited Iloilo, Guimarás, and Joló, and had excellent opportunities of studying from the decks of vessels the terracing of Bohol, Mindanao, and other islands. The military authorities afforded me all the facilities practicable without deliberately risking troops for the sake of information which can wait. I have to thank them for much kindness and for many privileges which rarely fall to the lot of a geologist. If the positive results of my stay in the islands are small, it has




Longitud E. del Meridiano de Greenwich

enabled me to get a better grasp of the geological situation than I could have acquired without an inspection of the country, and it is to be hoped that the digest here presented will aid my successor in making better headway.

The Spanish geologists have dealt in much detail with earthquakes and with mineral springs. These subjects are not included here, but the reader interested in them will find the literature cited in the bibliography (p. 108). It is intended that in most cases this report should enable the field geologist to dispense with other papers; but for field work in either Panay or Cebú, Mr. Abella's memoirs on those islands will be requisite.

It appears certain that Malaysia forms a single geological province. I have therefore made the attempt to draw upon Borneo, Java, and the Banda Islands for instruction and suggestion. Junghuhn, Verbeek, and other Dutch geologists have done a vast amount of work which can not safely be neglected in dealing with the geology of the Philippines. Messrs. Alfred R. Wallace, Dean C. Worcester, and F. S. Bourns also have contributed to geological knowledge of the islands through their studies of the distribution of living forms in Malaysia.

In treating the subjects of the various sections of this report a geographical arrangement of each has been adopted in order to facilitate perusal. The information available is so fragmentary that any attempt to treat separate areas completely would fail. For the purpose of making it practicable to combine data locally I have prepared a special index of provinces (p. 126), by means of which the reader will be able to collect the facts presented for any single province. The latitudes of this index are intended to assist such readers as are unfamiliar with the geography of the country in orienting themselves.

Geographical names in the Philippines are a source of much trouble. This arises partly from the fact that various cartographers have heard native names a little differently. Thus, a river in Mindanao is called on maps both Craán and Gran, which are clearly two attempts to reproduce the same word. Much worse than this is the native attitude toward natural objects, which they regard from what may be called a village standpoint. Thus, a famous mountain is often designated Majayjay for no better reason than that a village near it has that name. To the native, it would seem, a river is merely the water passing such and such a town, so that for him the stream has as many names as there are towns on its banks.

The phonetic Spanish system of spelling native names is a great convenience. All Filipino names are pronounced as if they were Spanish, and, when properly written, there is but one possible way either of pronouncing the syllables or of accenting the words. Spanish names usually follow exceedingly simple rules of accentuation, and,

when there is an exception to the general rules, this is indicated by a written accent. The reader must be warned, however, that the accents on native names are often carelessly treated by Spanish printers, no doubt through unfamiliarity with the correct accent. I have tried to write the names correctly in this paper, because it is intended for use in the field, and geologists will find that natives will fail to comprehend geographical names which are mispronounced. It is to be hoped that the present excellent method of name writing will be preserved in Government reports.

In consulting the literature readers will find that maps to which they will need to refer are drawn to different prime meridians. For this reason I have usually given only latitudes. The islands are so narrow that it is little trouble to run down a latitude and find a position marked on the map. Some Spanish maps count longitude from Madrid, others from the observatory at San Fernando, near Cadiz. French authors count from Paris, and the usage in Germany is variable. In dealing with miscellaneous maps and charts of the Philippines, it is convenient to know the following longitudes:[1]

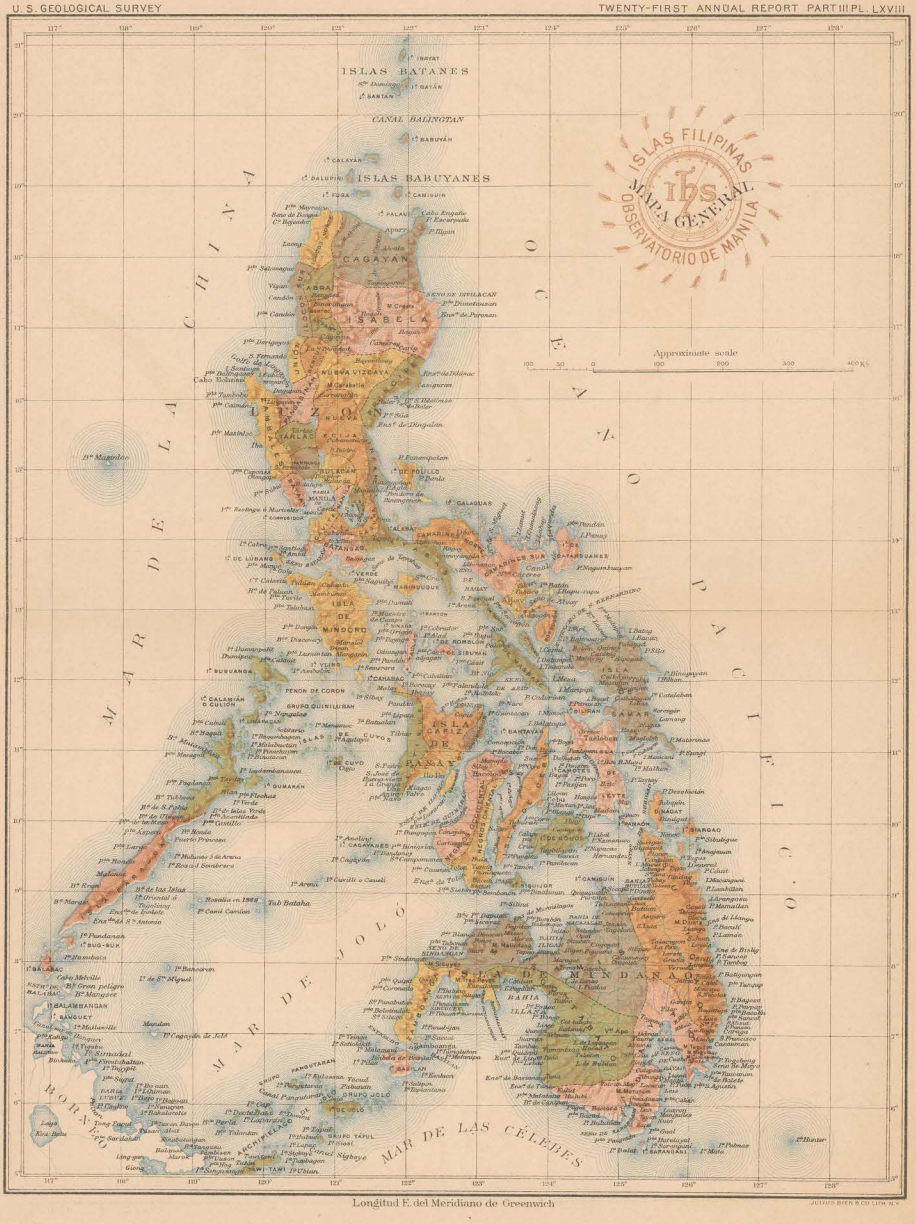
| | ° | ′ | ″ | |
|---|---|---|---|---|
| Greenwich Observatory | 0 | 0 | 0 | |
| Madrid Observatory | 3 | 41 | 21 | W |
| San Fernando Observatory | 6 | 12 | 24 | W |
| Paris Observatory | 2 | 20 | 14 | E |
| Berlin (Urania) Observatory | 13 | 36 | 53 | E |
| Ferro | 17 | 20 | 0 | W |
| Manila Cathedral | 120 | 58 | 8 | E |

NOTE ON SOME AREAS IN VARIOUS PROVINCES AND DISTRICTS IN THE PHILIPPINE ISLANDS.

[By Enrique d'Almonte.]

| District of Sámar: | Square kilometers. |
|---|---|
| Island of Sámar | 12,606 |
| Island of Capul | 40 |
| Island of Daluripi | 37 |
| Islets N. of Sámar | 140.25 |
| Islets E. of Sámar | 24 |
| Tomonjol and Suluan | 87.50 |
| Islets W. and SW. of Sámar | 189.25 |
| Total | 13,124 |
| **District of Calamianes:** | |
| Cuyos Islands | 149 |
| Culión | 388 |
| Busuanga | 994 |
| Remainder of Calamianes | 395 |
| Total | 1,926 |

[1] The observations are taken from the Nautical Almanac, 1896, p. 492.


ISLAS BATANES
CANAL BALINGTAN
ISLAS BABUYANES
CAGAYAN
ISABELA
ISLAS FILIPINAS
MAPA GENERAL
OBSERVATORIO DE MANILA
Approximate scale
MAR DE LA CHINA MERIDIONAL
MAR DE JOLO
MAR DE LAS CÉLEBES
ISLA DE MINDORO
ISLA DE PANAY
ISLA DE NEGROS
ISLA DE CEBU
ISLA DE LEYTE
ISLA DE SAMAR
ISLA DE MINDANAO
PENON DE CORON
GRUPO CUYO
GRUPO CALAMIAN
GRUPO QUINILIBAN
ARCHIPIELAGO DE SULU
BORNEO
Longitud E. del Meridiano de Greenwich

| | Square kilometers. |
|---|---|
| Joló Archipelago, including Tataran | 2,560 |
| Balábac Island and adjacent islets, including Cagayán Joló | 604 |
| District of Leyte: | |
| Island of Leyte | 7,109 |
| Island of Panaón | 187 |
| Island of Biliran | 512 |
| Adjoining islets | 62 |
| Total | 7,870 |
| District of Masbate and Ticao: | |
| Island of Masbate | 3,201 |
| Island of Ticao | 327 |
| Adjoining islets | 136 |
| Total | 3,664 |
| Province of Mindoro: | |
| Island of Mindoro | 9,653 |
| Semerara, Ilin, and remaining southern islets | 192 |
| Marinduque and adjacent islets | 918 |
| Lubang group | 215 |
| Other adjacent islets | 22 |
| Total | 11,000 |
| District of Romblón | 1,288 |
| District of Catanduanes: | |
| Island of Catanduanes | 1,720 |
| Adjacent islets | 85 |
| Total | 1,805 |
| District of Burias | 507 |
| District of Cebú: | |
| Island of Cebú | 4,188 |
| Adjacent islands | 458 |
| Total | 4,646 |
| District of Bohol: | |
| Island of Bohol | 3,685 |
| Adjacent islands | 121 |
| Total | 3,806 |
| Island of Siquijor | 271 |

## CRYSTALLINE SCHISTS AND OLDER MASSIVE ROCKS.

The exposures of crystalline schists and the older massive rocks in the Philippine Islands are neither good nor conveniently situated for study. As a matter of course they are scarcely to be found except in the mountains or in deep ravines. As a rule, they are heavily covered

with saprolite, soil, and dense vegetation, while the localities where they are to be found are largely in the possession of uncivilized tribes. The mountain system of northern Luzón and the eastern coast ranges of that island in the provinces of Infanta and Camarines Norte are largely composed of these rocks. They are also found on Lubang Island, in the sierras and seacliffs of Panay, and in the deep ravines of Cebú. On the east coast of Leyte there is a limited occurrence of crystalline schists, and the series is probably represented in Sámar. In the great southern island they appear in the provinces of Misamis and Surigao. The occurrence of metallic ores is suggestive of a still wider distribution of these formations.

The older rocks of the islands appear to embrace crystalline schists and gneiss, granites in small quantities, and possibly some syenite, while diorites and diabases and gabbros are abundant. The most important contributions to knowledge of these rocks are due to Messrs. Jagor, von Drasche, Montano, and Abella. It is a little difficult to correlate the information, which is fragmentary and not altogether accordant. Mr. von Drasche, who began his studies in the Zambales Range, compares the rocks which he met in the Caraballo Sur, the Cordillera Central, and the San Mateo Mountains with those of Zambales. Mr. Abella's most elaborate studies were made in Panay, but during his long residence in the archipelago he became familiar with many areas. His determinations in some cases fail to agree with Mr. von Drasche's. Mr. Montano's examinations were confined chiefly to Mindanao, where Mr. Abella also had made studies.

Aside from somewhat vague and casual mentions,[1] the first statements concerning the older rocks with which I have met are by Meyen and Itier. The former about 1832 observed that the limestones in which the somewhat famous caves occur near San Mateo, Manila Province, rest upon diorite.[2] Itier[3] a few years later drew attention to the character of the stream pebbles at Angat, in the Province of Bulacán. This locality lies at the eastern edge of the great central plain of Luzón, and in the mountains a few miles farther east is an important iron mine. Seemingly on the strength of these facts, Mr. von Drasche lays down on his map an area of crystalline schists directly east of Angat.

In his studies of the Zambales Range, which lies to the west of the Province of Pangasinán, Mr. von Drasche reached the conclusion that this sierra is composed chiefly of gabbroitic and dioritic rocks. What he calls diabase-gabbros are more or less peculiar, but are closely related to ordinary gabbros. The best exposure appears to be along

[1] Dana did not land in northern Luzón, but states that it is said to be covered with granite, gneiss, etc. (Wilkes Expl. Exp., Vol. X, 1849, pp., 539–545.) He cites no authority. Humboldt, in Cosmos, makes a similar statement on Dana's authority (Vol. IV, 1858, p. 404), and other writers have frequently cited Cosmos on this subject.

[2] Reise um die Erde, Part II, 1835, p. 237.

[3] Bull. Soc. géog., Paris, 3d series, Vol. V, 1845, pp. 365–389.

a trail across the range just to the northward of the coast town of Santa Cruz. This path follows a river called by Mr. von Drasche the Santa Cruz River, but which appears on Mr. d'Almonte's map as the Nayon. It crosses the divide in latitude 15° 51′. Most of the western slopes of the range consist of the gabbro in thick layers (Baenke) with northerly strike and western dip. In connection with the gabbro occur dioritic schists, but whether these are uralitic derivatives of the gabbro is not discussed. The green dichroitic hornblende lies in irregular patches among the plagioclases. The gabbro is granular, and to the naked eye shows olive-green and light-brown grains, both of which turn out under the microscope to be augite. This augite, he says, "exhibits a not inconsiderable dichroism between reddish brown and olive green." It seems probable that Mr. von Drasche was dealing with a mixture of green augite and brown rhombic pyroxene. The augite showed a tendency to a single cleavage. Portions of the rock are sharply banded. An analysis of this rock is given below. A similar rock was found on the eastern slope of the range, well down toward the plain of Pangasinán. It, too, was analyzed, and its composition is remarkable for the excessively small percentage of soda and potash. Among the gabbros on the western side, Mr. von Drasche found one which was olivinitic, the diallage being green and quite free from dichroism. This I take to mean that the appearance of olivine was accompanied by the disappearance of hypersthene. Serpentines were found along this trail. Farther south, on the Bucao River Pass (latitude 15° 13′), Mr. von Drasche also found gabbros and serpentines. In the latter he detected remnants of olivine and bronzite.[1]

In examining the mineral springs of the country Mr. Abella encountered compact argillaceous, ancient-looking slates at the eastern base of the southern end of the Sierra Zambales. They occur in the township of O'Donnell, at a place called Canan. It is noteworthy that they strike ENE. and have a northwesterly dip of 25°.[2]

On the San Mateo River in Manila Province access is afforded to the foothills of the eastern ranges, and here the rocks appear to have a marked similarity to those of the Zambales Range. It has already been mentioned that Meyen found diorites beneath the limestones. Near by Mr. von Drasche found coarse-grained gabbros on the Poray, a small tributary of the San Mateo. They contain hornblende as well as diallage, form thick layers, and dip to the eastward. Higher up the stream he met beds which are stratified, resemble sandstone, and are dark green. They consist of crystal fragments, mostly rounded and much decomposed. Mr. von Drasche had this material analyzed, and its chemical and mineralogical composition led him to regard it as a diabase tuff. It is unfortunate that the term tuff should be used

[1] Fragmente zu einer Geologie der Insel Luzón, 1878, p. 21.
[2] Manantiales, 2d study, 1893, p. 144.

by so many geologists to denote waterworn sediments derived from eruptive rocks. By a slight extension of the usage, arkose would be denominated granitic tuff, which would certainly be a retrogression in nomenclature. The excuse is, of course, that it is sometimes difficult to say whether such fragmental masses are pyroclastic or hydroclastic. In these days of microscopical study, however, so important a point should not be left uncertain, and tuff should be limited to essentially pyroclastic material.

At Maínit, on the Payaguán River, 6 kilometers from Boso-boso, Mórong Province, is the center of an extensive area of ancient slates. They are described as diabasic and are accompanied by diabasic conglomerates. The strata at Maínit strike N. 10° W., and dip eastward almost vertically.[1]

The following are the analyses made for Mr. von Drasche. I is the gabbro from the Santa Cruz or Nayon River, on the western slope of the Zambales Range; II is the gabbro from the eastern slope of the same range on the same section; III is the so-called diabase tuff from Poray Creek, San Mateo River. The analyst was Dr. Berwerth.

*Analyses of gabbros and diabase tuff.*

| | I. | II. | III. |
|---|---|---|---|
| $SiO_2$ | 50.52 | 48.93 | 51.69 |
| $Al_2O_3$ | 20.12 | 21.12 | 20.11 |
| FeO | 4.38 | ..... | ..... |
| $Fe_2O_3$ | ..... | 6.95 | 9.36 |
| CaO | 9.75 | 11.99 | 6.26 |
| MgO | 11.30 | 9.54 | 4.85 |
| $K_2O$ | 2.76 | .05 | 1.21 |
| $Na_2O$ | 2.48 | .41 | 1.97 |
| Ignition | .36 | .59 | 7.07 |
| Total | 101.67 | 99.58 | 102.52 |

Older massive rocks occur also in the Caraballo Sur and in the Caraballo Central or Cordillera Central of northern Luzón. The first definite statement known to me on the subject is by Centeno in 1875. The range which forms the eastern limit of the valley of the Abra River, or the northeastern branch of the Caraballo, he says is pyrogenic, in consequence of which the tributaries of the Abra which come from the eastward carry larger quantities of volcanic and plutonic rocks, such as trachytes, diorites, and various species of porphyry, granite, syenite, etc.[2] Semper traveled in this region, but was little impressed

[1] Abella, Manantiales, 2d study, 1893, p. 75.

[2] Memoria geológico-minera, 1876, p. 19.

with the presence of ancient rocks.[1] Among the specimens which he collected, however, Mr. Oebbeke found a quartz-porphyry from Cabayan, a village in the Province of Benguet, and a quartz-diorite from the Agno River, near the same place.[2] Mr. von Drasche crossed the Caraballo Sur, and made trips through the provinces or districts of Unión, Benguet, Lepanto, Bontoc, and Ilocos Sur, which lie along the Caraballo Central. The basal rocks in this last range, in his opinion, consist of diorites, diabases, protogine-gneiss, and chloritic schist.[3] Some details are as follows: To the northeast of Trinidad, the capital of Benguet, is a large area of diorite, and in seams in this rock occurs gold, exploited by the Igorrotes.[4] A portion of this diorite is quartzose. At the village of Amlimay, on the Agno, in Benguet, the lowest formation is quartzose schist.[5] At Vigan, the capital of Ilocos Sur, there are chlorite-schists and protogine-gneiss.[6] Both on the Agno and on the Abra plagioclase-hornblende-chlorite rocks underlie a formation named by von Drasche "the Agno beds,"[7] which is also found in the Caraballo Sur, on the Pinquiang River. The lowest portion of this formation consists of coarse breccias and conglomerates of the dioritic rock. The overlying strata are of finer grain, with transitions to sandstone, which are again succeeded by green and purple beds, these consisting of thoroughly decomposed rock and being filled with calcite veins. The Agno series is very coarsely bedded, and often faulted. Mr. von Drasche counts the Agno beds among the primitive rocks (Grundgebirge) of the region. No fossils were found in them.

Mr. von Drasche crossed the Caraballo Sur from Carranglán, in Nueva Écija, to Bambang, in Nueva Vizcaya. A few miles south of the crest lies the refuge which he calls Camarín Santa Clara. This he found surrounded by a beautiful, typical, fine-grained, massive syenite in place. From this point to the summit of the pass, a six hours' ride, he found everywhere in place a beautiful coarse-grained rock almost identical with the gabbro of the eastern slope of the Zambales Range.[8]

Mr. Abella's observations differ markedly from Mr. von Drasche's. In a paper dated in 1881, but seemingly written before he had read the Austrian geologist's memoir, Mr. Abella strongly insists on the predominance of diorites in northern Luzón. In a trip from Carranglán to Bambang and to Solano, a few miles north of Bambang, he found that not only the crest of the range consisted of diorite, but the underlying rock all the way from Camarín de Salazar (doubtless von Drasche's Camarín de Santa Clara) to Solano,[9] a distance of over 30 miles. In 1892, Mr. Abella again referred to this subject. He then examined his suite

[1] Die Philippinen und ihre Bewohner, 1869, p. 99.
[2] Neues Jahrbuch, Beil.-Band I, 1881, pp. 495, 497, 498.
[3] Fragmente, 1878, p. 42.
[4] Ibid., p. 33.
[5] Ibid., p. 35.
[6] Ibid., p. 41.
[7] Ibid., pp. 34, 37.
[8] Ibid., p. 27.
[9] Apuntos físicos y geológicos, 1884, p. 30.

of specimens collected in 1881, this time under the microscope, and found neither syenite nor gabbro, but only diorite. The diorites of the region are in part quartzose and so crystalline and granular, he says, that to the naked eye they resemble rocks of the granitic family.[1] As Mr. von Drasche appears to have relied on megascopical inspection, the weight of evidence is on the side of Mr. Abella.

In the Caraballo Central also Mr. Abella is very positive that diorites are the oldest exposed rocks, agreeing only partially with Mr. von Drasche. The peak of Mount San Tomás, or Tonglón, in Unión Province, famous as the site of a great earthquake in 1641, is a holocrystalline, somewhat quartzose, hornblendic, chloritic diorite. This rock in various facies extends far to the north, south, and east of Tonglón and is probably continuous to the Agno River. Some of its facies are augitic and others porphyritic. At Galiano is a rock which Mr. von Drasche describes as unquestionably a hornblende-trachyte tuff.[2] Mr. Abella has examined this material at various points and studied its relation to the diorite massif of Tonglón, which it surrounds on the south and west. He pronounces it simply a sandstone composed of material derived from the dioritic area. Mr. Abella also gives many notes on a formation which would appear to be that named the Agno beds by Mr. von Drasche. It is extensively developed throughout Unión Province and in Benguet. It rests on diorite. The basal beds are conglomerates with more or less rounded dioritic pebbles, often of enormous size. The middle portion consists of sandstones, and the upper strata of clays containing lignite and fossil shells of species now living in the Philippine seas.[3] The supposed tuff at Galiano belongs to this same series. Such partial information as was available to Mr. Abella in 1893 concerning the Cordillera Central of northern Luzón, including its branches reaching to the China Sea on the west and to the Cagayán Valley on the east, led him to believe that it consists of a core of ancient diabasic and dioritic schists together with massive rocks belonging to the same type and epoch, which is cut at some points by very modern trachytes and andesites and is overlain, to the west at least, by the same limestones, conglomerates, sandstones, and clays which constitute the post-Tertiary formation of the central part of Luzón.[4]

Semper seems to be the only naturalist who made public any notes on the Sierra Madre of northeastern Luzón. Two of his specimens represent pre-Tertiary massive rocks. Of these, one comes from the range near the coast town Palanan, latitude 17° 5′. It is described by Mr. Oebbeke as a peridotite containing diallage, enstatite, and pikrite. The other specimen probably comes from the western foothills of the same range. It was a pebble in the brook called Dicamuni, and this

[1] Terremotos de 1892, 1893, p. 32.
[2] Fragmente, 1878, p. 31.
[3] Terremotos de 1892, 1893, p. 33.
[4] Manantiales, 2d study, 1893, p. 18.

brook is said to be "in the land of the Minangas." Semper's map shows Minanga in latitude 17°, at or about the locality of the settlement named Malunú on Mr. d'Almonte's map.[1] This pebble, according to Mr. Oebbeke, is a norite.

The cordillera of Baler and La Infanta, lying to the east of the great plain of Luzón, is described by Mr. Abella in much the same terms as the Caraballo Central. It consists of diabase and diorites, in part schistose, pierced by modern volcanics.[2] To this range belongs the spur containing the San Mateo caves and the gabbroitic area near by them examined by Mr. von Drasche, of which mention has already been made (p. 13).

The foregoing notes cover all the occurrences of ancient massive rocks and crystalline schists known to me north of Laguna de Bai. Immediately south of the lake neo-volcanics appear to stretch quite across Luzón. In the southwesterly prolongation of the island, however, there are patches of the rocks in question. Of these the most northerly is in Tayabas Province and was visited by Mr. von Drasche. This very small area lies just to the west of Antimonan, in latitude 13° 59′. The rock is a greatly decomposed, green talc-chlorite schist with a high easterly dip.[3]

One of the most important areas in the whole archipelago surrounds the ports of Parcale and Mambulao, in Camarines Norte.[4] This is the most promising auriferous district known in the islands, and the rock is also of special lithological interest. Roth describes it as follows:

> On the northeast coast of the province, the country between Paracale[5] and Mambulao consists of gneisses and hornblende-schist in which there are rich quartz veins. The mountain lying a quarter of a league north of Mambulao, and the mountain north-northeast of Mambulao (divided by the Mount Dinaan Brook), consist of gneiss, in which the white layers are separated by thin, discontinuous, uneven layers of tombac-brown mica. The white layers are composed of a mixture of fine-grained quartz, some orthoclases, and plagioclases. The rock is said to contain gold. The mountain half a league northwest of Paracale, Mount Dinaan, and the stretch between Paracale and Mambulao consist of hornblende-schist. The fresh rock from Mount Dinaan is dark colored through the preponderance of rather coarse hornblende, narrow discontinuous white stripes being due to aggregations of plagioclase in small crystals. Besides these minerals there is some pyrite and brown mica. The magnet extracts no magnetite from the powdered rock. The weathered rock between Paracale and Mambulao strikes east and dips to the south at 40°, is gray-green, soft, intersected by stringers of magnetite, and converted sometimes into serpentine-bearing talcose schist, and sometimes into talcose serpentine-schist.[6]

[1] For further details as to this locality see footnotes to Mr. Martin's paper which follows this report.
[2] Manantiales, 2d study, 1893, p. 16.
[3] Fragmente, 1878, p. 59.
[4] Till within a few years there were two provinces, called Camarines Norte and Camarines Sur. Early in the last decade they were united into a single province, Ambos Camarines. About the same time the southeast end of Albay was separated from it, and designated the Province of Sorsogón.
[5] Roth writes Paracali, which is not now the accepted form.
[6] Jagor's Reisen, 1873, p. 344.

This quotation contains the second unquestioned reference to orthoclase among the pre-Tertiary massive rocks discussed in this notice. Judging from the distribution of gold and iron mines on Mr. d'Almonte's map, this area of ancient rocks should stretch from Mambulao to near Daet. Between Paracale and Mambulao Mr. von Drasche found a layer (dike?) of peridotite, about a hundred paces in width, which projects into the sea.[1]

In Camarines Sur there are diorites on the southwest coast just to the westward of the port of Calbajan. They are not schistose, the grain is variable, and the feldspar is relatively anorthitic, since it is completely decomposed by hot chlorhydric acid. The hornblende is black. The rock contains magnetite and some pyrite.[2]

In Sámar Jagor found no ancient rocks in place, but sediments which he collected on the north coast appeared to Roth, after panning, to be derived from gneiss or mica-schist. From the Basey River, on the south coast of the island, Jagor brought home pebbles which Roth considered an oligoclase porphyry.[3]

In Leyte, on the east coast, half a league north of Tanauan, Jagor observed a projecting rock consisting of chloritic quartz-schist.[4]

At Culión, in the Calamianes, Paleozoic schists and quartzite are said to occur.[5]

The Island of Lubang lies to the northwest of Panay, about latitude 13° 50′. Dana[6] reported, "Luban contains copper pyrites in talcose and chlorite slate, and the same formation extends into Mindoro, where it passes into serpentine, specimens of which were contained in the cabinet of Señor Roxas." At San José too, on the coast of Panay, the same geologist saw pebbles of talcose schist. This island has since been investigated by Mr. Abella, not exhaustively, yet with much care.[7] The commonest ancient rock of Panay is a quartz-diorite of granular texture, or a tonalite, in which labradorite is the predominant feldspar, and the quartz is in part granular, in part interstitial. The ferromagnesian silicates are reddish biotite and green fibrous hornblende. Magnetite is absent. This rock of granitic type is associated with others which are semi-porphyritic and contain no mica. There are also quartzless diorites connected with the other varieties by transitions and carrying some magnetite. Mr. Abella further describes rocks containing both augite and hornblende, which he classifies with the diabases, but he does not discuss the question how far the green fibrous hornblende of the diorites may be uralitic.

The diabases are less abundant. They also are labradorite rocks. "The crystals of augite are individualized and well characterized, but what chiefly distinguishes these diabasis from the diorites is that, both

[1] Fragmente, 1878, p. 62.
[2] Jagor's Reisen, 1873, p. 348.
[3] Ibid., pp. 352-353.
[4] Ibid., p. 220.
[5] J. E. Tenison-Woods, Nature, Vol. XXXIII, 1886, p. 231.
[6] U. S. Expl. Exp. 1849, Vol. X, p. 539.
[7] La Isla de Panay, 1890, p. 97.

in the groundmass, and especially as inclusions in the pyroxene, there is a great abundance of ferrous iron, and above all of magnetite, which was not found in the diorites." Whether the structure is ophitic is not stated, but I infer from the absence of mention of minute augites that the groundmass is feldspathic, so that the rock might perhaps be classed as an ancient, holocrystalline pyroxene-andesite. At one locality (Mount Násog) much decomposed gabbro was found. Certain picrites, though accompanying the rocks described above, may possibly, in Mr. Abella's opinion, belong with the neo-volcanic group, while the serpentines met he classifies with the older group. Tuffs appear to have accompanied the diorites and diabases, and stratified rocks, including the lignitic beds, intervened between the eruption of these rocks and the neo-volcanic andesites and basalts.[1] In Mr. Abella's map of Panay the ancient and neo-volcanic rocks are not differentiated. The massive rocks are mainly confined to the range which forms the eastern boundary of the Province of Antique, and to the divide which forms the western boundary of Concepción. Excellent tonalites, fit for quarrying, Mr. Abella says, occur on the shore, on the west coast, at Tinanagan, in latitude 11° 44′ 30″, some 5 miles westerly from Pandan; and also on the east coast at Colasi, in latitude 11° 4′ 30″. He suggests this rock as a substitute for Hongkong granite, which is largely employed for paving in Manila.

In the Island of Negros I did not chance upon any ancient rocks. I should expect to find such in the watershed of the southwest coast of Negros, a region which I was unable to visit, rather than in the main volcanic sierra of the island.

Cebú is covered for the most part by a mantle of coral, 100 or more feet in thickness, which reaches from the crest of the island to the sea. In some localities, however, the coral is absent, a condition due, at least in part, to stream erosion. One such exposure occurs in the foothills of the main range, to the west of the capital town, also named Cebú, and extends for several miles both up and down the island. A similar exposure lies on the western slope of the central range nearly opposite that just mentioned. Other areas of minor extent are found toward the ends of the island. A portion of these denuded areas is occupied by schists and pre-Tertiary massives. They have been examined by Mr. Abella, and his specimens were determined microscopically by Mr. José MacPherson. At a single point, Bagbad,[2] Mr. Abella found an amphibolic slate, and he inclines to the opinion that the geological foundation of the island is of this character. The oldest massive rocks are almost exclusively diorites, often much jointed, and sometimes exhibiting traces of schistosity. Dioritic tuffs accompany the diorites. The only exceptional specimens noted are felsophyres,

[1] La Isla de Panay, 1890, p. 109.

[2] I have not been able to find this point on the map, or any note as to its precise locality, in Mr. Abella's memoir on Cebú.

which appear in this case to be porphyritic diorites, a single actinolite rock from the hot springs of Cagbao,[1] and a single granite. The granite comes from the upper part of the Panoypoy Brook, and therefore from a point 3 or 4 miles to the northwest of Consolación, a town lying 8 miles or so to the northeast of Cebú. Of these specimens Mr. Abella says: "Until other more detailed investigations disclose the part played by these rocks we can only consider them as accidental."[2]

On the Guadalupe River, which empties into the sea at the town of Cebú, I met with a rock which is probably allied to Mr. Abella's granite. It occurs in the stream bed about three-quarters of a mile above the point at which the river debouches into the coastal plain, or some 4 miles from Cebú. It is a fine-grained, greenish-gray rock, containing chlorite and some pyrite. It has been much crushed and jointed. Under the microscope it appears thoroughly granular, and is composed of striated and unstriated feldspar, quartz, hornblende, iron ore, and other minor constituents. It is somewhat decomposed. A considerable portion of the feldspars is unstriated. The predominant plagioclase is oligoclase, but there are a few grains of labradorite, one of them neatly inclosed in oligoclase. A few individuals might possibly be interpreted as albite, but these were not so oriented that they could be certainly determined. The unstriated feldspars have a smaller index of refraction than balsam, and are on the whole more decomposed than the plagioclases, being largely filled with sericitic mica. The quartz is interstitial, and is much cracked, no doubt by pressure. The hornblende also appears to be of somewhat later development than the feldspars. It is green and fibrous, but there seems no evidence that it is uralitic. The abundant chlorite and epidote are certainly in part derived from the hornblende. There is a moderate quantity of magnetite and seemingly a little ilmenite, surrounded by leucoxene. A few apatites and zircons were observed. To make certain of the proper classification of the rock the following partial analysis was carried out by Mr. George Steiger:

| | Per cent. |
|---|---|
| CaO | 2.66 |
| $K_2O$ | 1.07 |
| $Na_2O$ | 6.19 |

Estimating the amount of hornblende at 5 per cent, and supposing a tenth part of this mineral to be CaO, the analysis is compatible with the following hypothetical composition:

| | Per cent. |
|---|---|
| Quartz | 25 |
| Hornblende | 05 |
| Labradorite ($Ab_1An_1$) | 07 |

[1] This place is 3 or 4 miles northwest of Minglanilla, a town 6¼ miles southward of Cebú. Possibly, and indeed probably, this specimen is identical with the amphibolic slate from Bagbad, which may be a small village near the springs.

[2] Rapida descripción . . . de Cebú, 1886, pp. 96–101.

| | Per cent. |
|---|---|
| Oligoclase ($Ab_4An_1$) | 42 |
| Albite | 15 |
| Orthoclase | 06 |

The amount of unstriated feldspar, however, is much in excess of 6 per cent; and I am forced to the conclusion that the rock is composed largely of soda-orthoclase. It can not, however, be classed otherwise than as a diorite. It seems not improbable that Mr. Abella's granite may be a rock with a larger percentage of a similar orthotomic feldspar.

Mr. A. F. Renard found among the specimens of the *Challenger* expedition a pyroxene-olivine rock which he compares to a basalt, but inclines to think pre-Tertiary and a melaphyre. It was collected in a river bed near Cebú, Cebú.[1]

The late Mr. William Ashburner, a well-known American mining expert, examined a gold-quartz vein on the Island of Panaón in 1883. This island lies immediately to the south of Leyte, from which it is separated only by a channel a few hundred yards in width. The mine lies just south of Pinutan Point and is marked on Mr. d'Almonte's map. Ashburner reported the walls of the vein as greenstone-porphyry.[2] This term would not exclude "propylitic" neo-volcanics, but in all probability points to diorite or diabase.

Concerning the great Island of Mindanao, only scattered observations are available. Sainz de Baranda[3] noted the occurrence of serpentine on the east coast of the island at Canmahat and in Misamis Province at Pigtao. Mr. Centeno states that at Pigholugan, near Cagayán, in the Province of Misamis, there are quartz veins in talcose schists. The auriferous districts of the Province of Surigao may, he points out, be regarded as a continuation of the Misamis district. The most notable deposits here are in the mountains of Canimon, Binuton, and Canmahat, a day's journey southward from the town of Surigao. The terrane is here composed of much altered talcose slate and serpentine.[4] Mr. Semper collected on the Maputi, which is an upper tributary of the Agusan River in Surigao. Here he found a uralitic gabbro and a chloritized, aphanitic, augite-plagioclase rock, containing a few plagioclase phenocrysts. The specimens have been described by Mr. Oebbeke.[5] They are probably facies of the melaphyres found by Mr. Montano. Mr. Ashburner examined a slate belt in the extreme northern portion of the island, about 8 miles to the southward of the town of Surigao, at the headwaters of the Cansuran River. It contains auriferous quartz stringers. Mr. Montano collected melaphyres

[1] Voy. of *Challenger*, Vol. II, pt. 4, 1889, pp. 160–175.

[2] Manuscript report of Mr. Ashburner, 1883, shown me by his clients.

[3] He also mentions crystals of rutile from an island called Bigat, which is unknown to me. Anales de Minas, Madrid, Vol. II, 1841, pp. 197–212.

[4] Memoria geológico-minera, 1876, p. 49.

[5] Neues Jahrbuch, Beil.-Band I, 1881, p. 498.

at a number of points in eastern Mindanao. Such are the eastern shore of the Bay of Butuan, the eastern coast of the island between Bislig and Catel, and the divide between the waters which flow northward into Butuan Bay and those which flow southward into the Gulf of Dávao. The river of this southern drainage basin Montano calls the Sahug. Other authorities give it different names. In its headwaters he found float consisting of melaphyre and quartz-porphyries. Melaphyre he found again at Pujada Bay near Cape San Agustín. Quartz breccias also occur on the divide between Pujada and the Gulf of Dávao. Serpentine accompanies the melaphyre to the south of Bislig.[1]

Mr. Minard visited the gold-bearing region of Misamis, the northwestern province of Mindanao. The sandstones and conglomerates of the Iponan Valley, dipping 12°, are said to be broken through at many points by diorite and serpentine. The pebbles of the conglomerates include diorites, augite-porphyry, serpentine, jasper, and marble.[2] Some years later Mr. Abella made a reconnaissance of this region, examining the gold deposits along the courses of several rivers, all of which empty into Macajalar Bay. They are the Iponan, the Cagayán, the Bigaan, and the Cutman. In this region he found two considerable areas of old slates. One of these touches the Iponan River 10 or 12 miles from the sea. The other is intersected by the Cutman and approaches the sea within 2 miles, near the town of Agusan, which lies at the mouth of the Cutman River. Alluvial deposits fringe the shore of the bay and follow the streams. Otherwise the country, as depicted by Mr. Abella, is covered with strata provisionally referred to the Miocene. The slates are described as metamorphic and in part steatitic. The pebbles of the Tertiary conglomerates consist of such slates, serpentinoid rocks, and many varieties of "trachytic rocks." I think that at the date of his memoir, 1879, Mr. Abella used this term for neo-volcanic rocks not basaltic in appearance. The description of the fossiliferous rocks overlying the slate leaves no doubt that they are Tertiary or Recent, a fact which it is difficult to reconcile with Mr. Minard's statement that they are cut by serpentine and diorite. In the placer at the Bigtog, tributary to the Cagayán, Mr. Abella found slightly rounded, large pebbles of orthoclase.[3]

A few miles northwest of Zamboanga (in southwestern Mindanao), at Caldera, Dana observed hornblendic and talcose schist in pebbles,[4] and on Malanipa, about 13 miles E. by S. from Zamboanga, the *Challenger* expedition collected serpentinized peridotite, studied by Mr. Renard.[5]

[1] Mission aux îles Phil., 1879–1881, pp. 272–277.
[2] Bull. Soc. géol. France, 5th series, Vol. II, 1874, pp. 403–406.
[3] Mem. acerca de los criaderos auríferos . . . Misamis, 1879, pp. 4, 18, 32, 45.
[4] U. S. Expl. Exp., Vol. X, 1849, p. 539.
[5] Ibid.

The foregoing fragmentary notes cover all the information available concerning the crystalline schists and pre-Tertiary massive rocks. There is, however, a second line of evidence on this subject which is perhaps not without value, although it is inconclusive. In all cases in the Philippines of which details are known, crystalline schists accompany gold-quartz veins, copper ores, iron ores, and galena. It is therefore probable that where nothing is known of the geology except the occurrence of these ores crystalline schists exist. This deduction leads to the inference that the northern end of the Cordillera del Norte, being auriferous, consists in part of such schists, and the gold of northern Zambales may be taken into account in considering the massive rocks there. A belt of iron ores over 40 miles in length and presumably accompanied by schists passes east of Angat in the same direction as the trend of the neighboring sierra. The islands to the eastward of central and southern Luzón would seem to be composed in part of schists, and with them may be considered the peninsula of Caramoan, which, as well as the islands Polillo, Luhuy, Catanduanes, and Rapurapu, contains gold. To the southward of Luzón the islands Capul, Masbate, and Marinduque contain copper, while Sibuyan and Masbate produce some gold. Southern Negros has gold deposits; copper is reported from Balábac, and gold from Joló. Thus, if this class of evidence is admissible, crystalline schists occur in all the more important portions of the archipelago except Palawan or Paragua, of which next to nothing is known.[1]

A mere inspection of any chart would lead to the inference that such must be the case, for most of the platform on which the islands stand is exposed, while wherever the earth's surface is sufficiently incised crystalline schists or allied granular rocks are laid bare. Of the age of the rocks under discussion nothing is known directly, and it is probable that several eras are represented. When the neo-volcanic rocks come to be discussed it will be found that they belong for the most part to the same chemical and mineralogical types as the pre-Tertiary massives. There appears to have been in earlier times one period at least of volcanism very similar to that still progressing in the archipelago. Very probably it, too, was accompanied by an important uplift of the region. It is noteworthy that the older massives are very deficient in potash. The only orthoclastic rocks noted are a specimen of quartz-porphyry from Cabayan in Benguet; a gneiss from Paracale, Ambos Camarines; a granite from Cebú, and some pebbles from Misamis. Among the neo-volcanics, also, lime-soda feldspars vastly predominate over sanidine.

In Borneo the central portions of the mountain ranges are composed largely of crystalline schists. These are older than slates, which there

[1] On chart 1731 of the Hydrographic Office, which is from a British survey in 1851 by Commander W. T. Bate, Mount Kapoas, on Palawan, in latitude 10° 48′, longitude 119° 17′, is marked granite. Without further information I hesitate to accept this as a lithological determination, though it is not improbable.

is some paleontological evidence for considering Devonian, and they may be Archean. Both in Borneo and in Sumatra the older massive rocks appear separable into two groups of different ages, an older granitic-dioritic group and a younger diabase-gabbro series. The granites, quartz-porphyries, syenites, diorites, tonalites, etc., are intimately associated with the crystalline schists, which are doubtless in part dynamometamorphic forms of these rocks. There are also some later intrusions or extrusions of these rocks. On the other hand, the greater part, if not all, the rocks of the gabbro-diabase series are younger than Carboniferous strata. In most places in Borneo there are no strata between the Carboniferous and the Eocene, and many of these pyroxenic rocks may be of any intermediate age. At Mount Tamban, in South Borneo, however, Mr. Verbeek found gabbros which appeared to be partly Eocene and partly Miocene.[1]

There is nothing in these relations inconsistent with Mr. Abella's generalization that the dioritic rocks are the oldest in the Philippine Islands.[2] That geologist would unquestionably include as dioritic the schists of similar composition which accompany them. In so far as the older orthoclase rocks exist in the Philippines they certainly belong chronologically with the diorites. As for the diabase-gabbro series, their age relatively to the diorites in the archipelago has not yet been worked out in detail. It would seem probable that some at least of these pyroxenic rocks are much younger than the great mass of the diorite.

## LITHOLOGICAL NOTES ON THE VOLCANIC ROCKS.

It will surprise no one to learn that the lithology of the volcanics occurring in the archipelago is in a very imperfect condition. Baron von Richthofen's paper of 1862 was published before the introduction of the microscope into the study of rocks. The first microscopical work done on Philippine collections was, I believe, that of Roth on Jagor's specimens, and was published in 1873. It is of great value, but many modern methods of determination were still unknown. Mr. von Drasche's notes on rocks, excepting gabbro, are meager. They appeared in 1878. Prof. Carl Semper's collections, made early in the sixties, were examined after the publication of Mr. von Drasche's memoir by Mr. K. Oebbeke in the laboratory of Professor Rosenbusch, and, with analyses by Mr. A. Schwager, were described in 1881. This is a very thorough investigation, but the number of localities represented is not large. Mr. Abella gives microscopical

[1] T. Posewitz, Borneo, Geology of the Mountain Land, pp. 137–172.
[2] Apuntos físicos y geológicos, 1884, p. 30.

determinations in his memoirs on Cebú, 1886, and on Panay, 1890, but does not appear to have made use of the microscope in his earlier papers concerning Luzón. Mr. Joseph Montano's rocks (1885) were examined by Mr. Ch. Velain, but few details are given in his memoir.

In compiling what is known of these rocks and their distribution it will perhaps be most perspicuous to begin by lithological descriptions derived from study of my own very imperfect collections and culled from the memoirs just mentioned. The distribution of the lavas can be more conveniently discussed by itself. In examining thin sections I have endeavored to take full advantage of the methods of feldspar determination so ably developed by Mr. Michel Lévy, and not less attention has been paid to the microlites of the groundmass than to the phenocrysts.

The Island of Talim, in Laguna de Bai, furnishes a series of thoroughly typical basalts, some of them resembling obsidian in appearance, though in reality nearly holocrystalline. They are characterized by ophitic structure and the predominance among the feldspars of anorthite ($Ab_{11}$ $An_{200}$). The phenocrysts are usually zonal, the outer zone approaching or reaching calcic labradorite in composition. The microlitic feldspars vary in composition more than the phenocrysts, and range from anorthite to sodic labradorite, showing, as do many rocks, either that the residual mother liquor was very far from being homogeneous or that the rock inadequately represents the magma, being, perhaps, a fractional precipitate. All of these basalts contain olivine, chiefly in large crystals, and in none of these could I find rhombic pyroxenes. The augite appears to be younger than the olivine, and is in no way remarkable.

Basalts which are probably in every respect similar to these are described by Mr. Oebbeke from the Island of Basilan, at the town of Isabela, and from an islet off the coast about 6 miles due west of Isabela, called Lampinigan.[1] A somewhat decomposed specimen containing glass gave Mr. Schwager the following composition:

*Analysis of basalt containing glass.*

| | Percent. |
|---|---|
| $SiO_2$ | 51.32 |
| $Al_2O_3$ | 15.48 |
| $Fe_2O_3$ | 4.48 |
| FeO | 6.70 |
| MnO | 0.39 |
| CaO | 8.68 |
| MgO | 6.54 |
| $Na_2O$ | 3.06 |
| $K_2O$ | 1.11 |
| $H_2O$ | 1.10 |
| Total | 98.86 |

[1] Neues Jahrbuch, Beil.-Band I, 1881, p. 489.

Mr. A. F. Renard[1] describes a decomposed rock from a river bed near Cebú, Cebú, which may be a basalt or a pre-Tertiary melaphyre. He inclines to the latter hypothesis because the rock contains epidote, but points out that this fact does not exclude its reference to the basalts. The specimen was collected by the *Challenger* expedition.

The next well-defined group of rocks should, in my opinion, be classed as labradorite-basalt. I collected specimens of such a rock in the ravine just east of Paete, which lies on the east side of Laguna de Bai, about 2 miles to the northward of Santa Cruz. It contains abundant olivine but no rhombic pyroxene. As is well known, these minerals are rarely found together. The olivine is older than the augite. The slide contains an unusual number of determinable feldspar phenocrysts, almost totally devoid of zonal structure, among which I found only calcic labradorite. The microlites, on the other hand, include both labradorites and a little andesine. The phenocrystic feldspars are not sufficiently numerous to produce ophitic structure, but the microlites do form such a network, filled in with minute augites. The groundmass differs so essentially from that of the andesites that to call this rock an olivine-andesite would seem to me misleading. Near the same spot I found a very coarse porphyry, with feldspars half an inch in length, embedded in a fine-grained dark paste. It reminded me at once of the material of Tuolumne Table Mountain, which has been so interestingly discussed by Mr. H. W. Turner. As seen under the microscope, the same description given to the foregoing specimen applies, except for the great size of the phenocrystic feldspars and the absence of andesine in the groundmass. I also collected a labradorite-basalt in the Island of Negros, about 16 miles northeast of the volcano Canlaón, on the Talabe River. In this rock, however, there is hypersthene as well as olivine, and the feldspar of the groundmass consists only of the two labrodorites. With these rocks I place that of the mountain just to the southeast of the town of Joló (Tumantangis). In this the only phenocrysts are olivines, while the ophitic groundmass consists of calcic labradorite, the interstices between them being filled with augite, magnetite, and a little olivine.

In Panay Mr. Abella[2] has discovered leucite-nepheline-basalts.

A very curious rock defying strict classification comes from southern Negros, about 3 miles west of Dumaguete, the massif to which it belongs being andesitic. The specimen originally contained hornblende as the sole phenocrystic ferromagnesian silicate, but this has been completely converted into the ordinary "black border" of magnetite and augite. Outlines remaining leave no doubt of the original mineral. The inner portions of the somewhat sparsely distributed feldspar phenocrysts are sodic labradorite ($Ab_1 An_1$), but they

[1] Bull. Acad. roy. Belgique, 3d series, Vol. XI, 1886, pp. 95–105; and Voy. of *Challenger*, Vol. II, pt, 4, 1889, pp. 160–175.

[2] Isla de Panay, 1890, p. 107.

show a strongly marked outer zone which, instead of being more silicic, is less silicic than the kernel. These outer rims give the angles of extinction of calcic labradorite, of course, for the same crystallographic positions found for the sodic labradorite of the interior portions. The rims also seem to differ otherwise from the ordinary zonal structure, their inner boundaries being more rounded than the periphery and apparently disregarding crystallographic form, just as if the outer portions of sodic labradorites had been changed to the calcic species by external attack. Some small feldspars are embedded in the hornblendes. These are sodic labradorite and are not inclosed in the more anorthitic mineral. The groundmass contains a large number of microlites suitable for determination. Many of them show nearly square cross sections and can be determined by a method which I have indicated in my report on the gold fields of southern Alaska.[1] Some of these microlites show albite twinning and are demonstrably bounded by the base and brachypinacoid. The long sections of microlites in this rock are also in many cases determinable. The result is that the majority of the microlites are anorthite and the remainder calcic labradorite, which is certainly a very curious state of affairs. This groundmass contains nearly equal quantities of feldspar and augite with a moderate amount of magnetite, but its structure is not ophitic. The specimen came from a brecciated flow and must have been formed under abnormal conditions, most likely, I should say, at the periphery of a moving mass of magma. The position in which it was found seems to show that it is a facies of andesite.

A somewhat similar rock, from the new volcano of Camiguin de Mindanao, has been described by Mr. A. F. Renard. The rocks there collected by the *Challenger* expedition are pyroxene- and hornblende-andesites, the former predominating, and including as constituents bronzite and augite. Olivines are found occasionally. In the pyroxene-andesite he found the feldspar phenocrysts composed of species ranging from andesine to labradorite. They show zonal structure, and the outer zones extinguish at greater angles than the inner ones, in contravention of the ordinary rule. The microlites are labradorite. Mr. Renard comments thus: "We have, then, to admit that the acidity of the magma decreased in proportion to the development of the feldspar."[2]

There are many specimens in my collection which seem to me normal andesites, some of them from the same neighborhood as the aberrant rock just described. One such, collected somewhat south of Valencia, from the same massif, is a very fresh hornblende-andesite, containing a little augite, but no hyporsthene, the phenocrystic feldspars being chiefly calcic labradorite, while the microlites are chiefly sodic labradorite, a few being andesine. There is the usual quantity of iron ore,

[1] Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 32.

[2] Bull. Acad. roy. Belgique, 3d series, Vol. X, 1885, pp. 734–751, and Voy. of *Challenger*, Vol. II, pt. 4, 1889, pp. 160–175.

apatite, zircon, much glass, and no suggestion of ophitic structure. The Island of Corregidor and the neighborhood of Mariveles, at the mouth of Manila Bay, was the only volcanic region which I was able to study without being armed and guarded, and I have a better suite of specimens from that region than from other localities. Excepting a dike (which is dacite), all the rocks I could find along the shore or in the foothills of the Mariveles Range, or among the pebbles brought from higher altitudes by the streams, are andesites. In texture they vary from the basaltic to the trachytic type, and there are agglomerates and tuffs in abundance; but they are all essentially labradorite rocks without ophitic structure. For the most part they are pyroxene-andesites, containing augite and a dichroic rhombic pyroxene, but one gray rough rock, which is quarried for use in Manila, is hornblendic. In one specimen only from this region I was able to detect a single minute square crystal, which gave an extinction of 41° and must be anorthite. As a rule the phenocrystic feldspars are $Ab_3$ $An_4$, while the microlites are more sodic, ranging downward to andesine. Nearly all these rocks are more or less glassy. I found no olivine. I am rather explicit about the rocks of this locality because Roth [1] calls the rock of this region dolerite.

On the west coast of Negros the country is alluvial, and the beautiful volcanic range ending to the southward in the ever-steaming volcano of Canlaón is distant; but the streams near Bacólod bring down volcanic pebbles which appear to be exclusively andesite, and chiefly hornblende-andesite. A slide shows a glassy rock in which hornblende, in phenocrysts and microlites, is the only ferromagnesian component. This is greenish brown in tint, very dichroic, and extinguishes at a low angle. The feldspars, large and small, are labradorite, chiefly of the sodic variety. Magnetite, apatite, and zircon complete the components of this simple rock. On the Talabe River, on the east side of Negros, nearly opposite Bacólod, I also found vast quantities of andesite pebbles, brought down from the volcanic range. One is a glassy pyroxene rock in which the only notable feature is an interesting variation in the zonal structure of the feldspars. In two phenocrysts a zone of anorthite ($Ab_{11}$ $An_{200}$) was sharply determined inclosing calcic labradorite and inclosed by calcic labradorite. It is difficult to make sure how such fluctuations can occur. Near Dumaguete, in southern Negros, I also found an otherwise normal andesite which contained one phenocryst and a microlite which were anorthite. Underlying the corals in eastern central Cebú, about 2 miles west of Naga, and again on the Guadalupe River to the west of the town of Cebú, I found very normal hornblende-pyroxene-andesite with labradorite feldspars.

[1] Jagor, Reisen, 1873, p. 341. I think Jagor's labels must have gone wrong.

Mr. Oebbeke[1] gives descriptions of various andesites, with analyses of rocks, and sometimes of components as well. In Mr. Semper's collection he found far more augite-andesites than hornblende-andesites. Of the latter, one is of especial interest. It is a white pumice from Magalang in the Pampanga, just to the west of Mount Aráyat. The feldspars appear megascopically very like sanidine. The hornblende is green. The rock also contains some scales of very dark mica, the angle between the optic axes of which is relatively large. The microscope and analysis show that the phenocrystic feldspars are $Ab_1An_1$, but near the oligoclastic limit of that species. The groundmass is glass with a sprinkling of magnetite. A specimen of hornblende-andesite from the small Island of Limasaua,[2] just south of Leyte, examined by Mr. Oebbeke, contains feldspars which do not give sharp extinctions, as Mr. Fouqué observed in certain sanidines, the dark tint passing across the section as the slide is revolved. This rock also contains a somewhat abnormal quantity of potash for an andesite. The analysis is given below.

The rocks of the Semper collection from Mariveles correspond with my own in most respects, being labradorite rocks, more or less glassy, without ophitic structure. Portions of the Mariveles rocks examined by Mr. Oebbeke were found to carry hornblende in addition to augite, and some grains were detected of a mineral which is probably olivine. In one respect my results differ from Mr. Oebbeke's. He found the augites strongly pleochroic. Such crystals, when isolated and examined separately, gave finite extinctions. Their analysis gave Fe (Mn) : Ca : Mg = 1 : 1.2 : 3, and the conclusion is drawn that the mineral is not a rhombic pyroxene. In my slides all the pleochroic pyroxenes cut parallel to the axis give zero extinction and seem to me unquestionably rhombic, while in the individuals which gave sensible extinction angles I could detect no dichroism.

Mr. Oebbeke finds the rocks of Taal volcanic augite-andesite, while Mr. von Drasche[3] regarded them as dolerite, except certain ejecta which "might perhaps be classed as augite-andesites." According to Mr. Oebbeke, all the specimens have a silica content of between 56 and 58 per cent, and the olivine is accessory only. He states, however, that in the case of certain specimens a doubt might arise as to which group they belonged with. The main mass of the crater is a labradorite rock containing phenocrysts of augite and plagioclase in a groundmass which is not ophitic and is largely glassy. Whether certain decomposed yellowish grains were referable to olivine could not be determined. An analysis is given in the table below, as well as of the essentially similar rock of Great Binintiang, a small crater at the northwest end of the Taal Island.

[1] Neues Jahrbuch, Beil.-Band I, 1881.
[2] Oebbeke writes Limansaua, which appears to be incorrect.
[3] Fragmente, 1878, p. 51.

*Analyses of andesites.*

[Analyst, A. Schwager.]

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| $SiO_2$ | 54.48 | 54.62 | 58.42 | 56.02 |
| $Al_2O_3$ | 19.44 | 16.96 | 17.64 | 16.52 |
| $Fe_2O_3$ | 1.80 | 4.50 | 5.66 | 5.02 |
| FeO | 4.90 | 4.27 | 4.00 | 5.51 |
| MnO | ..... | .35 | .48 | .36 |
| CaO | 7.08 | 8.56 | 4.50 | 4.20 |
| MgO | 3.72 | 5.20 | 2.54 | 4.67 |
| $Na_2O$ | 3.58 | 3.26 | 4.44 | 5.83 |
| $K_2O$ | 3.32 | 1.80 | 2.52 | 1.66 |
| $H_2O$ (ignition) | 1.70 | .73 | .42 | .47 |
| $TiO_2$ | ..... | Trace. | .31 | ..... |
| Total | 100.02 | 100.25 | 100.93 | 100.26 |

I. Somewhat abnormal hornblende-andesite from Limasaua Island, just south of Leyte.

II. Augite-andesite from Mariveles Point.

III. Augite-andesite from main crater of Taal.

IV. Augite-andesite from Binintiang crater at Taal.

I found an interesting dacite on the Island of Corregidor, at the entrance to Manila Bay. It forms a wide, irregular dike crossing the island from north to south just east of the little settlement, San José, and terminates in a bold white cliff, visible from the south passage, or Boca Grande. This rock is affected by a system of rectilinear pressure joints, and some considerable dynamic action has occurred since its intrusion. It is blindingly white, and shows to the naked eye, besides feldspar, only some small quartzes and minute, opaque mica scales. Under the microscope the mica is brownish green, unusually opaque, and extremely dichroic. There are no other ferromagnesian silicates. There are few phenocrystic feldspars, and these are sodic labradorite. Two or three quartzes also appear. The bulk of the rock is made up of feldspar microlites, with just a sprinkling of magnetite and a little apatite. The slide contains hundreds of microlites of almost exactly square cross section. They seem divisible into two groups, one giving angles of extinction relatively to the sides of about 43°, while the other gives angles of about 38°. If the bounding faces of these microlites were the base and brachypinacoid, these angles would indicate anorthite and calcic labradorite. On closer examination I found that a fair proportion of these little crystals showed truncation of two corners and that a smaller portion were twinned, the plane of contact, however, running diagonally across the squares. It is thus evident

that the bounding faces of the square microlites in this rock are the hemidomes, *n* and *e* or (021), instead of the base and brachypinacoid. Hence the determining angles of extinction are about $\frac{1}{2}^\circ$ and $4\frac{1}{2}^\circ$ and the corresponding feldspars are the two oligoclases, $Ab_3An_1$ and $Ab_4An_1$. This result is confirmed by examination of the long sections of the microlites, all of which extinguish at extremely small angles. Not having hitherto seen microlites bounded by hemidomal faces alone, I was particularly careful to test the development of the feldspar microlites in the andesites and basalts described in this paper, but found no similar cases among the more anorthitic feldspars of these rocks. So far as I know, dacite has not been discovered elsewhere in the archipelago, but it occurs in the Moluccas.

Besides basalt, the andesites, and dacite, there is reason to suppose that trachyte and rhyolite occur in the Philippines. Baron von Richthofen determined as trachyte a rock which is found in contact with the nummulitic limestones on the peninsula of Binangonan, and Mr. von Drasche concurs in the determination. Among Jagor's specimens Roth describes a white pumice containing a little dark mica and feldspar which seems to be sanidine. It was collected between the villages of Yriga and Buhi in the Province of Camarines Sur. Mr. von Drasche describes as trachytic a tuff which occurs over most of the western portion of the inland plain of Luzón from Mount Aráyat westward to the watershed. At Pórac, in Pampamga, he found in a tuff fragments of which he says:[1] "The rock of which these lumps consist is an uncommonly foamy, pumice-like, blindingly white, sanidine trachyte. In the cavities there are numerous white, large, cracked sanidines and thick, short, columnar hornblende crystals." Farther westward he found this pumiceous rock passing into "sanidine-hornblende-trachyte, with a compact groundmass which is sometimes white and sometimes brick red." At the Canan hot springs in O'Donnell, Tárlac Province, Mr. Abella found dikes of a very pretty sanidine-trachyte, of porphyritic texture, cutting ancient-looking slates.[2] At Galiano (Unión) Mr. von Drasche found a trachyte tuff which was microscopically examined.[3] "In a powdery, brown groundmass lie numerous scraps of dichroic hornblende and rounded feldspar grains. Both ingredients are fairly fresh. The feldspars seem to be of two kinds, one orthoclastic and the other plagioclastic." Mr. Semper's specimen from Magalang, which Mr. Oebbeke determined as hornblende-andesite, certainly came from the area regarded by Mr. von Drasche as trachytic tuff. It must also have resembled the Pórac specimen strongly in external appearance. Mr. von Drasche's description of the Galiano specimen seems to leave it open to question whether it is a potash rock, while Mr. Abella denies that it is a tuff at all, pronouncing it a sedimentary rock derived from the degradation of an adjoining diorite

[1] Fragmente, p. 12. [2] Manantiales, 1893, p. 144. [3] Fragmente, p. 31.

area.[1] Without further study this rock can scarcely be accepted as trachyte. Of the trachyte in the Binangonan area I find no lithological description, and Roth, judging from Jagor's specimens, thought the occurrence dubious. Mr. Semper's collections seem to have contained no trachyte. Mr. Abella describes a single trachyte from Panay at Barbaza, Province of Antique, which he inclines to regard as an accidental local facies. "In a decomposed and completely amorphous magma [devitrified glass?] together with granules of augite, there are to be seen in this rock feldspars which show most clearly Carlsbad twinning, and although there are also visible some plagioclases, they are less abundant and not so characteristic as the orthoclases." This passage reads as if Mr. Abella depended upon Carlsbad twinning to differentiate orthoclase, but he may, of course, have employed some other and really applicable test.[2]

Mr. von Drasche found rhyolites in the Province of Bontoc (Luzón). Of such an occurrence he writes:[3] "It is a hard, white rock with splintery fracture. In the dense groundmass are visible sanidines with glassy luster, and gray, opaque feldspar prisms, quartz in formless grains, and small augites, certainly a rare combination of minerals. Under the microscope the groundmass resolves itself into a confused mass of crystals, in part colorless, in part brown, the latter being perhaps augite (?). Those gray feldspars consist of the same mixture, very strange to say, and are separated from the rest of the groundmass by a dark border. There are few augites; magnetite occurs in very pretty crystals. All the phenocrysts are rendered very impure by groundmass and contain numerous glass pores." It is not impossible that hard, white, splintery dacite, such as I collected in Corregidor, may sometimes have been mistaken for rhyolite, while it seems highly improbable that Corregidor should be the only point on the line of the Sierra Zambales at which dacite exists.

The basalts and andesites of our Asiatic province might have come from Alaska or from the western Cordilleras of North America, so far as their composition and structure are concerned. There is the same unexplained adherence of the feldspars to definite types, only emphasized by cases of exceptional composition. There is the same general uniformity in the groundmass of the rocks, accompanied by the occurrence of numerous exceptional microlites and not very infrequent reversals of the ordinary rule of deposition, according to which the more calcic feldspars are precipitated before the more sodic species. There can be little doubt that detailed field study in the Philippines will reveal most of those variable associations of massive rocks which of late years have claimed so large a share of the attention of lithologists. The principles which underlie rock formation are clearly worldwide, and I do not doubt that they extend to other planets.

[1] Terremotos en Luzón durante 1892, 1893, p. 33.
[2] Isla de Panay, 1890, p. 103.
[3] Fragmente, p. 39.

Bunsen showed that magmas, so far as they are homogeneous liquids, are to be regarded as solutions. Considerable latitude, however, is permissible in defining that portion of such a magma which is to be regarded as the solvent. The simplest relations appear to me to result when the eutectic mixture of the substances involved is considered as the solvent. This mixture is definite and, at any given pressure, has a constant composition, inalterable by partial solidification. At temperatures above its point of solidification a eutectic mixture is capable of dissolving a greater or smaller excess of any of its constituents, so that with a single given eutectic solvent, solutions of variable composition may be produced in infinite variety. For instance, there is a well-known and technically important eutectic mixture of lead and silver which, when superheated, will dissolve further quantities of either lead or silver and may serve as the base for an endless variety of alloys. If we knew all about magmas, it seems fairly certain that we could define a number of eutectic mixtures, each, when heated above its melting point, yielding an infinite variety of solutions corresponding to rocks of an infinite variety of compositions. Thus, if a labradorite-basalt is conceived as a eutectic mixture, capable at sufficiently high temperatures of dissolving more feldspar and olivine, it is easily conceivable that rocks of this class should be found containing many large feldspars or no feldspathic phenocrysts, much olivine or none at all, while the groundmass, representing the eutectic mixture, would maintain a nearly uniform composition and character, independent of the phenocrystic composition.

From this point of view the groundmass of rocks would be more interesting and important than the phenocrysts, while it has usually been studied with less care, because of the greater difficulties in the way of mineralogical determination. The groundmass would either consist substantially of the eutectic mixture or afford a closer approximation to it than does the whole rock.

It is difficult to imagine that the comparatively small number of elements which enter largely into the composition of massive porphyritic rocks should form any very great number of independent eutectic mixtures; and it seems to me that it would be possible to elaborate a eutectic classification of those rocks which have consolidated from the liquid state—I mean the porphyries—each rock group representing a series of solutions in one eutectic liquid. Such a classification would also have certain geological advantages over others, for the composition of the groundmass of rocks largely determines their orogenic significance. The capacity of a magma to flow during injection or after ejection depends chiefly on the viscosity and the latent heat of the groundmass or, approximately and in the most important class of cases, on the properties of the eutectic solvent. Commonly the

phenocrysts are mere flotsam in the stream of liquid rock, and do not seriously interfere with its capacity to flow.

Even among the rocks which represent solidified fluids there is a class not subject to such a classification as is here proposed. It seems an inevitable conclusion from the laws of precipitation that there must be many rocks which have been formed by fractional crystallization. There is no difficulty in seeing how this process might go on, but the greatest difficulty in comprehending how it could be obviated altogether. Especially must this be true of dikes and laccoliths, where convection currents (incomparably more effective, except at distances within a few centimeters, than any process of molecular flow) must feed the crusts growing on the containing walls with saturated or supersaturated solutions.[1] Now, such fractional precipitates are essentially impure. Either in nature or in the laboratory, they represent neither the substance dissolved nor the solvent or mother liquor, but only fortuitous mixtures of the two—crystals of precipitate, including and entangling variable quantities of mother liquor; crusts, which vary in composition from millimeter to millimeter. Rocks of such origin appear to me insusceptible of any strict classification and fit only to throw a dim light on the qualitative composition of the magma, which they represent, indeed, but only partially and irregularly. Were a eutectic classification worked out, it would probably be easy to recognize these impure partial precipitates, which would then receive the scant attention they deserve. It is hoped that the laboratories of the United States Geological Survey will be able to throw some light upon rocks of eutectic composition within a moderate time.

## NOTE ON THE DISTRIBUTION OF THE VOLCANIC ROCKS.[2]

Anything like a comprehensive description of the distribution of volcanic rocks in the Philippine Islands is as yet quite impossible. 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. Crystalline schists appear again in Camarines Norte. But to the north, the west, and the south of this area volcanic rocks are abundant. 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

[1] Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 257.

[2] References already given in the preceding section are omitted in this note.

to the other of that exquisite island, is volcanic. According to Semper, all of 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 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 Yriga and Buhi, a pumice-like tuff was considered trachytic by Roth. Mr. von Drasche found the rock at the base of Maquíling, not far to the southward of the town of Calamba, on Laguna de Bai, 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. On that shore I collected basalt, but was obliged to remain under cover of the guns of the *Napindán* and could not get inland. The trachytes recur on the San Mateo River, near the caves about 5 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 the Pampanga, and to the westward of that town in the foothills of the Cordillera de Mabanga; 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 provinces of Lepanto and Bontoc also Mr. von Drasche found trachytes abundant, but closely associated with andesites and basaltic rocks. The important copper deposits of Mancayan 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 Patlin River, about 2 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 Maranglá and Cospién, and on the other between the town and the river Capatían, forming the volcanic line of the hills Dayagdag, Taoagan, and Patlín."[1] I am not in possession of maps showing these hills by name, but they will doubtless be identified with ease from O'Donnell.

Mr. von Drasche also found rhyolites, or, as he calls them, quartz-trachytes, in these northern provinces. He met with this rock a short distance to the northwest of Mancayan, the central town of the copper district in the Province of Lepanto. The rhyolite lay in blocks along the Abra River. On the road from Sabangan to Bontoc, capital of the province of the same name, he also found rhyolite, which, in this district, appears to occupy an important area.

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. Most of the notes on these rocks refer to isolated localities or volcanic cones, and they can not be delimited areally until a geological survey of the islands is made. Some of these notes will be reserved for the remarks on volcanoes, which will claim attention presently. The Island of Talim, in Laguna de Bai, 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 Jagor's specimens, and this determination was accepted by Mr. von Drasche, who did not visit the locality. I suspect that some of Jagor'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 Bai 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 later period may be regarded lithologically as a repetition of the earlier one. In the Samaráquil 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

[1] Manantiales, 1893, pp. 18, 19, 144.

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 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 2 miles from the town, a considerable sheet of hornblende-pyroxene-andesite.

In the Island of Leyte, at Mount Dagami, according to Roth, Jagor collected fresh hornblende-andesite. Dagami is the name of a town in northeastern Leyte which Jagor visited, but he probably collected his specimen on Mount Manacagan, as he calls it, a few miles south of Buráuen. He speaks of the rock of this mountain as "a very hornblendic trachyte."[1] On the Island of Limasau, 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,[2] is andesite. He also found andesite north of Lake Dagum on Mount 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 Butuan, 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. J. Itier[3] states that from Mount Pico, in the center of Basilan, basaltic ridges, not over 500 meters in height, run E. and WNW.

Near Joló, on the island of the same name, I found basalt. This island is mentioned by Mr. Kotô[4] also as basaltic, as are the Calamianes.

[1] Jagor's Reisen, 1873, p. 221.

[2] Rap. sur une mission aux îles Philippines, 1879–1881, p. 287.

[3] Descrip. des îles Solo: Bull. Soc. géog., Paris, 3d series, Vol. V, 1846, pp. 311–319.

[4] Geol. structure Malayan arch.: Jour. Coll. Sci. Tōkyō, Vol. XI, 1899, pp. 114, 117.

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 seem to stretch in an almost unbroken, nearly flat area from near Lingayén Gulf southward past Manila, past 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 Bai 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.[1] 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.[2] 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,[3] in which opinion I entirely agree with him.

The volcanic rocks of the Sunda Islands and the Banda Islands are seemingly in all respects similar to those of the Philippines. In the Dutch and English possessions in the Far East there is the same preponderance of pyroxene-andesite accompanied by hornblende-andesites and basalts. Leucite rocks, rare in Asia, occur on the small Island of Bawean, to the south of Borneo, and in eastern Java, as well as in Panay,[4] and dacite accompanies andesites in the islands of the Uliasser group,[5] while trachyte seems to be rare. The similarity extends beyond specific names. Mr. Oebbeke[6] made direct compar-

[1] Dana obtained many specimens of plants from the tuff, mostly palms, seemingly of recent species. No vertebrate remains have been detected so far as I have been informed, though the Spanish geologists have been on the watch for them.

[2] Sir A. Geikie notes that at one eruption of Sakurajima (Japan) it was possible to walk a distance of 23 miles on the pumiceous material floating in the sea. Text-book of Geol., 1893, p. 215.

[3] El monte Maquilin, 1885, p. 24.

[4] Kotô, loc. cit., p. 88.

[5] K. Martin, Reisen in den Molukken, geol. Theil, 1898, p. 219.

[6] Neues Jahrbuch Beil.-Band I, 1881, p. 488.

isons between the Semper collection and the specimens in Professor Rosenbusch's cabinet from other parts of Malaysia. He concludes that "there is scarcely a type which is not represented on all the islands alike." Mr. J. L. C. Schroeder van der Kolk examined Mr. Martin's rock specimens from the Moluccas. The only massive rocks were granite, peridotite, dacite, and pyroxene-andesite. The dacites are separated into two groups, one being highly pyroxenic and containing labradorite, while in the other the ferromagnesian silicates are represented by biotite and the feldspars are less calcic. Sanidine enters into the second group of dacites in varying quantities, and there seem to be transitions to rhyolite.[1] The dacite of Corregidor is akin to this second group, and it is probable that other of van der Kolk's types occur in the Philippine Islands.

## VOLCANOES, ACTIVE AND EXTINCT.

A considerable number of mountains in the Philippines have ejected ash or lava recently, or since the occupation of the country by the Spaniards. Many other cones are plainly volcanoes of no ancient date, and concerning some of these it is doubtful whether or not they have been active during the last four centuries. The accounts of early Spanish writers, chiefly priests who were intent on other matters, are in part very vague and ambiguous. I shall endeavor to collect here such information as seems important concerning all the volcanoes known with certainty to have been active, and also the available data as to the principal cones which are clearly extinct or dormant volcanoes. The latter group could doubtless be increased almost indefinitely. At the close of this section (pp. 55–56) appears a little tabular statement on the subject.

Beginning at the south, there is at the southern end of Mindanao a group of volcanoes none of which is known to have been in eruption since January 4, 1641. On that date there was a disturbance in the Philippines which extended far and wide. It has been discussed at length by Perry and others, but most satisfactorily by Jagor.[2] The original information is contained in a report to Pedro, archbishop of Cebú, printed by Raymundo Magisa in Manila in 1641. The original is extremely rare. It is reproduced in the Obras Filosóficas of J. E. Nierembergius and in Zúñiga's Estadismo de las Islas Filipinas. This last I have seen. It is alleged that three outbursts took place on this

[1] Sammlungen des geologischen Reichs-Museums in Leiden, Vol. V, 1896, p. 70.

[2] The incident was investigated by order and commission of the archbishop, but the report is anonymous. The document appears among Retana's appendices to Zúñiga's work, and is evidently reproduced with care.

day in different portions of the archipelago, accompanied by earthquakes, which were also felt in Cochin China and Cambodia. A Spanish squadron was off the south coast of Mindanao at the time and some of the ships were almost overwhelmed by volcanic ash. These ships, which were approaching Cape San Agustín from Zamboanga, were then "in the neighborhood of an island called Sanguil, on which the volcano had broken out." The name of this island has led to much confusion. In the original report it appears as Sanguil, while Nierembergius has Sanguiz, and the name appears in various other forms in literature, some of which are probably mere misprints. Perry came to the conclusion that the report referred to the Island of Sanguir, one of the Celebes group, but Semper and Jagor believe the volcano to have been in Mindanao. Even if Sanguil and Sanguir are originally the same word, the identity proves nothing, for in the Philippine Islands a number of geographical names are repeated. According to the Guía Oficial, the Sanguil language is still one of those spoken in the Province of Dávao (southern Mindanao), and the admirable Compendio de Geografía of the Jesuits says "the Sanguils inhabit a small area on the southern coast of Mindanao near Sarangani," which is one of the names of the southernmost cape of Mindanao. On the ethnological map of the Jesuits this area is shown. Most authorities seem of the opinion that this volcano was on the Sarangani Peninsula, in spite of the express statement that it was on an island. On the Jesuit map, however, as well as upon the charts of the Hydrographic Office, a volcano is marked on the island now called Balut, one of the Sarangani Islands. It lies in latitude 5° 25′ and is within 10 miles of the coast. The volcano is said to be now extinct. When this island is visited it will be worth while to observe whether conditions indicate an eruption of considerable violence within two hundred and fifty years. On the peninsula there is also a volcano called Sarangani by Jagor and Semper, but Butulan by Centeno and others. There is no certain record of an eruption of Butulan.

The second eruption of January 4, 1641, is described as occurring near Joló. The report runs: "And although, at the time, the darkness and atmospheric disturbance 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 lies our military station. The crater of this volcano is still open." Semper and Jagor 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 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 Igorrotes, "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 Mount San Tomás, or Tonglón, some 15 miles from Aringay, in Unión Province. This identification does not appear accordant with the original description, and how it was reached I have not succeeded in ascertaining.[1]

A group of volcanic cones exists a little to the northward of the Bay of Sarangani. They are extinct or dormant, so far as is known. Indeed, excepting their position, which is doubtless only approximate, I know nothing of them. Their names are Magolo, Matutum, and Malibato. Of these the first is entitled a volcano on the map of Mindanao in the Compendio de Geografía, and the second is similarly designated on Montano's map. Matutum is said to be visible from the sea at a great distance.

Mount Apo is the highest mountain in the Philippine Islands. It was ascended in 1880 by Mr. Montano[2] and Governor Joaquín Rajal, who found the altitude 3,143 meters, or 10,311 feet, and in 1882 by Messrs. A. Schadenberg and O. Koch,[3] who determined the height at 3,280 meters, equal to 10,761 feet. Mr. Velain determined Mr. Montano's specimens as andesite. The latter describes the mountain as in the solfataric stage, the cone being covered from about the 7,500-foot contour to the summit by a mantle of sulphur. An enormous crevasse opened in the flank of the mountain emits jets of sulphurous acid, which escape with a strident roar. According to the Guía Oficial, the summit consists of three peaks, of which the present crater forms the most southwesterly. There is a lake on the ridge from which issues a cold stream, while another ravine carries hot water. Though Apo is well known to be active, there is said to be no record of its eruptions. It is sometimes called Dávao, from the name of the gulf near which it lies. This gulf on old charts appears as Tagloc Bay.

[1] San Tomás is not volcanic. Mr. von Drasche says of it (Fragmente, page 30): "It is usually considered an extinct volcano, because a passage in a report on the simultaneous eruption of three volcanoes in January, 1641, points to it. Jagor gives a literal translation of this document, from which, however, it appears that (1) this outburst can be referred to any possible mountain in northwest Luzón, and (2) nothing whatever is said of a true eruption. The pertinent passage reads," etc. In the Spanish translation Mr. von Drasche's statement is represented by this phraseology: "Being in reality an extinct volcano, as is established by the following account which Jagor copies from a document dated in January, 1641, and referring to the simultaneous eruption of three volcanoes at that date." Mr. Abella, supposing the Spanish translation to be correct, comments thus: "If, indeed, the account of 1641, which Drasche copies, is confused, that which this geologist himself gives of the geological character of Tonglón is not less so."—Terremotos, 1893, page 30. A careless translation is an unconscionable thing!

[2] Rap. sur une mission aux îles Phil., p. 287.

[3] Cited by F. Blumentritt in Bull. Soc. acad. indo-chinoise de France, 1882-83.

Macaturin lies over 20 miles to the northeastward of Pollok Point, in Illana Bay. Berghaus called this mountain Illano. Semper called it Pollok or Sujut, and this last is the name given it on Jagor's map. Centeno alleges that this volcano has "ejected enormous blocks of conglomerates of various igneous rocks, like those which are to be seen to-day in the port of Pollok, distant seven leagues from the volcano." As appears from Perry, an eruption of Macaturin occurred in 1765, and the Guía Oficial notes eruptions in 1856, 1865, and 1871. The last was preceded by earthquakes which destroyed many villages. Mr. Centeno[1] gives on his map a volcano, Cottabato, just south of the Rio Grande and a few miles from the town. He observed many conical hills like Cottabato along the course of the river, but was prevented from making an examination of it or any of them. He gives no record of eruptions or of other details concerning this mountain.

One of the most interesting of Philippine volcanoes is on Camiguín, or, more specifically, Camiguín[2] de Mindanao, for there is another volcanic islet of the same name in the north. This one is close to Mindanao and in latitude 9° 12′. According to "information from Manila," reported by Jagor, this island up to 1871 consisted of three ridges. On the summit of one of them, Catarman, there was a crater lake the water level of which was subject to great fluctuations. Sometimes it dried up and sometimes, as in 1827 and 1862, it overflowed. Often it was agitated by evolutions of gas. No historical eruption had taken place.[3]

On February 16, 1871, according to Centeno,[4] earthquakes began to be felt in the island, which increased in severity until April 30. They then ceased suddenly, and a volcano appeared 400 yards southwest of the village of Catarman. At 3 p. m. a thick column of black vapor rose, with a strong odor of sulphur. It quickly became incandescent and set the woods on fire. At the end of a week a little volcanic cone 2 meters high had formed and "kept pouring lava into the sea, at the same time gaining in height and width; but such has been the activity of the crater that now, after four years of existence, it already measures some 1,500 feet in height above sea level, in addition to which it has acquired a breadth of half a mile." Roth takes his information from the Spenersche Zeitung, 1871, No. 167. "On May 1, at 5 p. m., a hill above the village of Catarman split, with heavy shocks and thunderous noise. Smoke, ashes, earth, and stones were thrown out. The crater had a length of 1,500 feet, a breadth of 150 feet, and a depth of 27 feet. At 7 p. m. a second eruption took place. No mention is made of a lava flow." The fissure-like shape of the crater here described is interesting and suggestive. As noted above, Centeno reports a

[1] Memoria geol.-min. de las islas Fil., 1876.

[2] The Compendio de Geografía writes this Camiguing. There is reason to suppose that the Spaniards have dropped a final g from a good many native names.

[3] Jagor's Reisen, p. 328.

[4] Ibid., p. 10.

stream of lava. In the Illustrated London News of October 7, 1871 (Vol. LIX, p. 327), there is a sketch of this volcano by Lieut. F. C. P. Vereker, but the editors have confounded the island with Camiguín de Babuyanes, in latitude 19° 10′. The cut represents the island as covered with mountains of impossible steepness and shows the eruption progressing in a depression near the foot of one of the mountains.

Camiguín was visited by the *Challenger* expedition in 1875. It is described as a dome, 1,950 feet in height, without any crater, but still smoking and incandescent at the top.[1]

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 Negros. It is called Magaso. 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″.[2] 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[3] feet, so that it would rank with Datá, and be exceeded only by Halcon, Apo, and Mayón. It is visible from near Iloilo 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.[4] 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 Jagor's Travels this mountain appears under the name Malaspina.

The Island of Siquijor is sometimes called Fire Island, and this seems to have led to the inference that there was a volcano upon it. According to Mr. Semper, this inference is entirely false. There are neither craters nor hot springs upon it. He is of the opinion that the spectacle of the natives fishing by torchlight at night led the early Spaniards to christen the island Isla de Fuego.

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[1] Voyage of H. M. S. *Challenger*, Narrative, Vol. I, 1885, Part II, p. 653, with a cut.
[2] Derrotero del Arch. Fil., by Capt. C. de Arana, Madrid, 1879.
[3] Bowditch's Navigator and British Admiralty charts.
[4] Mendez de Vigo, Hist. geog. geol. y estad., Vol. II, 1876, p. 173.

According to Mr. Semper, extinct volcanoes exist in nearly all the islands. Cebú and Bohol, like Siquijor, show none; but they exist, he says, on Leyte, Sámar, and in the western mountain region of northern Mindanao, while in the high range of Palawan such extinct volcanoes raise themselves far above the mean crust of the sierra to which they belong.[1] Same of the peaks are said to be more than 2,000 meters (6,561 feet) in height. In the Compendio de Geografía mention is made of a volcano named Calayo and situated in Pulangui. In another passage Pulangui is said to be a town in northeast Paragua (or Palawan). As I have met with no reference to such a volcano in the eastern islands, or to any other town of this name, I suppose the volcano to be in northeast Palawan. According to Mr. Mendez de Vigo,[2] there are two mountains on the Island of Dumaran, close to the northeastern end of Paragua, which often emit smoke and sulphurous fumes, but are not known to have ejected streams of lava. They are called Alivancia and Talasiquin.

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. N., 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.[3]

On the line of Palawan, but close to Borneo and to the south of the small Island of Banguey, an islet rose from the sea during the earthquake of 1897, according to Mr. R. M. Little,[4] but the rock is described as grayish-white sandstone, and no indications of volcanic action are noted.

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 Buráuen, in the northeastern portion of the island, and were visited by Jagor.[5] The more southerly is called Mount Danán. The other is called the crater of Kasiboi, and lies, according to Jagor, on a mountain named Manacagan. This mountain, on Mr. d'Almonte's map, is called Himaiacagan. Jagor 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 Buráuen) forms a brook with a temperature of 50° R. = 145° F.[6] The Guía Oficial mentions a volcano at Buráuen called Caolangojan, which, I suppose, is another name for one of those just referred to.

The Island of Bilirán is well known for its sulphur deposits, the best in the archipelago. The sulphur occurs in solfataras, some of which

[1] Die Phil. u. ihre Bewohner, pp. 16, 31.
[2] Hist. geog., geol., y estad., Vol. II, 1876, p. 23.
[3] Cruise of the *Marchesa*, 1889, p. 175.
[4] Geog. Jour., 1898, p. 298.
[5] Reisen, 1873, p. 220.
[6] Ibid., p. 354.

are extremely hot, Mr. Abella[1] 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 Bilirán to those near Buráuen in Leyte (writing Buranen, however, doubtless by mistake), 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 Maripipi and other small volcanic islands with Bulusán on Luzón. Maripipi, by the way, is represented by Mr. d'Almonte as a conical island, almost round, about 3½ miles in diameter and 3,000 feet high. Its plan is very much like that of a volcanic cone. The chief rock of Bilirán is described by Mr. Abella as containing greenish and black hornblende and phenocrystic feldspars in a feldspathic groundmass, while augite and magnetic iron are sometimes visible. This description makes it substantially certain that the rock is hornblende-andesite.

In Panay a few warm springs seem the only present manifestations of volcanic activity. There is a peak on Mindoro, the elevation of which is 2,700 meters (8,858 feet). It is called Halcon or Alcon, but I can ascertain nothing further about it.[2] Near the port of Galera, according to Mendez de Vigo, there is a small, very deep lake, which smells of sulphur and may be a crater.[3]

The southeastern portion of Luzón is famous for its volcanoes, active and extinct. Of these the most southerly is Bulusán. It lies on the Strait of San Bernadino, and 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.

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. Jagor's barometrical measurement in 1859 was 2,374 meters. The Spanish Hydrographic Commission, according to Mr. Abella, gives 2,522 meters. Mr.

[1] La Isla de Bilirán, 1885, p. 10.

[2] Kotô speaks of it as a volcano, but without citation: Geol. struct. Malayan arch., 1899, p. 119.

[3] Hist. geog., geol., y estad.

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 he 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,[1] 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[2] 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 (Jagor, 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[3] 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

[1] El Mayón, 1885.

[2] La erupción del volcán Mayón en 1897, Manila, 1898.

[3] Emil Stöhr, Der Vulkan Tengger auf Ost-Java, Naturwiss. Verein der Rheinpfalz, Dürkheim, 1868, p. 200.

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[1] (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.

A large number of extinct or dormant craters exist between Mayón and Laguna de Bai. Only one of these has certainly been known to break out since the occupation of the country by the Spaniards. The magnificent cone of Banájao, 7,382 feet in height, towers over Laguna de Bai, and is visible from Manila Bay. Its crater, now 700 feet deep, was occupied by a lake till 1730, when, according to the Estado Geográfico, a violent eruption took place, bursting the southern side of the crater and pouring out both water and incandescent lava. Since then it has been dormant. The Estado Geográfico also alleges that Iriga, in the Province of Camarines Sur, underwent eruption in 1641, but Jagor 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, but there seems to be little of special interest known about them which can not be included in the table on pages 55–56, where they are catalogued.

Solfataras and hot springs are numerous throughout this region. One of the more remarkable occurrences of this nature is near the base of Mount Malínao, in the Province of Albay, a short distance from the town of Tiui and at a small settlement called Naglabong. Some of the springs here deposit siliceous sinter, similar to that of the Yellowstone, Iceland, and New Zealand, in various fantastic forms, and pyritous deposits of recent date are also found. The water was analyzed by Rammelsberg for Roth and Jagor. In 100,000 parts he found 7.5 silicic anhydride, 25.4 lime with a trace of iron, 0.2 magnesia, and abundant chlorides, but no sulphates. The occurrence is enthusiastically described by Jagor and has been discussed by Mr. Abella among the subordinate volcanic emanations of Malínao (1885). Mr. Abella found still more silica in this water, viz, 0.28 per thousand parts, or 28 per hundred thousand. He compares his results with Rammelberg's on the erroneous assumption that the German chemist's results are per

[1] The vertical outline is the hyperbolic sine curve. A discussion may be found in my report on the gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, 1898, pp. 20-25.

thousand parts.[1] Mr. Abella confirms the absence of sulphates in this water. He found the temperature of the water at various vents from 52° to 106° C.[2]

The hot springs at Los Baños on Laguna de Bai, at the base of Maquíling, are very well known, largely because they are so accessible from Manila, and have long been supposed to possess remarkable curative properties by the natives.[3] I shall not attempt, however, to include in this paper any account of the numerous hot and mineral springs of the Philippines. They form the subject of two memoirs by a special commission, of which Mr. Abella was chairman.

The Taal Volcano is a very peculiar one and, when order prevails among the natives, is readily accessible from Manila. It has consequently often been described, both by Spaniards and by others. Chamisso visited it in 1818, Hofman in 1825, the Wilkes exploring expedition and Delmarche in 1842, Semper in 1859, and von Drasche in 1876. Of the accounts published by these travelers, Semper's is the most instructive, and he collected the specimens from which Mr. Oebbeke determined the lava as andesite. Most of the accounts, however, leave much to be desired, because the travelers did not remain long enough to make any detailed surveys. The most complete account of Taal is to be found in Centeno's memoir, written in 1883, and accompanied by maps and sections.

Taal lies on a small volcanic island in the lake of Bombón.[4] The island has an area of some 220 square miles. There is a relatively large central crater and several smaller extinct ones. Of these latter, that at the northwest corner of the island is known as Great Binintiang, or Binintiang Malaquí, and that at the south end as Little Binintiang, or Binintiang Munti. 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 Cosima 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 by measurement, at least very approximately, that of Bombón Lake itself. The following analyses by Mr. Centeno show the composition of the solid residue in one liter of water from (I) the yellow or more northerly lake and (II) the green lake. The

[1] Perhaps another case of careless translation. I have not seen the Spanish translation of Jagor.

[2] Emanaciones volcánicas subordinadas al Malinao. 1885.

[3] The precise locality is called Maínit, a name which occurs at many hot springs in the Philippines and is said to be the Malay word for hot. The French traveler, de la Gironière, called Mount Maquíling Maínit because it is close to this hamlet.

[4] Old writers use the form Bombong.

temperature of the yellow lake is 100° C.; that of the other pool is high, but it could not be approached on account of its steep banks. The soil of the crater is heated to about 50°. The inner walls of the crater are so steep as to make descent into it very difficult.

*Analyses of solid residue in hot waters from crater of Taal Volcano.*

| Constituent. | I. | II. |
|---|---|---|
| | *Grams.* | *Grams.* |
| Sodium chloride | 15.9412 | 30.8588 |
| Potassium chloride | 0.7095 | 3.4716 |
| Ferric chloride | 4.1907 | 9.6736 |
| Ferrous sulphate | 0.5693 | 1.6772 |
| Aluminic sulphate | 0.9360 | ..... |
| Magnesic sulphate | 1.3200 | 3.0600 |
| Calcic sulphate | 0.5100 | 0.4644 |
| Sodic phosphate | 0.5867 | 0.7620 |
| Free sulphuric acid | 1.5855 | 1.4888 |
| Free chlorhydric acid | ..... | 7.8264 |
| Silica | 0.6400 | 0.7400 |
| Total | 26.9889 | 60.0228 |

The concentration and acidity of these waters seem remarkable. I know of none elsewhere closely resembling them.

Taal has had some violent eruptions since the beginning of the Spanish occupation, the worst being in 1754. The earliest known record is by Father Gaspar de San Augustín, who wrote in 1680. His 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[1] 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, proceeded to the volcano in order to exorcise and sanctify it. He had himself let down into the crater, "which had two mouths, 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 Lipa [SE] has a width of a quarter of a league, and through the other, which is smaller, the volcano

[1] Conquistas de las Philippinas, Madrid, 1698, p. 254. This book may be seen in the Boston Public Library.

began to send out smoke in such quantities that" a fresh exorcism was clearly requisite and was duly solemnized. From that time up to 1680, the date of writing, no fire or smoke had issued from the volcano. It appears from this description that Taal over two hundred years ago must have been very much in the same condition as it is to-day, excepting that deer would perhaps find a visit to the salt deposits in the crater more difficult now than in the days of Friar Gaspar.[1]

Eruptions are recorded at Taal in 1709, 1715, 1716, and 1731. From the account of Father Francisco Bencuchillo, quoted by Centeno, it appears that the outbreaks of 1709 and 1715 were confined to the island, doing no damage on the outer shores of the lake. Incandescent stones were thrown out, "and a great fire ran like a river all across the island" (corrio por toda la isla). Mr. Centeno finds no trace of continuous lava flows on the island which are anything like so recent as the last century, and believes that the accumulation of red-hot ejecta on the slopes of the volcano must have conveyed a false impression to the inhabitants watching the destruction of their property from a distance. In 1716, according to Father Francisco Pingarrón, rector of Taal, as quoted by Centeno, a more serious eruption took place. After sounds mistaken for discharges of artillery had been heard, fire was descried bursting from the volcano on the island at the side toward Lipa, on a point called Calavite. This point is now called Calauit, and is the southeastern corner of the island. The fire then shifted into the lake in the direction of Mount Macolod, throwing up water and ashes in immense, bubbling masses, rising like towers into the air. The water grew hot and black, fish 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 Bencuchillo writes, "fire broke out in the lake in front of 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 Calauit and have been washed away at a later date. It

[1] Le Gentil (G. J. H. J. B. le Gentil de la Galaisière), in his Voyage dans les mers de l'Inde, a l'occasion du passage de Vénus, 6 Juin, 1761, Vol. II, 1781, p. 18, translates this account, quoting the author as Gaspard, and stating that "at present many wild boars [sangliers] come to the neighborhood, to which they are attracted by the saltpeter which they find about the lake." The dictionary meaning of salitral is saltpeter deposit, but the term is still used for almost any deposit of efflorescent salts, very much as alkali is employed in the far West for deposits bearing little resemblance to hydrated oxides of the alkaline metals. In Father Gaspar's day chemical distinctions were almost unknown, and the use of the word salitral can not have been more definite than it now is. Perry (ibid., p. 66) still further improves on Gaspar, and states that many wild boars come to the neighborhood, attracted by the sulphur! Perhaps he thought even such a preposterous assertion credible of a country where the horses still insist on having molasses.

would be interesting to examine the existing islets with a view to estimating their age.

I have given somewhat full details of these eruptions because Mr. Semper thus summarized the early history of Taal: "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 Binintiangs alternated with one another till at length, in 1749, the middle crater burst out, silencing the other two. From this time on it has assumed the rôle of bringing to the inhabitants of the neighboring villages, in the smothering ashes, death and at the same time a blessing." The benefaction, he explains, is the fertile soil into which the ash is transformed. He gives no authorities for the eruption of the Binintiangs, nor do Perry and Centeno refer to any. Mr. Semper is a careful writer, but possibly he has confused the accounts of eruptions on the eastern side of the island with indications of past eruptions on the western side afforded by the little craters with long names. Mr. Centeno states that Little Binintiang is now base-leveled, and though geologically recent is very ancient. Great Binintiang still emits hot steam, but Centeno does not appear to consider its last eruption very recent.[1]

The greatest eruption of Taal took place in 1754. It consisted only of 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 round the projecting ruins. The eruption began, according to Bencuchillo, on May 15, and continued with intervals till December 1, when it ceased and a typhoon supervened, lasting two days, and destroying all the volcano had left. In the tropics nature has wonderful powers of recuperation. "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 unimprovable healthfulness charm the people into a prompt forgetfulness of past disasters." No great eruption has occurred since 1754. In 1808 and in 1873 there were outbreaks, but the damage done seems to have been confined to the island itself.

Lake Bombón has a rudely oval form with a mean diameter of about 12 miles. I have not been able to ascertain its level, but the surface can not stand many feet above the sea, for the Rio Pansipit, which connects the lake with the Gulf of Balayan, is only about 6 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

[1] The Guía Oficial, however, speaks of vague reports of eruptions of Binintiang Malaquí.

shore that the lake has not a single affluent. The entire surrounding region is composed of volcanic material, 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; so 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 foca[1] 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.[1] 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.[2]

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 the Zambales Range into the Gulf of Lingayén. In such circumstances the actual distribution of tuff from the Taal vent would be intelligible.

[1] Pepandajan or Papandayang, at its eruption in 1772, has been regarded as a prominent instance of collapse. Lyell wrote: "It was estimated that an extent of ground of the mountain itself and its immediate environs, 15 miles long and fully 6 broad, was by this commotion swallowed up in the bowels of the earth." (Principles, 11th ed., 1877, ch. 30.) But Junghuhn showed that no collapse at all occurred. Such an area, with 40 villages and nearly 3,000 human beings, was buried under ejecta, raising the level of the country. (Java, Germ. trans., 1854, 2d part, p. 97.)

[2] Mr. von Drasche, while assenting to the theory of collapse, nevertheless speaks of Bombón as "a crater lake," and Mr. Kotô refers to it in the same way (loc. cit., p. 119). It might be questioned whether the term crater is properly applicable to mere sinks, even of volcanic origin, but that is a matter of usage. In this particular case the ambiguity of the term leaves me in doubt whether Mr. Kotô shares my view or Mr. von Drasche's.

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-Lingayen 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 tuffs of Manila Province came from Bombón.

Returning to enumeration of volcanoes, there are to the southeast of Lake Bombón two mountains supposed to be extinct vents, but of which next to nothing is known. One of them is called Malarayat, a peak of which is called Sosoncambing, and the other is Tombol.[1] About the same latitude and off the western coast is the alleged volcano Ambil. Mr. Semper investigated this case and could find no evidence that there has been any eruption on this island in historical times. On the charts what appears to be a crater is shown with an elevation of 2,500 feet.

In the Sierra de Mariveles there are no present signs of volcanic activity beyond hot springs, but the range is unquestionably of volcanic origin. Prominent points upon it are Pico de Loro on the southern headland of Manila Bay, the Island of Corregidor, Nagouliat Peak, and Butilao Peak. It has been alleged that there is a crater on Corregidor, but I found none. Mr. von Drasche has suggested that Corregidor and the little island Pulo Caballo are parts of the rim of a large crater, and this appeared probable to me too during a visit to these islands.

North of the Mariveles Mountains lies the Cordillera de Cabusilan, which contains volcanic-looking peaks (sketched by Mr. von Drasche), especially Pinatubo, but I know nothing further about them.

Mount Aráyat is a striking object, even from the mouth of the Pásig River, looming up over an extensive plain in solitary grandeur. The merest glance is sufficient to show that it is a monadnock and in all probability volcanic. There are two peaks, of which only one is visible from the south. It is densely wooded and shows no crater, according to Mr. von Drasche, who regards the rock as dolerite. Mr. Oebbeke, who examined specimens from both peaks, says that the groundmass is chiefly feldspar, and he classes it as an olivine-bearing augite-andesite. Aráyat must have been extinct for a very long time.

It has already been noted that San Tomás, or Tonglón, on the eastern boundary of Unión Province, is not a volcano, either active or extinct.

[1] Mr. Semper collected augite-andesites from Mount Binay and the mountains of southern Batangas which have been described by Mr. Oebbeke. I can not find Binay on the maps, where it is probably represented by some other name.

On the other hand, Mount Datá is regarded by Messrs. Semper, Jagor, and Espina as an extinct volcano. Mr. Hans Meyer ascended Datá in 1882 and by barometer found the height 2,245 meters. He found a lake some 1,100 yards in diameter on a bench on the eastern slope of the highest part of the mountain.[1] This is perhaps a crater lake. This traveler says nothing of the rock, but at Mancayan, only about 5 miles from the peak, the rock is sanidine-trachyte, according to Mr. von Drasche.

The remaining volcanic mountains of the archipelago lie in one group at its northern end. Mr. James Horsburgh mentions the little island Camaguín de Babuyanes as having formerly been a volcano, and says that on the west end of the Island of Babuyan Claro there is a volcano.[2] Meyen states that in 1831 the latter underwent a violent eruption. Semper says Babuyan Claro seems to be continually in eruption and that Camaguín is now in the solfataric stage. In 1856 a new volcano made its appearance not far from Camaguín, at the Didica reefs, or Farallones. It is called the Didica Volcano. 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, when Mr. Semper saw it, the volcano was constantly active, and in four years had reached a height, according to his triangulation, of 700 feet. He was unable to visit the spot. There is, finally, a volcano on the main Island of Luzón, in the eastern coast range, some 25 miles south of Cape Engaño. 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."[3]

In the following table are collected the principal data available concerning 20 active and 29 extinct or dormant volcanic vents. I may repeat here that San Tomás and Siquijor, or Fire Island, are omitted because it has been shown that they are not volcanoes. Calayo, supposed to be on Palawan, is left out because there are no data as to its position, while I have no means of separating the positions of the two volcanoes said to exist on Dumaran de Paragua. The principal synonyms are given, that which seems most appropriate being put first. The latitude and longitude are only approximate and have been read from maps. So far as possible Mr. d'Almonte's maps have been used to fix positions and elevations. Mr. Abella's determination of altitude has been taken for Mayón and Mr. Montano's for Apo. A number of the heights of Luzón volcanoes are those originally determined by Jagor, but I do not know the sources of all of Mr. d'Almonte's

[1] Weltreise, 1890, pp. 253–287. Meyer had a paper in Globus, 1883, which I have not been able to see.
[2] The India Directory, or directions for sailing to and from the East Indies, 2d ed., 1817, p. 328.
[3] Die Philippinen, 1869, pp. 14, 98.

figures. Many of them are doubtless his own. The longitudes of the table are for the prime meridian of Greenwich. In the section on "Sources of information" the Greenwich longitude of other prime meridians is noted.

*Active and solfataric volcanoes.*

| Name. | Province. | Approximate— Latitude. | Approximate— Longitude E. of Greenwich. | Height in feet. | Rock. *a* | Date of eruption. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | | |
| Babuyán Claro... | Batanes ..... | 19 30 | 121 56 | ..... | ..... | 1831, 1860. |
| Camiguín de Babuyanes. | .....do ..... | 18 55 | 121 52 | ..... | ..... | Solfataric. |
| Didica ..... | .....do ..... | 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 *b* .. | 1709, 1715, 1716, 1731, 1749, 1754, 1808, 1873. |
| Banájao or Majaijai. | Laguna..... | 14 2 | 121 27 | 7,382 | Andesite *c* .. | 1730. |
| Mayón or Albay . | Albay ..... | 13 16 | 123 39 | 8,970 | Andesite *b* .. | 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, 1896, 1897, 1900. |
| Bulusán..... | Sorsogón ..... | 12 47 | 124 1 | ..... | ..... | 1852. Solfataric. |
| Guinon (Bilirán Island). | Leyte..... | 11 32 | 124 28 | ..... | Andesite *d*.. | Solfataric. |
| Kasiboi or Caolangojan? | .....do ..... | 10 55 | 124 53 | ..... | Andesite *e* .. | Do. |
| Danán ..... | .....do ..... | 10 54 | 124 53 | ..... | Andesite *e* .. | Do. |
| Alivancia..... | Paragua ..... | 10 30 | 119 48 | ..... | ..... | Do. |
| Talasiquin ..... | .....do ..... | 10 30 | 119 48 | ..... | ..... | Do. |
| Canlaón ..... | Negros Oriental .. | 10 25 | 123 6 | 8,192 | Andesite? *f*. | 1866, 1893. |
| Magasu ..... | .....do ..... | 9 15 | 123 9 | ..... | Andesite? *f*. | Solfataric. |
| Camiguín de Mindanao. | Misamis ..... | 9 12 | 124 42 | 1,950 | Andesite *g* .. | 1871, 1875. |
| Macaturin, or Pollock, or Sujut, or Illano. | Cottabato..... | 7 36 | 124 26 | ..... | ..... | 1765, 1856, 1865, 1871. |
| Apo or Dávao .... | Dávao ..... | 7 3 | 125 17 | 10,311 | Andesite *h* .. | Solfataric. |
| Sanguil or Sangir (Balut Island?). | .....do ..... | 5 25 | 125 19 | 3,117 | ..... | 1641. |
| Joló..... | Joló..... | *i* 6 5 | *i* 120 58 | ..... | Basalt? *f*.... | 1641. |

*a* The queries indicate that the composition of the volcano is inferred from specimens collected near it, but not on it.

*b* Oebbeke. *d* Abella. *f* Becker. *h* Velain.
*c* v. Drasche. *e* Roth. *g* Renard. *i* Uncertain.

*Extinct or dormant volcanoes.*

| Name. | Province. | Approximate— Latitude. | Approximate— Longitude. | Height in feet. | Rock. |
|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | |
| Datá | Lepanto | 16 57 | 120 55 | 7,364 | Trachyte? *a* |
| Aráyat | Pampanga | 15 13 | 120 42 | 2,880 | Andesite. *b* |
| Pinatubo | do | 15 9 | 120 19 | 6,050 | |
| Butilao | Bataan | 14 43 | 120 21 | 4,376 | Andesite? *c* |
| Nagouliat or Mariveles | do | 14 31 | 120 26 | 4,678 | Andesite? *c* |
| Corregidor | do | 14 23 | 120 32 | 640 | Andesite, dacite. *c* |
| Pico de Loro | Cavite | 14 13 | 120 36 | 2,270 | Andesite? *c* |
| Talim | Mórong | 14 20 | 121 13 | 1,519 | Basalt. *c* |
| Maquíling | Laguna | 14 8 | 121 10 | 3,724 | Basalt. *d* |
| Cristóbal | do | 14 3 | 121 24 | 5,288 | Basalt? *d* |
| Malarayat and Sosoncambing. | Batangas | 13 58 | 121 11 | | Andesite? *b* |
| Tombol | do | 13 49 | 121 10 | | Andesite? *b* |
| Ambil | Mindoro | 13 48 | 120 16 | 2,500 | |
| Loboo | Batangas | 13 39 | 121 16 | 3,451 | Andesite? *b* |
| Labo | Camarines Norte | 14 1 | 122 46 | 5,092 | Andesite. *a* |
| Colasi | do | 13 58 | 122 59 | | Andesite. *d* |
| Isarog | Camarines Sur | 13 41 | 123 21 | 6,450 | Andesite. *d* |
| Iriga | do | 13 26 | 123 26 | 3,976 | Basalt and andesite. *a* |
| Malínao | Albay | 13 26 | 123 34 | | Basalt. *d* |
| Mazaraga | do | 13 18 | 123 35 | 4,442 | Basalt. *d* |
| Pocdol or Bacon | Sorsogón | 13 5 | 123 54 | | |
| Mainit or Sapongan | Surigao | 9 28 | 125 33 | 1,115 | |
| Cottabato or Taviran | Cottabato | 7 6 | 124 18 | | |
| Cagayán Joló | Balábac | 6 59 | 118 30 | | |
| Magolo | Dávao | 6 19 | 125 6 | | |
| Matutum | do | 6 11 | 125 10 | | |
| Malibato | do | 6 8 | 125 2 | | |
| Butulan or Sarangani | do | 5 42 | 125 18 | | |
| Balut or Sanguil (?) | do | 5 24 | 125 20 | 3,117 | |

*a* v. Drasche. *b* Oebbeke. *c* Becker. *d* Roth.

## VOLCANIC BELTS.

So large a portion of the Philippines consists of volcanic rock as to make it manifest that there must be in the archipelago a considerable number of volcanic belts. Such zones form one of the most prominent features of Malaysia as a whole, and when these are passed in review it appears that the volcanic structure of the Philippines must bear complex and interesting relations to that of the entire region. J. D. Dana[1] was, I believe, the first to call attention to the linear disposition of the volcanic islands of the Pacific and to refer this arrangement to geotectonic principles. Naumann,[2] Perry,[3] Suess,[4] Junghuhn,[5] Centeno,[6]

[1] U. S. Expl. Exp., Vol. X, 1849, pp. 11–23, 415–436.
[2] Lehrb. der Geognosie, Vol. I, 1858, p. 93.
[3] Phén. volc.: Mém. Acad. de Dijon, Vol. VIII, 1860, p. 31.
[4] Antlitz der Erde, Vol. II, 1888, pp. 213–217, etc.
[5] Java, Vol. II, 1854 (German trans.), p 807.
[6] Memoria geológ.-min. Fil., 1876, p. 7.

Wichmann,[1] Verbeek,[2] Martin,[3] Molengraaf,[4] Kotô,[5] and others have contributed to the subject, which, however, still requires much study, especially with reference to the Philippines.

The Nicobar Islands, Sumatra, Java, and the Little Sunda group lie along the edge of a vast submarine precipice, or, in other words, at the very abrupt limit of the continental plateau. Lines of folding and volcanoes, Tertiary and modern, accompany the course of this southern limit of Asia. Some of the most active and remarkable volcanoes of the world are here. Papandayang, in West Java, had a great eruption in 1772, destroying 40 villages. Galung Gung in 1822 destroyed 114 villages; and it is some measure of the violence of the Krakatoa explosion of 1883 that over 36,000 people perished. Off the eastern coast of the Philippines there is also a rapid deepening of the sea bottom, marking the eastern edge of the continental plateau, and here, too, there is a series of active or extinct volcanoes which stretches from close to Formosa southward to the Moluccas. According to Naumann, these two great lines meet in the volcanic island of Nila, about latitude 6° 30′ S., longitude 129° 35′ E., but later studies show that, while in a generalized way this statement represents the distribution of the main volcanic lines, the volcanic systems of the Banda Sea are very complex. In this neighborhood submarine elevations connect Malaysia and Australia, and complexity of structure is therefore to be expected. As many as three curved folds appear to exist here with a common center near the middle of the Banda Sea. They certainly serve to connect the Sunda volcanic line with the Formosa line; but, though considerable study has been devoted to the subject, the evidence is not sufficiently full to unite geologists as to the actual linear connections between volcanic localities. The Formosa line seems clearly to continue along the eastern coast of the Philippines southward through Gilolo, in the Moluccas, but Kotô and others regard Buru and Ceram as a recurved portion of one of the concentric Banda Sea arcs, and as running in this locality perpendicularly to the Formosa line. For the present purpose it is not needful to enter into minutiæ concerning the Banda Sea area.

Within the region outlined by the submarine cliffs of the continental plateau and by the great volcanic arcs lie Borneo, Celebes, and the western portion of the Philippines, as well as the peninsula of Malacca and its continuations, Bangka and Billiton. These latter are closely connected, structurally and otherwise, with the Nicobars and Sumatra, and they are of minor interest so far as the Philippines are concerned.

[1] Gesteine von der Insel Kisser; Beiträge zur Geologie von Ostasien, Vol. II, 1887, p. 197. Neues Jahrb., 1893, pt. 2, p. 176. Petermanns Mitteil., 1893, p. 18. Zeitschr., D. geol. Gesell., 1893, p. 543.

[2] Verbeek et Fennema, Descrip. géol. de Java et Madoura, 1896, p. 993.

[3] Reisen in den Molukken, geol. Th., 1897, p. 57. [4] Petermann's Mitteil, Vol. XLI, 1895, p. 203.

[5] Geol. structure of the Malayan archipelago: Jour. Coll. of Science, Tōkyō, Vol. XI, pt, 2, p. 83. This is in part a very convenient review.

On the other hand, 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 Talaut 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 Mount 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 coast. More obscure is a line which starts apparently in Panay and is marked in the Joló Sea by the Cagayanes, including Cagayán de Joló, for which the Government of the United States is now negotiating with Spain. 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. Verbeek, 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 (or Taiwan), but the relations of the Zambeles Range and the Caraballo del Norte are not evident on mere inspection.

The interpretation of these topographic features is more or less difficult and uncertain. Lines of folding must of course be discriminated from ranges due to erosion, and while volcanic outbursts are apt to mark anticlines, this is not an invariable rule. The question of continuity is sure to arise in discussing volcanic belts, and it is sometimes assumed that where any considerable gap occurs between areas of volcanic ejecta the fissure system connecting vents is also lacking. This does not seem to me a correct inference. As I read them, volcanoes represent points on a zone of active dislocation where a powerful resistance leads to the dissipation of epeirogenetic energy. Dislocation without attendant volcanism is common enough even in volcanic regions, for active volcanoes are characteristically accompanied by inactive or extinct ones, and from this association it is only a step to volcanic zones in which spots exist where there neither are nor ever have been volcanic vents. These gaps I suppose to mark portions of the fissure system so related to the zone as a whole that resistance to dislocation is never intense enough to supply the latent heat of fusion to the hot rocks on the isobathic surface of melting.

It follows as a matter of course, from these and similar considerations, that minute study of the structure and lithology of a country is needful to a satisfactory elucidation of its volcanic and tectonic system,

a topographic sketch being quite insufficient for the purpose. Nevertheless, when it is distinctly understood that a discussion of the subject is intended only to be tentative and suggestive, speculation may lead to the accumulation of facts which otherwise would be overlooked.

Perry[1] 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 Macaturin and Sanguil; it took in Ternate and probably reached the Banda group. Mr. von Drasche[2] 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,[3] distinguished two systems, one passing through Aráyat, Taal, central Mindoro, Canlaón, and Macaturin; the other through Mayón, Buráuen (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 Philippines toward Formosa, but without specifying the relations of the northern portion to the more southerly lines. Mr. Abella[4] called attention to the continuity of the volcanic phenomena in Leyte northward through Bilirán, Maripipi, etc., to the volcano Bulusán, and to Mayón in southern Luzón, as well as southward to the eastern coast range of Mindanao. Mr. Kotô[5] 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 Bilirán 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 Macaturin, Magaso, Canlaón, and Taal. Mr. Kotô, 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 Zambeles; leaving the shore at Mariveles, it intersects Ambil and follows Palawan to Kina Balu, in Borneo, reaching the center of that great island.

These notes suffice to show that, so far as details are concerned, there is considerable diversity of opinion. To my thinking, too much effort has been made to show unbroken continuity of volcanic zones. Fissures occur far more often in parallel systems than singly, and just as dikes frequently jump from one fissure of such a system to another,

[1] Documents, etc., 1860, p. 35. [2] Fragmente, p. 3. [3] Mem. geológ. min., 1876, p. 8.
[4] Isla de Bilirán, p. 11. [5] Geol. struct. Malay arch., p. 112.

so I think do the greater volcanic phenomena. Fissures, furthermore, commonly occur in two systems, cutting one another at a large angle, and there are somewhat clear indications that such is the case with the volcanic belts in the Philippines south of Manila. These two systems are approximately parallel to the two prongs of Masbate, but each is curved, the centers of curvature lying in the China Sea, one of them much to the southward of the other. I should consider, provisionally, that the elevations of northwesterly trend, such as the mountains of eastern Mindanao, Leyte, Tayabas, Mindoro, northwestern Panay, and perhaps the northern extremity of Palawan, belong to the one system, but represent a considerable number of different though associated fissures. The trends of the northeasterly character also seem to belong to one system. The western fork of Masbate appears to continue to northeastern Panay, but to be interrupted with an offset in the southwestern portion of that island. The southerly prolongation, it seems to me, is to be found in the Cagayanes. Of course Palawan, Negros, excepting the southern end, and the Basilan-Joló group belong in this system. So nearly as I can make out by plotting, the two systems intersect at pretty constant angles of about 60°. A fairly consistent and satisfactory scheme of short arcs can be arranged in this way for the ranges south of Manila, but I hesitate to print my diagram, because a map conveys an impression of certainty and definiteness which in this case would be erroneous.[1]

To the northward of Manila the same scheme of ranges seems less plausible. I am almost inclined to think that the Sierra Madre and the Caraballo del Norte, which are composed largely of crystalline schists, are each made up of short arcs belonging to each system. Some support for this guess is to be found in Mr. d'Almonte's large map of Luzón, where the watersheds show several zigzags. This region is perhaps a "horst" in Mr. Suess's sense. As for the Sierra Zambales, it seems to me most probable that it continues southward through Pico de Loro and Cape Santiago to the lofty Alcon Peak, in Mindoro, and so into Panay, for a series of hot springs extends southward from Mariveles through Pico de Loro to Balayán, near Cape Santiago, in Batangas Province.[2] The western range of middle Luzón would thus be affiliated with the system with a northwesterly trend. Mr. von Drasche, however, calls attention to the fact that the Sierra Zambales exhibits a remarkable double repetition of the two main directions of Luzón, one northerly, the other northwesterly.[3] With Aráyat I can do no better than leave it in its impressive loneliness.

It is not only in the matter of volcanic zones that the Sunda and Banda islands are homologous with the Philippines. The volcanic

[1] Dana called attention to the symmetry exhibited in the trends of the islands. "Thus the body of Luzón is at right angles with the southern extremity; Palawan is at right angles nearly with Mindoro," etc. He also points out that both of the two systems of trends are curved.

[2] Abella, Man. min., 2d study, 1893, p. 70.

[3] Op. cit., p. 21.

rocks of the southern islands, as has been pointed out above, are substantially indistinguishable from those met with in the Asiatic dependency of the United States. These islands are occupied to a large extent by Tertiary strata, and have undergone slow, recent uplift marked by raised coral reefs. Even their older massive rocks seem much the same as in Luzón, but they also contain Paleozoic and Mesozoic strata, not yet discovered in our possessions.

## NOTES ON HISTORICAL GEOLOGY.

Pre-Tertiary strata are entirely unknown in the Philippine Islands. Whether they are absent or merely undetected is questionable. If they are absent, it must either be because the elevation throughout the Paleozic and Mesozoic was as least as great as it now is, or else because the sediments of those periods have since been removed by erosion. In either event it might be expected that the archipelago would stand on a very extensive submarine plateau, built up of sediments derived from the land area. Such is not the case; the islands now stand high, and about three-quarters of the total platform area is dry land. Furthermore, the greater part of the submerged territory lies either immediately west and south of Sámar, and thus between the Visaya Islands, or about the Joló group; while a rise of 100 fathoms[1] would add very little to the area of either Luzón or Mindanao. There is thus no physiographical reason to suppose pre-Tertiary strata absent.

Still less does analogy point to the absence of Paleozoic or Mesozoic beds, for both are fairly abundant in the Sunda Islands, while manifold similarities show that they and the Philippines belong to a single geological and to a single zoological province. If such strata exist, it may be that they are so folded up with the greatly disturbed Eocene that they have not hitherto been differentiated. From the descriptions of Surigao and Misamis, it would seem, too, that considerable areas of slate are there exposed and that portions of these rocks are not highly metamorphosed. This region may possibly yield fossils. In carrying on geological investigations in the Philippine Islands, the indications afforded by the constitution of neighboring islands should evidently be borne in mind, for if the similarities which might be expected do not manifest themselves, the cause of difference demands elucidation.

In Borneo pre-Tertiary strata appear to be somewhat extensively developed. Of the supposed Devonian, Mr. Posewitz[2] writes as follows:

> On the islands of the Malay Archipelago the oldest slates, in which up to a short time ago no fossils had been found, are included in the so-called "old slate-formation," to distinguish them from the "younger slate-formation," which, in Sumatra, is

[1] This is, of course, not a mere arbitrary depth, but approximately the lower limit of wave action.
[2] Borneo, Its Geological and Mineral Resources, p. 164, London, 1892.

included by Verbeek in the Culm Measures. Their distribution is very extensive, as they occur in all the islands. In Borneo they contain gold; in Bangka and Billiton, tin. With regard to the age of these phyllites, it was only known up to quite lately that they were pre-Carboniferous, as the Carboniferous strata in Sumatra are underlaid by them. In recent years, however, fossils have been found in west Borneo, which, however, are so badly preserved that up to the present an exact determination of their age has not been made. But the fossil evidence is not against the view that the formation might be Devonian.[1]

It is perhaps from analogy with these slates that Mr. Montano pronounces the ancient massive rocks of the Philippines "principally Devonian."[2] It would certainly be surprising if none of the older schistose rocks of the Philippines should turn out to be equivalent to the old slate of Borneo. In Sumatra, Verbeek considers this old slate as Silurian or Devonian, or a mixture of both.[3] The Carboniferous is known to exist on Borneo and other of the Sunda Islands. It seems to pass by insensible gradations into the underlying slates, but to be separated by a sharp unconformability from the overlying rocks. It is composed of sandstones and limestones, often standing on edge. It is extensively developed in north Borneo.[4] The Upper Jurassic (weisser Jura) has been detected in west Borneo in rock previously supposed to belong to the "old slates,"[5] and from the same region Liassic fossils have been described.[6] In Sarawak, too, an Oolitic fossil has been found.[7]

The Cretaceous is also represented in the mountains of west Borneo. Specimens collected by van Schelle near Sajor, on the River Seberuang, were determined by Boettger and Geinitz as Upper Cretaceous. The extent of the Cretaceous is unknown.[8]

Most of the area of Borneo is occupied by Tertiary strata, and there seems no doubt that all three divisions of the Tertiary are represented. Their delimitation is not so certain.

In the Island of Timor occur both Permian and Triassic strata, fossils from which have been identified by Mr. Rothpletz.[9] With them are found nummulitic limestones containing *Alveolina*, and capped by reef limestones. This island further contains a series of massive rocks very like that of the Philippines. On this subject and for further information the reader will do well to consult Mr. B. Kotô's excellent review.[10]

The age determination of the Malaysian formations, both Mesozoic and Tertiary, is a matter of extreme difficulty, and has led to much

[1] Jaarboek van het Mynwezen in Nederlandsch-Indië, 1886, II, p. 122.
[2] Mission aux îles Phil., 1881, p. 272. Montano gives no grounds for his assertion.
[3] Posewitz, Borneo, p. 166. Verbeek, Sumatra's Westkust, pp. 237–238.
[4] Posewitz, ibid., p. 167.
[5] Fr. Vogel, Samml. geol. Reichs-Museums en Leiden, Vol. V, 1896, p. 127.
[6] P. G. Krause, ibid., p. 154.
[7] R. B. Newton, Geol. Mag., 1897, p. 407.
[8] Posewitz, ibid., p. 173.
[9] Am. Naturalist, 1891, p. 959.
[10] On the geologic structure of the Malayan Archipelago: Jour. Coll. Sci., Tôkyô, Vol. XI, 1899, pp. 83–120. This paper contains a few inaccuracies of statement concerning the Philippines.

unavoidable difference of opinion, because the subject can be approached from different points of view. No deposits have yet been discovered which serve to establish a direct connection between Tertiary strata of the East Indies and those of the North Temperate Zone, nor does the configuration of Eurasia give much hope that such a terrane will be discovered. It is to America that geologists must turn for a direct correlation of formations in the two zones, and studies there will doubtless throw much light ultimately on the East Indian faunas of the past. This is no place for a full review of the literature of the Malaysian Tertiary, but a few notes on the subject, and especially on the Eocene, will be useful to those readers of this paper who happen to be unfamiliar with it.

Junghuhn,[1] in his great work on Java, attempted no divisions of the Tertiary, and even expressed doubts as to the validity of Lyell's three sections of that period. In 1858 F. von Hochstetter[2] segregated the Eocene into three divisions, but in 1866 he modified his views so far as to refer the highest of these to the Miocene. The two remaining Eocene series were:[3]

(*a*) Lower group; coal-bearing system. Many exploitable seams of bituminous pitch coal in quartzose sandstone and clay slate. Fossil tree trunks common, but few fossil shells, or none at all.

(*b*) Upper group. Orbitulite and nummulite limestones; with compact limestones and older coral limestones, heavily developed beds, greatly tilted in certain localities.

The Miocene he also divided into two groups of marly, tuffaceous beds.

Mr. Verbeek, in 1875, in conjunction with Böttger, Geyler, and von Fritsch, subdivided the Eocene of Borneo into three stages, as follows:[4]

Stage $\alpha$, sandstones with indurated clays, clay slate, and coal seams.
Stage $\beta$, soft shales and marls.
Stage $\gamma$, limestones.

The observations and collections of Mr. Verbeek and others led to much controversy, in which Mr. Martin and Mr. Wichmann, both of whom have made journeys in the Malaysian Archipelago, took an active part. Mr. Martin, in 1879-80, laid down broad principles of correlation which appear very important.[5] He held that mere comparison of species or genera in tropical and boreal rocks could lead to no trustworthy conclusions, the tropical faunas being radically different from the coeval European faunas. Age determinations, in his opinion, should be made by comparison between fossil tropical faunas and the

[1] Java, Vol. III, 1854 (Germ. trans.), p. 91.
[2] Jahrb. K.-k. geol. Reichsanstalt, Wien, Vol. IX, 1858, p. 294.
[3] Reise der österreichischen Fregatte *Novara* um die Erde., geol. Theil, Vol. II, 1866, p. 149.
[4] Die Eocänformation von Borneo und ihre Versteinerungen, 1875, p. 4.
[5] Tertiärschichten auf Java, allg. Theil, 1879–80, p. 21. See also Sammlungen des geol. Reichs-Museums in Leiden Vol. V, 1899, p. 259.

living fauna in the same region. Yet even this method is held to be inapplicable in the precise form worked out for the European Tertiary, for in the Tropics physical conditions vary so much less than in boreal regions that the extinction of species must be less rapid, and therefore a greater proportion of living species is to be anticipated in a Tertiary formation of Malaysia than in a homonymous formation of Europe. On these grounds he declined to recognize Mr. Verbeek's Stage $\gamma$ as Eocene, and expressed himself dissatisfied with the determination of Stage $\beta$.

In 1883 Mr. Verbeek made a change of no very great importance in his classification of the Eocene by adding at the bottom an unfossiliferous basal conglomerate, and by characterizing his divisions thus:[1] Stage I, breccia stage; Stage II, quartz sandstone stage; Stage III, marl sandstone stage; Stage IV, orbitoide stage. In 1892 fossil evidence forced him to change his opinion as to $\beta$ and $\gamma$, or III and IV, and he referred the lower of these to the Oligocene and the latter of them to the Upper Miocene[2] thus reaching much the same opinion as Mr. Martin had expressed.

While this report was in preparation, Mr. Martin published a paper on the division of the fossiliferous strata of Java, which he classifies as follows:[3]

Quaternary; consisting of fluviatile and marine deposits, the latter rich in Mollusca and at some localities in remains of whales.

Upper Pliocene; represented by the Kenden beds, rich in remains of *Stegodon* and *Cervus*, containing also *Pithecanthropus erectus* Dub.

Pliocene-Miocene, or the Java series, possibly including some pre-Miocene rocks. This constitutes the greater part of the Island of Java and most of the fossils from the island which have been described come from it. Among them are *Lepidocyclina* and *Cycloclypeus*. This series extends northward through the Philippines to central Japan.

Eocene; marine beds of small extent with nummulites, *Alveolina* and *Orthophragmina*. They contain coal.

Cretaceous limestone with *Orbitolina* from Banjumas. This rock is not known to exist at any other point in Java.

For the purposes of Philippine geology it is important to remark that the series which carries the black lignites accompanied by quartzose sandstones, has been regarded by all the geologists cited, and by most others, as Eocene; while there appears to be a gap in the Miocene of the Sunda Islands which may correspond to an unconformability there, and which answers to a very pronounced discordance in the Philippines.

The Tertiary of the Philippines is fairly well developed, but very insufficiently investigated. In presenting his determinations of the

[1] Top. en geol. Beschrijving van Sumatra's Westkust, 1883, pp. 315 et seq.

[2] Neues Jahrbuch für Mineralogie, etc., 1892, part 1, p. 66.

[3] Die Eintheilung der versteinerungsführenden Sedimente von Java: Sammlungen des geologischen Reichs-Museums in Leiden, Vol. VI, 1900, pp. 135–245.

fossils in the Semper collection Mr. K. Martin has luminously reviewed the whole Philippine Tertiary, and his paper should be in the hands of every student of the geology of the archipelago. For this reason I have translated it in full, instead of attempting a mere condensation, and my version will be appended as a complement to this sketch. While it is possible that future investigations may make minor changes in Mr. Martin's conclusions, they appear adequately to represent the best results which can be reached until much further investigation of the islands has been accomplished.

The Eocene has been recognized, thus far, only in the nummulitic limestones. These were first discovered by Baron F. von Richthofen at Binangonan on Laguna de Bai, in Mórong Province. They were detected in stone quarries northeast of the town, where the limestone projects in a pillar-like mass through trachyte. The nummulites are mentioned as belonging to several species, but no specific determinations are given. He considers the barren limestone of the caves near San Mateo and those of Jala-Jala on Laguna de Bai of the same age. The limestones are crystalline at their contact with trachyte. At Zamboanga (Mindanao) he found similar limestones, though no fossils; and believed that the excellent brown coal found in the Bay of Sibuguey, in Zamboanga Province, belongs to the same formation.[1] Mr. Abella also found nummulitic limestone in Cebú, at Ginagdanan, a gulch within about three-fourths of a mile from the Esperanza coal mining prospect, in the township of Compostela, a few miles to the north of west from the town of that name. This is on the east coast of Cebú, in latitude 10° 25′. The position of the mine seems to be marked on Mr. Abella's map, though not its name. The fossils were so imperfect that the species could not be determined.

Mr. Abella in describing his Compostela section gives the following notes: "In the rocks of this section we found among the lignites and sandstones of the mines only a few fossil plants, which were indeterminable; and among the limestones certain indistinct forms half converted into spar which could afford no certain indication as to their age. Nevertheless, in breaking some pieces of limestone from Ginagdanan, we found included in the compact mass certain forms which, though specifically indeterminable, should be considered as nummulites in the opinion of various competent persons." He adds that such was the opinion of Mr. José MacPherson, who perceived a striking similarity between specimens of these strata and those of nummulitic limestone in the Province of Cadiz, Spain, which he had studied.[2] It should be added that the strata between the mine and the fossil locality are very highly inclined, a part dipping to the northward and a part to the southward; so that the lignite and the fossiliferous limestone

[1] Zeitschr. D. geol. Gesell., Vol. XIV, 1862, pp. 357-360.

[2] Isla de Cebú, 1886, p. 109.

might be of very different ages so far as the stratigraphy is concerned.

Chiefly on the strength of this discovery, Mr. Abella regards a large area in Cebú as Eocene. It consists of "clays and marls in a compact or slaty condition; sandstones, calcareous sandstones, and conglomerates; compact or crystalline limestones and some lignite seams; all of these in beds which have undergone extreme disturbance."[1]

I must confess that the paleontological evidence as to the existence of the Eocene in the Philippines seems to me far from satisfactory. In Borneo no nummulites, it is said, occur in Mr. Verbeek's Stage $\alpha$, the only beds now considered Eocene, while one species is found in the Oligocene ($\beta$) and four in the upper Miocene ($\gamma$).[2] In British India, Burma,[3] and Timor, indeed,[4] nummulitic Eocene is recognized, but it would seem probable a priori that the Philippine nummulitic beds would be comparable with those of the adjacent Island of Borneo rather than with the far-away formations of Burma and Timor. I can see no reason as yet why the Binangonan limestones may not be Oligocene or even Miocene.[5] On the other hand, there seem to me structural reasons for correlating the lignitic series of Cebú with Verbeek's Stage $\alpha$, as will be explained a little later. While desiring further light, however, I fully recognize Mr. Martin's authority on the paleontological question involved.

Two horizons of the Upper Miocene have been detected. The earlier is revealed by the collections of that model explorer, Semper. He found fossiliferous beds in the valley of the Rio Grande de Cagayán, Province of Isabela, Luzón, which are characterized by a typical mullusk *Vicarya callosa* Jenk, var. nov. *semperi* Mart. They occur in the neighborhood of a place which Semper calls Minanga, in latitude 17°, which seems to be the town named Malunú on Mr. d'Almonte's map. It may be that Minanga is the name of a suburb (barrio) of Malunú. A considerable number of species where collected on the banks of the Catalangan River, and on the banks of the Ilaroen, which latter appears to be identical with the Tarretic of the Spanish geographer's map. Another important locality is the brook called by Semper Dicamui and seemingly also Dicamuni. In a note to Mr. Martin's paper I have given reasons for believing that this stream is also near Minanga. The same *Vicarya* was also collected by Semper at Alpacó, in Cebú. This is in the coal region not far from Naga, and seemingly comes from a marl overlying the Eocene limestones, which is referred to by Mr. Abella as cropping at the head of the arroyo Sibod.[6]

[1] Isla de Cebú, 1886, p. 95.
[2] Posewitz, Borneo, 1892, p. 197.
[3] Geikie, Text-book of Geol., 1893, p 981.
[4] See Kotô, loc. cit., p. 92.
[5] While there is little doubt that tropical strata, both in the East Indies and the West, have been regarded as more recent than they are because of the strong similarity of fossil shells to living species, it should be noted that in the Torrid Zone masses of coral limestones are sometimes transformed with great rapidity into masses so dense as to bear great lithological resemblance to rocks of far greater antiquity.
[6] Isla de Cebú, 1886, p. 114.

The occurrence and character of this marl require attention both for its own sake and because of its relations to the other rocks of Cebú. After having described the massive rocks of the island and the contorted lignitic series, which he considers Eocene, Mr. Abella proceeds to describe his Quaternary formation, and, incidentally, certain marls. Extracts from these descriptions had best be given in literal translation because of the importance of the points involved.[1]

Surrounding the rocks hitherto described on every side, lies an essentially calcareous terrane, which, in general terms, may be said to pass over into the coral reefs on the coast and to rise toward the interior, forming masses as high as those in Mount Mangílao. In addition to the limestones, there is exposed at many points beneath them a bed of marl, more or less argillaceous, which must be referred to this formation, since its stratification is always concordant with the limestone and it contains fossils similar to those found in the limestone. This bed can only be seen toward the central portion of the island and toward the south, in its widest portion, generally appearing at the bottom of the deepest ravines. [At Magdagoog, in the district of Consolación, which is on the eastern coast, he found such a marl dipping at 20° to the southeast. It is grayish white, and almost plastic when extracted, but hardens rapidly on exposure.] Among the many fossils found in it, in addition to the species which are mentioned later, we found the genera *Cancer*, *Dolium*, and *Cyclolites*. This *Cyclolites* we also found in the Compestela road where it crosses the first hills near the coast. * * * At Mount Alpacó, again, appears another bed of gray fossiliferous marl, analogous to that at Magdagoog, but in circumstances which are entirely exceptional in the matter of position. In fact, it is found isolated, overlying the mass of compactly crystalline limestone of the old road to the mines, and seemingly with a dip of 50° to the northeast. In it we collected a large portion of the well-preserved fossils, which, when determined, as we shall see further on, have turned out to be identical with living species, demonstrating the recent age of the bed. Moreover, we have found other marls, identical in composition and containing similar fossils, always lying under the limestones with conformable stratification, not only at the bottom of the beds of the rivers Bairan and Sapangdacó, but also in the gulch Jaguimit of the Pandan Valley so close by [the Alpacó locality]. We must, therefore, rationally suppose, as we have previously indicated, that some landslide or other local convulsion has brought this marl bed into a certain sort of association with the nummulitic limestone of Alpacó, at a distance from the coarse limestones of the coast, to which formation it must be referred. [The reference in the last sentence is to the passage[2] noticed by Mr. Martin. At Jaguimit, Mr. Abella says the stratification of the older series is very confused and difficult of elucidation, the dips being 45° to the NE., while a little more to the westward they are 40° to the SE.] Continuing farther toward the valley of Alpacó a trench is crossed which, at that point, is excavated in a rather crystalline limestone. This, judging from its position, would seem to be related to the limestone of Sáyao, but appears to dip in the contrary sense; that is to say, at 55° to the NNE., its stratification, however, being confused and difficult of exact determination. Moreover, to complete the confusion above the limestone, even at the head of (en vertientes de) the Sibod gulch, appears a stratum of fossiliferous marl, which can not be considered as belonging to this terrane either on account of its lithological character or because of the fossils which it contains.

The head of Sibod Gulch seems to be on Mount Alpacó (1,526 feet) and less than 2 miles from the mines, which stand 978 feet above sea level. When Semper visited the mines he must have crossed this marl

[1] Isla de Cebú, 1886, pp. 120 to 126. [2] Ibid., pp. 113–114.

bed, which contains well-preserved fossils and would seem, from Mr. Abella's description, to be the only known locality thereabout where good fossils occur or are likely to be found. Mr. Abella states that the lignitic series (at least except at this one locality) contains no material resembling this almost plastic marl, and such is certainly my observation both in Cebú and in Negros. In the lignitic series he was never able to find any well-marked fossils. Hence, it is highly improbable that Semper could have found so striking an object as a determinable *Vicarya* excepting in this marl. Mr. Martin in his paper on the Philippine Tertiary made no express mention of the material attached to Semper's specimen, but had this not been compatible with its derivation from marl, Mr. Martin would never have concluded it "very probable that at this point Eocene limestones are overlain by Miocene marls."

In response to a letter of inquiry Mr. Martin has been good enough to write me as follows:

In the Semper collection, and labeled "fossils from the argillaceous strata of the coal mines at Alpacó," there are fragments of a light-colored, bluish-gray, friable earthy marl, which is full of fossils. After moistening, these last are easily extracted; but the shells were in part fragmentary when they were embedded; others were well preserved, but have been injured by careless handling or remain only as casts. For these reasons I have been able thus far to identify no species and only the genera *Pecten*, *Cardita*, and *Conus* (?). There are, however, also numerous Foraminifera and among them with certainty a few *Orbitoides*. Accordingly, these marls can not be younger than the Miocene; possibly they are still older, a point which there is reason to hope may be determined by examination of the middle chamber. Judging from the adherent matrix, the same beds have yielded a small *Natica* and a small *Ancillaria*, both in a large number of well-preserved specimens. Perhaps the *Vicarya*, too, is from the same beds, for from its state of preservation it must come from strata which are petrographically extremely similar. If the marl with *Orbitoides* should turn out to be Miocene, it will be in the highest degree probable that the *Vicarya* belongs with them.[1]

Taking all these various circumstances into consideration, it is practically certain, to my thinking, that Semper's *Vicarya* came either from the same marl beds where Mr. Abella also collected a considerable number of different species or from a stratum conformably associated with them. These, however, have all been determined by the Spanish geologists as post-Pliocene. Unfortunately, in his list of 29 fossils belonging to living species, Mr. Abella does not give the localities separately. The discovery of living species in the marl does not, of course, preclude its determination as Miocene. Strangely enough, however, not one of the fossils determined for Mr. Abella by Mr.

[1] Later Mr. Martin was so obliging as to write "that the *Orbitoides* referred to belong to *Lepidocyclina*, as has been determined in very interesting sections prepared from them. The strata concerned are therefore post-Eocene and older than the Pliocene. They correspond to an horizon of the Java group and are to be regarded as Miocene."

The inferences drawn in the text are thus confirmed by very weighty evidence. The information reached me only in time for insertion as a footnote, the small type of which will not derogate in minds of professional readers from the importance of the fact recorded.

Gonzalez Hidalgo is specifically identical with Mr. Martin's list of Miocene fossils from near Minanga, unless "Capucimex" is a misprint; but the following correspond generically:

Conus insculptus Kiener.
Fussus [Fusus] colosseus Lam.
Murex capucimex [capucinus?] Chem.
Murex endivia Lam.
Venus magnifica (?) Sow.

I can see no reason for doubting that Mr. Abella is correct in regarding the Alpacó marl as belonging with the series the most striking portion of which is the mantle of coarse coralline limestone. Mr. Kotô, however, infers from the literature that Semper's fossil determines the age of the lignite.[1] Now it is absolutely certain that there is one great unconformability both in Cebú and in Negros. It lies between the lignitic series and the coral mantle. Mr. Abella's observations seem to show that certain marls form the most ancient portion of the coral-reef series. He regards the Alpacó marl bed as exceptional, seemingly, however, only because it is not accompanied by the coarse reef coral. I see nothing incomprehensible in this. In the neighborhood of Mount Úling, a few miles to the northward of Alpacó, I had ample opportunity to observe that the blanket-like mass of reef coral has been cut away, undermined, and dissolved by surface waters. That at some point or points the soft but relatively insoluble marl should remain, after the removal of the superjacent limestone, would not be wonderful, and such I suppose to be the origin of the Alpacó bed. As most of the marl beds occur in the bottoms of water courses, it is not impossible that the Alpacó exposure shows lower beds of the marl than any other with which Mr. Abella met, and that this accounts for the absence of *Vicarya* from his collections.

Mr. Hidalgo's fossil determinations would make the entire coraliferous superjacent series of Cebú Pleistocene. This does not accord with Mr. Martin's conclusions for other portions of the archipelago, where he regards the older coral reefs as Pliocene. It is almost impossible to believe that the vast mass of coral on Cebú, rising as it does to the very crest of the island, and in latitude 9° 45′ reaching 2,362 feet in elevation, does not include representatives of the older reefs. On the other hand, taking Semper's fossil for a guide, considering also the astonishing regular terracing of the southern end of the island, the prevalence of terraces nearly everywhere throughout its extent, and the even, horizontal crest of the northern part of Cebú, the following conclusion might be drawn: Ever since the later Miocene there has been a continuous, very slow, rise of the island and extension of its land area, raising above water successively Upper Miocene, Pliocene, and Pleistocene beds, the total uplift amounting to over

[1] Loc. cit., p. 117.

2,000 feet. Now this is almost word for word the conclusion which Mr. Martin has reached with reference to Java.[1]

The difference between Semper's discovery and Mr. Abella's results seems quite inexplicable if Mr. Hidalgo's determinations are precise. It is therefore most desirable that some colleague should reexamine Mr. Abella's Cebúan fossils, which are doubtless accessible in Madrid. It is an extremely important feature of the foregoing discussion that, if the conclusion is correct, the lignitic series of Cebú is separated by a great unconformability from the lowest Miocene strata yet known in the Philippine Islands. As the upturned lignitic series is also much eroded, a long period also elapsed between the folding of the beds and the epoch of *Vicarya callosa*. Hence also the lignitic series may be assumed to be as old as the Eocene. The analogy of other islands renders it very improbable that it is as old as the Chalk.

That a great upheaval took place late in the Eocene and early in the Miocene, the effects of which were felt from the Pyrenees to the East Indies, is well known. Eocene beds are found in the Himalayas up to an elevation of over 16,000 feet.[2] It is natural to connect the crumpling and upheaval of the strata of Cebú with this great earth movement. On the other hand, I am surprised to find little or no reference to such a convulsion in Borneo. While the $\alpha$, or sandstone, stage, sometimes dips at angles of over 40°, it is often far less inclined. The later beds, however, seem to lie at still smaller angles, and perhaps unconformabilities will yet be found.[3] It would thus appear as if the thrust which folded Cebú came from the Pacific, and that its effects were most intensely felt at no very great distance from the edge of the continental plateau.

In the Island of Negros, the folding of the lignitic series has been similar to that in Cebú. The predominant rock of this series along the Talabe River is sandstone, which is accompanied by shales and some limestone. The whole series is considerably indurated. The strata are much distorted and faulted. The strike is usually to the east of north, or nearly in the direction of the axis of the volcanic range. The dips are from 30° to 70° or more, and it is clear that the coral-reef formation, which is continuous for some miles from the coast, rests on the upturned edges of the lignitic series.

In the Island of Panay, which has been described by Mr. Abella, the structure is less clear. In the interior of the ranges he found thin lignite seams and strata comparable in their lithological character with those of Cebú. The limestones are in part crystalline, and they contain traces of organisms, probably Foraminifera, but nothing deter-

[1] Neues über das Tertiär von Java, etc.: Samml. des geol. Reichs-Museums, Vol. V, 1895, p. 28. "There can be no doubt that, since the later Miocene, there has been a continuous and very slow extension of the land area, which has laid bare in succession the Upper Miocene, the Pliocene, and the Quaternary strata." Verbeek's Stage $\gamma$ is found at one point at an elevation of 1,088 meters.

[2] Geikie, Text-book of Geol., 1893, p. 979.

[3] Posewitz, Borneo, 1892, pp. 178, 181, 206.

minable. The strata are disturbed and folded. The strikes are in general northerly and seem, as a rule, to follow the local directions of the ranges. The dips often reach high values, and the strata are sometimes practically vertical. The angles of dip usually decrease from the axes of the ranges. These older rocks, regarded by Mr. Abella merely as Tertiary for lack of fossils, are surrounded by relatively recent, coarse, coralline limestones, containing a few fossils belonging to living species. They pass over into living reefs at some points along the shores. They seem to be confined to much lower altitudes than are the corresponding rocks in Cebú. On Mr. Abella's principal section, in latitude about 11°, they first appear near Janíuay, which has an elevation of 82 meters, and something like 100 meters seems to be their limit.

Nowhere could Mr. Abella discover a discordance between these coarse coralline rocks and the underlying strata, as he is very careful to point out.[1] That there must be an unconformability somewhere in the strata of Panay between the vertical beds of the mountain crests and the flat limestones of the coast, seems almost certain. It is hardly possible to imagine conditions under which such an amount of disturbance and folding could be brought about in the upland rocks without involving unconformability. The most evident trial hypothesis is that the strata immediately underlying the coral rock belong to a formation not earlier than the Upper Miocene, and that the discordance is to be looked for below this horizon instead of at contact with the limestone. The relations of the strata in Panay seem to form a connecting link between the conditions in Cebú or Negros and those of Borneo.

On the reasonable hypothesis that the black lignites of the Philippines are of Eocene age, this formation is very generally distributed through the southern provinces of Luzón and throughout the Visayas. For details the reader is referred to the section of this paper dealing with Mineral Resources, but the localities in question may be enumerated here in general terms. Black lignites seem to occur in Tayabas, Camarines Sur, Albay, and the Island of Catanduanes, in Sámar, Masbate, Marinduque, northern and southern Mindoro, and in Leyte. While nothing definite is known of the various coal seams in eastern Mindanao, it is probable that some of them resemble the Cebúan fuel. On the Gulf of Sibuguey, in southwest Mindanao, there is black lignite of a high quality.

It may further be noted that at the town of Libón, in Albay, there is coal and also a building stone containing fish scales.[2] This locality may afford an opportunity for an important study.

The occurrence of *Vicarya* at Alpacó has led me into a long digression from the enumeration of deposits, but where so little is known

[1] Isla de Panay, 1890, p. 91.

[2] Roth, in Jagor's Reisen, 1873, p. 349.

concerning the stratigraphy and the fossil faunas, a thoroughly systematic treatment of the geology of a region is impracticable.

A higher horizon, though probably also Upper Miocene, is represented by the foraminiferous marls occurring in Zambales Province along the west coast of Luzón up to 400 feet altitude, between Paláuig and Santa Cruz. The Foraminifera of these rocks were investigated by Mr. Felix Karrer.[1] Tuffs occur in the range of hills on the coast of Aringay, Unión Province, Luzón, which Mr. Martin thinks perhaps equivalent to the Zambales strata just mentioned. He considers it possible that both these series belong in the Pliocene. This formation has not been identified elsewhere and the fossils may easily be overlooked, most of the specimens being less than 2 millimeters in length.

In discussing the crystalline schists and older massive rocks, reference has been made to a series called by Mr. von Drasche the Agno beds. They are extensively developed in Benguet and Unión provinces (northern Luzón), and unquestionably represent a basal conglomerate overlain by sandstones and clay. Mr. von Drasche at first classed them as primitive, afterwards as Paleozoic;[2] while Mr. Abella, who seems to have devoted more time to them, says that the upper strata contain lignite and fossil shells of surviving species. There seems nothing in the Spanish geologist's description incompatible with the hypothesis that the lower part of the Agno beds represents the basal conglomerate formed during the Miocene subsidence of the Philippines. It is somewhat tempting to seek in them the equivalent of Mr. Verbeek's breccia stage of the Eocene, which consists of unfossiliferous strata underlying Stage $\alpha$; but the absence in the region of Benguet of the Cebuan lignitic series and the character of the organic remains appear to indicate that this portion of Luzón was above water during Eocene times.

In Misamis, surrounding the gold fields, Mr. Abella found a large area of sedimentary rocks lying upon ancient slates.[3] It stretches eastward from Iligan for at least 30 miles, and from this line northward to the western headland of Macajalar Bay. Its southern and eastern limits are unknown. The beds consist of conglomerates, calcareous sandstones, marls, and limestones. Mr. Abella compares them to the Nagelflue and the Molasse of Switzerland, but I should regard the likeness as interesting rather than as important. More significant is their resemblance to Mr. Verbeek's Stage $\beta$ or III. They are somewhat distorted, a dip of 35° to the north being noted at one point. They contain numerous organic remains, especially in the hill ESE. of the town hall (tribunal) of Tagsulip, but the fossils are very imperfect. Mr. Abella thought himself justified in referring one specimen to *Turbinolia*. This fossil and the general character of the deposit led

[1] His memoir is appended to von Drasche's Fragmente.
[2] Neues Jahrbuch für Mineralogie, etc., 1879, p. 265.
[3] Criaderos auriferos de . . . Misamis, 1879, passim.

him to refer the formation provisionally to the Miocene, a step which seems to me reasonable in the circumstances. Mr. Abella was not in Misamis to make paleontological studies, but to report on the gold fields. The region evidently promises results to the paleontologist.

Off Joló Bay, at the little island called Marongas, I found the rocks soft conglomerates and sandstones, containing fragments of coral and basalt pebbles. The strata are considerably tilted, and a heavy basalt dike intersects them. Possibly these strata are of the same age as the Misamis beds just referred to.

Concerning the Pliocene and post-Pliocene, Mr. Martin reaches the following conclusions:

> The beds of the Agusan River (Mindanao) are Pliocene. It is probable that as such are also to be counted the hard, light-gray marls of the River Salac y Maputi (Mindanao) and the clay beds of Paranás (Sámar), as well as the older coral reefs of the Philippines, especially those of Benguet, which are assuredly not older than the Pliocene.
>
> Quarternary are the shell banks which stand 15 feet above the level of Laguna de Bay (Luzón), and those on the beach at Paranas, and again on the south coast of Sámar, where, at Nipa-Nipa, these beds reach an elevation of 60 feet above sea level. Here, too, belong the fossil coral reefs, which are intimately connected with the living reefs and are widely distributed in the Philippines. With them belong the recent limestones of Cebú.

For further details the reader is referred to the accompanying paper by Mr. Martin, but one or two additional localities may be noted. According to Charles Darwin, Mr. Cuming found a large bed of fossil shells on the Rio Grande de Cagayán, in the Province of Isabela, at Cabagan. This town lies in latitude 17° 25′. The fossil-bearing stratum is about 50 feet above the river, and the fossil shells are said to be certainly of the same species as those now living on the shores of neighboring islands.[1] Cabagan is about 30 miles from Semper's localities, near Minanga or Malunú. I am not aware that Mr. Cuming's specimens have been described. Mr. Karrer states that Mr. Hugh Cuming made collections in the Philippines, and that, excepting the Foraminifera turned over to Dr. Carpenter, his "collection of mollusks is reported to have been acquired by the British Museum (Brady)."[2] It is to be hoped that some of the paleontologists interested in the Far East will examine it. Mr. Cuming is said to have spent the years 1837–1841 collecting in the Philippines. When geological explorers can again reach the upper waters of the Cagayán, they will doubtless endeavor to establish stratigraphical relations between Cuming's locality and Semper's.

Mr. von Drasche heard reports of the occurrence of recent shells in the great plain of Luzón, but did not see them. Semper regarded the reports as probable, but did not investigate the matter. Centeno, however, gives details of interest.[3]

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[1] C. Darwin, Structure and Distribution of Coral Reefs, 2d ed., 1874, p. 178.

[2] R. von Drasche, Fragmente, 1878, p. 84.

[3] Mem. geológ.-min., 1876, p. 21.

In the townships of Tárlac and [San Miguel de] Camiling, close to the lakes of Canaren and Mangabol, some deposits of marine fossils were found in 1861 by that enlightened naturalist, Father Antonio Llanos. In the former, about half a league north of the settlement, in a place called Malitlit, there appear some beds which abound in fossil species belonging to genera which now exist in warm seas. Among the many species there found, only the following have been determined: *Berinices, Trochus, Griphea, Caryophillea, Meandrina, Astrea, Oculina,* and others. These shells are dug up by the natives to make lime. They sink shafts which cut the fossil beds at a depth of four or five varas [11 to 14 feet], after having passed through a thin bed of clay banded in different colors. The said beds rest upon one of a yellowish, soapy clay. The known extent of these deposits is very small. [Tárlac is on the railway and very accessible from Manila.] In the township of Camiling and, as we have mentioned above, near Lake Mangabol, at some 5½ or 6 leagues from the Gulf of Lingayén, at an elevation above sea level of not less than 250 feet, are found beds of fossils, analogous to those of Tárlac, which also the natives use to prepare lime. In addition to the species noted, there has been found at this latter point *Pholas.* The beds also contain some small mollusks upon which *Pholas* lived, such as *Physa, Balanus, Cerythium, Cytherina,* and others. The rock containing these specimens is a volcanic tuff, which consists of a conglomerate of ash, pumice, and clay. At many points it is found to be covered by a calcareous sediment upon which may be seen some fossil *Serpulas,* and these appear to belong to the species *hexagona.*

The lake here referred to appears on Mr. d'Almonte's map as the *Pinag* de Mangabol, because it contains water only in the wet season.

Semper collected *Potamides palustris* Linn. at Zamboanga. He also found *Potamides sulcatus* in the humus layer of the hill at Sinaan [Dinaan?] on the Island of Cebú.[1] Abella, too, reported this species from the post-Pliocene of the same island.

The coralline limestone which plays so large a part in Philippine geology has a number of peculiarities which are of geological importance. These are due to the mode of growth of the coral polyps, the limitations to their growth, and the solubility of the calcareous mass. It is well known, of course, that living corals are usually but not invariably confined to water not exceeding some 15 or 20 fathoms in depth, that they can not live when exposed to the air even at the lowest tides, that they flourish only when constantly washed by moderate currents of sea water, that fresh water or dirty water kills them, and that dead corals either dissolve away or are converted by a more partial process of solution into crystalline limestone.

While sediments tend to horizontal stratification, corals grow freely on steep surfaces; so that, on a rising island, the coral limestone tends to form an even layer approaching 100 feet in thickness and following the topography which previously existed. Thus in such cases actually coeval corals follow contours instead of surfaces; and if an island rises perpendicularly, the under portion of the highest corals is the oldest. In the Philippine coral rocks there is a very rude sort of stratification, which seemed to me on Guimaras, Negros, and Cebú to be only locally developed. Such a parting might be caused by a

[1] K. Martin, in Sammlungen des geologischen Reichs-Museums in Leiden. Die Fossilien von Java, Leiden, Brill, 1899, 4°, p. 211.

shower of volcanic ash, or by a flood of fresh water, or, perhaps, more frequently still, by mud. The rains accompanying typhoons are tremendous, more so, perhaps, than what is known in the United States as a "cloud-burst," while a typhoon extends over a large area. For example, in October, 1875, according to Mr. Abella,[1] the rains attending a typhoon brought down such torrents of mud from the ashy slopes of Mayón that 1,500 persons were overwhelmed and smothered, while the destruction of property was immense. This storm must have carried into the sea millions of tons of sediment and must have rendered the water temporarily quite unfit for coral growth. This, indeed, was an extraordinary case, but many of these hurricanes pass across the archipelago each year. In my opinion it can not be inferred that any pseudo-stratification of coral rock was ever horizontal unless there are special grounds for that opinion, and the observer must be very cautious in inferring upheavals from inclined stratification.

A marked peculiarity of the corals is that they grow upward to a limiting line or a plane, instead of seeking the lowest possible level, like sediments. Thus the crest of the Cordillera Central in the northern portion of Cebú is an even line many miles in length, which at once suggests base-leveling, but seems to be due in reality to what may be described as the summit-leveling of coralline growth. Similarly, barrier reefs and fringing reefs, when seen from a distance, simulate terraces and may lead to misinterpretation, although, like terraces, their upper surfaces indicate approximately the position of the surface of the water. The details of topography of coral reefs often differ markedly from those of sedimentary terranes. Thus, in northeastern Negros, on the Talabe, I found a series of hills flanking the main range with excessively steep slopes and crests only a few feet in width. They were composed of rough coral and seemed to represent barrier reefs.

Most of the caves in the Malaysian Archipelago are in the older coral rocks of Pliocene or early Pleistocene age, and this leads to a most curious method of geological determination. The swallows which build the edible birds' nests, *Hirundo esculenta*, frequent these caves, and, according to Mr. Posewitz,[2] where these nests are reported, Verbeek's Stage $\gamma$ may be inferred. Thus, Palawan (Paragua) is famous for its birds' nests, and it is therefore at least highly probable that the island is provided with a mantle of coral reefs of Pliocene age.

I shall not attempt to go into a discussion of atolls, of which I have made no studies. It is well known that Semper was led by his investigations of the corals among the Philippines and the Pelew (Palaos) Islands to dispute Darwin's subsidence theory, seemingly not altogether without success.[3] Semper brought much evidence to bear to show that only the exterior lateral surface of a mass of growing coral

[1] El Mayón, 1885, p. 10. [2] Borneo, 1892, p. 190. [3] Die Philippinen, 1869, p. 100.

flourishes, while the interior dies, decays, and yields to solvent processes. The recent field investigations of coral reefs in all quarters of the globe are, to a great extent, confirmatory of Semper's views. As exceptions to Darwin's theory, Mr. Alexander Agassiz mentions all the reefs which he has studied in Florida, Yucatan Bank, Cuba, Bermuda, the Bahamas, the West India Islands, the Galapagos, the Sandwich Islands, Australia, and the Fijis.[1]

In the Joló Archipelago, the charts indicate several well-developed atolls, such as Simonor Island (latitude 4° 52′, longitude 119° 50′) and Tumindao (latitude 4° 45′, longitude 119° 20′), as well as several in the Tapue group (latitude 5° 30′). The charts of this region also show innumerable coral reefs, which are bare at low tide and must therefore have been uplifted. In the Province of Benguet is a very famous atoll, first recognized as such by Semper, in which lies the provincial capital La Trinidad. It has been described by Semper,[2] von Drasche,[3] and Abella.[4] The elevation of La Trinidad is 3,960 feet (Abella). The atoll is about 2 geographical miles in diameter, according to Semper; the wall varies from 500 to 700 feet in height, the inner side is bare, and the slope is 25° to 35°. A stream passes through the craterlike valley, passing the wall by narrow slits.

The recent plains of the Philippines require little attention geologically, though they form the most valuable and thickly settled portion of the islands, and, indeed, this is the case throughout Malaysia. In large part these plains are areas of marine denudation and deposition, outer portions of the continental plateau which have been lifted above water level in very recent times. Recent unfossilized shells often occur scattered through the earth of these plains, as is the case on the southern outskirts of Manila, where intrenchments effected exposures. Wherever the land has been only peneplained it shows minute terracing, frequently to be seen along the course of the Pásig, and finely displayed on Binangonan Peninsula, Laguna de Bai. The streams, too, are engorged as a natural consequence of uplift. A portion of the lowlands consists of confluent deltas, which are usually composed of very rich land, and country of this description is naturally intersected by bayous, or, as they are called in our Asiatic territory, *esteros*. The environs of Manila Bay to the northward of the city consist chiefly of this delta country.

Laguna de Bai is an extremely shallow sheet of water, dammed back by a low swale of indurated tuff through which the Pásig River has cut its channel. The lake is only about 4 fathoms deep in the deepest portions, which are nearly on a level with the Bay of Manila. The lake bed seems to have changed somewhat since the Spanish occupation,

[1] The islands and coral reefs of Fiji: Bull. Museum of Comp. Zoology, Vol. XXXIII, 1899, p. 41. Interesting comparisons can be made between the geology of this group and that of the Philippines.

[2] Zeitschr. für. allg. Erdkunde, Vol. XIII, 1862, p. 84; and Die Philippinen, 1869, p. 18.

[3] Fragmente, 1878, p. 30.

[4] Terremotos de 1892, 1893, pp. 13, 38.

and a small island, Sunuli, which formerly existed near Los Baños, is now united to the mainland. Near the outlet, however, an old settlement, Pueblo de Bai, is now under water, seemingly in consequence of slight earth movements.[1] According to Martinez de Zúñiga, a town, called Tabuco, which existed according to official records on the western shore of the lake in 1603, is now under water, the settlement having been moved to the present village of Cabuyao, a few miles to the northwest of Calamba.[2]

The lake basin is merely a portion of the great plain of Luzón, separated from the main area by a slight undulation of surface. When the country stood at a little lower level it must have been an arm of the sea. Such is also the belief of the natives, among whom there are reports that it contains sharks. These have not been verified, so far as I know. A similar rumor, also unsubstantiated, exists concerning Lake Bombón, which is much lower and much closer to salt water than Laguna de Bai. Bombón, however, is several hundred feet in depth, and, as has been mentioned, I consider it a crater due to explosion.

I have already discussed the Pliocene and post-Pliocene uplift of the archipelago as indicated by the distribution of fossils. It must also be considered from the more striking physiographical point of view. Physical evidences that the islands are rising at the present time, or have been rising within a few years, abound from one end of the group to the other. It is also clear that the amplitude of the movement has been very great. Whether minor fluctuations, temporary subsidences of relatively small amount, have occurred is a delicate question which can not be definitely settled at present; but the distribution of living animals seems most easily accounted for on the hypothesis of oscillation.

Repeated mention has been made of the continuity which sometimes exists between the growing coral along shores of the islands and the coralline limestones on the land, but the distribution of instances exhibiting this relation has not been described. In intimate connection with it is the terracing either of the dead corals or of terranes which, for local reasons, are devoid of coral. It would be useless to set down all the cases noted of transition from living coral to exposed limestone. Semper[3] wrote: "Everywhere on the shores of the islands, on Camiguín to the north of Luzón and on Basilan near Zamboanga, on the eastern coast of Luzón and of Mindanao, as well as on Bohol and (according to report) on the Calamianes and Palawan, occur raised coral limestones, sometimes in long continuous patches, sometimes in isolated ones; and these limestones are continuous with the

[1] Abella, El monte Maquilin, 1885, p. 9.

[2] Estadismo de las Islas Fil., edited from manuscript by W. E. Retana, Madrid, 1893, p. 334. This work and its elaborate appendices are very valuable contributions to Philippine lore, though containing little of a geological nature excepting bibliography.

[3] Die Philippinen, 1869, pp. 18, 99.

living reefs, the two being connected by the waterworn lower portions of the limestones and the upper parts of the reefs, which are exposed at low water and are still rising." A glance at the charts of the archipelago will show how superabundant is evidence of this class. Semper was especially struck with the phenomena on the islet of Lampinigan, close to Basilan, where trachytic (really basaltic) talus above high water is cemented by coral, and a waterworn cave containing a pothole exists over 20 feet above the level of the highest tides. Similar observations have been made by all observers, and especially by Mr. Abella in his studies on Cebú and Panay. Dana long since stated, from information, that on Point Santiago, in the Province of Batangas, coral exists at an elevation of 600 feet. Mr. Abella, in describing the gold fields of Misamis, refers to the raised corals along the Bay of Macajalar as very abundant. The distribution of the localities here noted shows that the phenomena in question have been observed in all areas of considerable extent within the archipelago. Mr. Abella makes the interesting statement that the Caroline Islands are undergoing depression.[1] At Bacólod, in western Negros, the sea is shoal and muddy and there are no corals. The edge of the wide plain of western Negros stands a few feet above high tide, and the sea is encroaching upon it so rapidly that undermined cocoanut trees strew the shore or hang on the ragged edge of the little bluff. At Dumaguete, too, on the southeast coast, there are no raised corals, a fact which, I think, must have a connection with the volcanic nature of the locality, but between Dumaguete and Tanjay (a few miles to the northward) there are well-developed terraces. On the southern outskirts of Tanjay the old burial ground is on a broad knoll of decomposed coral more than 50 feet above tide level, and on the main coast road, a mile south of Tanjay, is a hillock of well-preserved coral. The first hills to the westward of San Carlos, northeastern Negros, are coral, some of which is at least 300 feet above the sea, and the natives say it is found far higher up in the mountains. On the Talabe there are sharp ridges of coral, elevated to at least 600 feet, which have been mentioned above as probably barrier reefs. The Island of Refúgio, lying off San Carlos and Talabe, is all coral, and it rises to 70 or 80 feet. Off the town of Cebú, Cebú, lies the Island of Mactan, on which Magellan was killed. The reefs about it are most interesting, for they are partially exposed, and terrace after terrace, of small altitude, can be studied there, the vertical intervals being only a few feet. One of the most marked levels, forming the tops of some reefs, is about 8 feet above the water, and the exposed portion is worn and dissolved into the most fantastic shapes. Some small masses stand on pedestals, like bowlders on a glacier, and others are cavernous. Mangroves and other plants have already taken possession of the upper surfaces. The lowest terrace appeared to me to correspond nearly to low low water. At Joló, also,

[1] Guía Oficial, 1898, p. 131.

there is evidence of uplift. There is a little island called Marongas, about 5 miles northwest of the town of Joló, composed of tilted sandstone and a basalt dike. It is partly surrounded by reef coral, some of which stands 2 or 3 feet above water. A storm beach about 5 feet in height here incloses a mangrove lagoon. One side of this pond is formed by the sandstone island, while the storm-beach barrier appears to rest upon coral reef. The circumstances seemed to me illustrative of atoll formation. It is alleged by Mr. Espina that in Palawan actual uplifts have been observed by residents.

High terraces, as well as low ones, are abundant throughout the islands. I should say that on the Island of Cebú it would be difficult to find a place from which there are not to be seen either horizontal coral ridges or incised terraces. Especially fine are the terraces on the southern exposures of Cebú and Bohol. Here the rocks as they rose have been exposed to the swell caused by the southeast monsoon, and the terraces are more sharply marked than they are in more sheltered situations. This part of Cebú must approach 2,000 feet in height, and is scored with a vast number of terraces, all of which are sensibly horizontal; nor could I perceive any division between them, such as would answer to a partial submersion followed by renewed uplift. In such a case it might be expected that the upper set of terraces would be less distinct than the lower set, the dividing line corresponding to the greatest temporary submersion, but nothing of the kind is perceptible. In steaming along the coast of Mindanao from Joló to Cebú it is evident that in that great island also terraces form one of the most prominent topographical features.

All the evidence thus far adduced, both paleontological and structural, points to a progressive uplift of the archipelago, beginning in the later Miocene and still proceeding. This evidence, however, is too fragmentary to be absolutely conclusive, and the possibility of minor fluctuations is not excluded. The distribution of living forms is certainly calculated to throw some light on the more recent history of the Philippines, and should be made to contribute all it can. At the same time it must not be forgotten that obstacles which seem geologically of small moment may limit the extension of species, as has been pointed out by Mr. Wallace himself.[1] The Island of Cebú affords a striking example of this fact, as will presently be noted. In dealing with the Philippines, Mr. Wallace regards the greater part of the birds and mammals as descended from Bornean forms, while, in his opinion, there is also evidence that a direct connection at one time subsisted between Luzón and continental Asia. He says: "Absence of a large number of Malayan groups would indicate that the actual connection with Borneo, which seems necessary for the introduction of the Malay types of Mammalia, was not of long duration, while the large proportion of widespread continental genera of birds would seem

[1] Jour. Royal Geog. Soc. London, 1863, p. 231.

to imply that greater facilities had once existed for migration from southern China, perhaps by a land connection through Formosa, at which time the ancestors of the peculiar forms of deer entered the country."[1]

Mr. Dean C. Worcester and Dr. Frank S. Bourns[2] have also examined the former distribution of land within the Philippine Archipelago as elucidated by the present distribution of the avifauna. It would appear that Cagayán Sulu, Balábac, Palawan, and the Calamianes have been more recently connected with Borneo than the remainder of the islands, while the Island of Cebú, strangely enough, seems to have been separated from the eastern islands of the archipelago for a very long period. At first sight it would seem that an induction of this character could scarcely be made from the distribution of winged animals, for other islands of the archipelago are in full view from every point of the shore of Cebú. The peculiarity of the Cebúan fauna is accounted for in Mr. Worcester's opinion by the lack of necessity for periodic migrations on the part of the birds. While in temperate climates most birds are compelled to make long journeys, in order to escape rigors of climate and to find proper food, birds in the Tropics may be hatched, grow old, and die in a single grove without being impelled, except by restlessness, to transgress its limit.

Negros, Panay, Guimarás, and Masbate, according to these zoologists, form a well-defined group of islands. So, also, do the islands from Sulu (or Joló) to Tawi-Tawi. On the other hand, they tell us that the chain of islands on the eastern side of the archipelago, from Luzón to Mindanao and thence to Basilan, show a very close relationship.

It seems impossible to understand such a distribution of the existing fauna unless it can be assumed that land connections formerly existed between islands now separated by considerable channels. It is fairly clear that in the early Miocene the whole area of the archipelago must have been continuous with Borneo, and that partial submergence followed; but if connections had never since existed between land masses which are now separated by water, each island might be expected to exhibit its own peculiarities, as do Mindoro and Cebú. The easiest way to account for the present distribution of life is to assume that at some time, perhaps during the Pliocene, there was a temporary uplift carrying the archipelago somewhat above its present level, so that some of the islands were connected, and that this uplift was followed by subsidence. There is an alternative, however, for it may be imagined that connections which once existed, in spite of a greater general submergence of the Philippines, were eaten away in relatively recent times by waves and tidal currents. This hypothesis,

[1] Geographical Distribution of Animals, Vol. I, 1876, p. 345.
[2] Proc. U. S. Nat. Mus., Vol. XX, 1898, pp. 549-625.

however, is of very dubious value. If, for example, Negros, Guimarás, Panay, and Masbate were now to be depressed, even 100 feet or so, a very wide interval, 30 miles or more, would exist between Negros and Panay, while nearly as great a distance would intervene between Panay and Masbate. It is almost incredible that, in these quiet land-locked waters, connecting isthmian areas of such extent have been cut away by wave action and left no monadnocks to tell the tale. Inspection of the charts seems rather to indicate, in the shoal waters which separate this group of islands, a submerged coastal peneplain.

If a fluctuation such as is here suggested has occurred, it would have produced a nonconformity of erosion which would probably be traceable on minute study. It should certainly be sought when opportunity offers.

Summarizing the foregoing facts and inferences, it would seem that the geological history of the Philippines is something 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 Binangonan is Eocene seems to me to be an unsolved question. After the Cebúan 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 conglomerate 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 volcanic 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.

Before dismissing the general geology of the Philippines, I may perhaps be excused for calling attention to a particular aspect of that difficult subject, the paleontology of the tropics. From one point of view it is more interesting and more important than that of temperate zones, for it must ultimately be made to contribute to the physical history of the globe. If the solar radiation has been variable during geological time, it must have left some paleontological evidences, however obscure, of change in insolation, especially near the equator; and it seems hardly conceivable that any decipherable record besides these evidences should exist of changes in the sun's thermal emanation. Several other causes, as well as change in solar radiation, would tend to bring about alterations in climate on the earth's surface. Variations in the eccentricity of the earth's orbit, and in the obliquity of the ecliptic, must influence climate; but at the equator only to an insignificant extent. Changes in the distribution of land would influence the distribution of the warm waters flowing from the tropics toward higher latitudes, but would seemingly not considerably affect climatic conditions at the equator. An alteration in the composition of the atmosphere would affect the radiation from the earth's surface; so that if the diathermancy of the atmosphere were decreased, the mean temperature of the globe would increase. How the effect of such a change would be distributed over the earth's surface has not, so far as I am aware, been adequately discussed. It is possible that it would tend rather to a uniform high temperature throughout the world than to an increase of mean temperature at the equator, because of the increased rapidity of atmospheric circulation. There can be little question that this problem can be, and will be, solved; and the light which paleontology is capable of throwing on the former mean temperature within the tropics will then tend to elucidate the history of the entire solar system. Geological exploration in Malaysia is a cause in which many have already laid down their lives, either meeting death with arms in their hands, like George Müller, F. W. Witte, and F. Hatton, or succumbing more painfully to disease, like L. Hörner and others; but the cause is worthy of the sacrifice, and they have afforded the world an example which should be cherished.

## MINERAL RESOURCES.

### COAL.

True (Paleozoic) coal does not exist, so far as I am aware, anywhere in Malaysia. The nearest approach to it is a black, pitchy lignite, similar to that of Washington. The difference between lignite and true coal lies mainly in the quantity of combined water, which not only diminishes the percentage of combustible material, but requires the expenditure of combustible constituents to convert it into steam or dissociated gases of the temperature of the flame. The black lignite is the most valuable mineral asset of the Philippines, and is widely spread from southern Luzón southward. It is difficult to trace its distribution in detail, because there are also brown lignites of small value at many points, while the reports are in large part not sufficiently explicit to determine which fuel has been detected. The black lignite is probably of Eocene age, like the very similar fuel of Labuan, in North Borneo, well known throughout the Far East, and other Bornean or Javanese lignites. The brown lignites in the Philippines probably correspond, both geologically and in quality, to the late Tertiary lignites of Borneo. The Japanese "coal" is also a lignite, and at least no better than the black fuel of the Philippines, which will do good service for all local purposes, and in case of need will answer for vessels of war. As will be seen later, its heating effect is approximately from two-thirds to three-quarters of that of the best Paleozoic steam coals, such as Cardiff.

Coal seams are recorded at a great number of localities in the Philippines, but in a large proportion of cases the information is insufficient to decide whether the occurrence is one of black Eocene lignite or the later brown lignite. The brown fuel in so heavily wooded a country would, in most cases, be economically worthless, but might be geologically important. To some extent a guide may be found in the mining concessions, for it is improbable that any one would go to the expense of taking up deposits of brown lignite. In the Island of Luzón concessions have been granted only in the extreme southeastern corner, the Province of Albay, but Centeno states that applications were made for concessions in Tayabas, though no work was done. I am not aware of any reason to believe that Eocene coals exist to the northward of Tayabas.

Thus the following localities in Luzón at which fossil fuel has been found[1] are probably, though by no means certainly, late Tertiary lignites. In Cagayán there is an occurrence at a bayou or slough called Calbong, in the township of Amulung. In Abra lignite is found on the river Malauas, in the township of Dolores. In Unión it occurs at Aringay. Mr. von Drasche was unable to learn anything of the deposit when he visited the town, but thought it might be in the tuff. Again,

[1] Guía Oficial, 1898, p. 125.

in the Island of Polillo there is lignite at a place called Burdeos, which is not on the map; so, too, at Norzagaray, in Bulacán, and at Montalbán, in Manila Province. This last is very probably associated with the nummulitic limestone. In Mórong Province there is lignite at Tatauiran Gulch and elsewhere.

In Tayabas a considerable number of coal mines are marked on Mr. D'Almonte's map, and these I am inclined to refer provisionally to the Eocene group. That more is not heard of them may very possibly be due to thinness of seams or other disadvantageous features. A group of these coal prospects centers at Antimonan, a port at the narrowest part of the Tayabas Isthmus. These mines are all within 15 miles of the town. Two are on Alabat, an island to the north. There are also two little islands to the south, Pagbilao Grande and Chico, each of which has coal, and two more prospects lie on the mainland to the southeast. Farther off in this same direction, in the region of Macaleton, is still another so-called mine.

In Camarines Norte there seems to be no coal, while in Camarines Sur it is found near Pasacao, on the southwest coast,[1] and also on the Caramuan Peninsula, which forms the eastern extremity of the province. Jagor[2] heard that coal was found at three localities in this peninsula. On the map a single one is marked. Opposite lies the Island of Catanduanes, which administratively belongs to the Province of Albay. In this island, according to Mr. Espina, there is coal at Bató, in the southeast corner. The localities just mentioned seem to lie at the edge of a field which stretches southward into Sámar and which is extremely promising. About 12 or 15 miles to the southward of Catanduanes lie the small islands of Carraray, Batan, and Rapurapu. Here the lignite is black, resembling bituminous coal in appearance; it is of excellent quality, is found in seams of good thickness, and is close to tide water. Mr. Espina, who has visited the place, gave me the following notes:

The seams are lignite and their thickness is very variable, but is always greater than 0.75$^{m}$, and never exceeds from 3$^{m}$ to 4.50$^{m}$. The dip varies from zero to 37° and 40°. The quality of the coal is fairly good, as is shown by the following analyses made in the Inspección General de Minas of seven specimens from the Bilboa mine, Viscaya district, Batan. [Six of the analyses are of the coal, and show very little variation; one is of the bituminous shale underlying the seams. The mean of the six coal analyses is as follows:]

*Mean of six analyses of coal from the Bilboa mine, Viscaya district, Batan.*

| | Per cent. |
|---|---|
| Hygrometric water | 13.518 |
| Volatile substances | 37.463 |
| Fixed carbon | 44.455 |
| Ash | 4.564 |
| Total | 100.000 |

[1] Espina, Ligerd Bosquejo, 1898, p. 157.

[2] Reisen, 1873, p. 166.

| | | |
|---|---|---|
| Carbon equivalent to combustible constituents | | 0.68035 |
| Carbon equivalent to volatile constituents | | 0.23560 |
| Calories of combustible portion | | 5,497.22800 |
| Calories of volatile portion | | 1,905.02750 |
| Quantity of steam at 100° from water at 40° | kilos | 6.24918 |
| Fuel requisite to produce 1 kilogram of steam | do | 0.16656 |
| Mean density | | 1.30 to 1.40 |

Color, jet black, with iridescence and high luster; hardness, less than steel; texture, laminar and cleavable; flame, reddish white with somewhat dense smoke; odor, very resinous; ash, yellowish, dull white; duration of flame, 1′ 45″.

A coal mine is marked on Mr. D'Almonte's map in western Albay, not far from Libón and a little south of Lake Bató. Roth[1] also says that a bituminous limestone from Montecillo, near Libon, contains fish scales. The stone is used for building. It would be interesting to ascertain whether a connection could be established between the coal and this fossiliferous limestone.

The Batan coal seems to reappear at Gatbó, not very far from Bacon, in Sorsogón Province. Among the seams here Centeno[2] says that one is from 4 to 8 meters in width, nearly vertical, and strikes N. 20° W. This coal was tried on steamers, and found satisfactory. A company undertook to exploit it, but with what success I do not know. The last Luzón locality is near Magallanes, latitude 12° 50′. Beyond its position on the map I have no information.

In Sámar, according to Centeno, the coal deposits of Sorsogón continue. He gives a locality, Loquilocon, and Mr. Abella mentions Gándara and Paranas. The last two towns are on the west coast, at a considerable interval. A line drawn through them would pass near Gatbó, and its direction would be very like the strike of the bed at the last-mentioned place, differing some 60° from the prevalent strike in Cebú.

There is coal at Cataingan, in southeastern Masbate, and two concessions have been granted. In Marinduque Mr. Espina reports coal, and so, too, at Subaan, on the north coast of Mindoro, but without details. In southern Mindoro, at Bulalácao, and on the adjacent islet, called Semerara, there are coal seams which appear to be important and on which there are mining concessions. Mr. Espina reports the quality as similar to that of Batan and the thickness of the beds as from 75 centimeters to 2½ meters. Centeno says that the croppings at Semerara are between high-water and low-water marks.

In Panay Mr. Abella found no important coal seams, but thought that the thin seams found, 8 or 10 inches in width, might perhaps be accompanied by others of more value now covered by soil. He notes especially Balete, Buruanga, and Valderrama, in Capiz Province, and Dingle, in Iloilo Province.[3]

[1] Jagor, Reisen, 1873, p. 349. [2] Mem. geol.-min., 1876, p. 35. [3] Isla de Panay, 1890, p. 201.

In the northeastern portion of Negros coal seams occur, lying 6 or 8 miles from the coast and in a line substantially parallel with it. They are exposed in the channels of the rivers Talabe, Calatrava (or Macasilao), and Luzón. It is said that some of the seams are of good width and quality. I visited that on the Talabe, but found nothing of value. Two seams were exposed; neither had over a foot of fuel, and they carried pyrite. The lignite was jet black, and seemed to belong to the same class as the Cebú lignites. The seams lay between walls of bituminous shale and dipped 30° NW. The stratification in the neighborhood was much disturbed. There were many pieces of float coal in the river, and very possibly there are other seams hereabout, but the natives professed to know of no other exposure. It was my intention to explore the entire belt of deposits, but an attack on my escort by a relatively large body of natives put an end to prospecting. This belt is well worth examination when the natives quiet down. Governor Larena also informed me of a coal deposit in southwestern Negros, to the eastward of Cabancalan. Efforts to obtain detailed information failed.

Cebú divides with Albay and Sorsogón the reputation of being the most important coal region of the archipelago, and it has been examined with care by Mr. Abella. The coal occurs chiefly on the eastern slope of the central range, between Danao, latitude 10° 30′, and Boljoón, latitude 9° 38′. It is also found on the west coast in the townships of Toledo (10° 17′), Balamban (10° 29′), and Asturias (10° 33′). The principal deposits are in the townships of Danao, Compostela (10° 26′), and Naga (10° 13′). In 1899, work was going on only at the Compostela mines, which were supplying coasting steamers in a small way. The existence of coal has been known to the natives for an indefinite period, and a mountain in the Naga district bears the name Úling, which is the Visaya name for coal. The Spaniards first became aware of the coal deposits in 1827. Since then work has been done in a fitful manner from time to time and at various points, but nowhere with energy and method.

While coal occurs in almost every township along the eastern coast, Mr. Abella properly protests against speaking of the region as a coal basin. The strata are sharply flexed, folded, and faulted. As I had occasion to observe near Mount Úling, the coal-bearing series not infrequently stands in a vertical position, and the conditions are such that continuity can not be depended upon. Most careful exploration would be needful in opening any mine, and the expenses of mining can not fail to be seriously increased by the position and fractured condition of the seams. At the same time, labor is cheap, the distance to the shore is only a few miles, and the Cebú coal should be able to compete with Japanese or Australian on the Manila market with a very handsome profit. The seams often reach 4 feet in thickness, and one at Compostela is over 8 feet in width. The strike is characteristically

to the east of north, or in the direction of the axis of the island, while the dip is westerly or easterly, according as the seam is on one side or the other of the local axis of folding. The dip is seldom under 30°, and rises to 80° or 90°. Some of the seams are of very good quality, being free from pyrite and standing the weather well. There are pyritous seams, however.

The best idea of the quality is to be had from Mr. Abella's assays. As is well known, the results of coal assays vary considerably with the method employed. For this reason, Mr. Abella very wisely assayed Cardiff coal and Australian coal at the same time and by the same method as his Cebú coals. As the chief point of interest in such tests is to ascertain the relative value of the material tested, the result is entirely satisfactory. Tests of some of these coals were also made on Spanish war vessels and under boilers at the arsenal at Cavite. In these last the quantity of water evaporated per unit of coal was 6.5 units. The conclusion drawn from the tests on the *Santa Filomena*, a government vessel, was that for the ordinary purposes of navigation the coal is acceptable even burned alone, but when mixed with one-third Cardiff coal the results are excellent. For further details of these tests, I must refer the reader to Mr. Abella's memoir, but I reproduce here his table of analyses. Only the first two of them fairly represent the coal below the surface unimpaired by weathering.

*Comparative assays of coals from Compostela and Danao, in Cebú, and foreign coals on public sale at Manila in August, 1878.*

| Source of the fuel. | Density. | Percentage composition. | | | | Flame. | | Coke, character. | Ash, color. | Carbon equivalent. | | Calories. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fixed carbon. | Volatile matter. | Moisture. | Ash. | Duration, minutes. | Character. | | | To the volatile matter. | To the combustible matter. | Of the volatile matter. | Of the combustible matter. |
| Seam of Esperanza tunnel, Caridad mine, Compostela. | 1.329 | 51.96 | 37.56 | 7.80 | 2.68 | 6 | Large, reddish.... | Almost fritted .... | Brick red ..... | 0.202 | 0.721 | 1,632 | 5,829 |
| Seam of Caridad tunnel, Caridad mine, Compostela. | 1.340 | 54.56 | 34.53 | 9.60 | 1.31 | 4½ | Regular, reddish . | Pulverulent ..... | Light red..... | 0.167 | 0.698 | 1,369 | 5,643 |
| Upper outcrop of Santa Rosa mine, Danao . | 1.319 | 57.94 | 31.75 | 9.23 | 1.08 | 4 | Regular, bluish... | .....do ..... | Reddish ..... | 0.083 | 0.662 | 671 | 5,353 |
| Bairán outcrop, Magallanes mine, Danao.. | 1.305 | 49.50 | 35.03 | 11.18 | 3.62 | 4 | Regular, light .... | .....do ..... | Yellowish red .. | 0.184 | 0.678 | 1,491 | 5,490 |
| Mantijá outcrop, Legaspi mine, Danao .... | 1.320 | 47.30 | 33.43 | 16.65 | 2.62 | 3½ | .....do ..... | .....do ..... | Red ..... | 0.075 | 0.625 | 605 | 4,642 |
| Upper outcrop, Magliji mine, Danao..... | 1.301 | 37.92 | 37.34 | 18.75 | 5.99 | 3 | Short, dark ..... | .....do ..... | Very red..... | 0.161 | 0.540 | 1,305 | 4,367 |
| Outcrop Baisabais mine (Cajumay and Jumayán), Danao. | 1.315 | 50.50 | 30.85 | 16.12 | 2.53 | 4½ | Regular, dark .... | .....do ..... | Yellowish ..... | 0.131 | 0.636 | 1,058 | 5,139 |
| Outcrop, Maulincop mine (Tagamacan, Balamban) Danao. | 1.262 | 48.09 | 31.68 | 17.20 | 3.03 | 5 | Regular, reddish .. | .....do ..... | Very red..... | 0.106 | 0.887 | 860 | 4,747 |
| Australian (mixed Newcastle and Sydney). *a* | 1.365 | 71.45 | 16.25 | 2.90 | 9.40 | 6½ | Large, bright, black tipped. | Porous, bright .... | Reddish gray... | 0.053 | 0.768 | 432 | 6,205 |
| English (Cardiff) *b* ..... | 1.389 | 83.00 | 8.60 | 4.50 | 3.90 | 5 | Short and dark... | Almost pulverulent. | Gray..... | 0.103 | 0.932 | 842 | 7,530 |

*a* We mixed in equal parts coal which we were assured came from the Wollerong mines (Sydney) and the Agricultural company's mines (Newcastle.)
*b* We were assured that the coal came from Cardiff.

I made a visit to the neighborhood of Mount Úling from Naga. All the mining prospects were abandoned and caved in, and the deep soil concealed exposures, except in the beds of the water courses. I saw several exposures, the best of which was in the bed of a brook called Cambagnao, to the southeast of Mount Úling peak, at an altitude of some 600 feet. Here a thickness of 4 feet was exposed, while the bottom of the seam could not be reached. The coal was bright and free from pyrite; the seam was nearly flat, with a slight southerly dip; the hanging wall was sandy shale. This coal was somewhat jointed. At a quarter of a mile below this exposure the strata in the stream bed are vertical. The crest of the range above the coal deposit is formed by a cliff of coral limestone 100 feet or so in height. It is perfectly evident, however, that the coral rock rests upon upturned and considerably faulted strata. A specimen of Mount Úling coal, from the claims of the Philippine Mining and Development Company, was analyzed in the laboratory of this Survey in June, 1900, by Mr. George Steiger, and gave the following results:

*Analysis of Mount Úling coal.*

| | Per cent. |
|---|---|
| Moisture | 8.74 |
| Volatile matter | 43.01 |
| Fixed carbon | 46.29 |
| Ash | 1.96 |
| Total | 100.00 |
| Sulphur | 0.36 |
| Phosphorus | 0.02 |

The coke sinters together slightly, but is not firm. The ash is red-brown.

It will be observed that this analysis corresponds pretty well with the analyses of Compostela coals by Mr. Abella. As is well known, the amount of fixed carbon obtained from a coal varies somewhat with the method of manipulation, so that this determination is largely a matter of convention. The method employed in the laboratory of the Survey is given in the report of the committee on coal analysis.[1]

I was not permitted by the commanding officer in Cebú, Colonel Hamer, to visit Compostela and Danao, because the natives were on the eve of a serious outbreak.

Leyte possesses coal, but even the name of the locality is unknown to me. It is said to be in the southwestern part of the island. An analysis made in the Inspección de Minas showed it to be of the same class as the Cebú coal, giving 5,800 calories.

In Mindanao and its adjacent islets coal is known to exist at many points, but beyond the presence of the seams I have been unable to ascertain anything. I can, therefore, only catalogue them. On the

[1] Jour. Am. Chem. Soc., Vol. XXI, 1899, p. 1116.

small Island of Dinágat, near the northeast cape of Mindanao, there is coal, at Tubajon. On the islet Siargao (near Dinágat) coal occurs at Numancia, on the west side, and at Cabúntug, on the east. Well down on the east coast, in latitude 8° 10′, is point Sancop, which is also a coal locality, as is the river Casauman, in latitude 7°, and Mati, or Matti, in latitude 6° 50′. On the south coast, in latitude 6° 4′, and on the same meridian as Iligan, is the river Craán, or Gran; and here, too, coal is found. Knowledge of all of these localities I owe to Mr. Espina. According to the Guía Oficial, there is coal a few miles north of Iligan, at Naauán, and the same authority gives a locality, Marasingan, which I can not find. A trustworthy Filipino told me that the coal at Naauán was good. Baron von Richthofen speaks of lignite of admirable quality from the Gulf of Sibugai to the northeast of Zamboanga, without specifying the precise locality. Coal is reported by Montero in Balabac.[1]

While it seems reasonable to class all the Visayan coals mentioned above as Eocene, because of their composition and the stratigraphical relations in Cebú and Negros, the same assumption is not justified in Mindanao for lack of knowledge. It would be in no way surprising, however, to find the coals of eastern Mindanao similar to those of Leyte, which is clearly a continuation of the Surigao Peninsula.

## GOLD.

There is scarcely a province in the Philippines in which gold has not been obtained by the natives, who are skillful pan miners and clever in dealing with accessible quartz. Gold mining is with them an ancient industry. It is said that Chinese writings of about the third century, A. D., report gold as the chief product of Luzon.[2] Before Magellan's arrival it seems certain that commerce was carried on with China, and that the Filipinos paid for silks and other manufactures in gold, trepang, dyewoods, and edible bird's nests.[3] The unconstrained life and dazzling possibilities of gold digging suit the happy-go-lucky temperament of the Filipino, and, since 10 cents a day is "wages," they have been able to work deposits down to a very low grade. Even the tricks of the trade are not unknown to them, and at the time of my visit to one army post the native miners nearly succeeded in inducing American officers to take an interest in gravel salted with brass filings. Some of the fields seem pretty well exhausted above water level, and it would be rash to assume that there is any really virgin ground among the alluvial deposits or any croppings not familiar to the natives.

The more important known gold fields are three in number, and the

[1] El arch. Fil., etc., su hist., geog., y estad., Madrid, 1886, p. 433.

[2] Dr. O. F. von Möllendorf, formerly German Consul at Manila, is quoted by Mr. F. Karuth as making this statement: U. S. Cons. Rept., 1898, p. 414.

[3] Jagor, Reisen, 1873, p. 10, citing Morga, Sucesos de las is. Fil., 1609.

most northerly of them lies about Mount Datá, in the country of the Igorrotes. Datá is in the Cordillera Central and in latitude 16° 55′. The second and best-known district is that of Camarines Norte, very accessible by sea, and about 115 miles to the E. by S. of Manila. The only other hopeful region is the northeastern portion of Mindanao and the adjacent islets.

The following note on gold in Luzón was compiled for me by Mr. Luis Espina from the records of the Inspección de Minas in Manila, of which he was in charge in September, 1898:

Gold is found in moderate quantities nearly all over the Island of Luzón, but more particularly and under conditions favorable for exploitation in the following townships and districts, proceeding from north to south:

1. Abra Province.
2. Village named Fidelisan, Bontoc Province.
3. Village named Suyuc, Lepanto Province.
4. Village named Tubuc, Lepanto Province.
5. Village named Dugon, Lepanto Province.
6. Village named Acupan, Benguet Province.
7. Village named Tabio, Benguet Province.
8. Village named Capunga, Benguet Province.
9. Village named Itogon, Benguet Province.
10. Village named Gapan, Nueva Écija.
11. Village named Peñaranda, Nueva Écija.
12. Village named Paracale, Ambos Camarines.
13. Village named Mambulao, Ambos Camarines.
14. Village named Labo, Ambos Camarines.
15. Village named Capalongan, Ambos Camarines.
16. Village named Maculabo,[1] Ambos Camarines.

In the Province of Abra gold is found in alluvial deposits, and in the sands of the river of the same name, as grains, and has an average fineness of 750 to 792 thousandths. In the Province of Lepanto gold occurs in three different ways—in veins, in alluvial deposits, and in river sands. Its fineness is from 0.792 to 0.833, and it is somewhat light colored because of a considerable silver content. It is usually accompanied by ores of silver, copper, iron, and lead. In the provinces of Bontoc and Benguet the deposits are in all respects analogous to those of Lepanto. In the Province of Nueva Écija the gold is exceedingly pure, brilliant in color, and 0.958 fine. It is found as rounded particles in alluvium and sometimes in small crystals.

The Igorrotes, who inhabit Abra, Bontoc, Lepanto, and Benguet, are extraordinarily reticent about their gold mining. Nearly two hundred years ago Morga wrote that the "Ygolotes" would not permit the Spaniards access to the mines.[2] Even Semper, who stood on intimate terms with the Filipinos, was not allowed to visit any gold mines in the Cordillera Central. An Englishman of long residence in northern Luzón, who had handled much Igorrote gold commercially, informed me that no outsiders of any race were permitted to visit the quartz mines or even to prospect for quartz, though such are sometimes allowed to wash gravels in the streams of the Agno and the

[1] Islet 10 miles from Mambulao.

[2] Sucesos de las islas Filipinas, Mexico, 1609, p. 134. This rare work is in the library of Harvard College.

Abra river basins. This concession, I take it, is a sign that the Igorrotes consider such gravels pretty well exhausted. As will be seen in the account to be given of the copper deposits, the Igorrotes are gifted with mechanical skill and are not afraid of solid rock. It is to be inferred that their quartz mining, though rude, is tolerably effective, and perhaps approaches Mexican work. The great topographical accentuation of their country favors tunnel drainage and must enable them, in many cases, to dispense with pumping or bailing. Beyond the information already given, I have been able to ascertain nothing of interest concerning this northern district, which, as has been noted elsewhere, lies in a region of crystalline schists and older massive rocks. I am aware of no indication that neo-volcanic rocks are so associated with the quartz veins as to lead to the hypothesis that the gold deposits are related to these eruptions. Indeed, throughout the archipelago the phenomena point to an age at least as great as the Mesozoic for the greater part of the gold, while analogy with other gold fields suggests that the Tertiary period of volcanism must have brought about a partial renewal of the conditions necessary and sufficient to lead to gold deposition. The corresponding phenomena, however, are yet to be observed.

The gold district of Camarines Norte is also in the gneissic rocks. Here quartz veins are found carrying, besides gold, iron pyrite, copper pyrite, galena, and zinc blende, sometimes also accompanied by lead chromate. At Labo, Centeno[1] notes that native copper is occasionally, yet rarely, observed in the veins, and Morga observes that the gold is alloyed with copper. The general direction of the veins in this region, according to Centeno, is north and south, except those of Gumihan and of Mount Lugás, which strike northwest. They are approximately vertical, and their width is from 1 to 5 inches, though at some points they are much wider, reaching 3 or 4 hands (palmas), but in such cases they become poorer.

Mr. von Drasche made an excursion from Mambulao to a locality called Dagupan, which had recently been opened up, and imparts the following information:

> The road from Mambulao leads southwesterly over black clay slates. These clay slates, of uncertain age, are intersected by numerous intensely corroded cellular quartz stringers, in which the gold occurs. The water courses carry numerous auriferous pebbles, and sand, which is washed for gold. At the time of my visit a great number of small shafts were also being driven, some 15 fathoms (Klafter) deep, especially at points where quartz stringers were visible at the surface. The very primitive methods of concentration naturally involve the loss of a great part of the gold, but the profits seemed to me good, for there were more than 700 men and women at work.[2]

[1] Memoria geológico-minera, 1876, p. 47.

[2] Fragmente, 1878, p. 63. I do not find Dagupan near Mambulao. There is gold at Tumbaga, a little west of south from Mambulao.

Of course there are numerous placer mines in this region, but of these there is nothing special to tell. Beach sands are also washed. Reports indicate that gold is found in the wall rocks as well as in the veins, but I suspect that this is for the most part an erroneous conclusion. In such a country the saprolite, or rotten rock in place, is often auriferous, even when the tiniest quartz stringers can not be found, and this is to be traced to the solution or replacement of small auriferous quartz stringers, the gold after the removal of the quartz remaining in the saprolite. Mr. von Drasche's statement that the stringers are corroded and cellular shows that such solvent action is going on, and miners should at least beware of assuming that there is gold in the solid rock, excepting at contact with veins.

Mr. Thomas Browne, a miner, informed me that, at Paracale, the rock is granitic and the nearly vertical veins strike N. about 40° E. He stated that there are veins as much as 20 feet in width ; and a chute in one is alleged to have given assays as high as 38 ounces to the ton. Such assays, of course, mean very little, for it is seldom that a gold mine offers no rich specimens.

The descriptions of Camarines Norte remind me greatly of the gold fields of the southern Apalachians, where also tiny veins and auriferous saprolite play a relatively large part. I can see nothing to indicate that Camarines will ever be very important as a gold-producing region. Certainly it is no "poor man's country," nor has it yet proved profitable to enterprises with capital. The industrial history of this district is one of decadence. It must have been of this region that Hernando Riquel wrote in 1574 in his "very true and certain account of what has recently been known concerning the new islands of the West." He says that in Luzón "there are many mines of gold in many parts which have been seen by Spaniards, and all say that the natives work it as they work silver mines in New Spain. And the metal has a continuous vein like the silver ore. Trials have been made, and the mineral presents itself so plentifully, that I do not write about it, lest they should suspect me of exaggeration [how convincing is such fine self-control!]; but it is sufficient to say that I swear, as a Christian, that there is more gold in this island than there is iron in Biscay."[1]

Tradition, indeed, indicates that the placers were originally very rich; and this there is no reason to doubt. According to Morga the natives worked them with more energy before the Spanish conquest than after it. Spaniards coming from Mexico early settled in Camarines Norte, and brought with them Mexican methods of treating the ore, which are still practiced there. In 1643 the Crown levied a royalty of a fifth, which was later reduced to a tenth. In Morga's time (1609) the reduced royalty yielded $10,000 annually, and Gemelli Carreri learned from the Governor at Manila that the product was $200,000,

[1] Broad sheet printed at Seville in 1574. Taken from App. 4 to H. E. J. Stanley's translation of Morga's Sucesos de las islas Filipinas, Mexico, 1609, London, for the Hakluyt Soc., 1868.

which is a reasonable figure, since such a royalty was sure to be evaded in large measure. Spaniards began to establish works on a larger scale about 1700, and ever since that time there has been a long procession of enterprises following one another to disaster and oblivion. The nearest approach to success seems to have been attained by Francisco Estorgo, in the middle of the last century. He, lucky man, after losing one fortune at Mambulao, made another at Paracale, and wisely went home to Spain. In 1876 Centeno reported that the production was 30 ounces a month, bringing about $10 per ounce, so that the annual gross receipts of the entire mining population were $3,600. It is to be hoped that expenses were small, and it is no wonder that Jagor found the people almost naked and extremely poor.[1]

For pulverizing the ore the natives use a species of trip hammer made by attaching a heavy stone, serving as a head, to a sapling. A second stone answers for an anvil. After placing the quartz on the anvil, the workman drives down the head, the elasticity of the sapling raising it again for a fresh blow. The crushed quartz is ground in an arrastre, concentrated in a batea, and washed clean in a cocoanut shell. In this last operation a soapy vegetable sap (gogo) is added, I fancy in order to prevent gold from floating.

In Panay, Mr. Abella gives a number of localities at which gravels have been washed for gold, seemingly without notable success. The best of them appears to be at Astorgá, a suburb of Dumárao. This town is in the Province of Capiz and its latitude is 11° 16′. No product is stated. In the Province of Iloilo gold is known at San Enrique and Barótoc Viejo. In Cebú there are old workings, but all of them were abandoned in 1886. Some of them had been opened on pyritous veinlets in diorite. In the Island of Sámar there is gold at Pambujan.

The Island of Panaón lies immediately south of Leyte. On its eastern coast is a settlement called Pinutan, and a short distance to the southeast of the town is a mine which was examined by William Ashburner. Several veins of quartz outcrop on the coast, and extend in a westerly direction into the mountain. These veins are parallel; they strike east and dip south. The wall rock is "greenstone-porphyry." There is some wall rock in the vein, and the sulphurets are chiefly pyrite, accompanied by galena and zinc blende. One vein, about 6 feet wide, has been worked to a considerable extent, some 871 tons having been treated up to 1883. The yield was $6 or $7 per ton.[2] Concessions for gold mining have been granted at Tigbauan, just south of Pinutan, and, according to the Compendio de Geografia, there was a productive mine at Inolinan. This name is borne by a point in the southwestern part of the Island of Panaón, but no settlement called Inolinan is marked on the map. The deposits of this island are evidently near together and doubtless in the same formation.

[1] Cf. Centeno, Mem. geológ.-min., p. 47; and Jagor, Reisen, pp. 141, 150.
[2] Manuscript report.

The mystery of the unknown still hangs about the Island of Mindanao, and there is an impression in many minds that it is an Eldorado. More is known of it than is generally supposed, and what is known justifies no extravagant anticipations. The auriferous regions are two; one of them lies immediately south of the Bay of Macajalar, on the north coast, in the province or district of Misamis; the other comprises the eastern coast range of the island, in Surigao Province, but is only known to contain gold in promising quantities near the northern end of that range. Of the two districts, that in Misamis is the more famous.

The Misamis gold field has been reported upon by Sainz de Baranda, Centeno, Minard, and Abella. The last-named geologist studied this region more thoroughly than the others, and is the chief authority on the subject.

The auriferous deposits include veins, placers, and river sands; the veins, however, have been worked only to a slight extent and were abandoned long before Mr. Abella's visit. Very little gold comes from the river beds. The placers lie near the rivers, but at some distance above them, and it is evident from the descriptions that the recent uplift of the coast has engorged the rivers to some extent.

Four rivers emptying into the Bay of Macajalar are flanked by placers. The most important is the Iponan, and the gravels are scattered along it for a distance of 12 miles. On the Rio Cagayán (not to be confounded with the great river of northern Luzón), or rather on a tributary, the Bitog, there are gravels for about 2 miles. There is a single placer on the Bigaan and two on the Cutman. The one locality where gold-bearing quartz in place is found is also close to the Cutman, less than 3 miles from the town of Agusan. These rivers are known to be accompanied by placers farther south than the latitude of Iligan—say 8° 10′—but that part of the country was in the hands of hostile Mohammedans and was inaccessible to Mr. Abella. The Moros worked them, however, doubtless by the same methods as the Christian Indians of the coast. Along the Iponan the gravels are found at an elevation above the river which usually does not exceed 66 feet, or 20 meters. They are not continuous, but occur in patches, the conditions showing that intermediate areas have been removed by erosion. They rest on marls or conglomerates, supposed to be Tertiary; and the miners distinguish three layers—black, grass-root soil; red, plastic clay; and the pay streak (dugcálon). The last consists of sand, quartz, pebbles of porphyry, and pebbles of magnetite. The pay streak runs from half a meter to 3 meters in thickness, and seems to average about 1.6 meters, or, say, 5¼ feet. Mr. Abella was at much pains to determine the amount of gold per cubic meter in the Iponan placers, and found it about 3.5 grams. The average fineness of the gold is 0.658, and the pay gravel would, therefore, run 1 pennyweight 3 grains per cubic yard in fine gold.

The placers of the other river basins just mentioned differ inconsiderably from those of Iponan. The gold from the Cagayán is a little finer, that from the Bigaan and the Cutman a little baser. The thickness of the pay streaks is within the same limits.

The river washings amount to nothing in the way of product. It is well to note that those engaged in it make from 12½ to 25 cents a day.

Quartz stringers carrying gold are found at Pigholugan Hill, on the right bank of the Cutman, between the gulches called Cabagcahan and Pigholugan. The rock is metamorphic argillo-siliceous slate, striking NNE. The stringers vary in thickness from 1.6 to 8 inches, and are nearly vertical, striking E. They contain wire gold as well as metal in scales, and a little arsenopyrite. There are ancient, abandoned, caved-in workings on this deposit.

It is a remarkable fact, pointed out by Mr. Minard, that the Misamis gravels contain platinum as well as gold, a statement confirmed by Mr. Espina, but not referred to by Mr. Abella. Mr. Minard also found in the placers flakes of lead, which he supposed to be native. In all probability, however, it is Spanish, much ammunition having been expended at various times in this region.

In working the placers the natives concentrate by a species of puddling and handle the concentrates with the batea and the cocoanut shell, which in the Philippines seems to take the place of the horn spoon in Mexico. Placers are worked only in the rainy season. I do not find in Mr. Abella's memoir any estimate of the output. Mr. Centeno puts it at about $27,000 per annum.

According to the Compendio de Geografía, the eastern range of Mindanao is auriferous from its northern extremity as far south as Caraga, latitude 7° 12′, but chiefly in the neighborhood of Surigao, Mainit, Taganaan, Placer (all within 20 miles of the northern cape), Lianga (latitude 8° 33′), and Suribao (latitude 8° 25′). Centeno gives some further details. In the townships of Taganaan the localities are Bagon-Duangan and Danao. In Placer Township the gold is found at Tinabingan. The most important district, he says, is in the mountains of Canimon, Binutong, and Canmahat, "a day's journey" (10 miles?) from the town of Surigao. Here there are veins, in talcose, serpentinoid slate, up to 3½ inches in width. Some are quartzose and others carry carbonates. In these, especially the latter, occurs gold with iron and copper pyrite, galena, and zinc blende. The rich veins, he says, strike east and west, while other poorer or barren veins take other directions. The veins are pockety and very little work has been done on them.

William Ashburner, a California mining expert of note, visited Surigao in 1883. He examined some washings on the Consuran River, where the Biga empties into it, 8 miles south of the town of Surigao. Here he found gold which was angular and, in one case, filiform. He met no quartz, and thought the gold must come from decomposed

eruptive rock. In discussing Camarines Norte I have referred to the fact that quartz may be removed by solution, or converted into silicates. Ashburner was informed that $20,000 had been taken out during the previous year. The placer is worked in the same way as are the placers on the Iponan. He also examined a slate belt at the head of the Consuran, which contained irregular gold-bearing pockety stringers of quartz and spar. This must be near the locality called Canimon by Centeno, and is perhaps identical with it. It evidently resembles Pigholugan in Misamis. Ashburner visited Placer to see a deposit forming a ridge between two small streams and rising to a height of 150 or 200 feet. Here he found fragments of auriferous quartz, which were being worked, but no vein. Neither in this region nor in the Island of Panaón was Ashburner able to find anything which he could recommend to his clients. Indeed, all the reports from Mindanao made by responsible engineers indicate very mediocre deposits, a large part of which is already exhausted.

In addition to the gold deposits described above in the Philippines, there are certain localities not known to be of any commercial value, but which are of interest because they tend to throw light on the distribution of the formations whence the gold is derived, presumably older massive and schistose rocks. Gold is found at Pamplona,[1] in the extreme north of Luzón, latitude 18° 25′, and is probably derived from the northern portion of the Cordillera del Norte. Another locality is Balincaguin,[2] in Zambales Province, latitude 16° 7′. A gold mine has been opened on the Island of Polillo, near the town of that name,[3] latitude 14° 50′. This island is on the east coast, and belongs to the Province of La Infanta. Lahuy[4] and Catanduanes[5] are islands lying to the eastward of Camarines Sur, and are both reported to be auriferous, as is the township of Caramuan, on the peninsula adjoining them. To the south of Catanduanes is the Island of Rapurapu,[6] which contains both coal and gold. Sibuyan Island[7] is north of Panay, and gold has been found there. At Lubang, on the island of that name, which belongs to Mindoro Province, Dana found gold-quartz veins and chalcopyrite.[8]

It has been alleged that Mindoro itself is auriferous, but this statement, I think, refers to the province rather than to the island; at least the only locality I have been able to hear of in this province, besides Lubang, is at Mospog,[9] on the Island of Marinduque, to the northeast of the Island of Mindoro. The natives wash gold from the sands of Masbate.[10] There is gold in northern Bohol, at Getafe,[11] and on Diná-

[1] Guía Oficial, 1898, p. 125.
[2] Ibid.
[3] Map of Luzon, d'Almonte, 1883.
[4] Guía Oficial, 1898, p. 125.
[5] Espina, op. cit., p. 171.
[6] Centeno, Mem. geológ.-min., 1879, p. 46.
[7] Ibid., and Sainz de Baranda, loc. cit.
[8] U. S. Expl. Exp., Vol. X, 1849, p. 539.
[9] Map of Luzón, d'Almonte, 1883.
[10] Compendio de geografía, 1892, pp. 23, 72.
[11] Guía Oficial, 1898, p. 125.

gat,[1] an island just north of the northern extremity of Mindanao. In Negros, as I learned from Governor Larena, alluvial gold is found in two rivers. One of them is the Nabulao, in the western portion of the island, and the other is the Zamboanguita, at the southern extremity. In Joló also gold is known to exist; at least, so I was assured while there.

## COPPER.

The only copper deposits which are known to be important are in the Province of Lepanto, near Mount Datá (latitude 16° 57′), and these are also the only ones concerning which any detailed information is available. They have been reported upon by Antonio Hernandez,[2] who visited them in 1850, and by José Maria Santos,[3] who examined them in 1861. They have been worked by that strange tribe of natives, the Igorrotes, probably before the Spanish discovery of the archipelago, and ever since. For a time they were also exploited by the Cantabro-Filipina Company of Mancayan, under the direction of Santos, whose death would appear to have crippled the enterprise.[4] Preliminary work commenced in 1856,[5] but production did not begin till 1864. From that year to 1874, 1,116 metrical tons (at 1,000 kilos) was produced,[6] but when von Drasche visited the place, in the winter of 1875–76, no work was going on. I have not heard that the company has ever resumed. A difficulty, and seemingly the chief one, is the inaccessible position of the mines on the divide between the headwaters of the Agno and the Abra.[7] When narrow-gauge railways pass up these valleys the question of transportation will be solved.

The chief deposits are at Mancayan, but in the same region there are veins also at Suyuc, Bumucun, and Agbao. These latter carry ores differing somewhat in composition from those of Mancayan, and, in the opinion of Santos, could be mixed with those of the greater deposit to advantage. Mancayan lies about 5 miles west of Datá, and the other localities can most easily be placed with reference to it.

As Santos describes Mancayan,[8] the veins would seem to be associated with a mass of quartz-porphyry, either caught up in an eruption of a neo-volcanic rock or bounded by parallel fissures through which lava has been extruded. It may be somewhat difficult to regard this view as final, but it seems more acceptable than Mr. von Drasche's assertion that the veins lie a lens of quartz embedded in trachyte.

The following notes are taken from Santos and for the most part are

[1] Compendio de geografía, 1892, pp. 23, 72; and Sainz de Baranda, Cons. geogn., etc., 1841.
[2] Revista minera, Madrid, Vol. II, 1851, pp. 112–118.
[3] Informe sobre las minas de cobre. . . . en Lepanto, Manila, 1862.
[4] Centeno, Memoria geológico-minera de las is. Fil., 1876, p. 44.
[5] Santos, Informe, p. 20.
[6] Centeno, op. cit., p. 45.
[7] The altitude does not seem to have been determined. I was told in Manila that it is about 5,000 feet.
[8] Op. cit., pp. 25 et passim.

literally translated. The Mancayan deposit appears in a deep ravine called Fabio or Magambang, on the south side of Mount Aban, one of the western spurs of the great Datá. At this locality there is a quartzose mass in a vertical position, not more than 80 or 100 meters in thickness, which strikes northwest and is exposed at the southeast by a great cut, partly due to the mining operations of the natives. Toward the northwest it is partially concealed and at a distance of 400 meters disappears under argillaceous porphyry,[1] which is more recent. The siliceous mass is of similar character throughout its extent; it is sometimes compact, sometimes crystalline, often porous, and always charged with iron pyrite. It contains decomposed feldspar in irregular veins or porphyritically disposed. The croppings are of columnar form. The whole mass is fissured or jointed in different directions, though the principal ore-bearing fissures strike WNW. On the strike of the quartzose mass, some 14 meters to the northwest, there are, as it were, small islands of quartz-porphyry in the argillaceous rock, which latter is there of small thickness. From these conditions it is to be inferred, according to Santos, that the quartzose mass under discussion, inclosing the ore deposits, is a body of quartz-porphyry completely metamorphosed by the advent of the argillaceous porphyry and subsequently by the process of ore deposition. Be the origin of the compact quartz what it may, it is at all events older than the argillaceous porphyry. This, by its own intrusive force and by the contraction attending its consolidation, produced the fissures or cracks, not only cleaving the quartz but continuing into its own mass; and these openings were filled with ore subsequently to the complete consolidation of the rock. Mr. Santos was led to this conclusion from inspection of a drift on a vein which, after passing out of the quartzose mass, followed the contact between it and the porphyry and at last struck into that rock, the strike of the vein making changes of direction to correspond with the course indicated. In the more important workings it is apparent that the ore occupies not only the larger fissures, which strike WNW., but also veins which have a different direction, the two systems forming a network or reticulated vein. At the time of Mr. Santos's visit three parallel veins were exposed, dipping at 70° to the NNE. They had a mean width of 1 foot. He inferred from the croppings and the old workings of the Igorrotes that there must be not fewer than six veins. As ores Santos recorded tetrahedrite, both antimonial and arsenical, chalcopyrite, chalcosite, peacock ore, the black oxide, and other oxidized or carbonated species, as well as iron pyrite. The chief ore is tetrahedrite. The gangue he calls white clay. Comb or ribbon structure is common and the proportion of the various cupriferous minerals is very variable.

[1] I understand Santos to mean by this term a quartzless, partially decomposed lava, which he, as well as von Drasche, regarded as trachyte.

Santos[1] made an effort to avoid the tendency to select rich specimens in sampling, and gives the following as the mean composition of the different ore breasts of the native workings:

*Mean composition of the ore breasts of the native Mancayan copper workings.*

| | Per cent. | | Per cent. |
|---|---|---|---|
| Copper | 16.64 | Iron | 1.84 |
| Silica | 47.06 | Loss | 0.25 |
| Sulphur | 24.44 | Total | 100.00 |
| Antimony | 5.12 | | |
| Arsenic | 4.65 | | |

After a preliminary sorting, which takes place in the mines, about 40 per cent of the ore carries over 10 per cent of copper, and more than half the ore contains above 6 per cent of metal.

Mr. Carl Zerrener[2] described enargite and covellite from specimens of Mancayan ores in 1869, and Mr. A. Weisbach in 1874,[3] from similar specimens, established the species luzonite, which he regarded as dimorphous with enargite. Mr. August Frenzel also has described the luzonite and other ores from Mancayan, as well as the matte.[4]

Mr. von Drasche visited Mancayan and made the following note:[5]

Mancayan was formerly the site of extensive copper-mining operations, which are now discontinued. The ore was known to and worked by the Igorrotes before the coming of the Spaniards. I am indebted to the friendly communicativeness of two Spaniards who were working over old dumps for some information about the occurrence of the ores, and I also went through some of the tunnels. The copper ores occur in a quartz lens embedded in sanidine-trachyte, the lens having, on the whole, an E.–W. elongation. In this ore [apparently misprint for quartz] the ores occur in parallel veins, which likewise strike east and west, so that the tunnels, which run north and south, cut all the veins. The veins are said to be locally as much as 7 meters wide, and have a steep dip. The distance separating these very regular veins is reported as generally very small. The ores are chiefly luzonite, enargite, and covellite, the first often in fine crystals. I also observed barite, calcspar, copper pyrite, malachite, stalactites of copper sulphate, arsenious acid, and a saponite-like mineral stained blue with copper salts.

Suyuc lies 3 or more miles by road southeast of Mancayan. Here the porphyry, instead of being argillaceous, becomes feldspathic and, according to Santos, is trachyte. Sometimes it is so granular as to be easily confounded with syenite. The copper ores contain peacock, chalcosite, and black oxide, but consist chiefly of mingled copper pyrite and iron pyrite. They occur in veins and are associated with a white, opaque, feldspathic mass full of veinlets of quartz and iron oxides. The Igorrotes have worked these deposits, but not extensively.

Three miles eastward of this deposit lies Bumucun. Here there is a vein at the bottom of a stream containing chalcopyrite, quartz, and fluorspar with smaller quantities of derivative copper ores. The vein

[1] Informe, p. 38. [2] Berg- und hüttenmännische Zeitung, 1869, pp. 105, 113.
[3] Min. Mittheil., suppl. to K.-k. geol. Reichsanstalt, 1874, p. 257.
[4] Min. Mittheil., 1877, pp. 203–204. [5] Fragmente, 1878, p. 36.

is 8 or 10 inches in width, strikes E., and dips N. almost vertically. The natives were able to go down only some 30 feet on account of water. This ore and that of Suyuc would, in Santos's opinion, be valuable at Mancayan, because they contain no antimony, little arsenic, and plenty of iron.

Agbao is a mile and a half south of Suyuc. It has three small veins within 3 feet, separated only by clay. They aggregate only 6 inches in width, strike NE., and dip SE., at 45°. The ore is tetrahedrite.

The copper mining and smelting of the Igorrotes is a very curious and interesting matter. This tribe is in most respects semibarbarous. They are heathens and live in squalor. Semper visited them and furnishes a really disgusting description. He also points out, however, that industrially they stand on an astonishingly high level, and show most remarkable skill in the working of metals as well as in their extraction. They have turned out not merely implements of small dimensions, but copper kettles no less than 3½ feet in diameter. From 1840 to 1855, according to Santos, as much as 20 tons of copper utensils and ingots were exported annually by the Igorrotes. They made pots, tobacco pipes, and ornaments. It was this trade which drew the attention of the Spaniards to the region. It was the opinion of Santos that the Igorrotes have Chinese or Japanese blood, and it is commonly believed that they are descended from Chinese invaders who brought the art of smelting with them. Their appearance and their customs are considered as indicating such an origin.

Their mining and metallurgy were first investigated by Hernandez, later and more fully by Santos. It is almost humiliating to find how well up in technology these dirty savages are, but perhaps the great discoveries in copper smelting have been common property ever since the age of bronze.

The following account is almost literally translated from Santos's memoir:

The ore-bearing territory is divided among the neighboring villages in proportion to the number of inhabitants, and any attempt to shift the claim limits leads to bloodshed. The property of each village is again divided among certain families, in consequence of which the district looks like a honeycomb. Winning in is accomplished by firing—[1] that is, by kindling a fire at suitable spots against the breasts, so that the tension of the aqueous vapor developed in the ore may split off flakes, this operation being assisted by the use of iron tools. The first sorting takes place in the mines, the rejected portion being left on the floor and so raising it that at subsequent firings the flame of the billets licks the face and much of the roof. The character of the rock and the imperfect nature of the process led to many cases of caving, some

[1] In 1869 I witnessed firing in the Rammelsberg mine at Goslar. It was there practiced only on Sundays. It is doubtless one of the oldest technical processes known to man.

of large extent. The ores won were classified into rich stuff and quartzose ore. The former went directly to the furnace, while the latter was subjected to a long and thorough roasting, during which, after a part of the sulphur, antimony, and arsenic had been volatilized, a sort of sweating of iron and copper sulphides took place. These substances united in globules of matte, which adhered to the exterior of the quartz fragments and, in great part, could then be separated from the gangue.

The furnaces consisted of circular depressions in a clay floor, and were 15 cm. in depth, with a diameter of 30 cm. A nozzle of fire clay, standing at an angle of 30° above the hole, united two bamboo pipes which were fitted into the lower ends of two cylinders made of pine logs, containing pistons packed with grass, which moved alternately up and down, furnishing blast.[1] When the furnace was ready they charged it with 18 or 20 kilos of rich or roasted ore, which, according to repeated assays, contains 20 per cent of copper, taking the remarkable scientific precaution to place the ore at the nozzle and the fuel against the wall of the furnace, this wall consisting of uncemented stones piled to a height of half a meter. After the fire was lighted and the blower put in operation, thick white and orange-colored fumes were thrown off, these being due to the partial volatilization of the arsenic, antimony, and sulphur, until at the end of an hour only sulphur dioxide was given off, and the temperature had reached the highest possible point. The blast was then stopped and the product removed. This consisted of slag (or rather of lumps of ore which on account of the quartz gangue were reduced to a porous mass through the eliquation of the metallic sulphides, and were not scorified because of lack of bases and of a sufficiently high temperature) and a very impure matte, weighing 4 or 5 kilos, with a content of 50 to 60 per cent copper. This matte, with that produced at other similar runs, was roasted in a strong fire for twelve to fifteen hours, with the result that a great part of the three volatile substances mentioned above was dissipated.

In the same furnace they set on edge the cakes of roasted matte, being careful in this operation also to place the charcoal against the wall, and, after blowing half an hour, obtained, first, slag consisting of a silicate of iron with indications of arsenic; second, a matte with 70 to 75 per cent of metal, which they took off in very thin crusts by means of sprinkling the exposed surface with water; third, black copper, more or less in quantity according to the degree of desulphurization of the material smelted, but always impure. The mattes obtained in this second operation were again roasted, with the precaution that the wood was interposed between the crusts to avoid fritting before the fire had driven off the objectionable components.

[1] This is a well-known Chinese blast engine, such as I have seen at the tin-smelting works in Bangka. It was in use in China long before bellows were abandoned in European works.

To avoid loss through oxidation in casting copper, either black or refined, they covered the furnace with a helmet-shaped fire-clay crucible, thus making it easier to lade the metal into molds of the same clay.

The black copper obtained at the second heat, and the matte from it also, but only after previous roasting, were submitted to a third smelting in the same furnace, this being reduced in size by the stone wall and by the addition of the crucible mentioned above. This heat produced an iron-silicate slag, and a black copper, which, after casting in clay molds, was forthwith disposed of commercially. This black copper contained 94 per cent copper and was rendered impure by yellow carbide of the metal and the oxide, formed superficially during slow cooling despite the precautions taken to avoid it by whipping the exposed surface with green boughs.

If the copper is to be employed to manufacture pots, pipes, or other household utensils and ornaments which these natives make with so much patience and skill, they apply a refining process differing from the preceding in only one feature: the amount of charcoal is diminished and the quantity of air increased, as the end of the heat is approached, for the purpose of oxidizing the carbide of copper.

Repeated assays have proved that, even when they treated ores with a mean content of 20 per cent, they got only 8 or 10 of black copper at the third heat.

Concerning the remaining copper deposits in the Philippines, scarcely anything is known except the localities in which they are to be found. In Mr. Abella's summary of mineral resources, in the Guía Oficial, he states that there is copper at Antamoc and at Casalugan in Benguet, but gives no details. In 1823 copper-mining concessions were applied for to work two deposits in a mountain called Taloo, near Antimonan, in Tayabas Province.[1] It is, perhaps, a legitimate inference that these localities are in the small area of crystalline schists there noted by Mr. von Drasche. At the same time application was made for claims 3½ miles south of Mambulao, at Iba, and on the Gulf of Guinobatan, 5 miles south-southwest of Mambulao. These places are in the Province of Camarines Norte and in the schist area. Jagor states that there was a shaft at the Iba locality said to be 84 feet deep. Two copper localities are marked on Mr. d'Almonte's map in Camarines Sur, east of the town of Caramuan, or Caramoan, near the shore of the channel which separates Catanduanes from Luzón. Roth refers to the copper of Caramuan as an indication that the mountains at this point are composed of crystalline schist. Jagor saw specimens of native copper coming from a locality north of Patag Cove.[2] This corresponds to one of the mines laid down on Mr. d'Almonte's map.

In the Island of Masbate, at Milagros, near Assit, native copper was

[1] Centeno, Memoria geológico-minera, 1876, p. 45. Several of these miscellaneous notes are from the same source.

[2] Jagor. Reisen, 1873, pp. 145, 347.

discovered in 1847. Centeno saw fine specimens. This mine was worked for a time, but the ore gave out or was lost. Masbate also contains gold, and the occurrence of these metals suggests a crystalline schist area in this little-known island. On the Island of Capul, between Sámar and Luzón, Centeno also notes copper pyrites.

In Panay Mr. Abella met with no deposit of copper, but saw stains at Mount Carauisan, latitude 10° 50′, Province of Antique. He thinks this corresponds to a report by the provincial governor in 1842 of the discovery of an extensive deposit a league from the town of Sibalom. From the natives of the region he could ascertain nothing about this ore. At Barbaza, in latitude 11° 12′, in the same province, Mr. Abella met a native who owned a specimen of native copper the source of which he refused to disclose, though stating that it was not very far away.[1]

In the Island of Marinduque, at Torrijos, the Guía Oficial states that copper occurs, without further information. At Lubang, on the island of the same name to the northwest of Mindoro, Dana found copper pyrite, probably only as an accompaniment of the gold.[2]

That copper pyrite is met with in the Surigao Peninsula of northern Mindanao among the gold fields is known. According to the geography of the Jesuit fathers, there is a workable deposit of good quality at the hamlet of Taganaan, 3 leagues from the town of Surigao. A merchant resident in Palawan informed me that there is copper in Balábac.

### ARGENTIFEROUS LEAD.

Galena is found in Camarines Norte in the area of the crystalline schists accompanying other sulphurets and gold. Concessions have been granted for lead mining at a mountain called Tingá, near Paracale, and at a hamlet named Imbong-imbong, in the township of Mambulao, but these ores were worked only for the gold. Centeno reports the Tingá occurrence as very rich, but the veins as only from 3 to 10 centimeters in width.[3] Paracale and Mambulao have a reputation among mineralogists as a source of lead chromate and vauquelinite. Jagor visited two localities, but found the specimens practically exhausted. One is near Paracale, in a gneiss hill ten minutes' walk from the village of Malaguit. The other is a mile and a half north by east from Mambulao, in the plumbiferous mountain Dinianan, which is composed of hornblende-schist. Roth states that the chromate is found in quartz veins and is accompanied by vauquelinite, like the occurrence in the Ural Mountains.[4] Caramuan, in Camarines Sur, is credited with lead ore in the Guía Oficial. It is probably associated with the copper deposits in that district.

[1] Isla de Panay, p. 197.
[2] U. S. Expl. Exp., Vol. X, 1849, p. 539.
[3] Memoria geológico-minera, 1876, p. 53; Guía Oficial, 1898, p. 127.
[4] Jagor, Reisen, 1873, pp. 144–145, 345.

In the Island of Marinduque, Province of Mindoro, at Torrijos, there is a lead deposit regarded by Mr. Espina as important.[1] The assays are said to give, for average ore, 56.55 per cent lead, 0.0096 per cent silver, and 0.0006 per cent gold. No further information is available.

Cebú contains lead ores upon which Mr. Abella has reported thus:[2]

> The most important metalliferous deposits, and indeed the only ones which deserve the name, yet discovered in the island are those of gold- and silver-bearing galena. They lie toward the center of the island, at Panoypoy, township of Consolación, and at Acsubing and Budlaan, in the township of Talamban, the first two being those which gave rise to the claims of the company known as *La Cebuana*. The deposits all consist of bunches, veins, and stringers of pyritous galena, which form an irregular network in the rock complex of the eastern area of the interior of the island. They lack system or regular direction, and form therefore a true *Stockwerk*.

Centeno found the ore extremely rich in silver and gold, but mining seems to have been abandoned.

In Mindanao Mr. Espina saw specimens of lead ores, but was unable to ascertain whence they came.

## IRON.

Something like a belt of magnetite deposits exists among the mountains lying to the east of the great plain of Luzón. The northern portion of this belt is 12 or 15 miles to the eastward of San Miguel de Mayumo, on the headwaters of the stream which passes through that place. In this neighborhood the positions of four mines are indicated on Mr. d'Almonte's map. A few miles east of south from this group lies a second, about 10 miles northeast of Angat. Here also four mines are shown, and this district has the reputation of possessing the most valuable iron ores in the archipelago. At a similar distance to the northeast of Bosoboso another iron mine has been worked. Ten miles north of east from Mórong there is still another iron mine, in the Province of Laguna de Bai. All of these deposits are in the foothills of the range which forms the western boundary of the Province of La Infanta and at nearly equal distances from the crest. The belt is 44 miles in length, and evidently stands in genetic relations to the range. According to assays made in the laboratories of the Inspección General de Minas, the Angat ores carry from 60 to 70 per cent of iron. The impurities do not seem to have been determined. I find in so serious a paper as Centeno's Memoria the statement that these ores contain 75 to 80 per cent of iron; but magnetite, though the richest of iron ores, can not contain more than 72 per cent of iron, as should be well known. Of the nature of the deposits I have been able to obtain no descriptions, except that the ore is abundant.

In Camarines Norte there is a mine of magnetic iron some 6 miles

[1] Espina, Bosquejo, 1898, p. 165.

[2] Isla de Cebú, 1886, p. 146.

south of Paracale on the Malaguit River. The Guía Oficial also mentions a deposit in the township of Mambulao at Calambayungan.

The Filipinos work the ores of Angat and of San Miguel de Mayumo. Unfortunately I did not succeed in seeing the process or in getting any satisfactory description of it. There is no doubt, however, that it is a bloomery process. The steel produced is chiefly made into plowshares, which are so good that they bring a much higher price than those of European manufacture. The process is probably nearly identical with that still in use in Borneo; but, if not, it would be most interesting to know what are the differences. I therefore make no apology for introducing here Mr. Posewitz's description, in which he follows C. H. L. M. Schwaner, who witnessed it:[1]

The cylindrical blast furnace has a height of 3 feet 4 inches and a circumference of 10 feet. The shaft has the form of a parallelopiped (8 by 6 inches) and becomes wider toward the top, having a pyramidal form. The smelting hearth is 25 inches long, 19 inches wide, and 9 inches high.

The material of which the furnace is constructed is a yellow clay, which is obtained from the banks of the rivers.

This material, having been kneaded and purified, is pressed in a cylindrical bark[2] mold having the dimensions of the furnace. It is allowed to dry for a month or more. The mold is then removed and the furnace bound round with Spanish cane (rattan), in order to give it greater strength and to provide against bursting. The dry-air process is completed by a small fire.

The smelting only lasts one day. The floor of the hearth is first covered with powdered charcoal to a depth of 2 inches, in the middle of which a hole is made, which serves to collect the iron. The tapping hole is closed by clay. A semicircular hole is left to let out the slag. The blast apparatus consists of a hollow tree stem, 5 feet 5 inches long and 3 inches in circumference [diameter?], open at the top and closed at the bottom. Directly above the floor there are 3 openings on the same level and close to one another. These openings are intended for the insertion of 3 bamboo tubes, 29 inches in length, through which the blast has access to the tuyers and to the furnace. The tuyers are made of baked clay. They are 11 inches in length, and narrow considerably in the part opening into the furnace. In the bellows there is a valve, which is made air-tight by feather down. It is worked by hand.

Burning charcoal is thrown from above into the furnace, and a gentle blast produced sufficient to cause the charcoal layer to glow. The furnace is then filled to two-thirds of its height with wood charcoal. The ores are first submitted to a roasting action by piling them up in layers between wood, igniting the pile, and allowing it to burn one day. The ore is then broken into pieces of the size of a nut, mixed with charcoal in the proportion of 1 to 10, and thrown into the furnace. Usually two hours and a half suffice to sink the ore, after which more ore and coal are added.

The slag is run off at intervals of twenty minutes, the tuyers being removed and the blast stopped for five minutes while the slag is running off. A drawback to this method is that a large part of the iron goes into the slag.

As soon as all the fuel is burned the tuyers are taken out and the stopping of the hole in the hearth removed. The iron, which is in the form of a viscid, molten

[1] Posewitz, Borneo, 1892, p. 433. In A. Marche, Luçon et Palaouan, Paris, 1887, p. 85, I find brief notes on the process at Angat, which seem to indicate that the process there employed is substantially the same as in Borneo.

[2] The English translation has cork, by error, for bark.

mass, is then drawn out of the furnace by means of wooden tongs, placed on a finely broken slag, and beaten with wooden hammers until it becomes smooth.

Such a mass, weighing 45 pounds, represents a day's work for four men, and costs 2 florins. It contains much slag, however, and, having been divided into ten parts has to be several times remelted and beaten with hammers until it is pure enough for smithy work.

While iron smelting has almost entirely ceased, this is not the case with the smithy work. Weapon smiths still exist who manufacture excellent blades. Especially worthy of mention are the works of the great industrial place, Negara, in south Borneo, of which the "Negara blades" have a widespread reputation.

The natives prefer their own iron to the European, as experience teaches that the keenness and durability of these weapons are superior to those of European manufacture.

## MISCELLANEOUS.

Petroleum has been discovered within a few years in the islands of Panay, Cebú, and Leyte, but is not as yet known elsewhere. In Panay it is found at Janiuay in the Province of Iloilo and is accompanied by natural gas. I have not heard that it is exploited. In Cebú oil is found on the west coast, at Asturias, Toledo, and Alegria. The well at Toledo (10° 17′) has been exploited to some extent,[1] and there is a concession for oil and one for coal at the same locality in this township. An oil concession has also been granted at Alegria. In Leyte oil occurs in the township of San Isidro, and has been taken up. This is probably the locality marked as a petroleum mine on Mr. d'Almonte's map on the west coast, in latitude 11° 15′, though this is closer to Villaba than to San Isidro del Campo. Mr. Espina states that petroleum from near Villaba is highly charged with paraffin.

Sulphur has been extracted under concession only at Bilirán, but the volcanoes and solfataras of the islands offer endless opportunities for "clandestine exploitation" all the way from Mount Apo, in Mindanao, to the volcano of Cagua,[2] near the northern extremity of Luzon. Jagor[3] gives a pleasant account of sulphur extraction a little south of Buráuen, in Leyte.

There have been various reports of the discovery of quicksilver in the Philippines; e. g., in Panay, Mindanao, and in the Province of Albay. All seem to be founded on accidental losses of exotic metal.

Excellent marble is found on the Island of Romblón, to the north of Panay. It is used in Manila for fonts and the like. In Cebú also there is a concession for marble at Tuburan (10° 43′). Marbles for building are quarried at Montalbán and at Binangonan (the nummulite locality) in Manila Province.

Kaolin is found at Los Baños, Laguna Province, and fictile clays at numberless points.

Stibnite from Bataan Province was seen by Centeno,[4] but there is no evidence that any valuable deposit occurs. So, too, zinc blende is known to exist, but only as a valueless sulphuret in gold-quartz veins.

[1] Guía Oficial, 1898, p. 128. [2] Ibid., p. 127. [3] Reisen, 1873, p. 221. [4] Mem. geol-min., 1876, p. 53.

# LIST OF BOOKS AND PAPERS ON PHILIPPINE GEOLOGY.

In the following list titles have been given somewhat fully, to facilitate reference, particularly at a distance from great libraries. In the preparation of this report all of the papers here listed, except one, have been consulted at first hand or in complete reprints, and I know of no other works of any value on the subject except two or three mine reports. In the text a number of works are referred to which deal with Malaysian geology, but not with that of the Philippines. Of these only Hochstetter, Posewitz, and Martin are catalogued here. The volume of Posewitz on Borneo makes an excellent introduction to Malaysian geology.

It should be noted that when a Spanish writer uses a double surname the latter is his mother's maiden name. The matronymic is not always employed; for instance, Centeno sometimes adds "y García" to his patronymic, but more often omits it. If in citations only one name is used, it must be the first and not the second.

1574. RIQUEL, HERNANDO. Very true and certain account of that which has newly been known of the new islands of the West, and of the discovery which they mention of China, which was written by H. R. secretary of the governor of them. Seville, Barrera, 1574. Broad sheet.

*In* English trans. of Morga, Sucesos, app. 4, p. 389.

1609. MORGA, ANTONIO DE. Sucesos de las islas Filipinas, Mexico, en casa de Geronymo Bahi, Ano 1609. Por Cornelio Adriano Cesar. 4°, 10 p. l. and 172 leaves.

This rare book may be seen in the library of Harvard College.

1698. GASPAR DE SAN AVGVSTIN. Conquistas de las islas Philipinas [sic]; la temporal por las armas del Señor Don Phelipe [sic] segundo el prudente y la espiritval, por los religiosos del orden de nuestro padre San Augustin; fvndacion, y progressos de sv provincia del santissimo nombre de Jesus. Parte primera. Madrid, Mvrga, 1698. Fol., 544 pages; index and preliminary matter not paged.

1792. JUAN DE LA CONCEPCIÓN. Historia general de Philipinas [sic]. Sampaloc, Moriano, 1792. Sm. 4°, 14 v.

Great eruption of Taal in 1754 described, v. 13, pp. 345–350.

1803. MARTINEZ DE ZÚÑIGA, JOAQUÍN. Historia de las islas Philipinas. Sampaloc, Argüelles, 1803. 8°, iv, 687 pp.

1814. MARTINEZ DE ZÚÑIGA, JOAQUIN. Historical view of the Philippine Islands; trans. from Spanish original of 1803 by John Maver. London, 1814. 8°, 2 vols.

1817. HORSBURGH, JAMES. The India directory, or directions for sailing to and from the East Indies. 2d ed. London, 1817.
Philippines, p. 328, where the volcanoes of the Babuyanes are mentioned.

1825. BUCH, LEOPOLD VON. Physicalische Beschreibung der Canarischen Inseln. Berlin, Academie, 1825. 4°.
Philippine volcanoes, pp. 375–378.
There is a French translation, Paris, Levrault, 1836, 8°, in which the passage relating to the Philippine Islands begins p. 437.

1829. CHAMISSO, A. VON. Bemerkungen und Ansichten auf der Entdeckungsreise von O. v. Kotzebue. 1829.
Philippines, v. 3, p. 92.

1829. HOFMANN, ERNST. Geognostische Beobachtungen aufgestellt auf einer Reise um die Welt in den Jahren 1823 bis 1826 unter dem Befehl . . . von Kotzebue.
*In* Archiv für Mineralogie, Geognosie, Bergbau, und Hüttenkunde, von C. J. B. Karsten, Berlin, 1829, 8°, v. 1, pp. 243–315.
Philippines, pp. 312–315, in which Taal and other volcanic masses are described.

1832. BERGHAUS, HEINRICH. Geo-hydrographisches Memoir zur Erklärung und Erläuterung der reducirten Karte von den Philippinen und den Sulu-Inseln (No. 13 von Berghaus' Atlas von Asia). Gotha, Perthes, 1832. 4°, 114 pp.

1835. MEYEN, F. J. F. Reise um die Erde . . . auf dem . . . Schiffe *Prinzess Louise* in den Jahren 1830–1832. Berlin, Sander, 1835. 4°.
Philippines, 2d part, p. 237.

1841. SAINZ DE BARANDA. Constitución geognóstica de las islas Filipinas.
*In* Anales de Minas, Madrid, 1841, 8°, v. 2, pp. 197–212.
Volumes 1 to 4 of this journal are in the library of the Museum of Comparative Zoology, Cambridge, Mass., and no more were published. They contain no other papers by this author.

1843. DELAMARCHE. On Taal Volcano in 1842.
*In* Comptes Rendus . . . Académie des Sciences, Paris, 1843, 4°, v. 16, p. 756.
Substantially the same account by Delamarche is printed in Bulletin de la Société de géographie de Paris, v. 19, 1843, p. 79.

1844. CHEVALIER, E. Voyage autour du Monde, exécuté pendant les années 1836 et 1837 sur la corvette "*La Bonite.*" Géologie et Minéralogie. Paris, 1844. 8°.
Chapter IX, pp. 231–256, deals with the geology of Mariveles, Manila, and Laguna de Bai.

1845. ITIER, JULES. Fragment d'un journal de voyage aux îles Philippines.
*In* Bulletin Société de géographie, Paris, 1845, 8°, s. 3, v. 5, pp. 365–389.

1846. ———. Extrait d'une description de l'archipel des îles Solo.
*In* Bulletin de la Société de géographie, Paris, Bertrand, 1846, 8°, s. 3, v. 5, pp. 311–319.

1849. DANA, J. D. U. S. Exploring Expedition during the years 1838–1842, under the command of Charles Wilkes, U. S. N. 4°. v. 10, Geology. Philadelphia, Sherman, 1849.
Philippines, pp. 539–548.

1850. BUZETA, MANUEL, and BRAVO, FELIPE. Diccionario geográfico, estadístico, historico de las islas Filipinas. Madrid, Peña, 1850. 8°, 2 v. (Half-title gives date of 1851).

1851. HERNANDEZ, ANTONIO. Report on copper in the district of Lepanto [Spanish].
*In* Revista minera, Madrid, v. 2, 1851, 8°, pp. 112–118.
This is much less detailed than Santos's paper of 1862 on the same subject.

1855. HUERTA, F. DE. Estado geográfico, topográfico, estadístico de . . . las islas Filipinas. Manila, 1855.
Geological notes passim.

1855. LA GIRONIÈRE, P. DE. Aventures d'un gentilhomme breton aux îles Philippines, avec un aperçu sur la géologie, etc. Paris, Lacroix-Comon, 1855. 8°.
Contains only loosely stated reports of no value. His communications to Perry are no better.

1858. HUMBOLDT, A. VON. Kosmos. Stuttgart, Cotta, 1858. 8°, 4 v.
Philippines, v. 4, pp. 404–409.

1859. HOCHSTETTER, F. VON. Schreiben an A. von Humboldt.
*In* K.-k. Akademie der Wissenschaften, Sitzungsberichte. Wien, 1859, 8°, v. 36, pp. 121–141.
This is a report on the volcanoes visited during his cruise in the *Novara*. Luzón, pp. 130–138.

1860. PERRY, ALEXIS. Documents sur les tremblements de terre et les phénomènes volcaniques dans l'archipel des Philippines. 4th part. Extrait des Annales de la Société d'émulation des Vosges, v. 10, 3d part, 1860, 8°, 110 pp., 1 map.

1861. SEMPER, CARL. Reise durch die nordöstlichen Provincen der Insel Luzón.
*In* Zeitschrift für allgemeine Erdkunde, neue Folge, vol. 10, Berlin, Reimer, 1861, 8°, pp. 249–266.
On this journey Semper collected important Miocene fossils near Minanga.

1862. RICHTHOFEN, F. VON. Vorkommen der Nummulitenformation in den Philippinen.
*In* Zeitschrift der Deutschen geologischen Gesellschaft, Berlin, Hertz, 1862, 8°, v. 14, pp. 357–360.

1862. SANTOS, JOSÉ MARÍA. Informe sobre las minas de cobre de las rancherías de Mancayan, Suyuk, Bumucun y Agbao en el Distrito de Lepanto, ilas de Luzón de las Filipinas. Manila, Press of the College of Santo Tomás, 1862. 8°, 72 pp.

1862. SEMPER, CARL. Reise durch die nördlichen Provinzen der Insel Luzón.
*In* Zeitschrift für allgemeine Erdkunde, neue Folge, v. 13, Berlin, Reimer, 1862, 8°, pp. 80–96.
This paper deals with northwestern Luzón and the raised atoll of Benguet.

1866. HOCHSTETTER, F. VON. Reise der österreichischen Fregatte *Novara* um die Erde, geologischer Theil. Wien, Government, 1866. 4°, v. 2.
This volume contains nothing about the Philippine Islands, but gives author's divisions of the Tertiary, p. 149.

1868. MORGA, ANTONIO DE. The Philippine Islands . . . Translated from the Spanish . . . by H. E. J. Stanley. London, Hakluyt Society, 1868. 8°, xxx, 413 pp.
This is a translation of Sucesos de las Islas Filipinas. It contains some appendices of value.

1869. SEMPER, CARL. Die Philippinen und ihre Bewohner; sechs Skizzen. Würzburg, Stuber'sche Buchhandlung, 1869. 8°, 143 pp., 1 map.
These interesting lectures deal with volcanoes and coral reefs, besides other matters. In the appended notes is included the author's paper on the coral reefs of the Pelew Islands, from Zeitsch. f. wiss. Zool., v. 13, pp. 563–569.

1869. ZERRENER, CARL. Nachricht über eine Anzahl aus verschiedenen Gegenden der Erde bei mir eingegangener interessanter Mineralien.
*In* Berg- und Hüttenmännische Zeitung, Leipzig, Felix, 1869, 4°, pp. 105–106.
In this paper copper ores from Mancayan are described.

1873. JAGOR, F. Reisen in den Philippinen. Berlin, Wiedmannsche Buchhandlung, 1873. 8°, xvi, 381 pp., 1 map.
This very important work contains among the appendices the papers of Roth and Virchow catalogued separately. An English translation exists, but is said to be bad and to omit the appendices. There is also a Spanish translation, which I have not seen.

1873. ROTH, JUSTUS. Ueber die geologische Beschaffenheit der Philippinen.

*In* JAGOR, F., Reisen, 1873, pp. 333–354.

This paper includes most of the essential facts known at the time it was written, and contains Roth's discussion of Jagor's lithological collection, with some paleontological notes by E. von Martens.

1873. VIRCHOW, RUDOLF. Ueber alte und neue Schädel von den Philippinen.

*In* JAGOR, F., Reisen, 1873, pp. 355–377.

This paper discusses particularly the Negritos. Virchow has since published other papers on the Philippine races, which, however, are scarcely geological. See Zeitschrift für Ethnologie, v. 15, 1883, p. 465; Sitzungsberichte der K. preussischen Akad. der Wiss., Berlin, 1897, p. 279; ibid., 1899, p. 14, etc.

1874. DARWIN, CHARLES. Structure and distribution of coral reefs. 3d ed., New York, Appleton, 1889. 8°.

Philippines, p. 180, where Cuming's observations are recorded, and map.

1874. MINARD, ——. Sur les gisements d'or de Philippines.

*In*, Bulletin Société géologique de France, Paris, the Soc., 1874, s. 3, v. 2, pp. 403–406.

1876. MENDEZ DE VIGO. Historia geográfica, geológica y estadística, de Filipinas. Manila, 1876. 8°, 2 v., maps.

Geological notes passim.

1876. CENTENO Y GARCÍA, JOSÉ. Ministerio de Ultramar. Memoria geológico-minera de las islas Filipinas. Madrid, Tello, 1876, 8°, viii, 64 pp., 1 map.

This appeared separately and also in Boletín de la Comisión del Mapa Geológico de España, v. 3, 1876.

1876. DRASCHE, RICHARD VON. Ausflüge in die Vulcangebiete der Umgegend von Manila.

*In* Verhandlungen der K.-k. geologischen Reichsanstalt, 1876, 8°, pp. 89–93.

1876. ———. Mittheilungen aus den Philippinen.

*In* Verhandlungen der K.-k. geologischen Reichsanstalt, 1876, 8°, pp. 193–198.

1876. ———. Aus dem Süden von Luzón.

*In* Verhandlungen der K.-k. geologischen Reichsanstalt, 1876, 8°, pp. 251–255.

1876. ———. Einige Worte über den geologischen Bau von Süd-Luzón.

*In* Mineralogische Mittheilungen gesammelt von Gustav Tschermak, Wien, Hölder, 1876, 8°, v. for 1876, pp. 157–166.

This volume of Mineralogische Mittheilungen appeared also as supplement to K.-k. geologische Reichsanstalt, Jahrbuch, v. 26, 1876.

1876. WALLACE, A. R. Geographical distribution of animals. New York, Appleton, 1876. 8°, 2 v.
Philippines, v. 1, pp. 345 and 359.

1877. FRENZEL, AUGUST. Mineralogisches aus dem ostindischen Archipel.
*In* Mineralogische Mittheilungen gesammelt von Gustav Tschermak, Wien, Hölder, 1877, 8°, v. for 1877, pp. 297–308.
Philippines, 302–304.
This volume of Mineralogische Mittheilungen appeared also as supplement to K.-k. geologische Reichsanstalt, Jahrbuch, v. 27, 1877.

1878. DRASCHE, R. VON. Fragmente zu einer Geologie der Insel Luzón (Philippinen), mit einem Anhange über die Foraminiferen der tertiären Thone von Luzón, von Felix Karrer. Vienna, Gerold's Sohn, 1878. 4°, 5 pl. (incl. 2 maps).
This book appears to include all the material of Von Drasche's earlier papers.

1878. MEYER, A. B. Earthquakes in the Philippines in 1876.
*In* Nature, London and New York, Macmillan, 1878, 4°, v. 18, p. 265.
Data from "Ateneo municipal." Mount Tabacon should probably be Mayón, but that mountain seems to have had no eruption in 1876.

1879. ABELLA Y CASARIEGO, ENRIQUE. Memoria acerca de los criaderos auríferos del segundo distrito del departamento de Mindanao, Misamis. Seguido de varios itinerarios geológicos referentes á la misma comarca. (Del Boletín de la Comisión del mapa geológico.) Madrid, Tello, 1879. 8°, 49 pp., 5 pl.
This is much the best authority on the gold field of Misamis, and contains suggestive remarks on the general geology of the region.

1879. ARANA, C. DE. Derrotero del archipiélago Filipino. Madrid, Government, 1879.
This is the official Spanish "sailing directions" for the Philippines; useful especially with reference to coral reefs. It contains erroneous determination of Mount Malaspina (Canlaón), viz, 1,390 meters.

1879. DRASCHE, RICHARD VON. Ueber paläozoische Schichten auf Kamtschatka und Luzón.
*In* Neues Jahrbuch für Mineralogie, etc., 1879, pp. 265–269.
The purpose of this paper is to suggest, on lithological grounds, that his Agno beds are Paleozoic.

1881. ———. Datos para un estudio geológico de la Isla de Luzón (Filipinas).
*In* Boletín de la Comisión del Mapa geológico de España, v. 8, 1881, pp. 269–342.
This is a translation of the Fragmente, 1878, and is in part very untrustworthy.

1881. OEBBEKE, K. Beiträge zur Petrographie der Philippinen and der Palau-Inseln.

*In* Neues Jahrbuch für Mineralogie, etc., Beilage-Band I, Stuttgart, Koch, 1881, 8°, pp. 451–501.

This is an extremely important contribution to the lithology of the Philippine Islands. The material was Semper's collection and the work was done in Rosenbusch's laboratory.

1883. CENTENO, JOSÉ. Memoria sobre los temblores de tierra ocurridos en julio de 1880 en la isla de Luzón. Madrid, Tello, 1883. 8°, 91 pp.

This paper appeared both separately and in Boletín de la Comisión del Mapa geológico de España, v. 10, 1883. It is entirely devoted to earthquakes and their causation.

1883. MEYER, HANS. Height of Datá, 2,245 m.

*In* Petermann's Mittheilungen aus Justus Perthes' geographischer Anstalt, Gotha, Perthes, 1883, 4°, v. 29, p. 194.

Quoting Globus, 1883, no. 11 et seq., to which I have not access.

1884. ABELLA Y CASARIEGO, ENRIQUE. Terremotos de Nueva Vizcaya (Filipinas) en 1881, informe acerca de ellos, seguida de unos apuntos físicos y geológicos tomados en el viaje de Manila á dicha provincia. Madrid, Tello, 1884. 8°, 131 pp., 1 pl. (map).

The apuntos, etc., form in fact a separate paper, quoted as such in this report. They appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 10, 1883.

1885. ———. El Mayón, ó volcán de Albay (Filipinas). Madrid, Tello, 1885. 8°, 23 pp., 2 pl.

This appeared separately and also in Boletín de la Comisión del Mapa geológico de España v. 11, 1884.

1885. ———. Emanaciones volcánicas subordinadas al Malínao (Filipinas). Madrid, Tello, 1885. 8°, 14 pp., 3 pl.

This appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 11, 1884.

1885. ———. El monte Maquilin (Filipinas) y sus actuales emanaciones volcánicas. Madrid, Tello, 1885. 8°, 28 pp., 2 pl.

This appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 11, 1884.

1885. ———. La isla de Bilirán (Filipinas) y sus azufrales. Madrid, Tello, 1885. 8°, 15 pp., 1 pl. (map).

This appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 11, 1884.

1885. CENTENO, JOSÉ. Estudio geológico del volcán Taal. Madrid, Tello, 1885. 8°, 53 pp., 4 pl.

This is much the most complete paper on the subject. It appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 12, 1885.

1885. CENTENO, JOSÉ. Noticia acerca de los manantiales termo-minerales de Bambang y de las salinas de monte Blanco. Madrid, Tello. 1885, 8°, 14 pp.
This appeared both separately and in Boletín de la Comisión del Mapa geológico de España, v. 12, 1885.

1885. JORDANA Y MORERA, RAMÓN. Bosquejo geográfico é histórico-natural del archipiélago Filipino. Madrid, 1885. Fol.
Geology, pp. 115–159.

1885. MONTANO, JOSEPH. Rapport à M. le ministre de l'instruction publique sur une mission aux îles Philippines et en Malaisie (1879–1881). [Paris, Hachette, 1885.] 34 pl., 2 maps.
This work is chiefly ethnological.

1885. RENARD, A. F. Le volcan Camiguín, aux îles Philippines.
*In* Bulletin de l'Académie royale des sciences, des lettres et des beaux-arts de Belgique, Bruxelles, Hayez, 1885, 8°, s. 3, v. 10, pp. 733–751.

1885. WEBSTER, H. A. Philippine Islands.
*In* Encyclopedia Britannica, 9th ed., Edinburgh, Black, 1885, 4°, v. 18, pp. 748–753.
Philippine geology, pp. 748–750.

1886. PLANT, FRANK S. Notes on the Philippines, with two maps.
*In* Journal of Manchester Geographical Society, Manchester, the Soc., 1886, 8°, v. 2, pp. 19–49.

1886. ABELLA Y CASARIEGO, ENRIQUE. Rápida descripción física, geológica y minera de la Isla de Cebú (archipiélago Filipino). Madrid, Tello, 1886. 8°, 187 pp., 6 pl., incl. map geologically colored and geological sections.
This appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 13, 1886.

1886. MONTERO Y VIDAL, JOSÉ. El archipiélago Filipino y las islas Marianas, Carolinas y Palaos, su historia, geografía y estadística. Madrid, Tello, 1886. 8°, xv, 511 pp., 2 maps.

1886. RENARD, A. F. Notice sur quelques roches des îles Cebú et Malanipa (Philippines).
*In* Bulletin de l'Académie royale des sciences, des lettres et des beaux-arts de Belgique, Bruxelles, Hayez, 1886, 8°, s. 3, v. 11, pp. 95–105.

1886. TENISON-WOODS, J. E. The geology of Malasia, southern China, etc.
*In* Nature, London and New York, Macmillan, 1886, 4°, v. 33, pp. 231–232.

1887. MARCHE, ALFRED. Luçon et Palaouan, six années de voyage aux Philippines. Paris, Hachette, 1887. 8°, 398 pp., 2 maps.

1888. SUESS, E. Das Antlitz der Erde. Vienna, Tempsky, 1888. 8°, 2 v.
Philippines, v. 2, pp. 213–217. Treats especially of alignment of volcanoes and contains good notes on the literature.

1889. GUILLEMARD, F. H. H. The cruise of the *Marchesa* to Kamschatka and New Guinea, with notices of Formosa, Liu-Kiu, and various islands of the Malay archipelago. 2d ed., London, Murray, 1889. 8°, 455 pp. and maps.
Notes on Cagayán de Joló, p. 175.

1889. POSEWITZ, THEODOR. Borneo; Entdeckungsreisen und Untersuchungen. Gegenwärtiger Stand der geologischen Kenntnisse. Verbreitung der nutzbaren Mineralien. Berlin, Friedländer, 1889. 8°.

1889. RECLUS, ÉLISÉE. Nouvelle géographie universelle, la terre et les hommes. Paris, Hachette, 1889. 8°, v. 14.
Philippines, pp. 515–580.

1889. RENARD, A. F. Report on the rock specimens collected on oceanic islands during the voyage of H. M. S. *Challenger* during the years 1873–1876. 4°, 180 pp.
*In* Report of the scientific results of the exploring voyage of H. M. S. *Challenger*, 1873–1876, London, Government, 1889, 4°, v. 2, part 4.
Philippines, pp. 160–175; nearly or quite a translation of Renard's two papers in Bull. Acad. de Belgique.

1890. ABELLA Y CASARIEGO, ENRIQUE. Descripción física, geológica y minera en bosquejo de la isla de Panay. Manila, Chofré, 1890. 8°, 203 pp., 5 l., and 5 pl. (incl. 2 maps of the island colored geologically).

1890. CENTENO and others. Memoria descriptiva de los manantiales minero-medicinales de la isla de Luzón estudiados por la comisión compuesta de los Señores José Centeno, Anacleto del Rosario y Sales, y José de Vera y Gomez. Madrid, Tello, 1890. 8°, 117 pp.
This appeared separately and also in Boletín de la Comisión del Mapa geológico de España, v. 16, 1889.

1890. MEYER, HANS. Eine Weltreise. Leipzig und Wien, Bibliographisches Institut. 1890. 8°.
Philippines, pp. 253–287, determined height of Datá.

1892. BARANERA, FRANCISCO X. Compendio de geografía de las islas Filipinas, Marianas, Joló y Carolinas. 3d ed. Manila, Bren, 1892. 12°, 192 pp., 3 maps.
An extremely useful little book, though not free from errors. Among other matters it contains an index of the principal towns and geographic features of the islands, pp. 121–162.

1892. POSEWITZ, THEODOR. Borneo; its geology and mineral resources, translated from the German by Frederick H. Hatch. London, Stanford, 1892. 8°, xxxii, 495 pp., 4 maps.

This work does not deal with the Philippine Islands, but is important for suggestive analogies. It contains a list of several hundred papers on Borneo.

1892. WALLACE, A. R. Island life. London, Macmillan, 1892. 8°.

Philippines, pp. 387–390.

1893. ABELLA Y CASARIEGO, ENRIQUE. Terremotos experimentados en la isla de Luzón durante los meses de marzo y abril de 1892, especialmente desastrosos en Pangasinán, Unión y Benguet. Manila, Chofré, 1893. 8°, 110 pp., 1 diagram and map.

The map is on a larger scale than any other known to me of the same region. The memoir is largely geological.

1893. ABELLA and others. Estudio descriptivo de algunos manantiales minerales de Filipinas, ejecutado por la comisión formada por Don Enrique Abella y Casariego, inspector general de minas, Don José de Vera y Gómez, médico, y Don Anacleto del Rosario y Sales, farmacéutico, precedido de un prólogo escrito por el Excmo. Sr. D. Angel de Avilés, director general de Administración Civil. Manila, Chofré, 1893. 8°, 150 pp.

The half-title is: Manantiales minerales de Filipinas; 2°, estudio descriptivo. This paper is largely geological.

1893. MARTINEZ DE ZÚÑIGA, JOAQUÍN. Estadismo de las islas Filipinas, ó mis viajes por este país. Publica esta obra por primera vez extensamente anotada W. E. Retana. Madrid, 1893. 8°, 2 v.; v. 1, 549+xxxviii pp.; v. 2, 118+629* pp.

Among the appendices is a valuable bibliography of Spanish works, 384 titles, and an index of geographical points, pp. 352–420. The report on the three eruptions of 1641 is reproduced in v. 2, p. 334.

1893. AGUILAR, J. N. Colonización de Filipinas. Madrid, Alonso, 1893. 8°, 414 pp.

Geology and mineral resources, pp. 345–409, seemingly without any original matter.

1895–1896. ELERA, CASTO DE. Catálogo sistemático de toda la fauna de Filipinas, etc. Manila, Colegio de Santo Tomás, 1895–96. 8°, 3 v.

The introduction contains geological opinions.

1896. MARTIN, K. Ueber tertiäre Fossilien von den Philippinen. *In* Sammlungen des geologischen Reichs-Museums in Leiden, 1st s., Leiden, Brill, 1888–1899, 8°, v. 5, pp. 52–69, 2 cuts.

This paper is translated as a complement to this report.

1897. LANZAS, PEDRO TORRES. Relación descriptiva de los mapas, planos, etc., de Filipinas existentes en el archivo general de Indias. Madrid, 1897. 12°, 55 pp.

*In* Archivo del bibliófilo filipino, W. E. Retana, Madrid, Rios, 1897, v. 3, pp. 445–497.

Maps chronologically arranged from 1565 to 1847.

1898. CORONAS, JOSÉ. La erupción del volcán Mayón en los días 25 y 26 de junio de 1897. Manila, Observatorio, 1898. fol., 55 pp., 1 leaf, 2 pl., 2 maps.

Father Coronas gives a succinct account of the earlier known eruptions. For geological information he refers to Abella's paper.

1898. BECKER, GEORGE F. Memorandum on the mineral resources of the Philippine Islands.

*In* U. S. Geological Survey, 19th annual report, part vi continued, pp. 687-693.

This paper was prepared as a report to Admiral Dewey, at his request. It was reprinted in A Treaty of Peace between the United States and Spain, 55th Congress, 3d session, document 61, part 1, Washington, Government, 1899, pp. 514-518; reprinted again in The Philippine Islands, report by Mr. Lodge from Senate Committee on the Philippines, 56th Congress, 1st session, document 171, Washington, Government, 1900, pp. 19-24.

1898. ESPINA Y CAPO, LUIS. Ligero bosquejo acerca de los principales yacimientos metalíferos de Filipinos. Manila, MS., 1898. fol., 191 l., folding tables and maps.

Report prepared at my request by official in charge of Inspección de Minas from material in that office.

1898. GOBIERNO GENERAL DE FILIPINAS. Guía oficial de las Islas Filipinas para 1898, publicada por la secretaría del Gobierno General. Manila, 1898. 8°, 1144 pp. and appendices.

Contains papers by heads of departments on the meteorology, resources, history, and government of the islands and much miscellaneous information. Abella is said to have written the section on Reino Mineral, pp. 124-131.

1898. HILDER, F. F. The Philippine Islands.

*In* National Geographic Magazine, Washington, D. C., 1898, v. 9, pp. 257–301.

1898. KARUTH, FRANK. A new centre of gold production. London, 1894.

Extracts and additional notes by author in United States Department of State, consular reports, 1898, 8°, pp. 414–423.

1898. WORCESTER, DEAN C., and BOURNS, FRANK S. Contributions to Philippine ornithology.

*In* United States National Museum, publication No. 1134, 8°, v. 20, pp. 349–625.

Deals with distribution of avifauna in a way to suggest changes of level.

1899. BECKER, GEORGE F. Brief memorandum on the geology of the Philippine Islands.
*In* U. S. Geological Survey, 20th annual report, 1898–99, 8°, part 2, pp. 3–7.
Prepared as a report to Gen. E. S. Otis, military governor.

1899. HERRMANN, RAFAEL. Besuch im Golddistrict von Camarines Norte (Luzón).
*In* Globus, Braunschweig, Vieweg, 1899, 4°, v. 73, pp. 10–12.

1899. KOTÔ, B. On the geologic structure of the Malayan archipelago.
*In* the Journal of the College of Science, Imperial University of Tōkyō, Japan, v. 11, part 2, published by the University, Tōkyō, Japan, 1899, 4°, pp. 83–120, 1 map.

1899. STIERE, J. B. Volcanoes and earthquakes in the Philippines.
*In* Scientific American, New York, 1898, fol., p. 395.

# MINING CONCESSIONS.

*Mining concessions in force in the Philippine Islands on August 17, 1897.*

| Name of mine. | Mineral exploited. | Locality. | Township. | Province or district. | Number of claims. | Area in square meters. | Grantees. |
|---|---|---|---|---|---|---|---|
| Ntra Sra del Carmen | Gold | Pinutan | Liloan | Leyte | 1 | 60,000 | |
| La Amistad | do | Tigbanan | do | do | 2 | 120,000 | |
| Bilbaina | do | do | do | do | 2 | 120,000 | Aldecoa & Co |
| Excess on the three preceding | do | | | | (a) | 20,056 | |
| Esperanza | do | Tumbaga | Mambulao | Ambos Camarines | 2 | 120,000 | |
| La Concepción | do | Imbong-imbong | do | do | 2 | 120,000 | |
| Trinidad | do | Dinaanan | Paracale | do | 2 | 120,000 | |
| Luisa | do | Colapnit | do | do | 2 | 120,000 | |
| Rosalía | do | Tinga | do | do | 2 | 120,000 | |
| Noria | do | La Noria | Mambulao | do | 1 | 60,000 | |
| Sta. Gertrudis | do | Calupcup | do | do | 1 | 60,000 | The Philippines Mineral Syndicate, Limited. |
| Animas del Purgatorio | do | Longos | Paracale | do | 2 | 120,000 | |
| San Antonio | do | Dinaanan | do | do | 2 | 120,000 | |
| María | do | Tumbaga | Mambulao | do | 2 | 120,000 | |
| Francisco | do | do | do | do | 2 | 120,000 | |
| San Juan | do | Salulong | Paracale | do | (b) 2 | 81,000 | |
| San Enrique | do | Gumamela | do | do | 2 | 120,000 | |
| San Pablo | do | Oguis | do | do | 2 | 120,000 | Bonancita M. Co. |
| San Antonio | do | Dinaanan | Mambulao | do | 1 | 60,000 | Eugenio Espedido. |
| El Secreto | do | Togús | Paracale | do | 2 | 120,000 | |
| Mi Porvenir | do | Mariconia | do | do | 2 | 120,000 | |
| Santa Marta | do | Manaug | do | do | 2 | 120,000 | Bonancita M. Co. |
| La Muy Rica | do | Carbongajar | do | do | 2 | 120,000 | |
| Nueva Galicia | do | Gumobacan-Bata | Mambulao | do | 2 | 120,000 | |
| Aurora | do | Gumobacan-Matandá | do | do | 2 | 120,000 | The Philippines Mineral Syndicate, Limited. |
| San Ramón | do | Gumaos | do | do | 2 | 120,000 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| San Rafael | do | Togús | Paracale | do | 2 | 120,000 | Nicolas Carranceja. |
| Registro No. 1 | do | Rio de Paracale | do | do | 1 | 60,000 | García, Beltran & Co. Mining Company. |
| Registro No. 2 | do | do | do | do | 1 | 60,000 | |
| Registro No. 3 | do | do | do | do | 1 | 60,000 | |
| Registro No. 4 | do | do | do | do | 1 | 60,000 | |
| Registro No. 5 | do | do | do | do | 1 | 60,000 | |
| Cusa | do | Colorán | do | do | 2 | 120,000 | |
| Pep | do | Togús | do | do | 2 | 120,000 | |
| Quim | do | do | do | do | 2 | 120,000 | |
| Santa Bárbara | do | Bejuquillo | do | do | 2 | 120,000 | Eugenio Espedido. |
| Felicidad | do | Dinaquitan | Mambulao | do | 2 | 120,000 | The Philippines Mineral Syndicate, Limited. |
| San Mauricio | do | Calupcup | do | do | 2 | 120,000 | |
| Doña Guillerma | do | Tagontón | do | do | 1 | 60,000 | La Bonancita Mining Co. |
| Doña María | do | Longos | Paracale | do | 2 | 120,000 | The Philippines Mineral Syndicate, Limited. |
| Margarita (investigation) | do | Pansol | do | do | c 2 | 120,000 | |
| Excess to south of San Antonio | do | Salulong | do | do | (a) | 18,200 | |
| Excess to north of San Antonio | do | Longos | do | do | (a) | 45,000 | |
| Excess of San Juan | do | Baluarte | do | do | (a) | 10,256.25 | |
| Santa Barbara | do | Manaug | do | do | 2 | 120,000 | La Bonancita Mining Co. |
| Don Carlos | do | Tagontón | do | do | 1 | 60,000 | |
| Leo Taxil | do | Casalogan | do | do | 2 | 120,000 | Ramón Caberudo. |
| San Vicente | do | Máquima | do | do | 2 | 120,000 | La Bonancita Mining Co. |
| Padre José | do | Lipata | do | do | 2 | 120,000 | |
| Nueva California, first | do | Casalogan | do | do | 4 | 240,000 | Martin Buck and Joaquín Casanovas. |
| Nueva California, second | do | Guiaman | do | do | 4 | 240,000 | |
| Nueva California, third | do | Casalogan | do | do | 4 | 240,000 | |
| Nueva California, fourth | do | Magsimato | do | do | 4 | 240,000 | |
| Nueva California, fifth | do | Cabisnuan y Colorán | do | do | 4 | 240,000 | |
| Germania | do | Capulugan | do | do | 4 | 240,000 | |
| Magallanes | do | Bonotan, Malagangao, Capinangan and Tinapahan. | do | do | 24 | 1,440,000 | |
| La Candelaria | do | Calangag, Pinaglambirán, Tiniguiban, Quinabagacayan. | do | do | 33 | 1,980,000 | Vicente Atienza. |

*a* Excess. *b* Incomplete. *c* Investigation.

*Mining concessions in force in the Philippine Islands on August 17, 1897*—Continued.

| Name of mine. | Mineral exploited. | Locality. | Township. | Province or district. | Number of claims. | Area in square meters. | Grantees. |
|---|---|---|---|---|---|---|---|
| San Félix | Gold | Cabúgao | Paracale | Ambos Camarines | 2 | 120,000 | Emilio Sprüngli. |
| San Ricardo | do | May Nanca | do | do | 2 | 120,000 | Juan Fernandez and S. Luis. |
| El Ángel | do | Delinquenta | do | do | 2 | 120,000 | |
| El Patriarca | do | Monte Maynanca | do | do | 2 | 120,000 | |
| San Alfredo | do | Calupcup | Mambulao | do | 1 | 60,000 | The Philippines Mineral Syndicate, Limited. |
| Santiago | do | do | do | do | 1 | 60,000 | |
| Caridad | do | Dinaquitan | do | do | 1 | 60,000 | |
| San Sebastián | do | Calupcup | do | do | 2 | 120,000 | |
| San Federico | do | do | do | do | 2 | 120,000 | |
| San Ciriaco | do | do | do | do | 1 | 60,000 | |
| Robinson group | do | Catigahan | do | do | 57 | 3,420,000 | William Urquhart. |
| Santa Balbina | do | Bulalácao | do | do | 2 | 120,000 | Calatino Flores. |
| San Nicolás | do | do | do | do | 2 | 120,000 | |
| La Concepción | do | do | do | do | 2 | 120,000 | |
| San Rafael | do | Tigbí | do | do | 2 | 120,000 | Aguedo Macandog. |
| La Aurora | do | Puló ni Antón | Gapan | Nueva Écija | 2 | 120,000 | Auturo Carlos Fleming. |
| Santa Calalina | do | do | do | do | 2 | 120,000 | |
| Pilar | do | Palidan | Mancayan | Lepanto | 2 | 120,000 | Rafael Yanguas. |
| Santa Rita | do | Cayaan | do | do | 2 | 120,000 | |
| San Luis | do | Dugoon | do | do | 2 | 120,000 | |
| San Antonio | do | Gatugat | do | do | 2 | 120,000 | |
| San Alberto | do | Rio Pacat | do | do | 2 | 120,000 | José Mills y Baralls. |
| Adela y Micaela | do | Arroyo Arup | do | do | 2 | 120,000 | |
| Pilar y Mercedes | do | Cali | do | do | 2 | 120,000 | |
| María Asunción y San Lorenzo | do | Balaan | do | do | 2 | 120,000 | |
| San Eugenio y Eduarda | do | Rio Abra | Cervantes | do | 2 | 120,000 | |
| San Fernando y San Isidro | do | Gubasan | Mancayan | do | 2 | 120,000 | Federico Lopez Pascual. |
| Encarnación | do | Deplás | Sagada | Bontoc | 2 | 120,000 | Saturnino Villaverde. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Capunga | do | Lusong | Tublay | Benguet | 2 | 120,000 | |
| Tabio | do | La Trinidad | do | do | 1 | 60,000 | Pablo Emilio Herrmann. |
| Acupan | do | Acupan | Itogon | do | 1 | 60,000 | |
| Nameless, known as Santa Bárbara | Copper | Arroyo Magambang | Mancayan | Lepanto | a 2 | 83,848.62 | Cántabro Filipina Co., now Venancio Balbás. |
| Cántabro Filipina, known as Santa Lucía. | do | do | do | do | a 2 | 83,848.62 | |
| De Hison | Iron | Sapang Bacal | Angat | Bulucán | a 1 | 111,798.16 | Hison's heirs. |
| Santa Lutgarda | do | Pinugayan | do | do | 1 | 150,000 | Anchuelo's heirs. |
| Constancia | do | do | do | do | 2 | 300,000 | Francisca Talag. |
| De Concha | do | Sapang Bacal | San Miguel de Mayumo. | do | a 2 | 125,772.93 | Conche's heirs. |
| San Pio V | do | do | do | do | 2 | 300,000 | Pablo Carlos. |
| Sapang Munti | do | Mantamuro | Angat | do | 1 | 150,000 | Francisco Sanchez. |
| Santa Rosalía | Sulphur | Monti Caibirán | Caibirán | Leyte | 2 | 120,000 | Prudencio Ruiz. |
| San Antonio | do | Cajúcao | Naval | do | 1 | 60,000 | |
| San José | Coal | Nabangig | Cataingan | Masbate | 4 | 600,000 | José Muños. |
| Santa Cruz | do | do | do | do | 4 | 600,000 | José Muños de Bustillo. |
| Magallanes | do | Bairán | Danao | Cebú | 2 | 300,000 | New Langreo Mining Co |
| Nueva Langreo | do | Manganas-anas | do | do | 2 | 300,000 | |
| Cebuana | do | Silangon | do | do | 2 | 300,000 | |
| Portiella | do | Bairan | do | do | 2 | 300,000 | |
| La Mestiza | do | Tugonón | do | do | 1 | 150,000 | |
| Ángeles | do | Licos | Compostela | do | 12 | 1,800,000 | Ramón Montañés. |
| San Julián | do | Silí | Danao | do | 8 | 1,200,000 | New Langreo Mining Co. |
| Santa María | do | Panian | Semerara | Mindoro | 2 | 300,000 | Antonio de Tribar. |
| Carolina | do | Siay | Bulalácao | do | 4 | 600,000 | Rafael Cascarosa y Martinez. |
| San Armando | do | Napisian | do | do | 4 | 600,000 | |
| San Rafael | do | Siay | do | do | 4 | 600,000 | |
| San Claudio | do | Napisian | do | do | 4 | 600,000 | |
| San Joaquín | do | Siay | do | do | 4 | 600,000 | |
| San Ramón | do | do | do | do | 4 | 600,000 | |
| San Clemente | do | Napisian | do | do | 4 | 600,000 | |
| Prudencia | do | do | do | do | 4 | 600,000 | |
| San Enrique | do | Tag-angilan | Compostela | Cebú | 4 | 600,000 | Ramón Montañés. |
| Rafael Reyes | do | Lupá | do | do | 2 | 300,000 | |

a Old.

*Mining concessions in force in the Philippine Islands on August 17, 1897*—Continued.

| Name of mine. | Mineral exploited. | Locality. | Township. | Province or district. | Number of claims. | Area in square meters. | Grantees. |
|---|---|---|---|---|---|---|---|
| Balerma | Coal | Pututan | Bacón | Sorsogón | 1 | 150,000 | Villanueva & Co. |
| Urgera | do | Bencalon | do | do | 1 | 150,000 | |
| Ganalda | do | Liguan | do | do | 1 | 150,000 | |
| San Francisco | do | do | do | do | 4 | 600,000 | Emilio Muñoz. |
| Perseverancia | do | Malabog | do | do | 1 | 150,000 | Villanueva & Co. |
| Sodupe | do | Napisay | do | do | 2 | 300,000 | Jacinto Gil y Gorroño. |
| Bilbao | do | Calanaga | do | do | 4 | 600,000 | |
| Lucus y Josefa | do | Caticatigahan | do | do | 1 | 150,000 | |
| Chifladura | do | do | do | do | 1 | 150,000 | |
| Presentación | do | Saburi | do | do | 2 | 300,000 | |
| Olaveaga | do | Aguis | do | do | 2 | 300,000 | |
| Carlota | do | Camansi | Danao | Cebú | 1 | 150,000 | Nueva Langreo Co. |
| Alfonso XIII | do | Actini | Toledo | do | 4 | 600,000 | Cornelio Roberto Blair Pickford. |
| María Cristina | do | Tidiong | do | do | 4 | 600,000 | |
| Progreso | do | Canlumampao | do | do | 2 | 300,000 | |
| Reina Regente | Petroleum | do | do | do | 2 | 300,000 | |
| Langob | Guano | Taguaya | Catmon | do | 2 | 300,000 | Ramón Montañés. |
| Santo Domingo Quarry | Marble | Sablayan | Montalban | Manila | 2 | 300,000 | Marcelo Dominguez. |
| Santa Matilde Quarry | do | May-Putí | Binangonan | Mórong | 2 | 300,000 | Ángel Tapia y Aragonés. |
| Santa Rosa Quarry | do | Mag-Manga | do | do | 2 | 300,000 | Fausto Tabotabo. |
| Do | do | Panahicon | Tuburan | Cebú | 2 | 300,000 | |
| Alfa Quarry | Kaolin | Lupang-Putí | Los Baños | Laguna | 2 | 300,000 | José Martín y Martinez. |
| Beta Quarry | do | do | do | do | 2 | 300,000 | |
| Delta Quarry | do | do | do | do | 2 | 300,000 | |
| Epsilon Quarry | do | do | do | do | 2 | 300,000 | |

*List of mines staked out after the above date, the titles of which are conceded and which only await registration in the general office of the treasury (hacienda).*

| Name of mine. | Mineral exploited. | Locality. | Township. | Province or district. | Number of claims. | Area in square meters. | Grantees. |
|---|---|---|---|---|---|---|---|
| San Rafael | Gold | Tigbí | Mambulao | Ambos Camarines | 2 | 120,000 | Aguedo Macandog. |
| Santa Balbina | do | Bulalácao | do | do | 2 | 120,000 | Catalino Flores. |
| La Concepción | do | Ibaba ng̃ Bulalacao | do | do | 2 | 120,000 | |
| San Nicolás | do | Gajugaju | do | do | 2 | 120,000 | |
| Ángeles | Coal | Tugnon | Compostela | Cebú | 8 | 1,200,000 | Ramón Montañés. |
| Alfonso XIII | Petroleum | Su-uy | San Isidro | Leyte | 1 | 150,000 | Smith, Bell & Co. |
| Alegría | do | Talayong | Alegría | Cebú | 1 | 150,000 | |
| La Esperanza | Gold | Cansuran | Surigao | Surigao | 52 | 3,120,000 | Williams Urquhart. |
| María y Leopolda | do | Tinabigan | Placer | do | 2 | 120,000 | José Cortés Dominguez. |
| Mundaca | do | Centuan | do | do | 2 | 120,000 | |
| Andres y Agustina | do | Isla Campiña | do | do | 1 | 60,000 | |
| Viscaya | do | Uacatan | do | do | 2 | 120,000 | |
| Castilla | do | Tinopan | do | do | 2 | 120,000 | |

# PROVINCIAL INDEX.

The following index is intended to enable the reader to collate the statements contained in the foregoing paper by provinces or districts, each locality mentioned there being represented here by a page reference opposite the province to which it belongs. In order to facilitate geographical acquaintance with the archipelago, the index gives also the name of the capital town of each province or district and the latitude thereof, so that if a reader who is unfamiliar with the islands desires to know where to look for any province, the data here presented will give him the information.

The provincial divisions of the Philippines were of two classes, provinces being administered by civil governors and districts by "politico-military" governors who were army officers. The distinction is now unimportant excepting that, in reading, confusion may arise unless the system is understood.

The list of provincial divisions is that given in the Compendio de Geografía of the Jesuit Fathers, 1892, and is that found on most maps. More recently some changes were made by the Spanish Government, of which two should be known to the reader. They are the division of Albay into the two provinces of Albay and Sorsogón, the latter being the more southerly, and the union of Camarines Norte and Camarines Sur into the single province of Ambos Camarines. As the purpose of this index is to assist in the use of the maps of d'Almonte, Abella, and the Jesuits, it would be inexpedient here to adopt the recent changes in administration, which will soon be replaced by some system of American origin.

*Luzón and adjocent islands.*

| Province. | Capital. | Latitude of capital. | | Page references. |
|---|---|---|---|---|
| | | ° | ′ | |
| Albay | Albay | 13 | 8 | 11, 45, 47, 54, 71, 75, 83, 84, 97. |
| Bataan | Balanga | 14 | 42 | 28, 30, 32, 36. |
| Batangas | Batangas | 13 | 45 | 29, 38, 48, 53, 77, 78. |
| Bulacán | Bulacán | 14 | 48 | 12, 84, 105. |
| Cayagán | Tuguegarao | 17 | 37 | 54, 83, 97. |
| Camarines N | Dáet | 14 | 5 | 12, 17, 84, 91, 92, 103, 104, 105. |
| Camarines S | Nueva Cáceres | 13 | 37 | 17, 18, 31, 35, 47, 71, 103, 104. |
| Ilocos N | Laoag | 18 | 13 | |
| Ilocos S | Vigan | 17 | 34 | 15. |
| Isabela | Ilagan | 17 | 8 | 16, 66, 73. |
| Laguna | Santa Cruz | 14 | 17 | 9, 25, 35, 47, 48, 77, 105, 107. |
| Manila | Manila | 14 | 36 | 10, 12, 13, 14, 35, 53, 76, 84, 107. |
| Mindoro | Calapan | 13 | 24 | 11, 12, 18, 45, 53, 71, 85, 97, 104. |
| Nueva Écija | San Isidro | 15 | 18 | 12, 15, 91. |
| Nueva Vizcaya | Bayombong | 16 | 27 | 15. |
| Pampanga | Bacolor | 15 | | 29, 31, 35, 53. |
| Pangasinán | Lingayén | 16 | 4 | 12, 35, 38. |
| Tayabas | Tayabas | 14 | 1 | 17, 38, 71, 83, 84, 103. |
| Unión | San Fernando | 16 | 38 | 15, 16, 41, 53, 72, 83. |
| Zambales | Iba | 15 | 21 | 12, 13, 14, 97. |

| District. | Capital. | Latitude of capital. | | Page references. |
|---|---|---|---|---|
| | | ° | ′ | |
| Abra | Bangued | 17 | 37 | 14, 83, 91. |
| Batanes | Santo Domingo de Basco | 21 | 7 | 54. |
| Benguet | Trinidad | 16 | 30 | 15, 16, 72, 73, 76, 91, 103. |
| Bontoc | Bontoc | 17 | 13 | 15, 32, 35, 36, 91. |
| Cavite | Cavite | 14 | 29 | 53. |
| Corregidor | San José | 14 | 23 | 28, 30, 32, 53. |
| Infanta | Binangonan de Lampong | 14 | 48 | 12, 17, 23, 84, 97. |
| Lepanto | Cervantes | 17 | 1 | 15, 35, 36, 54, 91, 98. |
| Mórong | Mórong | 14 | 31 | 7, 14, 31, 35, 36, 65, 73, 76, 84, 105. |
| Príncipe | Baler | 15 | 47 | |
| Tárlac | Tárlac | 15 | 30 | 13, 35, 36, 74. |

*Central Islands, or Visayas.*

| District. | Capital. | Latitude of capital. | Page references. |
|---|---|---|---|
| | | ° ′ | |
| Antique | San José de Buenavista | 10 44 | 12, 18, 19, 26, 32, 35, 36, 104. |
| Bohol | Tagbilaran | 9 38 | 11, 35, 44, 77, 79, 97. |
| Burias | San Pascual | 13 8 | 11. |
| Calamianes | Cuyo | 10 52 | 10, 18, 77, 80. |
| Cápiz | Cápiz | 11 35 | 85, 94, 97. |
| Cebú | Cebú | 10 18 | 11, 12, 19, 20, 21, 26, 28, 35, 37, 44, 65, 66, 74, 75, 78, 79, 80, 86, 94, 105, 107. |
| Concepción | Concepción | 11 13 | 19. |
| Iloilo | Iloilo | 10 42 | 71, 74, 80, 85, 94, 107. |
| Leyte | Tacloban | 11 15 | 11, 12, 18, 21, 29, 37, 44, 71, 89, 94, 107. |
| Masbate | Masbate | 12 24 | 11, 60, 71, 80, 85, 97, 103. |
| Negros Occidental | Bacólod | 10 42 | 19, 28, 36, 70, 74, 78, 86. |
| Negros Oriental | Damaguete | 9 20 | 11, 26, 27, 28, 37, 43, 78, 86, 98. |
| Romblón | Romblón | 12 34 | 11, 107. |
| Sámar | Catbalogan | 11 48 | 10, 12, 18, 44, 71, 73, 85, 94, 104. |

*Mindanao, Joló, and Palawan.*

| District. | Capital. | Latitude of capital. | Page references. |
|---|---|---|---|
| | | ° ′ | |
| Balábac | Balábac | 7 59 | 11, 80, 104. |
| Basilan | Isabela de Basilan | 6 45 | 25, 78. |
| Cottabato | Cottabato | 7 15 | 9, 42, 90. |
| Dávao | Dávao | 7 2 | 22, 37, 40, 41, 90. |
| Joló | Joló | 6 5 | 11, 37, 40, 73, 76, 78, 80, 98. |
| Misamis | Cagayán de Misamis | 8 30 | 12, 21, 22, 27, 37, 42, 44, 61, 72, 73, 90, 95. |
| Paragua | Puerto-Princesa | 9 45 | 23, 44, 54, 75, 77, 79, 80. |
| Surigao | Surigao | 9 48 | 8, 12, 21, 22, 37, 61, 71, 90, 95, 98, 104. |
| Zamboanga | Zamboanga | 6 57 | 22, 37, 65, 71, 74, 77, 79, 90. |

# CONCERNING TERTIARY FOSSILS IN THE PHILIPPINES.

By K. MARTIN.[1]

The occurrence of Tertiary deposits in the Philippines has long been known. As early as 1861 F. von Richthofen[2] reported on nummulites which he had discovered in limestones in place, close to the village of Binangonan, on Bay Lake, not far from Manila. R. von Drasche[3] represented these Eocene limestones, which also appear at various other points north of Binangonan, on his geological sketch map of southern Luzón; and von Richthofen furthermore expressed his opinion that the well-developed series of strata in the mountains of Zamboanga, on the southwest coast of Mindanao, likewise belong to the nummulite formation.

C. Semper collected a great number of fossils in the Philippines, but, while the rocks brought back by this naturalist have been worked up by K. Oebbeke,[4] the fossils have remained undescribed. Nevertheless, it was not unknown to Semper that these latter, at least in part, came from Tertiary strata, for he says: "Against this trachytic core (of the Philippines) lie numerous sedimentary strata at various elevations. They are fossiliferous sandstones and shales, whose mussels and snails are in part still found living in the surrounding seas. They surely, therefore, belong to a very recent period." Further on it is remarked, concerning the highest coral reefs, standing at elevations far above sea level, that "they seem to belong as far back as the Tertiary."[5]

J. Roth,[6] who, in 1873, compiled all the information then available, came to this conclusion: "In the Philippines, on a formation of crystalline schists, lie strata which are in part certainly Tertiary (Eocene), and abundant younger beds, raised banks, and coral reefs which contain mollusca of species still surviving in the Pacific." Shells from a

[1] Sammlungen des geologischen Reichs-Museums in Leiden, Vol. V., 1896, pp. 53–69. Translated by Mr. George F. Becker as a complement to his paper, published herewith, on the Geology of the Philippine Islands.

[2] Ueber das vorkommen von Nummulitenformation auf Japan und den Philippinen: Zeitschr. Deutsch. geol. Gesell., Vol. XIV, 1862, p. 357.

[3] Fragmente zu einer Geologie der Insel Luzón, mit einem Anhange über die Foraminiferen der tertiären Thone von Luzón von Felix Karrer, Wien, 1878.

[4] Beiträge zur Petrographie der Philippinen und der Palau-Inseln: Neues Jahrbuch für Mineral., Geol., Palæont., Beilage-Band I, p. 451.

[5] C. Semper, Die Philippinen und ihre Bewohner, Sechs Skizzen, Würzburg, 1869, p. 17.

[6] Ueber die geologischen Beschaffenheit der Philippinen: In F. Jagor, Reisen in den Philippinen, Berlin, 1873, p. 333.



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bank on the west side of the peninsula of Jalajala, in Bay Lake, were determined by von Martens as belonging exclusively to recent species. On the other hand, extinct as well as living species, according to the same naturalist, occur in yellowish-gray clays which lie near Paranas, on the west coast of Sámar. Banks of recent shells, however, were found also both at Paranas and on the south coast of Sámar, near Basey and Nipa-Nipa.[1]

The occurrence of Miocene in the Philippines was first established by Karrer through investigation of Foraminifera which came from the western slope of the Sierra Zambales on the western coast of northern Luzón. There occur "tuffaceous Foraminifera-bearing marls up to altitudes of 400 feet along the sea coast between Palauig and Santa Cruz, and perhaps still farther north."[2] These marls are compared by Karrar with those from Java and elsewhere. He reached the conclusion that the marls in question are younger than certain Javanese beds which at that time had already been assigned to the Miocene, but he calls attention to the fact "that the difference in age need not be considered so great as to necessitate assignment to different divisions of the Tertiary, since they probably represent only older and younger horizons." Accordingly, Karrer correlates the marls of the Sierra Zambales as younger Miocene.[3]

R. von Drasche pursued the comparison between the strata of Luzón and the Javanese Tertiary still further, taking as his basis the division of the strata of Java given by F. von Hochstetter.[4] He says: "The thick tuffs of northern Luzón may be included in group *a* of the Miocene (of von Hochstetter). In this group, too, are to be mentioned the foraminiferous marls of the Sierra Zambales. To group *b* belong the coral reefs of Luzón, which, in Luzón, and no doubt also in Java, may be characterized as Pliocene." It must be explicitly mentioned, however, that the Foraminifera determined by Karrer furnish the only paleontological evidence for these age determinations by von Drasche, so that, except so far as they apply to the marls of the Sierra Zambales, they must be characterized as mere suppositions.

Th. Fuchs investigated ill-preserved remains from the same coralline limestones of Luzón which were considered by von Drasche, according to the statements cited above, as probably Pliocene. According to this authority "the forms could all be referred to living species, and, indeed, without forcing matters at all." Fuchs says: "In fact, there is no objection to regarding them as entirely Recent."[5] In harmony with this statement Semper[6] mentions that in the hills of Aringay, northwest Luzón, he found a coral which is closely related to *Heteropsammia rotundata* Semp.

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[1] Roth, loc. cit., pp. 342, 352, 353. [2] R. von Drasche, loc. cit., p. 21. [3] Ibid, p. 84.
[4] Reise der östereichischen Fregatte *Novara* um die Erde, geolog. Theil, Vol. II, 1866, p. 149.
[5] R. von Drasche, loc. cit., p. 42.
[6] Ueber Generationswechsel bei Steinkorallen, etc.: Zeitschr. für wiss. Zoologie, Vol. XXII, 1872. p. 266.

The foregoing gives an account, I believe, of everything which is thus far known of Tertiary fossils in the Philippines. As is apparent, this is to all intents confined to the Nummulites from the neighborhood of Manila, and to the Foraminifera from the Sierra Zambales of northwestern Luzón. Even on that account the fossils which were collected by Semper, and which, after the death of that tireless naturalist, came into the possession of the Leiden museum would excite special interest. They acquire a greater importance from their localities, for a large part of them come from regions which were visited neither by Jagor nor by von Drasche, and which, indeed, have never been geologically investigated at all.

Now, in reviewing Semper's collection, I was at once struck with *Vicarya callosa* Jenk., which is known from Java and is described in detail below; and this induced me to make a closer comparison between the fossils of the Philippines and those of the Indian Archipelago, whereby it at once became apparent that a whole series of species, especially of the Javanese Tertiary, is common to both regions. Thus far, indeed, I have been unable to make a complete study of Semper's collection, and for the time being it has little further interest, because statements as to stratigraphical position are entirely lacking and the equivalent deposits of neighboring regions are still very insufficiently known. After completion of my monograph on the fossils of Java, however, I hope to undertake a more thorough study of the Philippine fossils, and to supplement this preliminary communication.

The species of the Semper collection which have thus far been determined are as follows:

| | Occurrence elsewhere. |
|---|---|
| Terebra Jenkinsi K. Mart. (Foss. von Java, p. 8) | M. |
| Terebra bandongensis K. Mart. (Foss. von Java, p. 10) | M. |
| Conus sinensis Sow. (Foss. von Java, p. 13) | P; L. |
| Conus insculptus Kien. (Foss. von Java, p. 14) | M; L. |
| Conus palabuanensis K. Mart. (Foss. von Java, p. 16) | J. |
| Conus Loroisii Kien. (Foss. von Java, p. 21) | M; P; L. |
| Pleurotoma gendinganensis K. Mart. (Foss von Java, p. 32) | P. |
| Pleurotoma carinata Gray (Foss. von Java, p. 37) | P; L. |
| Pleurotoma coronifera K. Mart. (Foss. von Java, p. 38) | E. (?); M. |
| Pleurotoma neglecta K. Mart. (Foss. von Java, p. 42) | M. |
| Turricula bataviana K. Mart. (Foss. von Java, p. 78) | P. |
| Fusus Verbeeki K. Mart. (Foss. von Java, p. 85) | M; P. |
| Latirus madiunensis K. Mart. (Foss. von Java, p. 88) | P. |
| Pyrula gigas K. Mart. (Foss. von Java, p. 90) | M. |
| Tritonidea ventriosa K. Mart. (Foss. von Java, p. 99) | M. |
| Nassa Verbeeki K. Mart. (Foss. von Java, p. 110) | P. |
| Murex Verbeeki K. Mart. (Foss. von Java, p. 123) | P. |
| Murex djarianensis K. Mart. (Foss. von Java, p. 124) | M. |
| Murex brevispina Lam. (Foss. von Java, p. 126) | M. (?); P; L. |
| Murex pinnatus Wood. (Foss. von Java, p. 127) | M; L. |
| Murex microphyllus Lam. (Foss. von Java, p. 127) | M; L. |
| Murex capucinus Lam. (Foss. von Java, p. 123) | —; L. |

| | Occurrence elsewhere. |
|---|---|
| Murex Grooti Jenk. (Foss. von Java, p. 131) | M. |
| Ranella spinosa Lam. (Sammlg. I, p. 201) | M; L. |
| Ranella elegans Beck. (Sammlg. III, p. 137) | M; L. |
| Ranella raninoides K. Mart. (Sammlg. I, p. 203) | M. |
| Ranella gyrina Linn. (not yet known from Java) | —; L. |
| Cypraea Smithi K. Mart. (Sammlg. III, 141) | M. |
| Strombus isabella Lam. (Notes Leyden Mus. III, p. 19) | Q; L. |
| Rostellaria Javana K. Mart. (Tertsch. Java, p. 50) | M. |
| Vicarya callosa Jenk. (Tertsch. Java, p. 62) | M. |
| Potamides Jenkinsi K. Mart. (Sammlg. III, p. 147) | P. |
| Turritella terebra Lam. (Sammlg. III, p. 171) | Q; L. |
| Natica mamilla Lam. (Tertsch. Java, p. 81) | M; L. |
| Arca granosa Linn. (Sammlg. III, p. 242) | P; L. |
| Cardita decipiens K. Mart. (Tertsch. Java, p. 110) | P. |
| Venus squamosa Lam. (Sammlg. III, p. 207) | P; L. |
| Clementia papyracea Gray (Tertsch. Java, p. 99) | M; P; L. |
| Corbula scaphoides Hinds. (Sammlg. III, p. 196) | M; P; L. |
| Callianassa Dyki K. Mart. (Sammlg. III, p. 36) | M; Q. |

The appended initials indicate the occurrence of the species in the Tertiary of other parts of the Indian Archipelago, as well as among the fauna of the present day. Thus E denotes Eocene; M, Miocene; P, Pliocene; J, later Tertiary in general; Q, Quaternary; L, living species.

The above-mentioned fossils are distributed among the following localities:

I. LUZÓN.

*1. Minanga; right bank of the Catalangan.*

| | | | |
|---|---|---|---|
| Fusus Verbeeki Mart. | M; P. | Rostellaria javana Mart | M. |
| Tritonidea ventriosa Mart. | M. | Vicarya callosa Jenk | M. |
| Murex brevispina Lam. | M. (?); P; L. | Natica mamilla Lam | M; L. |
| Murex pinnatus Wood | M; L. | Cardita decipiens Mart | P. |
| Ranella raninoides Mart. | M. | Venus squamosa Lam | P; L. |

*2. Minanga; right bank of the Ilaroen.*

| | | | |
|---|---|---|---|
| Terebra Jenkinsi Mart | M. | Ranella gyrina Linn. | L. |
| Terebra bandongensis Mart. | M. | Rostellaria javana Mart | M. |
| Fusus Verbeeki Mart. | M; P. | Vicarya callosa Jenk | M. |
| Murex Grooti Jenk | M. | Cardita decipiens Mart | P. |

*3. Right bank of the Ilaroen; 4 miles above Minanga.*

| | | | |
|---|---|---|---|
| Fusus Verbeeki Mart. | M; P. | Rostellaria javana Mart | M. |
| Murex brevispina Lam. | M. (?); P; L. | Natica mamilla Lam. | M; L. |
| Ranella raninoides Mart. | M. | | |

*4. Left bank of the Ilaroen; 1¼ miles above Goroen.*

| | | | |
|---|---|---|---|
| Murex djarianensis Mart. | M. | Ranella spinosa Lam | M; L. |
| Murex brevispina Lam. | M. (?); P; L. | Potamides Jenkinsi Mart | P. |
| Murex microphyllus Lam. | M; L. | Natica mamilla Lam | M; L. |
| Murex Grooti Jenk | M. | Cardita decipiens Mart | P. |

*5. Left bank of the Ilaroen; 4 miles above Goroen.*

Conus sinensis Sow..... P; L.
Conus palabuanensis Mart ..... J.
Fusus Verbeeki Mart..... M; P.
Ranella gyrina Linn ..... L.

*6. Foothills in front of Aringay.*

Conus Loroisii Kien..... M; P; L.
Pleurotoma gendinganensis Mart..... P.
Nassa Verbeeki Mart..... P.
Natica mamilla Lam ..... M; L.

*7. Hills close to Aringay.*

Pleurotoma carinata Gray..... P; L.

*8. Dicamui Brook.*

Vicarya callosa Jenk..... M.

*9. Satput.*

Cypraea Smithi Mart..... M.
Rostellaria javana Mart ..... M.

II. MINDANAO.

*1. Left bank of Agúsan River at Tagasáp.*

Latirus madiunensis Mart ..... P.
Murex microphyllus Lam ..... M; L.
Ranella raninoides Mart..... M.
Ranella gyrina Linn..... L.
Turritella terebra Lam ..... Q; L.

*2. Agúsan River between Pagasáp and Libuton.*

Turritella terebra Lam..... Q; L.
Venus squamosa Lam..... P; L.

*3. Maasin on the Agúsan.*

Conus insculptus Kien ..... M; L.
Turricula bataviana Mart..... P.
Murex Verbeeki Mart..... P.
Natica mamilla Lam ..... M; L.

*4. Salac y Maputi River.*

Murex Verbeeki Mart..... P.
Strombus isabella Lam ..... Q; L.
Natica mamilla Lam ..... M; L.
Arca granosa Linn ..... P; L.
Clementia papyracea Gray.... M; P; L.
Corbula scaphoides Hinds.... M; P; L.

*5. Zamboanga, river bank 2½ miles north of Zamboanga, upper stratum.*

Murex capucinus Lam..... L.

III. CEBÚ.

*Coal mines at Alpaco.*

Vicarya callosa Jenk..... M.

For a considerable number of species the exact localities are unfortunately entirely unknown. These are *Pleurotoma coronifera* Mart., *Pl. neglecta* Mart., *Pyrula gigas* Mart., *Ranella elegans* Beck., and *Callianassa Dyki* Mart.

The most interesting of these fossils are those collected from the bank of the Catalangan River and the Ilaroen. These are two small streams which at Minanga empty into the Ilagan, a right-hand tributary of the Rio Grande de Cagayán, which debouches on the north coast of Luzón. The Catalangan, "a narrow mountain torrent," is the less important and flows from the east. The Ilaroen comes from the south.[1] Unfortunately Semper's notes on his journey in this neighborhood bear the impress of haste. Lack of food and illness prevented exact observations, and consequently his report contains no precise information as to the localities of the Tertiary fossils from the Catalangan and the Ilaroen.

Among these fossils *Vicarya callosa* Jenk. is of the utmost importance, because this characteristic genus, of which only two species are known, may be considered as a good guide-fossil to the tropical Miocene. For *V. callosa* Jenk. has hitherto been found only in the upper Miocene of Java, and *V. Verneuili* d'Arch. occurs only in the Gaj series of western India, which also belongs to the Miocene. According to this indication, there would be Miocene beds in place both on the bank of the Catalangan and on that of the Ilaroen. The other fossils from the same localities are in complete harmony with this supposition. From the right bank of the Catalangan, as appears in the list given, there are in the collection 10 species, of which 6 are extinct, 8 are known in the Miocene (unquestionably), and 4 have hitherto been found only in the Miocene deposits of the Indian Archipelago. From the right bank of the Ilaroen at Minanga 8 species have been determined, among which only 1 is still living, while 6 occur in the Miocene, and 5 of these exclusively in the Miocene. Each of the localities, even taken by itself, thus points unambiguously to the occurrence of the Miocene near Minanga, and it may be considered as beyond question that the strata of the two localities are coeval. On this assumption all the fossils of Minanga may be regarded as a single group. This method of dealing with the subject gives 14 different species, of which 9, or 36 per cent,[2] are extinct, 11 are Miocene, and 7 are exclusively Miocene. Judging from all these facts, the strata at Minanga are to be classed with the upper Miocene bed which exists in Java in the locality denoted by Junghuhn by *O* and at Selatjau on the Tji Longan.

It is also presumable that the remaining fossils which were collected from the bank of the Ilaroen above Minanga and Goroen (Nos. 3 to 5 of the above list) were taken from upper Miocene strata. Further-

[1] Compare the map in Semper's Philippinen, and, further, Semper's journey through the northeast provinces of the Island of Luzón: Zeitschr. für allg. Erdkunde, Neue Folge, Vol. X, 1861, pp. 256–258. In the latter paper one of the streams is called Ilagon or Ilaron, but both on the labels and on Semper's map it appears as Ilaroen, so that I must consider this last form the correct one. [On Mr. d'Almonte's map, Semper's Minanga seems to be represented by Malunú. The stream from the east is called Catalangan, but that from the south is put down as Tarretic. Polynomial streams form an abiding source of confusion throughout the Philippines.—G. F. B.]

[2] This should read 36 per cent still alive or 64 per cent extinct.—G. F. B.

more, there must be such also on the brook Dicamui, since thence also comes a specimen of *Vicarya callosa*. Unfortunately I was unable to determine certainly where this brook is, yet it is presumably identical with the Dicamuni, which flows, according to Oebbeke, "in the land of the Minangas on the west side of the cordillera of northwest Luzón."[1] The same typical fossil of the upper Miocene, *Vicarya callosa*, occurs finally at the coal mines of Alpacó, on the island of Cebú, to the north of Mindanao. These mines lie in the interior of the island, in a southwesterly direction from the town of Cebú and to the northwestward of Naga.

Abella y Casariego, who has drafted a general geological map of Cebú,[2] divides the rocks into a core of eruptives and superimposed strata of the Nummulite formation, post-Pliocene limestone, and finally Recent alluvium. The determination of the post-Pliocene strata depends upon a thorough investigation of the remains found in them, of which twenty-nine could be identified with living species, while no extinct species whatever were found.[3] Paleontological proof is also given for the existence of the Nummulite formation,[4] but it must be regarded as very questionable whether the entire system of strata[5] considered as belonging to it ought to be regarded as Eocene. That at least a part of this system must be excluded is proved by Semper's find; for according to the map of Abella y Casariego the mines of Alpacó, at an elevation of 298 meters, are also in the Eocene, which, as shown above, is incorrect. The strata which contain *Vicarya callosa*, however, seem to be the same which have attracted the attention of the Spanish naturalist and which crop out on the slope of Sibod. In fact, according to Abella, the limestones at this point are covered by a fossiliferous marl which can not be classed with them either on petrographical grounds or by its fossils.[5] Although the conditions are not described with the clearness which would be desirable, it must be considered very probable that, in this region of Cebú, Eocene limestones are overlain by Miocene marls.

In addition to the localities already dealt with, the neighborhood of Aringay in Luzón requires attention first of all. This place lies in the northwestern portion of the island, on the northeast coast of Lingayén Bay, and Semper visited it from the capital of the district of Benguet,[6] which is likewise called Benguet, or, also, La Trinidad. It

[1] Ibid., p. 498. [I have heard of no tribe of Minangas. According to Semper's text and his map, Minanga is in "the land of the Irayas," a well-known tribe in the Province of Isabela. The probabilities are strongly in favor of the hypothesis that Dicamui or Dicamuni is a brook near the Catalangan, and that in the phrase quoted from Oebbeke northeast should be substituted for northwest. In Ilocos I can find no suggestion of similar names, and Semper correctly labels that part of the country "land of the Igorrotes." Minanga is one of the few names entered on Semper's map in northern Luzón.—G. F. B.]

[2] D. Enrique Abella y Casariego. Rapida descripción física, geológica y minera de la Isla de Cebú, Madrid, 1886.

[3] Ibid., p. 125. [4] Ibid., p. 109. [5] Ibid., p. 114.

[6] Reisen durch die nördlichen Provinzen der Insel Luzón: Zeitschr. für allg. Erdkunde, 1862, p. 86.

is in this sense that his descriptive terms "foothills in front of Aringay" (Vorhügel vor A.) and "hills close to Aringay" (nächster Hügel von A.) are to be understood, since they manifestly indicate a reference to the road followed. According to von Drasche, a range of hills, 200 to 300 feet in height, lies between Aringay and the sea, following the narrow strip of alluvium which accompanies the coast. This range is steep on the side toward the sea, and at the point in question is composed of light-yellow earthy tuff. Layers of tuff are also exposed, according to this authority, at many points between Aringay and Benguet,[1] but these tuffs toward the interior, even at Galiano, are "no longer earthy, but quite hard, crystalline and sandstone like." Probably on this account Semper states[2] that sandstones form the entire western slope of the Cordillera from Benguet to Aringay, but he particularly states that this rock, "at all events the upper strata of it, is absolutely devoid of fossils." The *Heteropsammia* already mentioned, which Semper collected, can not, therefore, come from the neighborhood of Galiano, as von Drasche supposed. They can come only from the range of hills parallel with the shore near Aringay, from which also the fossils that I have determined, embedded in a dirty, gray, sandy marl, must also have been derived. This range of hills at Aringay, then, must belong to the later Tertiary, as the fossils enumerated prove, and the conditions suggest that they may be coeval with the strata which are developed as tuffaceous marls along the seacoast between Paláuig and Santa Clara, claimed by Karrer as late Tertiary. The fossils thus far identified, however, are insufficient to determine whether the sediments of Aringay are referable to the Miocene or the Pliocene.

The position of Satpat, on Luzón, from which two Miocene fossils mentioned above were obtained, I have unfortunately been unable to ascertain.

As for Mindanao, it can not be demonstrated from specimens which have been investigated that Miocene strata occur there, for I have but a single species, *Ranella raninoides* Mart., which is known only in the Miocene.[3] On the other hand, it is clear that there are upper Tertiary beds along the Agusan River. If it were permissible to assume that all the fossils of the list given above originated in equivalent beds,

[1] Fragmente, pp. 29–31.

[2] Ibid., p. 84. [Abella asserts positively that these rocks are sandstones derived from a dioritic area. Terremotos experimetados en la Isla de Luzón durante . . . 1892, Manila, 1893, p. 33.—G. F. B.]

[3] Marine Miocene is assumed, however, by Casariego in Mindanao, in his Memoria acerca de los criaderos auríferos del segundo distrito de Mindanao: Bol. de Comisión del Mapa geológ. de España, Vol. VI, Madrid, 1879. This paper, which is noticed in Neues Jahrbuch, 1883, I, p. 355, I have unfortunately been unable to consult, and on what grounds the determination of the strata in question as Miocene rests is not inferable from the notice. [Abella, whose mother's maiden name was Casariego, relied chiefly on the petrographical character and geognostic position of these beds in referring them provisionally to the middle Tertiary. In the limestones of the hills surrounding Pigtao, on the Iponan River, he found imperfect fossils, including one which he thought himself justified in referring to the genus *Turbinolia*, Loc. cit., pp. 35, 46.—G. F. B.]

and their state of preservation makes this probable, there would be in all 10 species, 6 of them, or 60 per cent, still living; 4 species occur in the Miocene and the same number in the Pliocene; but of these last three are known only from the Pliocene. These are *Latirus madiunensis* Mart., *Turricula bataviana* Mart., and *Murex verbeeki* Mart. All this argues the occurrence of the Pliocene on the Agusan River, and in harmony with this indication is the exceedingly fresh appearance of the fossils at hand.

The same age finally may be ascribed to the fossils from the river Salac y Maputi in Mindanao; for although of the 6 species determined from this locality no fewer than 5 belong to the present fauna, yet of these latter 4 reach back to the Miocene and Pliocene and a single species, *Murex verbeeki* Mart., is known only in the Pliocene. Of the deposit at Zamboanga nothing definite can be said as yet on the strength of the solitary fossil *Murex capucinus* Lam.

To the age determinations of Philippine fossils it is proper to add that their state of preservation resembles that of the Javanese fossils to a very remarkable extent—to such a degree, indeed, that the specimens from the two regions might easily be confounded. The same statement is true of the tuffs and marls in which they were embedded, and this accords with the fact that the younger massive rocks of the Philippines show an extraordinary likeness to those of the East Indian Archipelago.[1]

Collecting the results of the investigations thus far made, we get the following general scheme for the fossil-bearing strata of the Philippines:

### 1. Eocene.

To this formation belong the nummulitic limestones from the neighborhood of Manila (Luzón) and of Cebú. The same formation is perhaps developed at Zamboanga (Mindanao).

### 2. Upper Miocene.

(*a*) Tuffs and sandy marls which are equivalent to the upper Miocene of Java exist in the neighborhood of Minanga, in the valley of the Rio Grande de Cagayán (Luzón). Deposits of the same age are to be found also on the stream Dicamui, the position of which could not be ascertained, and finally at the coal mines of Alpacó (Cebú).

(*b*) Tuffaceous, foraminiferal marls from the western slope of the Sierra Zambales (Luzón), which are younger than the beds enumerated under *a*, and which possibly belong in the Pliocene. Perhaps equivalent to these are the masses of tuff which form the range of hills on the coast at Aringay (Luzón) and which certainly belong to the upper Tertiary.

[1] Roth, Ueber d. geolog. Besch. d. Philippinen, p. 338. Oebbeke, Beiträge, p. 453.

### 3. Pliocene.

The beds of the Agusan River (Mindanao) are Pliocene. It is probable that as such are also to be counted the hard, light-gray marls of the river Salac y Maputi (Mindanao) and the clay beds of Paranas (Sámar), as well as the older coral reefs of the Philippines, especially those of Benguet,[1] which are assuredly not older than the Pliocene.

### 4. Quaternary.

Quaternary are the shell banks which stand 15 feet above the level of Laguna de Bay (Luzón), and those on the beach at Paranas, and again on the south coast of Sámar, where, at Nipa-Nipa, these beds reach an elevation of 60 feet above sea level. Here, too, belong the fossil coral reefs, which are intimately connected with the living reefs and are widely distributed in the Philippines.[2] With them belong the recent limestones of Cebú.

### Vicarya callosa Jenk., var. nov. semperi.

Vicarya (?) callosa Jenk. Javan fossils: Quart. Jour. Geol. Soc. 1864, Vol. XX, p. 57, Pl. VII, fig. 5. Martin, Tertiärschicht. auf Java, p. 62, Pl. XI, fig. 3.

The turreted shell consists of flattened whorls, which are separated from one another by a distinct but not incised suture, and carry a number of sharply defined spiral beadings. Even on the older part of the shell five such beadings are visible, the last of which runs immediately in front of the after suture of the whorl, and is much stronger than the two beadings which lie immediately in front of it. Then follows a strong ridge, again succeeded by a very slender one on the anterior edge. On the younger parts of the shell sharp knots are situated on the last spiral of the whorls. They number eight to nine, and with the growth of the shell become modified into short, sharp prongs which stand at right angles to the axis of the shell. In front of this row of prongs, which accompanies the suture, only three spiral beadings are observable, of which the first two are the strongest, while the fifth spiral beading of the older turns is covered by the succeeding whorl. The incremental lines are smoothly but deeply bent into the shape of an S, in such a way that the deepest incurvation, corresponding to the incision of the exterior lip, lies between the two strong spiral beadings on the frontal termination of the whorls.

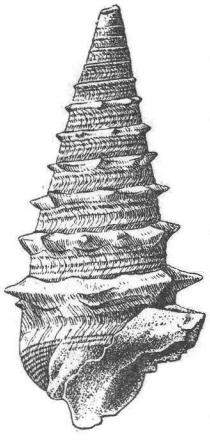

Fig. 103.—*Vicarya callosa* from Minanga.

The terminal whorl carries in front of the suture several more spiral beadings of variable strength. The canal is short and bent backward,

[1] Compare Semper, Zeitschr. für allg. Erdkunde, 1862, p. 84; and Philippinen, p. 18; also von Drasche, Fragmente, p. 31.

[2] For distribution see Semper, Philippinen, p. 18.

the pillar is provided with a distinct fold, the interior lips being swollen and thickened in such a way that the thickening on the left forms a half-moon-shaped swelling which rests on the terminal whorl and is prolonged as a tongue to the right. The exterior lip is not preserved, but, judging from the incremental lines, it has the same shape as in *V. Verneuili* d'Arch. The length of the largest complete individual is 74 mm., and this size, to judge from the material at hand, is rarely or never exceeded.

A slight variation from the foregoing usual development is brought about by the interpolation of a fine additional beading between the two spirals which include between them the incision of the outer lip. In other cases these spirals are inconspicuous at this point, while between the horns two longitudinal beadings are developed.

*V. callosa* Jenk. from Java is never provided with such prominent beadings as is the fossil here described, and only in very isolated cases is the sculpture of the latter feebly indicated on the former, so that the spiral sculpture of the Philippine fossil affords a good distinction. The Javanese form is also larger and stouter, and its prongs have a different character, while the callosity of the inner lip reaches farther back and here, as a rule, envelops a prong of the previous whorl. Nevertheless, the relationship of the fossil under discussion to the Javanese *V. callosa* Jenk. is so close that I can regard it only as a local variety of the latter.

FIG. 104.—*Vicarya callosa* from Dicamui Brook.

From *V. Verneuili* d'Arch. (Descript. d. anim. foss. de l'Inde, p. 298, Pl. XXVIII, fig. 4) it is easy to distinguish the Philippine form, as well as that from Java; for the species from British India, in addition to the principal row of knobs, bears spirals provided with delicate granules. Moreover, knobs along the suture of the younger portion of the shell are not transformed into prongs, as in the Javanese fossils, and still more in those from the Philippines; and finally, the callosity of the inner lip is differently shaped.

No other representatives of *Vicarya* are yet known, for the fossil which Hislop described as *V. fusiformis* Hislop (Foss. shells of Nagpur, Quart. Jour. Geol. Soc., Vol. XVI, p. 177, Pl. VIII, fig. 36) certainly can not be grouped with the species mentioned.

I have before me fourteen individuals and fragments of the Philippine variety of *V. callosa* Jenk., which I wish to call var. *Semperi*.

Fig. 1 comes from Minanga, from the right bank of the Catalangan.

Fig. 2 comes from the brook Dicamui in Luzón.[1]

Finished October, '95.

[1] These figures have been reduced to three-fourths the size of the original, to facilitate copying.—G. F. B.