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### THE GOLD DEPOSITS OF THE PHILIPPINE ISLANDS.<sup>1</sup>

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#### INTRODUCTION.

The Philippine Islands form a part of the series of curved island chains, festooning the eastern coast of the continent of Asia from the Andaman to the Aleutian Islands, and lie between 4° and 21° N. latitude. The number of the islands in the Philippine group is variously given as from one to two thousand, as it is difficult to make a distinction between true islands and rocks. The largest island, Luzon, has an area of about 122,000 sq. km., the second, Mindanao, about 94,000, and the total area of the Philippines exceeds 300,000 sq. km.

The great majority of the natives belong to branches of the Malay race; Mohammedans (Moros) in the south along the southern coast of Mindanao and in the Sulu Archipelago; Christian tribes of varying degrees of civilization in the coastal regions of the central and northern islands; and savage tribes in the interior highlands.

The islands were first known to Europe through Magellan's discovery in 1524, and were a Spanish colony until they came into American possession in 1898, as a result of the war with Spain. The natives had been in rebellion against the Spanish

<sup>1</sup> Published by permission of the Director, Bureau of Science, Manila.

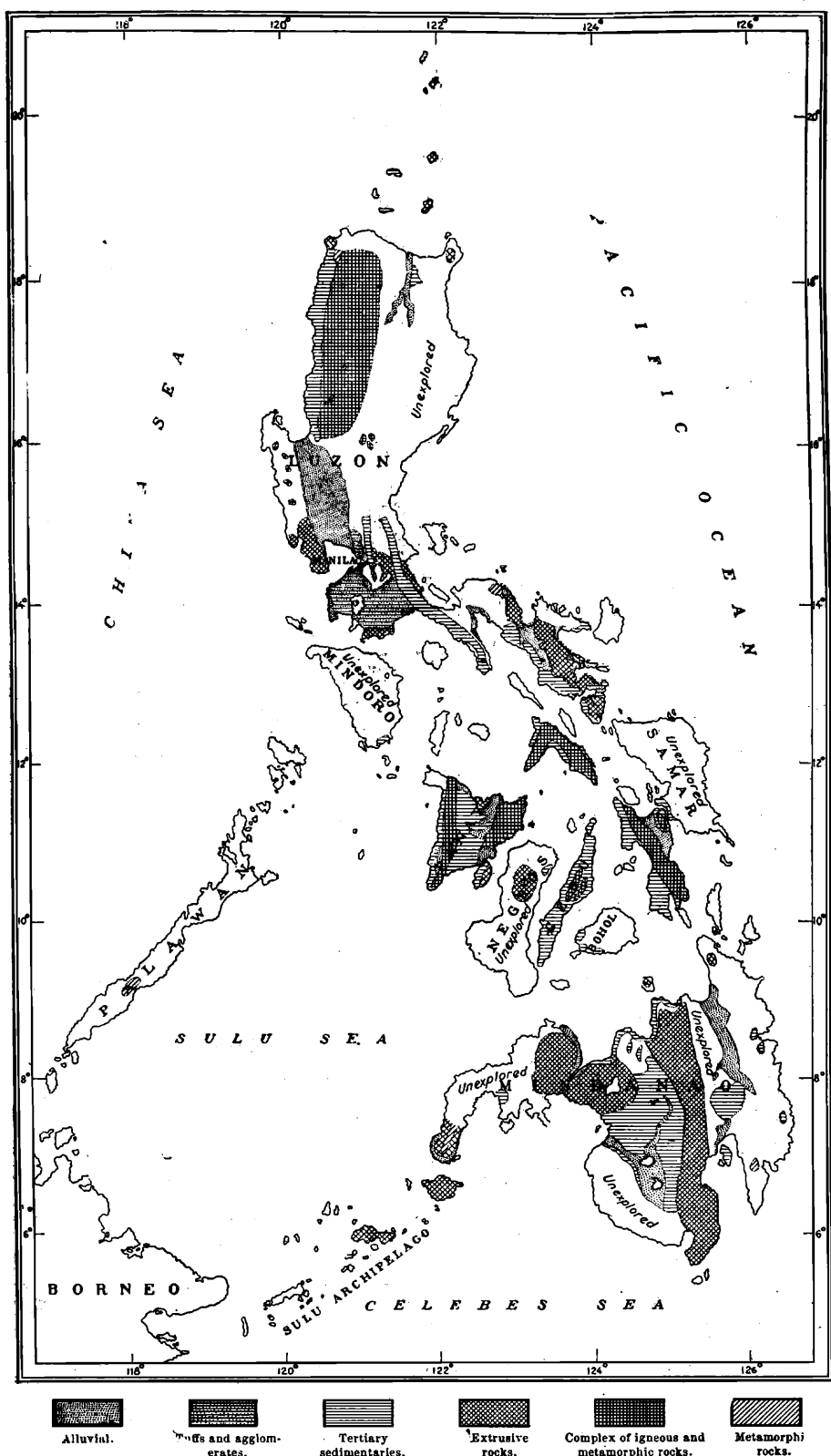


FIG. 11. Geological Map of the Philippines.

government since 1896, and an insurrection broke out against the Americans in 1899, which was not suppressed until 1902, with sporadic outbreaks in different islands until 1906.

#### GEOLOGY.

As first pointed out by Becker,<sup>1</sup> the southern islands are arranged according to two main curved systems intersecting at angles of about 60 degrees. To the inner series belong the islands of Palawan and Culion, and parallel to this line, the group formed by the Sulu Archipelago, the Zamboanga peninsula of Mindanao, the islands of Negros, Cebu and Panay, and the western arm of Masbate. The northern part of Borneo continues this trend to the southwest. The curve of the outer series has a greater radius, and a center of curvature to the south of the first. It includes the two transverse ranges of Mindanao, the islands of Leyte and Samar, the eastern arm of Masbate, the southern part of Luzon and probably the island of Mindoro. To the southward this series is continued in the Sangir group and the island of Celebes in the Dutch East Indies. The islands do not follow one another in regular lines but are slightly offset, so that the longer diameters of successive islands are roughly *en échelon* in their arrangement. In the larger features of their distribution they follow the two dominant trends of crustal movement, in all probability the inner series being of earlier date.

On the large island of Luzon the relation of structure to topography is less clear. Southeast of Manila are the active and extinct volcanoes of the Taal Group. Northwestward from Manila Bay, the Zambales Range runs parallel to the coast as far as the Gulf of Lingayen, and in the eastern part of the island an unexplored cordillera runs northward until it joins a transverse knot of mountains, the Caraballo Sur, in about latitude 16° N. Between these two ranges is the broad Pampanga valley covered with alluvial deposits, which are underlaid by late Tertiary water-laid tuffs. Two mountain ranges branch out to the northward

<sup>1</sup> Becker, G. F., "Report on the Geology of the Philippine Islands," U. S. G. S. 21st Annual Report, Pt. III., pp. 487-614.

from the Caraballo Sur. The eastern is the unexplored Sierra Madre range, extending northward to the volcanic islands between Luzon and Formosa, and known to contain a core of older crystallines flanked, on the west at least, by Tertiary sediments. Between the Sierra Madre and the western range, the Cordillera Central, is the broad synclinal Cagayan valley containing Tertiary limestones. To the westward of the Cordillera Central is a small coast range.

While the central ranges of a majority of the islands contain metamorphosed sediments, no fossiliferous formations of earlier date than the Oligocene have been found and it is not at all certain that pre-Tertiary sediments exist.<sup>1</sup> In the Tertiary series marked unconformities exist in the Miocene, and between the Miocene and Pliocene.

The distribution of volcanoes follows the anticlinal lines, though it is not possible, as has been attempted by earlier writers, to group them into comprehensive volcanic belts. Series of volcanoes along anticlines are well shown in the Sulu archipelago, the islands of Negros, southern Luzon and the line of volcanoes of the northern islands.

The Philippines appear to owe their present form to the great upheaval at the close of the Miocene. This was accompanied by intense volcanic action and in two, at least, of the three important mining districts, vein formation followed the period of volcanism. Periods of later uplift are shown in the comparatively undisturbed Pliocene and Pleistocene coral limestones whose terraces surround the shores of the majority of the islands. Late Pleistocene depression, or rather an increase in the volume of the ocean water,<sup>2</sup> is abundantly shown both in the distribution of life in different islands, showing former land connections,<sup>3</sup> and in the submarine topography. This change of level appears to

<sup>1</sup> Smith, W. D., "Philippine Geology," *Min. Res. of the P. I.*, Manila, 1910, pp. 54-56. Contains table of Philippine stratigraphy.

<sup>2</sup> Daly, R. A., "Pleistocene Glaciation and the Coral Reef Problem," *Amer. Jour. Sci.*, Vol. 30, 1910, pp. 297-308.

<sup>3</sup> Worcester, Dean C., and Bourns, F. S., "Contributions to Philippine Ornithology," U. S. Nat. Mus. Pub., No. 1134, Vol. 20.

have amounted to between sixty and a hundred and fifty meters, and is of economic importance, first in the production of so many good harbors by the drowning of river valleys and, secondly, in allowing a probably deeper zone of oxidation in the veins than would have been the case had the land remained at its present level or been recently uplifted.

#### THE MINING DISTRICTS.

Although gold is widely distributed throughout the older crystalline and volcanic rocks of the central ranges of most of the islands, it is only in three regions, the Baguio, Aroroy and Paracale districts that development is at all advanced. The reasons for this lie partly in the difficulty of exploration in a tropical and savage country, and partly in purely local causes. Political difficulties have also delayed the introduction of capital. During the last five years, however, the gold production has increased from practically nothing in 1905 to almost \$300,000 in 1909, but the more important mines have not as yet attempted any large production, and have wisely confined their efforts to development work.<sup>1</sup> Such success as has attended American mining here is due to the fact that the volunteer regiments forming the first army of occupation were composed of men of the western states, many of whom were experienced miners and prospectors. To those who remained in the islands after receiving their discharges, the credit for the present development of our mineral wealth is due. In both Baguio and Aroroy the first American prospectors were on the ground in advance of the troops. In the former district these pioneers reached the field before the outbreak of the insurrection in February, 1899, and were obliged to obtain passes from the rebels on their return to the American lines. In the Aroroy district the pioneer prospector was twice made prisoner by the insurgents before the island of Masbate

<sup>1</sup> The report of the director of the U. S. Mint for 1910 shows an apparent falling off in Philippine gold production. This is due, however, to the fact that a large proportion of the gold now mined in the islands is sold in Japan. The production for 1910 is a marked increase over that for 1909 though exact figures are not yet available.

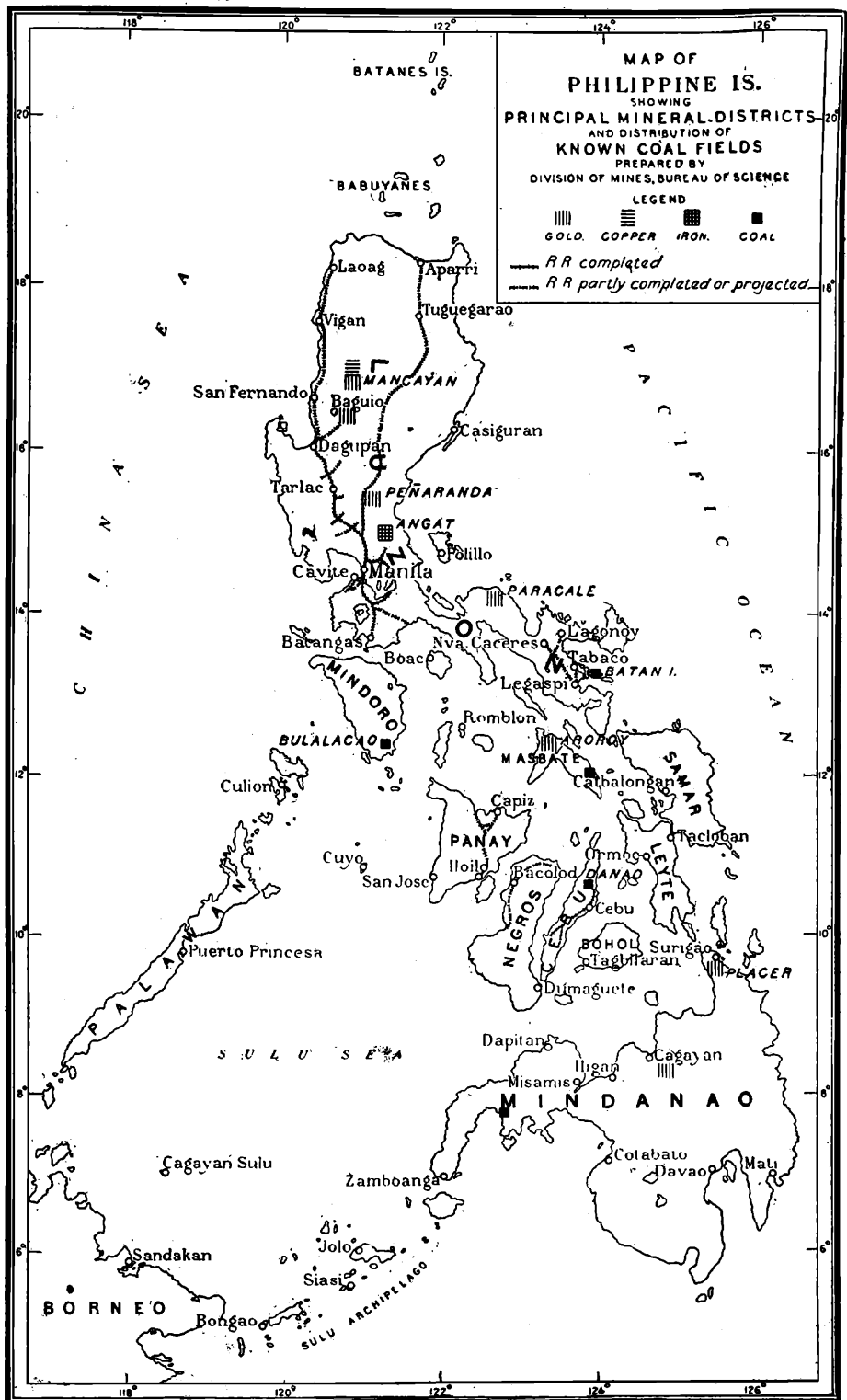


FIG. 12.

was fully occupied by the American troops, and the first miners more than once had to defend themselves against attacks from bands of *ladrones*.

*The Baguio District.*—Of the three mining districts, the most important in point of production, is that of Baguio in the sub-province of Benguet in central Luzon. Here shallow work has been carried on for an unknown time by the Igorot savages, but in Spanish times the difficulties of transportation and the unsettled state of the country prevented development. The Igorot workings consist of small open cuts and tunnels, often so narrow as to be impossible of access to the white man, the rock being broken by fire and crushed in stone mortars.

These naked savages are good metallurgists and in the copper district of Lepanto to the north of Benguet have been smelting copper since before the Spanish conquest. In the Baguio region to-day the Igorot is very clever at alloying the gold he expects to sell to the Americans or Chinese, with just the right amount of copper to allow it to pass unsuspected.

Since the American occupation a good road has been built to the district from Dagupan, the terminus of the Manila Railroad, and in the near future the railroad will be continued to the district itself. At present three stamp mills and two cyanide plants are in operation. The production for 1907 was \$78,000, 1908 \$140,000, and 1909 \$122,000. The falling off for 1909 was due to heavy floods, which partially wrecked all three mills, stopping work for three months.

The mining district lies a short distance south and east of the town of Baguio, the summer capital of the Philippines, on a tableland of about 1,500 meters elevation between the Cordillera Central and the coast range, and comprises an area of over 100 square kilometers. This tableland is deeply dissected by the canyons of the Bued, Sili and Antamok rivers. The latter flows through heart of the mining district and supplies the power for the mills.

Although this district is the most important of the three in point of production no detailed study of the geology has yet been made.

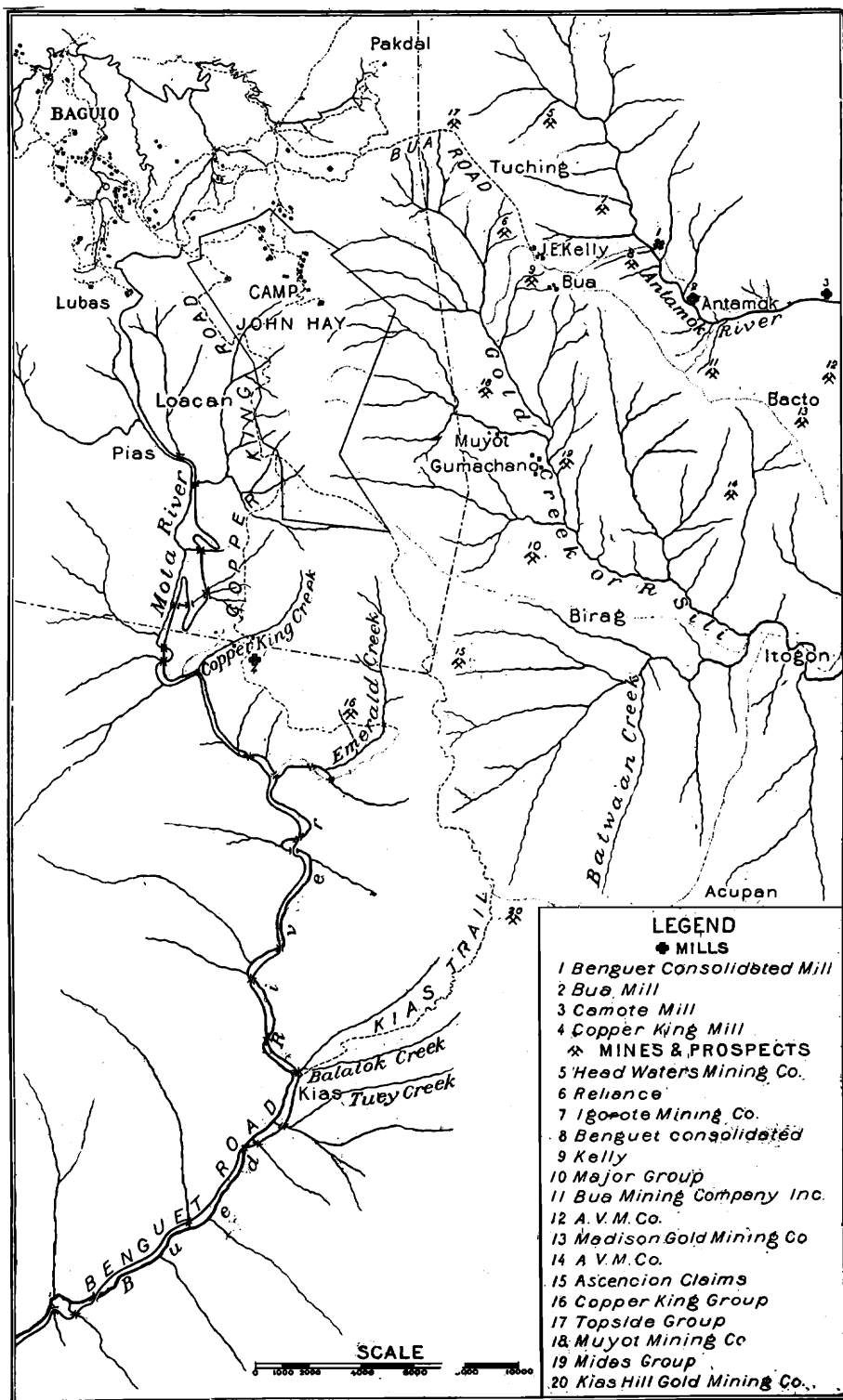


FIG. 13. Map of the Baguio District.



From Eveland's reconnaissance<sup>1</sup> it appears that there is a basal mass of diorite of similar composition to that forming at least a very large part of the Cordillera Central, associated with which is quartz diorite, probably intrusive. This basal mass in early Tertiary times formed an island upon whose shores were laid down a conformable series of early Miocene sediments. Following the great crustal movements of the Miocene extensive volcanic action took place, giving a series of augite-andesites with subordinate hornblende andesites and pyroclastic rocks. The period of vein formation followed the igneous activity.

According to Eddingfield,<sup>2</sup> the majority of the veins are fissure veins in andesite, although contact deposits between andesite and limestone and between andesite and diorite have been reported. The veins often occur in groups of four and about 250 have been uncovered. They vary from one-half to six meters in width, and attain a maximum of 15 meters. The strike is almost invariably east, normal to the trend of the mountain ranges, and the dip generally steep to the south.

The gangue varies greatly, consisting in different veins of white quartz, banded crystalline quartz, calcite, calcite and rhodocrosite, brown manganese oxide and quartz, silicified and mineralized andesitic dikes and brecciated quartz. As a rule the gold content is about 50 per cent. free milling, though, in the few veins where telluride ores occur, no free gold is found. The gold occurs both free and included in pyrite, and in rare instances as a telluride, and generally largely alloyed with silver, the silver content being occasionally as high as 33 per cent. Manganese oxide and rhodocrosite are often very prominent, but no copper, lead or zinc minerals are present. The ore is not of high grade, 15 grams to the metric ton being common, though richer patches are sometimes met with.

The Baguio district has many natural advantages for cheap mining. The deeply incised river valleys allow of most of the

<sup>1</sup> Eveland, A. J., "Notes on the Geology and Geography of the Baguio Mineral District," *Phil. Jour. Sci.*, Sec. A, Vol. 2, pp. 203-233, 1907.

<sup>2</sup> Eddingfield, F. D., "The Baguio Mineral District," *Min. Res. of the P. I. Bureau of Science*, Manila, 1910, pp. 14-17.

mining being carried on by adits, as well as offering excellent mill-sites, and good water power is available. The labor situation is not at present pressing. Cheap Igorot labor, though generally useless underground, is available for surface work, such as road building and cutting timber. Underground and about the mills, the steadier Christian natives from the coast must be employed. Japanese are often used for timbermen and carpenters. The most serious disadvantages are the comparative scarcity of timber, the great distance from the coast, making transportation difficult and expensive, and the danger from landslides and floods.

The two most important companies operating in this field are the Bua and the Consolidated.<sup>1</sup> The former is working two narrow veins, one of quartz from one half to one meter in width, and the other of rhodocrosite from one to two meters wide. The ore is mined by overhead stoping, the stopes being filled with waste broken in mining. The mill consists of two three stamp batteries with copper plates. The tailings are cyanided in six sand leaching tanks. The Consolidated is working a wider vein and has so far confined its efforts to development work. The mill consists of six stamps, the tailings from the plates being classified and leached by a sand and slime leaching plant, and the leached slimes filtered in a Ridgeway vacuum filter. Other mines of importance are the Camote, operating a three-stamp mill, the Headwaters, now installing a ten-stamp mill and cyanide plant, and the Kelley group, the latter being of especial interest as here three intersecting veins, with strikes of N. 60° W., N. 60° E. and N. 34° W., at variance with the usual east-west strike, carry tellurides, but no free gold.

Development work has progressed further in the Baguio district than elsewhere in the islands and a large increase in production may be expected in the near future.

*The Aroroy District.*—The Aroroy mining region lies near the northeastern point of the island of Masbate. As it has been my good fortune to make a preliminary study of the geology,

<sup>1</sup> Eddingfield, *loc. cit.*, p. 16.



MAP OF THE AROROY DISTRICT.

I shall describe this district in greater detail.<sup>1</sup> Masbate owes its unique two-pronged shape to the junction of the two anticlinal trends of the southern islands. The two ranges are in part composed of older sediments, largely slates, intruded throughout large areas by diorites and more basic plutonic rocks, and associated with a large amount of later volcanics, chiefly augite-andesite and pyroclastics, with more basic rocks. Along the southern shores, and inland on the flanks of the mountain range, scattered outcrops of a dark blue limestone are to be found, of lower Miocene or Oligocene age. In the southeast part of the island is a sedimentary series of Miocene age, containing coal, resting upon schistose quartz diorite. These sediments are bent into sharp folds whose axes follow the prevailing northwesterly trend. On the northwest corner of Masbate a similar formation, consisting of shales, limestones and conglomerate, but as far as now known, without coal, extends southwestward along the western shore of the island. The dip here is quite gentle and generally to the west.

The mining district is situated in a group of hills to the east of Port Barrera, a deep bay extending southward for a distance of about 13 kilometers. Mount Vil-lon, the highest mountain in the district has an elevation of about 400 meters, and differs from the other hills in having a northeasterly trend. The majority of the veins outcrop in the three hills, Mt. Aroroy (255 meters), Mt. Bagadilla (350 meters) and Mt. Kalakbao (220 meters) which show a pronounced northwesterly trend, due to the resistance to erosion offered by the quartz veins.

Neither the Guinobatan River nor its northern branch, the Bangon Creek, follow the strike of the quartz veins, but cut obliquely across them, suggesting superposition of an older drainage system. The Lanang River presents a very peculiar course, apparently the result of successive stream captures, for instead of flowing down the broad valley to the north of the Lanang range, its earlier course, it twice cuts through the range in deep gorges.

<sup>1</sup> "The Aroroy Mining District," *Min. Res. of the P. I.*, Bureau of Science, Manila, 1910, pp. 18-25.

The oldest rocks in the area are a series of slates occupying an irregular belt of lowland running northward from the western flank of Mt. Vil-lon to the eastern slope of Mt. Aroroy, with scattered outcrops in the northern part of the district. No fossils have been found, but judging from its position, its extreme contortion and considerable metamorphism, it is my belief that these sediments may be provisionally classed as pre-Tertiary, the earliest fossiliferous formation found here being the little disturbed sedimentary series across the bay.

In the northern part of the area these older sediments are intruded by quartz-diorite, which forms the small hills north of Mt. Aroroy.

As in the Baguio region, volcanic rocks and their pyroclastic derivatives cover by far the larger portion of the district, but here show greater petrographic variety. Augite-andesite is here, as elsewhere in the Philippines, the commonest igneous rock. With the appearance of olivine the augite-andesite passes into a basalt, while on the other hand the presence of hornblende in place of the augite gives the hornblende-andesite, often difficult to distinguish from the augite-andesites in the decomposed rocks so frequently met with, owing to the alteration of the feldspar minerals. At one place enough quartz is found under the microscope to bring the rock into the rank of dacite. The greater part of the more basic rocks are basalts differing from one another and from the augite-andesite in the relative proportions of olivine, the varieties of the feldspars present and the relative preponderance of the feldspar minerals. From their scattered distribution it is probable that they occur in dikes cutting the andesites and earlier rocks. A leucite-tephrite is found in a single outcrop, probably as a dike cutting the agglomerate. This is all the more likely as a dike of a similar though more decomposed rock cuts the sediments on the Gold Bug claim.

Pyroclastic rocks cover the greater part of the central portion of the area. Most of these rocks are agglomerates, containing large angular blocks often exceeding half a meter in width, and always derived from augite-andesite. With the agglomerate are

small beds of andesitic tuff and volcanic ash, but these are comparatively unimportant. Where contacts are found, the strike is northwest and the dip rather gentle to the southwest.

Waterlaid sediments derived from the augite-andesite are found in two localities, in Panique Creek, and on the Gold Bug claim, at the mouth of the gorge of the Guinobatan, in both cases suggesting temporary lacustrine conditions.

On a small southerly spur of Mt. Bagadilla, just at the eastern end of the gorge of the Guinobatan River, at an elevation of about 150 meters, is a small outcrop of a dark blue limestone of lower Miocene or Oligocene age, similar to that found in places along the main range of the island. Thick jungle surrounds the outcrop, and the field relations are consequently uncertain.

South of the Lanang River is a rather coarse conglomerate composed largely of basalt pebbles, evidently the basal member of the sedimentary series. Above this in the hills between the abandoned meander and the mass of andesite forming the lower gorge of the Lanang is conglomerate and sandstone, dipping about  $20^{\circ}$  to the southwest.

On the northern shore of the westward embayment of Port Barrera, a fine grained gray shale containing shells of Lower Miocene age outcrop on the beach. This shale is considered by Dr. W. D. Smith to be identical with that found above the coal measures in Cebu and Batan, and, in the hope of finding similar coal seams, was here prospected by drilling to a depth of fifty meters, but only shale encountered. This evidence, together with that furnished by the topography of the country, makes it clear that Port Barrera was originally a river valley eroded in the soft shales and drowned in a recent depression. Hence, it seems probable that the low land lying south of the head of this bay represents the lower portion of the shale, and it is here that the coal measures should be looked for. Above the shale is an unconformity marked by 8 or 10 meters of conglomerate which contains pebbles of augite-andesite and vein quartz, evidently derived from the Aroroy district. Above the conglomerate are several beds of limestone belonging to the Upper Miocene or Pliocene.

Large mangrove swamps are found along the southern shore of Port Barrera, estimated by Whitford<sup>1</sup> as about ten square kilometers in area.

Probably in late Eocene or Miocene times came the uplift which bowed up the southeasterly anticline which to-day forms the backbone of the Island of Masbate. Accompanying this was a period of vulcanism, which was followed by the principal period of vein formation. The universal northwesterly trend of the main series of veins is evidence that the fissuring was resultant upon the continued bending up of the anticline. Even later than the period of vein formation, there may have been further igneous action, as shown in the dike on the Gold Bug claim. In all probability the leucite tephrite is of the same late date. A little later, or perhaps contemporaneous with the intrusion of these later dikes there was fissuring and faulting in an east and west direction in the region of the present Guinobatan River, giving the minor series of east and west veins which fault the older and more important series.

After the period of vein formation came submergence and the laying down of the marine sediments, now found in the extreme southern part of the area and in a later phase on the western shores of Port Barrera.

The veins of the Aroroy district were undoubtedly worked in early times, even before the Spanish conquest. In the account by Gemelli Careri<sup>2</sup> of his trip around the world, an interesting description of the district is given. His ship put in at harbor on the island of Masbate, evidently Port Barrera, and he describes the mines as follows:

"They say Masbate is thirty leagues in compass, eight in breadth and proportionably long. Its ports are commodious for any ship to water. In it live about 250 Indian families which pay tribute in wax, salt and civet. But those that dwell in the mountains and come from other parts are more numerous. Here are such rich gold mines, 22 carats fine, that

<sup>1</sup> Whitford, H. N., "Report on Forest Conditions in the Mining Region of Aroroy, Masbate, P. I.," *Min. Res. of the P. I.*, Manila, 1910, pp. 72-78.

<sup>2</sup> "A Voyage Around the World," by John Francis Gemelli Careri, 1695-1698. Translated from the Italian. Published in a collection of voyages by Awnsham and Churchill, London, 1704.

the mate of the Galleon St. Joseph, aboard which I went over to New Spain, going ashore in one of them in a very short time dug out an ounce and a quarter of pure gold. They do not at present work these mines for want of industry in the Spaniards, who have commission every year from New Spain to lay out some hundred thousands of pieces of eight, with an allowance to them of ten per cent., take no care to look for gold in the mines. As for the Indians, if they have but a dish of rice, they never mind that precious metal, and if they gather any in the rivers it is when they are pressed for tribute and then they gather as much as serves to pay it."

The various members of the Spanish Inspeccion de Minas, who, during the latter half of the last century, wrote on the mineral resources of the Philippines, make no mention of Aroroy.

Old workings are found everywhere throughout the district, generally in the form of deep narrow open cuts, now partly caved in, whose walls show rounded faces as if worked by means of fire. Stone mortars and pestles are often found, showing the primitive nature of the ore treatment. There are also a few workings of later date, which consist of irregular gophering along rich streaks, sometimes opening out into small stopes and again narrowing down to inclined passages barely large enough to admit a man's body. The only mining of which the natives have any tradition was that an arrastra was worked about a hundred years ago, the ore being obtained from the old workings on Boston hill. The ore here is a hard quartz, and was broken by building fires against the face. Modern mining began with the American occupation. Unfortunately, between 1905 and 1907, there was a boom and three stamp-mills and two dredges were set up before any development work had been done. The district is now recovering from the collapse which followed, and honest development work is the rule.

The veins are confined to the igneous rocks, and, though small stringers of quartz and calcite are very common in the older slates, it is not to be expected that in rocks of this character large fissures should be developed as in the more resistant igneous and pyroclastic rocks; and it is reasonable to suppose that, should the underground workings on the three hills ever reach the level of



the slates, the veins will be found to split up into similar small stringers. As in Baguio, the veins are, as a rule, wide and regular. From two to six meters is a common width, with a maximum of 16 meters. Transverse faulting is rare, but motion parallel to the walls is the rule, particularly on the footwall. All the important veins follow a northwesterly direction and show very steep dips, those to the north of Guinobatan River to the northeast from  $70^{\circ}$  to vertical, while those on the southern side dip to the southwest from  $50^{\circ}$  to  $80^{\circ}$ . A few veins do not follow the dominant northwesterly strike, but have a nearly east-and-west course. These fault the main vein system, and are probably of no great commercial importance.

So far practically all the work has been done in the oxidized zone, and it is only in a few places that the unaltered form of the ore can be seen. This is typically a very hard dark blue quartz carrying irregular amounts of pyrite, the dark color being due to finely divided particles of manganese oxide. Small veins of more crystalline quartz cut across the fine grained dark quartz which makes up the body of the ore. Near the walls, especially the footwall, faint banding may sometimes be observed. In many veins calcite is a prominent gangue mineral in the sulphide zone. It is generally massive and dark blue or gray in color, similar to the quartz. Rhodochrosite has never been found in connection with these manganese bearing calcite ores, though in similar ores in Baguio this mineral is present. The calcite, where found, is generally associated with quartz in more or less parallel bands in the same vein, and when a piece of what appears to be massive calcite is dissolved in hydrochloric acid, it is always found to leave an intricate network of fine quartz ribbons.

The oxidized zone shows a marked change of appearance. Lines of weakness parallel to the walls have acted as channels for the surface water with the result that concentration of the different minerals in parallel bands has been accomplished, especially near the footwall, where the motion has been greatest. The calcite has been largely dissolved out and carried away, and the quartz has become bleached through the loss of its manga-

nese content, while the manganese oxide is deposited in bands, and less commonly, patches, sometimes of sooty wad, but more commonly broken quartz covered with manganese oxide. Similarly the pyrite has been oxidized and deposited in reddish bands of iron oxide. The quartz in the narrower bands is white, sometimes stained with iron oxide, and the larger bands show unoxidized cores of blue pyritized quartz. In the central parts of the veins, where the movements have not been so intense and the banding consequently not so pronounced, "honeycomb" quartz is formed by the loss of the calcite and manganese.

In different parts of the district all stages of alteration can be seen from the first bleaching of the blue quartz along small fissures to the final stage of oxidation where bands of massive quartz a meter or more in thickness have been completely bleached. In the oxidized zone the country rock is much altered near the veins, especially on the footwall side, this alteration often extending for several meters from the walls of the vein. The typical alteration product is a brown clay-like rock generally showing traces of its original porphyritic or fragmental structure, and much stained by manganese. This decomposed rock, whether of igneous or pyroclastic origin, has the local name of "porphyry." It is characteristically cut by a great number of small quartz and more rarely calcite stringers, which often carry values.

The comparatively great depth of the zone of oxidation found here, the Colorado workings being still in oxidized ore at a depth of over 100 meters below the summit of Mt. Bagadilla, is consequent upon the recent geologic history. The evidence furnished by the drowned valley of Port Barrera, and to a less degree by the Lanang River, show that the land in recent geologic times stood at a level probably over 50 meters above its present elevation. It remained at this level long enough for a broad valley to be eroded and consequently long enough for the oxidizing surface waters to reach a greater depth than would have been possible under conditions existing today.

In the oxidized zones of different veins differences in value

are noted between the veins carrying noticeable amounts of manganese and those in which iron oxide forms the metallic portion of the gangue. As far as a limited observation extends, all veins which on their outcrops show rich ore are those in which manganese oxide is not prominent. Evidence from development work, though very meager, seems to show that the values in these veins do not increase downward as is the case with the manganese-bearing veins, and in some at least decrease greatly a few meters from the surface. The manganese-bearing veins, on the other hand, which at their outcrop may be nearly barren, carry values increasing progressively downward. This increasing value in moderate depth is shown in many cases, but most clearly by samples taken in the 30-meter raise to surface from the upper level of the Nancy mine of the Eastern Mining Co. In this case there was an increase downward from the outcrop from less than one gram to over six grams per ton.

It is interesting to note how closely the conditions here agree with the hypothesis advanced by W. H. Emmons<sup>1</sup> relative to secondary enrichment, in the oxidized zone, of gold veins carrying manganese oxide. The Aroroy district is favorably situated for such enrichment, as the more important veins are only three or four kilometers from the sea coast and in a region of comparatively heavy rainfall, the average annual precipitation being about 1,400 millimeters. Consequently a high percentage of chlorine is to be expected in the surface waters. On the other hand, the increase in air circulation in the veins as compared with the country rock, is evidence that the broken and loose nature of the ore in the larger veins may allow mechanical transportation of the fine gold by downward flowing surface waters. In the lower level of the Colorado, an adit run on the vein, the air was found to be much better than in much shorter cross-cuts in the country rock. In the lower level of the Nancy a cross-cut was carried in from the side of the hill, and cut the vein at a

<sup>1</sup> Emmons, W. H., "The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits in the United States," *Bull. Am. Inst. Min. Eng.*, October, 1910, pp. 767-838.

depth of 90 meters below surface. Before the vein was reached there was great difficulty with the air, but as soon as the banded alternate broken and massive quartz was cut there was found to be a sufficient supply.

It had been considered that the segregations of the different minerals into bands must affect their values, and it was taken for granted that the more massive bands of quartz were barren, but careful sampling did not bear this out. As a rule, it may be said that the best values occur in rather irregular paystreaks, with a tendency to follow the footwall.

In the sulphide zone the prospects are not so favorable. The hard blue quartz will, of course, be more expensive to mine and mill than the broken material of the oxidized zone, and whatever has been added to the values by concentration or enrichment will be lacking. However, the depth to which the oxidized ore has been shown to extend seems to insure the future of the district.

The gold is only about 25 per cent. free milling, apparently due to the manganese oxide and though alloyed up to 10 or 20 per cent. by weight with silver, contains practically no copper and the ore is well suited to cyanide treatment. The veins outcrop on the hills, allowing the greater part of the oxidized ore to be removed by adits, and this, with the wide veins of shattered ore, makes mining cheap. The district is abundantly supplied with excellent timber, which at present is all obtained from the mining claims themselves. There is no good water power available, but the immense mangrove swamps which border the bay will furnish cheap firewood, and Philippine coal is obtainable at reasonable figures. The position of the district also gives it a great advantage. The mines are situated from three to seven kilometers inland from an excellent harbor, only a day's steaming from Manila, and consequently supplies are cheaper here than at other mining camps. At present the labor problem is also less pressing, and there has, up to now, been little difficulty in securing plenty of laborers at slightly lower wages than are paid elsewhere. It is estimated that in the more favorable situated mines, ore assaying over \$3.50 a ton can be handled at a profit.

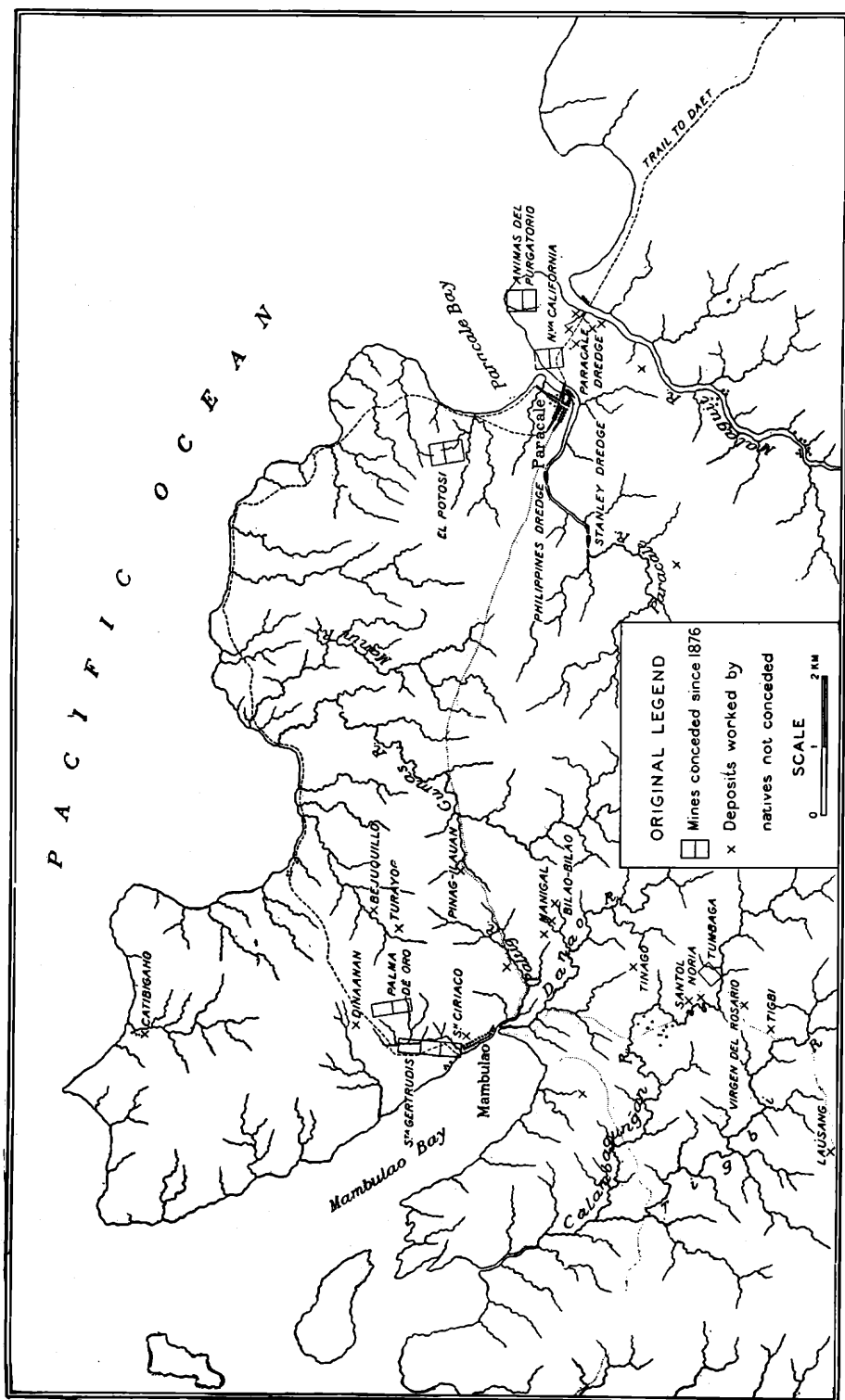


FIG. 14. Map of the Paracale District.

Two dredges formerly at work on the supposed placer grounds of the district have been unsuccessful, but this has been due in great measure to faults of management in one case and a combination of misfortunes in the other.

*The Paracale District.*—The third important district is that of Paracale<sup>1</sup> in the northern part of Ambos Camarines on the east coast of Luzon. During the Spanish times and before the Spanish conquest, until the insurrection of 1896, a large amount of gold was taken from the richest of the oxidized ores and the richest placers. One of the first military expeditions of the Spaniards after establishing themselves in Manila, was that of Juan Salcedo to take possession of these mines. Becker<sup>2</sup> quotes from a delightfully naïve report by one of the early Spanish writers. Hernando Riquel writing in 1574, says, "Trials have been made and the mineral presents itself so plentifully that I do not write about it, lest they suspect me of exaggeration, 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." Gemelli Carneri<sup>3</sup> states apparently on good authority, that the production in 1697 amounted to \$200,000.

The natives in this district are fairly skilled miners and the women especially are very clever with the wooden batea. The accompanying photograph shows a model of a small dredge of native construction used on the rivers. The dredge is anchored by the spud in the center, and the pole, on the end of which is a hemp cloth bag, let down and a small amount of gravel brought to surface. This is then panned in the batea, or *faberik*, as it is locally called. At very low tide the Paracale River is often crowded with dugout canoes or *banças* containing native women. The women work in pairs, one staying in the *banca* and the other standing up to her neck in water. The one in the water dives

<sup>1</sup> Ickis, H. M., "Camarines Gold Field," *Far Eastern Review*, Manila, Vol. 4, pp. 50-57, 1907. Ferguson, H. G., "Metallic Mineral Resources," *Mineral Res. of the P. I.*, Manila, 1909. Smith, W. D., "The Paracale-Mambulao District," *Min. Res. of the P. I.*, Manila, 1910.

<sup>2</sup> U. S. G. S., 21st Ann. Rept., Part 3, 1901, p. 579.

<sup>3</sup> Quoted by Becker, *loc. cit.*, p. 579.

down and fills the *faberik* with sand, which the other pans down to the black sand, which is washed out into a cocoanut shell. Later the black sand is carefully spread out on a dark cloth and the colors picked out with needles. The native women are so good at panning that one is always employed for this work in the crews of the testing outfits.

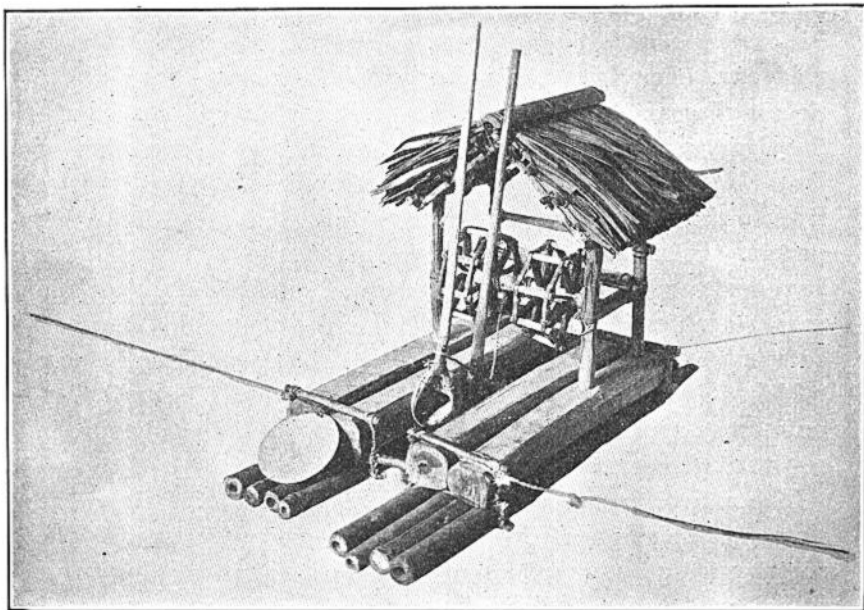


FIG. 15. Model of Native Dredge, used on the Paracale River.

Mining operations were carried on in a very crude manner until 1892, when work on a larger scale began. A small dredge, a ten-stamp mill and a small Huntington mill were installed between 1892 and 1896. Of these, the only survivor of the insurrection was the Huntington, which was repaired and used for a short time at one of the mines. The war and insurrection and the confusion in regard to titles, which followed, delayed operations for several years, but, in 1907, a small New Zealand dredge began work, and there are now three dredges and one twenty-stamp mill in the district, with prospects of more in the near future.

This district shows entirely different types of ores, though, unfortunately, no detailed study has yet been made. As far as is known, the region consists of a complex of pyroxenites and diorites, overlaid by sandstones and slates, all much metamorphosed and intruded by a mass of granite, the granite itself being gneissic and the whole complicated by andesitic and basaltic flows and dikes of various ages. It is in the vicinity of the granite intrusion that the principal veins are found, though it seems that none of the veins so far uncovered, are contact deposits, but cut both the granites and the older rocks.

Topographically the region is mature and the hills have gentle slopes, consequently the water level is comparatively near the surface; and the zone of oxidation a shallow one. The different ores show great mineralogical variety. While quartz is the usual gangue, calcite is not uncommon, and galena, zinc blende, pyrite, chalcopyrite and other copper sulphides, gold tellurides and free gold form the concentrates.

Two mines have now been developed to some extent. At one the ore consists of small calcite stringers containing different sulphides, together with tellurides and free gold, and often extremely rich, assays above \$500 a ton being reported. These stringers occur in a zone of about ten meters width in a dark slate. The second mine has three parallel veins, which occur near the contact between the gneissic granite and the diorite schist, but cut both rocks. The ore is not of as high a grade as that of the former, but the veins are wide, there being reported to be large ore reserves assaying above \$10 per ton. The gangue is quartz, containing copper sulphides and some free gold, which give a large proportion of concentrates, about one to seven. Although only the gold deposits of the district have so far been developed, other minerals are known to exist. Native copper has been found in small streams flowing north into the Malaguit River and in a clay, apparently a much decomposed andesite, in the vicinity. Apparently extensive deposits of hematite and magnetite are also known to exist south of the Malaguit River and near Mambulao Bay.



The two rivers, the Paracale and the Malaguit, which empty into the sea near the town of Paracale, are the sites of the principal placers. Both flow through wide valleys which contain large areas of available dredging ground. The principal values are obtained at a depth of from 10 to 14 meters in a layer of very rich quartz gravel averaging less than one half meter in thickness. This streak is so rich that, notwithstanding large losses due to its poor construction, the dredge first in operation obtained nearly two grams of gold per cubic meter of total ground dredged, excluding the values contained in the larger fragments of gold-bearing quartz saved for future crushing. It was not uncommon to see the tailings pile crowded with native women at work with their *faberiks*.

It is probable that the extremely rich ground now being worked is near points where the river cuts veins, the outcrops of which have not yet been discovered. The quartz pebbles brought up by the dredge are generally angular or subangular, and the gold caught in the riffles is usually sharp, and sometimes crystalline. The placer gold is from 95 to 98 per cent. pure. The granite bedrock beneath this deposit is much decomposed, and easily cut by the dredge buckets, making it possible to secure a large proportion of this rich gravel. There is a surface deposit of vegetable matter from two to five meters in thickness, which makes dredging difficult. Below this is a sticky gray clay, which contains some values. This clay balls excessively, and carries away gold from the tables. Again the black sand has proved a difficult problem and the proportion of fine material is larger than is usually met with.

*Other Districts.*—The three districts just described are the only places in the Philippines where mining is at all advanced. In other parts, preliminary prospecting has shown the existence of promising lode and placer deposits, and, when sufficient capital is available, no doubt new districts will be developed.

According to reports by Goodman<sup>1</sup> and Eddingfield<sup>2</sup> there is

<sup>1</sup> Goodman, M., "Gold Placers of Neuva Ecija," *Far Eastern Review*, Manila, Vol. 4, pp. 88-89, 1907.

<sup>2</sup> Eddingfield, F. T., "Neuva Ecija," *Min. Res. of the P. I.*, Manila, 1910, pp. 26-28.

a large area of placer ground, approximately 1,500 sq. km. in extent, along the eastern tributaries of the Pampanga River in the southern part of Nueva Ecija near the town of Peñaranda. The region is a rather flat plain watered by small wet weather streams. The gold-bearing sand is found in two layers, the upper reaching from one to two meters below surface, and underlaid by a "false bottom" of clay or sandstone of varying thickness, which overlies another similar bed of pay gravel, the total depth to bedrock varying from 8 to 12 meters. The upper sand has long been washed by the natives, and sluicing operations on a larger scale were carried on from 1890 to 1896 and again since 1905.

The gold occurs in extremely thin flakes, commonly under 3 mm. in diameter, though flakes up to 2 cm. diameter have been found. With the gold is a small amount of platinum, stated to amount to about one third of one per cent. of the gold content. Iridium has also been noted. Although values exceeding 15 cents per cubic meter were obtained in testing, dredging would be subject to several disadvantages, as the sand contains a large proportion of sticky clay, and, in parts of the area considerable amounts of black sand, besides which the flaky nature of the gold gives the fines a tendency to float. The gold is also said to be rusty and not readily amalgamable. The shortage of water during the dry season, the danger of heavy floods during the rains, and the passive hostility of the natives, are also drawbacks.

The portion of the cordillera from which this gold is derived, has never been explored, being inhabited by hostile savages, nor have the rivers draining eastward; but in the highlands of Bulakan and Rizal, in the southward continuation of the same range, both lode and placer deposits have been found, though the unsettled nature of the country has delayed exploration.

Concerning other regions there is little to say as yet. Prospects are being developed throughout the whole length of the Cordillera Central of Luzon, and this range will probably furnish other districts besides that of Baguio. At present prospecting is being carried on at the southern end of this range in the

province of Pangasinan and in the extreme north in Ilocos Norte. Many of the copper veins of the Mancayan-Suyok district north of Baguio also show considerable values in gold. Lately what is considered a continuation of the Paracale district has been found in the mountains to the southward, and promising placer ground southwest of Paracale at the head of Ragay Gulf is being tested. On the island of Catanduanes off the east coast of southern Luzon, lode and placer deposits are being developed. In the Visayan islands, besides the Masbate district already described, the northern part of the almost unexplored island of Mindoro contains placer grounds, and placers are likewise known to exist on the islands of Cebu and Panay. On the island of Marinduque quartz veins with auriferous pyrite and silver-lead deposits are being developed. On the island of Panaon, just south of Leyte a mine was worked to some extent during the Spanish régime but has not been reopened since the insurrection. Becker,<sup>1</sup> quoting from a manuscript report by Ashburner, states that there are here several quartz veins, one of which is two meters in width, carrying pyrite, galena and zinc blende, with gold values of \$6 or \$7 per ton.

The interior of the great island of Mindanao is not yet in a state to allow of prospecting, but promising placer fields are known to exist in Misamis and Surigao. Abella<sup>2</sup> studied the Misamis deposits in 1877 and stated that there are both bench and valley placers, small and discontinuous, but in places exceedingly rich, his assays often showing values of from 3 to 6 grams per cubic meter. The gold is derived from the quartz veins of Pigholugan, some distance inland. As described by Nichols<sup>3</sup> the Pigholugan region consists of slate and serpentine. Three systems of very narrow quartz veins traverse the region and at their intersections rich pockets are found.

<sup>1</sup> *Loc. cit.*, p. 581.

<sup>2</sup> Abella y Casariego, Enrique, "Memoria acerca de los criaderos auríferos del segundo distrito del departamento de Mindanao, Misamis," *Bol. del Com. del Mapa Geol. de España*, Madrid, 1879. English translation by W. D. Smith. *Min. Res. of the P. I.*, Manila, 1910, pp. 63-71.

<sup>3</sup> Nichols, J. C., "Notes on the Pigholugan and Pigtao Gold Region, Island of Mindanao," *Trans. Am. Inst. Min. Eng.*, Vol. 31, pp. 611-616, 1901.

In 1907 the deposits in the vicinity of Placer Bay on the Surigao Peninsula were visited by Goodman.<sup>1</sup> He found the prevailing country rock to be andesite cut by a series of narrow quartz veins, often not exceeding a centimeter in width, running in general about N. 55° E. Some of the richer of these stringers have been mined in a small way by natives. The placer ground derived from these veinlets is worked to some extent by the natives by means of crude sluices. Goodman considers this region a very promising field for hydraulic mining as rough tests showed values of over \$1.00 per cubic meter.

#### GENERAL CONDITIONS.

To anyone who has seen the rapid development of mining camps in America or Australia, progress in the Philippines must seem insignificant. In the first place it must be remembered that in the Philippines travelling is difficult and slow. Communication between the different islands, while now in a fairly satisfactory state, was very uncertain in the early days, and prospecting in the jungle is extremely difficult work and requires a greater outlay than the average prospector is able to secure. Nowhere in the Philippines is there a poor man's country, where the prospector can wash enough gold to cover his expenses, as the natives, everywhere clever at panning, have skimmed the cream off of whatever very rich surface deposits once existed. Until recent years it has been almost impossible to secure sufficient capital for even the best propositions, owing in part to the uncertainty in regard to the political future of the islands, which held back investors from everything Philippine, but chiefly to the provision in the Philippine mining law, which attempts to limit the number of claims held by one owner. Section 33 of the Act of Congress of July 1, 1902, limits the locator to the possession of one claim on each lode, a provision which, were it not for the fact that it is absolutely impossible of enforcement, would be the death blow to Philippine mining. In other respects our mining

<sup>1</sup> Goodman, M., "The Gold Fields of the Surigao Peninsula, Mindanao," *Min. Res. of the P. I.*, Manila, 1909, pp. 40-44.

laws are excellent. A lode claim is 300 meters square with vertical side and end lines, doing away with the confusion resulting from extralateral rights, with provisions for assessment work and patent similar to the American law.

The labor question is becoming more serious. The Filipino, while possessing many good qualities, cannot be regarded as an efficient laborer. Chinese labor is absolutely excluded by law, and white manual labor is impossible in a tropical country. The recent increase in Philippine industry, following more settled conditions and the general belief in the permanence of American occupation, has created a great demand for native labor, and consequently there has been a considerable rise in wages without any increase in efficiency. Indeed, increased wages often make for loss of efficiency, as the Filipino, when he consents to work, works to gain money for a definite end, whether it be for the cock-fight, or for the purchase of a game-cock, carabao, wife, or other luxury, and when this is attained, retires until he feels the necessity for something else. On the other hand, the native is quick and willing to learn, and the ignorant peasant, who in his first day's work tries to carry his wheelbarrow on his head, will soon, if handled with patience and firmness, develop into a fairly capable miner, who takes great pride in his work. At present the wages of ordinary labor vary in different camps from forty to sixty cents per day, and of miners from fifty to eighty cents, but it must be remembered that aside from the inefficiency of the individual, the added cost of the closer superintendence required, makes the cost of work done higher than in America. In all the districts a limited number of Japanese carpenters and timbermen are employed. These are never found to be as satisfactory as Chinese and command wages of from ninety cents to two dollars per day. Native laborers always do best when housed and fed by the employers. As their food consists exclusively of rice and fish, a native is well fed at a cost of from six to ten cents per day. As a skilled laborer the trained native does excellent work, and native blacksmiths, engine drivers, chemists and draughtsmen are splendid workers in their lines, when in

subordinate positions, where they can fall back upon the white man for advice and assistance when new conditions confront them. In positions of responsibility, even the best trained native is incompetent, as his lack of initiative makes him helpless, while his conceit is always bringing him into difficulties. The different tribes vary somewhat in their quality as laborers. The Christian tribes make steadier workers, though less trustworthy than their mountain brothers, and the Ilocanos and Visayans are preferred to the Tagalogs.

Except for the labor question, affairs in the Philippines are in a very satisfactory state. The insular government is doing whatever is possible to aid commercial and industrial development. Good roads are being built and maintained, on the larger islands railroads have been built under government guarantee, and the inter-island transportation service has been made efficient under a wisely planned system of government subsidies. The services of the members of the various government bureaus, particularly those of Science (including the Division of Mines), Agriculture and Forestry, are always at the disposal of the intending investor. There is a government assay office connected with the Division of Mines, where commercial assaying is done, and assays are made free for prospectors in undeveloped districts. An ore testing laboratory is planned where runs of ore will be made at cost, relieving miners from the long delay involved in sending test shipments of ore to America or Australia. At present, while mining engineers are so scarce in the islands, arrangements have been made, whereby the services of one of the staff of the Division of Mines can be secured for private work or surveys. In addition to this is, of course, the regular geologic and topographic work of the division, the results of which are published in Section A of the *Philippine Journal of Science*, and the annual bulletin of the "Mineral Resources of the Philippine Islands."