Geology and Mineral Resources of the Maimón-Hatillo District Dominican Republic

GEOLOGICAL SURVEY BULLETIN 964-D

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By A. H. KOSCHMANN *and* MACKENZIE GORDON, JR.

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By A. H. Koschmann and Mackenzie Gordon, Jr.

ABSTRACT

The Maimón-Hatillo district, in the southern part of the Province of La Vega about 90 kilometers north of Ciudad Trujillo, contains important prospects of iron, nickel, and copper and showings of cobalt, manganese, and chrome. The district is part of the Cordillera Central and is a region of moderately low mountains separated by broad valleys.

The oldest rocks are of known Cretaceous and probable Cretaceous age. These strata have been intruded by ultramafic and syenitic rocks and are unconformably overlain by a series of volcanic rocks of probable Tertiary age. The Cretaceous rocks are probably more than 12,000 feet thick and have been subdivided into four formations. The two older formations are (1) a chert and (2) an apparently younger massive limestone with interbedded slate and calcareous mudstone. Only the limestone, which contains reef-forming pelecypods, can be definitely dated. The two younger formations, chiefly of volcanic origin, are (3) a sericite schist derived from rhyolitic flows and tuffs that is interbedded with nonschistose members of latitic and andesitic rocks and with lenses of conglomerate, quartzite, chert, and limestone and (4) sedimentary tuffs with an intercalated greenstone that is probably a flow.

The intrusive igneous rocks include a sill-like mass of ultramafic rocks in the western part of the district and three stocks of syenite in the eastern part. A mass of hornblende schist that encloses a small irregular body of hornblendite is exposed at the western edge of the area, and this mass is tentatively included with the intrusive rocks. The volcanic rocks of probable Tertiary age have not been divided into formational units. They include tuffs, breccias, and flows of latite, rhyolite, and andesite. The volcanics are restricted to the northeast corner of the district.

The Quaternary deposits are mainly alluvium covering the valley floors. Locally there is a blanket of lateritic soil on the ultramafic rocks and on the greenstone. This lateritic mantle carries appreciable quantities of iron and nickel.

The rocks of the district are deformed both by folding and by faulting. The strata assigned to the Cretaceous dip homoclinally westward, but the relation of the schistosity to the bedding suggests that they form part of a broad regional southeastward-plunging anticline of which only the western limb falls within the area mapped. Transverse faults cut the greenstone into numerous fault blocks, and a large strike (?) fault is thought to have been obliterated by the intrusion of the ultramafic rocks. The time of deformation has not been accurately determined and is tentatively assigned to the Laramide.

Following deformation the region was subjected to a long period of erosion that produced a topography of considerable relief. The present major drainage lines were probably established at that time, and the volcanic rocks assigned to the Tertiary were deposited on this irregular topographic surface.

Iron is found in two types of deposits: (1) magnetite deposits in the eastern part of the district and (2) laterite deposits in the western part. The magnetite seen by the writers occurs in residual boulder deposits that were derived from the weathering and erosion of lenses or irregular masses of contact-metamorphic origin, largely formed in the Cretaceous limestone near the syenitic stocks. Twenty analyses give an average of 67.97 percent iron. At several localities these deposits are reported by H. A. Meyerhoff (personal communication, August 2, 1948) to overlie lenses of magnetite in place in the limestone.

The lateritic iron deposits are derived from the weathering of the ultramafic rocks and greenstone. Much of the laterite has been removed by erosion, but locally the deposit on benches and on the flat tops of ridges appears to be of appreciable thickness. The available data are inadequate, and a soil-auger survey is recommended to determine the thickness of the laterite and to sample the more favorable deposits.

Nickel occurs as a minor constituent of the laterite and in small irregular veins in the ultramafic rocks. The laterite contains from 0.78 to 1.35 percent NiO, and the veins contain from 2.78 to 8.55 percent NiO. Data are not available for an estimate of tonnage or grade, but a program of trenching and sampling probably would reveal a considerable volume of laterite and sporadic veins. The commercial value of the nickel prospects depends on the progress made in treating low-grade nickel silicate.

Disseminated copper carbonate in the sericite schist on Loma de la Mina, in the eastern part of the area, has been partly prospected. The showings warrant further exploration.

Cobaltiferous psilomelane, containing 25.3 percent MnO and 4.5 percent CoO, occurs in lumps in the laterite at the southeast end of Loma Caribe.

Deposits of manganese and of chromite appear to be small.

INTRODUCTION

LOCATION OF THE AREA

The Maimón-Hatillo district, as defined in this report, occupies a roughly trapezoidal area of approximately 360 square kilometers just east of the geographical center of the Dominican Republic. It lies within the Bonao quadrangle, in the southern part of the Province of La Vega, between longitudes 70°10′ and 70°25′ W. and latitudes 18°50′ and 19°00′ N. (See pl. 18.) The principal town in the area is Monseñor Nouel, formerly known as Bonao and so shown on the map, 90 kilometers north of Ciudad Trujillo, the capital and largest city of the country.

PREVIOUS WORK

As far as is known, the Maimón-Hatillo district is the most highly mineralized area in the Dominican Republic or, in fact, the entire island of Hispaniola. Deposits of iron, copper, and nickel have been known here for many years, but the date of their discovery is lost in legend.

There is little information available concerning the earlier work done in the district. Sir Robert H. Schomburgk (1853, pp. 738–740), telling of a visit to Hatillo in 1853, wrote that at an early date the

Spaniards had worked the copper deposit on Loma de la Mina, 4 kilometers southeast of Hatillo. W. M. Gabb (1873, pp. 142–143), who organized a short-lived geological survey of the republic in 1870, stated that this deposit had been known "for generations" but that surface prospecting there had been terminated "many years ago." The magnetite-hematite deposit at Hatillo and several others nearby have been described briefly, or have been mentioned, by Schomburgk (1853, pp. 739–740), Gabb (1873, pp. 141–142), Brinsmade (1918, pp. 356–358), Ross (1921, pp. 228–231), and Meyerhoff (1941). Ross also described the occurrence of laterite on Loma Peguera and mentioned the presence of nickel there. Meyerhoff mentioned chrome and nickel on Loma Peguera as well as on Loma Caribe.

During the years 1919 and 1920 the Topographic Branch of the United States Geological Survey completed a survey of a part of the Republic. Their topographic map of the Bonao quadrangle was used as a base for the present geologic map.

PRESENT INVESTIGATION

The field work upon which this report is based was carried on from December 19, 1941, to March 10, 1942. Headquarters were established at Hatillo and then moved, in the order named, to Loma Peguera, Maimón, Hato Viejo, Caribe, and Monseñor Nouel. Headquarters were so chosen that the entire area could be conveniently covered on horseback, although more inaccessible parts of the district were explored on foot. Occasionally it was necessary to obtain the services of a man with a machete to cut trails through the thick growth of vegetation that covers some of the slopes.

The writers made a detailed geological reconnaissance of the region, including a study of the mineral deposits and the preparation of a geologic map (pl. 19). This map is the first of its scale and amount of detail ever made in the so-called basal complex of the Cordillera Central, the central mountain chain that traverses the Republic in an east-west direction.

ACKNOWLEDGMENTS

The writers take this opportunity to express their appreciation to the officials of the Dominican Government—particularly Sr. Marino E. Cáceres, Secretary of State for Agriculture, Industry, and Labor—for their splendid cooperation in affording every facility for a study of the country. The sindicos and alcaldes of towns and villages within the Maimón-Hatillo district extended similar courtesies, and Dr. Howard A. Meyerhoff, mineral adviser to the Dominican Government, kindly made available an unpublished report that he had prepared on many of the mineral localities, including the iron deposit at

Hatillo. Sr. Dionico "Compay" Vasquez of Piedra Blanca served most efficiently as guide during the writers' entire stay in the district.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The Maimón-Hatillo district, in the north-central part of the Cordillera Central, is a region of broad, moderately low mountains separated by broad valleys (pl. 19). Most of the mountains are elongate in a northwest-southeast direction corresponding to the general strike of the stratified formations and to the alinement of the intrusive bodies.

Several moderately high, massive hills and ridges, the highest in the district, lie in the southwestern part of the area and are underlain by the more resistant rocks. The highest point in the area, a peak on the main ridge of Loma Siete Cabezas 3.7 kilometers east-northeast of Piedra Blanca, reaches an altitude of 720 meters. The crests of the ridges in this part of the district are commonly rather sharp where underlain by the intrusive greenstone and the sedimentary tuffs and flat-topped where underlain by the intrusive ultramafic rocks. La Trinchera, the broad, massive mountain at the northeast corner of the district, has an altitude of 580 meters. It is underlain by massive chert that forms gentle, subdued slopes somewhat roughened by projecting massive outcrops.

In the central part of the district the hills and mountains underlain by schist are broad, with rather sharp peaks and ridges that vary in altitude from 150 to 546 meters. In the north-central part the topography is rugged where the hills are underlain by massive limestone and subdued where the lower hills and slopes are underlain by syenite, a rock that weathers readily in the humid tropical climate.

The maximum relief in the area is about 665 meters. The lowest point is on the Río Yuna where it crosses the northern boundary of the district at an altitude of 55 meters above sea level. All the major streams have wide flood plains, and in the vicinity of Maimón there are extensive, gently sloping terraces that range from 100 to 130 meters in altitude.

The Río Yuna and its tributaries, comprising one of the three large stream systems in the Republic, drain the Maimón-Hatillo district. These streams are fast flowing, their beds generally are boulder-strewn, and most of them have cut down through the alluvial cover to bedrock at some points along their courses. The Río Yuna is from 1 meter to 2 meters deep within the district and is crystal clear. Its west to east course through the district is very irregular; it alternately flows in a direction roughly parallel to the general structural trend of the region and, probably following shear zones or other zones of weakness that are not exposed at the surface, cuts almost at right angles to this trend. After leaving the Maimón-Hatillo district the Río Yuna (pl. 18) enters the broad Valle de Cibao and follows a rather tortuous course to the head of the Bahía de Samaná.

The main tributary of the Río Yuna is the Río Maimón, which has cut a deep gorge across the ultramafic rocks and the greenstone between Piedra Blanca and Maimón. Its general course, like that of the Río Yuna, is across the structural trend of the region; shear zones, serpentinized ultramafic rocks, and the displacement of the greenstone along its banks indicate that the river follows a fault. Shear zones or faults may control, also, the course followed by the Río Leonora, a tributary of the Río Maimón; the course of the Río Leonorita, a tributary of the Río Leonora; and the course of the Río Tocoa, a tributary of the Río Sin.

Most of the other large streams flowing into the Río Yuna follow the general structural trend of the region. These streams include the Yuboa, Sin, and Margarita, emptying into the Yuna from the southeast, and the Yujo and Cab-Imai, flowing into it from the northwest.

Rainfall is sufficient to keep the larger streams flowing throughout the year, but many smaller feeder streams flow only intermittently. During severe storms, particularly in the rainy seasons, the Yuna and some of its tributaries overflow their banks and spread their waters over flood plains, sometimes causing damage to crops, livestock, and habitations. Schomburgk (1853) recorded a rise in the level of the Río Yuna, during the hurricane of 1851, of "upwards of forty feet," but damage to crops by floods in more recent years has been relatively small because the inhabitants have located their small plantation homes in clearings on the slopes of the hills.

CLIMATE AND VEGETATION

The district has a tropical climate that is somewhat moderated by the mountainous character of the country. During the writers' stay from December to March the days were moderately warm and the nights cool.

No accurate meteorological data are available for the mapped area. At La Vega, a town 42 kilometers northwest of Monseñor Nouel along the Carreterra Duarte, W. D. Durland (1922) recorded an average of 1,700 millimeters total annual precipitation over a 7-year period. Precipitation is probably somewhat greater, however, in the Maimón-Hatillo district than at La Vega. Durland pointed out that at La Vega there is an apparent tendency toward two rainy seasons, one from May to July and the other from the latter part of September through November. During the time the writers spent in the area most of the rain fell during short, severe storms, generally less than an hour in duration, but there were misty periods that sometimes lasted an entire day. Rainfall was sufficient at all times to keep many sections of the trails muddy, particularly where they were shaded by thick, junglelike growth.

The vegetation of the area consists of two distinct ecologic types, according to the classification of Durland (1922): the "pine forest" type and the "partly evergreen hardwood forest" type. It has been pointed out by Durland and also by Gabb (1871, pp. 127–129) that the first of these types, which is characterized mainly by a single species of pine (*Pinus occidentalis*), is confined largely to areas of lateritic soil. In the Maimón-Hatillo district this type is found in other lime-deficient areas as well, notably over the chert of La Trinchera and in scattered patches over the sericite schist. A slender species of fan palm or "guano" palm, which grows to a height of 7 or 8 meters, is common in areas of lateritic soil but was not found over the chert. Evergreen hardwoods are particularly common in the areas underlain by volcanic and silicic intrusive rocks, where they completely cover the hilltops; they grow, also, in moist places at the bases of slopes and over the alluvial flats. They are festooned with aerial roots and bear a thick mass of foliage that shuts off most of the direct sunlight. Entwined with the evergreens is a rank growth of vines and, in some places, of yabacoa, a species of climbing grass that is edged with minute recurved barbs. Travel through this dense, junglelike growth is exceedingly difficult.

The royal and canna palms thrive in areas of limy soil and grow in abundance on much of the alluvial land, on low limestone hills, and scattered over the areas of volcanic rocks. Considerable stretches of open, grassy savanna, with a few isolated trees or clumps of trees, cover a great deal of the area underlain by schist and also parts of the alluvial flats. A broad-leafed species of grass, through which travel is extremely arduous and uncomfortable, grows to a height of 2½ meters on the steeper slopes and crests of the sharp ridges formed by the sericite schist.

POPULATION AND CULTURE

The Maimón-Hatillo area has a population of several thousand inhabitants, who are dependent chiefly on agricultural pursuits for their living. Although in general the area is mountainous, it includes a large proportion of fertile and arable land both in the valleys and on many of the slopes. Agriculture is diversified and on a small scale sufficient for family needs; bananas, rice, and yucca are the chief crops raised. The grassy savannas afford grazing for sufficient cattle to satisfy local demands. Only cacao is grown in some abundance for export from the district.

The pine forest on top of Loma Peguera supports a small lumber industry; a sawmill, not in use in 1942, is situated near the base of the southeast slope of Loma Peguera near the 168-meter bench mark.

Several towns and villages are within the limits of the mapped area, but a great part of the population lives on small farms that are rather evenly distributed in the bigger valleys. Monseñor Nouel (Bonao), the largest town in the district, reported to have been founded by Columbus in 1494, has a population of several thousand persons; it is the most important town between Ciudad Trujillo and La Vega and has electric-light and telegraph facilities. Maimón, Piedra Blanca, Juma, Caribe, and El Verde are the principal villages, each with a population of 200 to 500 people. Hatillo and the rest of the villages probably have populations of less than 200.

The district is accessible by means of the Carreterra Duarte, a surfaced highway that passes through Piedra Blanca and Monseñor Nouel and links the central and northern parts of the Dominican Republic with the capital city. This road is the main artery of communication over which all supplies are trucked. Monseñor Nouel can be reached in an hour and 40 minutes by automobile from Ciudad Trujillo.

An earth-top road linking Piedra Blanca with Cotui, a town about 25 kilometers to the northeast of the mapped area, was under construction in 1942. This road follows the south bank of the Río Maimón to Maimón and then follows the south bank of the Río Yuna most of the rest of the way to Cotui. In March 1942 it had been completed from Piedra Blanca for a distance of 2 kilometers toward Maimón and from Cotui to within a kilometer and a half of Hatillo. At that time it was thought that the road would be ready for automobile travel by the end of 1942.

The principal means of communication between the villages is by way of broad or narrow trails. Parts of these trails are muddy most of the time, and there are many stream crossings. Giving access to the slopes of the hills are various trails and footpaths, whose condition and location vary greatly with changes in the location of the small hillside plantations.

GEOLOGY

GENERAL OUTLINE

The geologic formations of the district (pl. 19) comprise four main groups: (1) a thick series of sedimentary and volcanic rocks of known Cretaceous and probable Cretaceous age, (2) intrusive igneous rocks probably of late Cretaceous or early Tertiary age, (3) an unclassified series of volcanic rocks probably of early Tertiary age, and (4) alluvial and residual deposits of Quaternary age.

The rocks of known Cretaceous and probable Cretageous age are subdivided into a lower group of formations, chiefly of sedimentary origin, and an upper group, chiefly of volcanic origin. The lower group includes chert and limestone; the upper includes sericite schist and a formation of two sedimentary tuff members with an interbedded greenstone that is probably a flow. All these formations dip southwestward; they generally crop out in belts trending northwestward. They extend over the entire mapped area, form the basement on which the younger bedded rocks were deposited, and are the host for the intrusive rocks.

The intrusive igneous rocks include a sill-like mass of ultramafic rocks in the western part of the district and three stocks of syenite in the eastern part. A mass of hornblende schist in the southwestern part of the mapped area, probably derived from a quartz diorite, also is tentatively included with the igneous rocks. The ultramafic body was intruded essentially at the contact between the greenstone and the upper sedimentary tuff, except in the northern part of the area where it cut at a low angle across the upper sedimentary tuff. Stocks of syenite were intruded into the lower members of the sericite schist or at the contact between the limestone and the sericite schist.

The Tertiary(?) volcanic rocks, found only in the northeast corner of the district, unconformably overlie the chert and the tilted Cretaceous limestone.

The Quaternary alluvial deposits form the floors of the valleys, and residual deposits cover many slopes. Although classified as Quaternary, part of these residual deposits may be older. They include a lateritic mantle on top of the ultramafic rocks, in part a blanket deposit of weathered nickeliferous material.

CHERT OF UNKNOWN AGE, PROBABLY CRETACEOUS

DISTRIBUTION AND CHARACTER

The chert, which apparently is the oldest formation exposed in the district, crops out over an area of at least 18 square kilometers on the lower slopes of La Trinchera, a broad mountain near the northeast corner of the mapped area. It is not known to crop out elsewhere in the district or even on the higher parts of that mountain, which, however, were not completely mapped because of their virtual inaccessibility.

The chert is milk white, though some of it is surficially stained light yellow brown or dark red brown by iron oxides. It is massive and structureless, and although fine-grained it has the general appearance of quartzite. It is greatly fractured and recemented by secondary quartz; locally many of the late fractures are filled with magnetite or hematite.

At no place was it possible to obtain strike and dip readings on the chert. Any bedding or stratification planes that may have been present originally have been completely destroyed. The rock is monotonously uniform in texture and composition, and variations were seen at very few places. In one locality original quartz sand grains were seen embedded in a dense matrix, also conglomeratic quartzite with irregularly shaped, subrounded quartz pebbles, some of them a centimeter or slightly larger in diameter. This outcrop is at an altitude of 260 meters and is half a kilometer north of the Arroyo Margarita and a kilometer west of a small hill formed by a large fault block of limestone in the chert (pl. 19). Brecciated quartzite or quartzitic conglomerate crops out on the north bank of the Arroyo Margarita and a kilometer west of the block-faulted limestone hill. A few original quartz sand grains were seen, also, in a road cut, 2½ kilometers southeast of El Plantano, where the unfinished Cotui-Piedra Blanca road skirts the south side of a low, rather isolated chert hill on the south bank of the Río Yuna.

A study of the chert in thin section shows that it consists chiefly of fine-grained, typical cherty quartz, with disseminated grains and veinlets of hematite and magnetite and fine-grained, disseminated leucoxene. There are minor, though significant, amounts of mosaic quartz that for the most part represents pebbles and fragments of quartzite. Chalcedony was found in one thin section, where it lines or fills cavities, and secondary veinlets of fine-grained quartz are present in several thin sections.

In a thin section cut from the rock collected east of the fault-block hill of limestone north of the Arroyo Margarita, the original rounded to subrounded sand grains of quartz are embedded in cherty quartz and are estimated to make up 5 percent of this rock. A thin section of the quartzitic rock collected west of the same hill shows fragments and pebbles of quartzite, as much as 4 millimeters across, that consist of mosaic quartz in cherty quartz. Several thin sections cut from the chert at other localities show patches and irregular areas of quartz similar to that in the quartzite, grading rather abruptly, though not sharply, into cherty quartz. Whether or not these areas represent original quartzite fragments is not clear.

ORIGIN

The origin of the chert was determinable neither from the field evidence nor from the microscopic study of thin sections. Its structureless and massive character and its whiteness give it the appearance of quartzite in the field. The relatively large amount of fine-grained quartz in the rock revealed under the microscope, however, suggests that it may be derived from silicification of a preexistent rock. The primary rock, the original character of which has been obliterated, may have been a limestone or a volcanic rock but was probably not a sandstone. The quartzite breccia from the north bank of the Arroyo Margarita and the chert with quartz sand grains collected in the valley of the Arroyo Margarita suggest a quartzose rock as the primary rock. However, the presence of isolated sand grains in the chert with their original outlines preserved is not readily explained if a sandstone is assumed to have been replaced, as it seems improbable that such grains would remain after replacement of an aggregate of sand grains. Rather, their presence and preservation suggest that they were originally embedded in material of unlike character such as carbonate or volcanic rock, both of which are in general readily replaceable by silica.

RELATION TO ADJACENT ROCKS

The stratigraphic relation of the chert to the other rocks in the district has not been established. The entire mass of the chert lies across the strike of the Cretaceous limestone with which it is in fault contact. Along the west side of La Trinchera it is faulted against beds of black calcareous slate interbedded with poorly fossiliferous limestone that has a dip equal to the regional dip of the limestone formation and strikes directly toward the chert. Evidence of a fault between the chert and the limestone is found in the presence of fault gouge and breccia between the two and a great deal of secondary hematite and limonite along joints and shear planes near the contact. These features are particularly well displayed by the exposures in a small stream that flows southward along the north-south fault between the lower slopes of La Trinchera and a narrow limestone ridge approximately 2 kilometers southeast of Hatillo. They are shown, also, by exposures along the contact on the north side of the Arroyo Margarita, half a kilometer east of the small fault-block hill of limestone. In the lower course of the Arroyo Margarita faulting has been more complex and the chert is in contact with a sericitic schist that normally overlies the limestone. In other parts of the district the limestone is overlain, apparently in a simple continuous sequence, by a great thickness of volcanic and sedimentary rocks, none of which bears any resemblance to the chert on La Trinchera. It is therefore assumed that this mass of chert normally lies stratigraphically below the limestone and has been faulted upward into contact with the limestone.

AGE

The stratigraphic evidence that the chert was faulted upward into contact with the limestone indicates that it is older than the limestone, but how much older is not known. No similar chert was seen elsewhere in the Dominican Republic, so that the question as to whether it occupies a stratigraphic position immediately underlying the limestone or whether other lithologic units normally lie between the two cannot yet be answered. In view of the uncertain relations, the chert is considered to be of unknown age, probably Cretaceous.

CRETACEOUS SYSTEM

LIMESTONE FORMATION

DISTRIBUTION AND CHARACTER

The limestone formation extends from the east-central part of the northern border of the mapped area southeastward for a distance of almost 15 kilometers. It is well exposed north of the Río Yuna, where it forms a prominent mountain, just east of the village of Sabana Grande, that is known locally as Loma del Caballero. South of the Río Yuna the formation is exposed on Loma Jengibre, a northeastward-trending ridge at the base of La Trinchera. Discontinuous patches of the limestone are present along the southwestern and southern flanks of La Trinchera; they have been mapped to a point 1½ kilometers due west of the village of La Laguna.

The limestone formation consists of massive limestone beds with some slate and calcareous mudstone in the upper part. The limestone is uniformly medium to dark blue gray, rather fine grained, and compact. It occurs in beds from several centimeters to as much as 50 meters in thickness. Where the limestone has been intruded by syenite stocks it has been locally altered to a rather coarsely crystalline white marble, and associated with it are deposits of magnetite and hematite (pp. 330, 342, 344).

Black calcareous slates interbedded with the limestone are well exposed at two localities along the unfinished Cotui-Piedra Blanca road. The first of these localities is 1½ kilometers west of El Plantano, at the northwest edge of a small north spur of La Trinchera; there an outlier of black calcareous slate, about 200 meters in length, is unconformably overlain by a latite outlier of the Tertiary(?) volcanic series. The second locality is about 4 kilometers southwest of El Plantano, in a road cut along the southeast side of Loma Jengibre, 250 meters south of the most northeasterly peak on this hill. There the slate is interbedded with limestone that contains a few poorly preserved caprinids and other fossils.

Calcareous mudstones are more widespread than the slates but apparently occur only in the upper part of the formation. A thickness of almost 200 meters of calcareous mudstone was observed 1.2 kilometers southwest of Sabana Grande where it forms a low, indistinct ridge that parallels the regional strike of the limestone and is adjacent to an apophysis of syenite extending northwestward. A much larger body of calcareous mudstone surrounds the southern end of the syenite stock in the Arroyo Margarita near the eastern edge of the mapped area. The mudstone crosses the ridge that trends eastward from Loma de la Mina and occupies most of the upper part of the valley of the Río Tocoa. It is best exposed on the slopes of the 408-meter peak a kilometer west-southwest of the Margarita iron deposit. There it is seen to be a well-cemented calcareous mud, in places showing sheet jointing; locally it grades into impure limestone. At most exposures in the valley of the Río Tocoa the mudstone has been weathered to a soft, light-tan clay and is hardly distinguishable from weathered exposures of the tuffs higher in the stratigraphic section, except that imperfect cleavage, a feature not shared by the tuffs, generally is preserved. In the Tocoa Valley the mudstone grades upward into the overlying sericite schist, and the contact between the two could not be satisfactorily traced.

THICKNESS

The thickness of the limestone formation (pl. 19) could not be measured, but it is more than 400 meters on Loma del Caballero and possibly reaches a total of 1,000 meters. In the limestone hills northeast of Loma del Caballero sharply truncated ridges suggest that some step faulting has taken place, but definite evidence of this faulting was not observed.

AGE

Fossils collected by the writers from the limestone at two localities along the edges of the main area of outcrop indicate that it is late Lower Cretaceous in age. These fossils have been studied by W. P. Woodring and L. W. Stephenson, of the United States Geological Survey, who report as follows:

G2. Provincia de la Vega, Maimón-Hatillo district, Loma del Caballero, 2 kilometers west-northwest of El Plantano, east side of main mass of first outcrop of limestone just west of alluvium along Río Yuna:

Peruviella (?).
Requienia or *Toucasia*.
Caprinid, cf. *Amphitriscoelus*.
Caprinid, cf. *Caprinuloidea*.
Age.—Cretaceous, probably late Lower Cretaceous.

G1. Provincia de la Vega, Maimón-Hatillo district, east bank of Río Cab-Imai at foot of west slope of Loma del Caballero, a kilometer northwest of Río Yuna and 1½ kilometers southwest of 303-meter peak of Loma de Jengibre [sic]:

Nerinea.
Peruviella (?).
Age.—Presumably same as G2.

In an earlier study of the limestone formation by Wythe Cooke (1921, pp. 59–60), who observed it at the caves of Las Guácaras, north of Loma de Sierra Prieta, and also at Hatillo, no fossils were found, but its age was determined on the basis of stratigraphic and structural relations to be Eocene or older.

CRETACEOUS(?) SYSTEM

SERICITE SCHIST

DISTRIBUTION AND CHARACTER

The sericite schist is the most extensive formation in the mapped area. It crops out in a band 6 kilometers wide and has been traced continuously along the strike for a distance of 24 kilometers. It is typically exposed in the hills surrounding the town of Maimón. The lower part of the schist forms a row of rather massive mountains known from northwest to southeast as (1) Loma de los Pinos Altos, (2) Loma Aguardo and its southeastward extension, Loma Mogote, and (3) Loma de la Mina, which is south of the Río Yuna. The upper part of the schist forms the main mass of Loma Pesada at the northwest and a row of low hills, the Cerros de Maimón, to the southeast. The formation is of economic interest because the copper deposit on Loma de la Mina is enclosed in it and several of the magnetite boulder deposits on Loma Aguardo and Loma Mogote apparently have been derived from pockets in it.

Most of the schist is thoroughly foliated, but the degree of foliation differs from place to place and some members are only slightly foliated. On fresh surfaces the schist is whitish to light buff gray and, locally, light greenish gray; commonly it weathers to a neutral or buff gray.

The schist has been derived chiefly from volcanic rocks, including tuffs and flows of rhyolite, latite, and andesite. However, the alteration that these rocks have undergone in general precludes their identification in the field, and no attempt was made to map separate units. The formation also includes members easily recognized as sedimentary rocks, including limestone, conglomerate, quartzite, and chert.

A study of these rocks under the microscope shows that the rhyolitic members are partly or thoroughly schistose, whereas the latitic and andesitic members are distinctly less schistose and in places are not foliated. In the rhyolitic schists the quartz phenocrysts show undulatory extinction, but neither the quartz nor the feldspar phenocrysts have been crushed or altered. The groundmass has been mildly foliated, consists of a microgranular aggregate—probably of quartz and feldspar showing subparallel orientation—and is interspersed with oriented sericite shreds. In some thin sections the matrix is banded and the sericite occurs in distinct bands or lenses. Most of the thin sections show disseminated epidote or zoisite, and a brown pleochroic mineral—probably biotite or vermiculite—is also present. An appreciable amount of chlorite, to the exclusion of sericite and biotite, was found in only one thin section cut from a specimen collected on Loma Pesada.

The less foliated rocks, including latite and andesite and, less commonly, rhyolite, are altered to a comparatively minor degree. The secondary constituents are epidote, biotite, and sericitic minerals—probably including both sericite and one or more of the clay minerals. This group of rocks is exposed at points along and in line with the main ridge of Loma Mogote and the main ridge of Loma Aguardo. The best example, however—a nonschistose, red to greenish, porphyritic andesite—is exposed in the bed of a small creek tributary to the Arroyo Margarita, 100 meters northwest of the syenite stock. Under the microscope it shows a "felted" groundmass with flow structure surrounding subangular phenocrysts of sericitized feldspar. Amygdaloidal cavities are abundant and are filled with quartz, chiefly chalcedony and minor amounts of an isotropic mineral that is probably a zeolite.

The sedimentary members occur in the middle and upper parts of the schist. A very fine grained, light buff-gray chert is exposed on a prominent hill 250 meters south of the Río Tocoa and 3 kilometers southeast of the summit of Loma de la Mina. Interbedded with the chert is a banded, light- to dark-gray, siliceous rock—presumably a quartzite—which is slightly more granular than the chert. Massive quartzite containing remnants of the original quartz sand grains is exposed near the top of the schist in the bed of a small arroyo crossed by the old trail that skirts the base of a prominent ridge about 4 kilometers southeast of Maimón. A layer of conglomerate in the schist is exposed on top of a spur trending southwestward from the summit of the main ridge of Loma Mogote, half a kilometer southwest of the small subcircular syenite stock. The conglomerate contains pebbles as much as 2 or 3 centimeters in diameter.

Limestone lenses were found in the sericite schist at three separate localities. The largest lens crops out at the summit and along the west slope of the main ridge of Loma Mogote, a short interval stratigraphically below the conglomerate layer, and part of it lies adjacent to the southwest edge of the syenite stock. The second lens is exposed capping a low ridge on the lower slopes of Loma de la Mina, 1.3 kilometers southwest of the summit; it is approximately 10 meters thick and overlies an exposed thickness of 60 meters of sericite schist. The third limestone lens lies at the contact between the sericite schist and the overlying lower sedimentary tuff near the southeast boundary of the mapped area, where it was traced along the strike for a distance of 1.3 kilometers. It ranges in thickness from about 40 to 100 meters. In general the limestone in these lenses is unaltered and lithologically resembles the limestone of the underlying formation. The limestone in the lens on the slopes of Loma de la Mina, however, is somewhat impure and contains thin micaceous layers along the bedding planes. Unfortunately no fossils were found in these lenses.

A large quantity of secondary quartz is highly characteristic of the sericite schist, particularly of the upper part. It occurs in irregular veins and in lenses as much as a meter in thickness, and it is especially useful as a means of identification where the schist is covered by a thin mantle of soil or alluvium. The largest and the most abundant quartz veins were seen on the slopes of a hill about a kilometer east of Hato Viejo.

THICKNESS

The schist is obviously very thick, but the poor exposures and the absence of horizon markers within the formation afford little opportunity to determine whether any part of it is repeated through strike faults or folds. Though the schist has been squeezed and has been intruded by the syenite stocks, the dips observed are consistently to the west, indicating no abnormal disturbance. The dip of the schistosity averages 60° to 65°, but that of the bedding of the sedimentary members and of the underlying limestone is less. If an average dip of 40° to 45° is assumed for the bedding of the schist, and if repetition or omission by faulting is not considered, the thickness of the schist would be about 4,000 meters.

RELATION TO ADJACENT ROCKS

Though the limestone underlies the adjacent schist, Cooke (1921, pp. 59–60), as a result of brief reconnaissance work in the district, believed that the limestone was younger than the schist and that it owed its position to faulting. He nevertheless recognized from the exposures at Hatillo that "the dip of the limestone, were there no fault, would carry the rock beneath sericite schists of the basal complex."

Evidence secured in the course of the writers' field work, indicating rather clearly that the sericite schist stratigraphically overlies the limestone, may be briefly summarized as follows: (1) The regional strike and direction of dip of the limestone and the sericite schist are virtually the same. (2) The limestone dips under the schist at all points where the relations could be observed in the 18 kilometers along which the contact was mapped. (3) The calcareous mudstones, which at some localities are interbedded with the limestone, appear to grade upward into the sericite schist in the valley of the Río Tocoa. (4) The sericite schist contains lenses of limestone that appear identical lithologically with the limestones of the limestone formation and that are equally unaltered. (5) Although faults in the vicinity of Hatillo are suggested by the irregular course of the Río Yuna, field evidence is lacking to show the presence of a major strike fault. A throw of at least 13,000 meters would have been required to drop the limestone formation to its present position if it were younger than the thick section of the overlying sericite schist, tuffs, and greenstone.

AGE

No fossils were found in the sericite schist formation, but its stratigraphic position overlying the limestone indicates that it is not older than Cretaceous, and the amount of metamorphism it has undergone suggests that it probably is not younger than Upper Cretaceous.

SEDIMENTARY TUFFS AND GREENSTONE

GENERAL STATEMENT

Overlying the sericite schist is a group of sedimentary tuffs with an interbedded greenstone, probably a flow. They form a stratigraphic unit that is divided as follows: a lower sedimentary tuff, a greenstone, and an upper sedimentary tuff. As these rocks conform in attitude to the Cretaceous sedimentary rocks below and are much more metamorphosed than the series of early Tertiary(?) volcanic rocks that unconformably overlies the lower part of the Cretaceous section to the northeast, they are referred tentatively to the Cretaceous system.

LOWER SEDIMENTARY TUFF

The lower sedimentary tuff crops out in a narrow discontinuous band forming a number of low ridges and hills at the western base of Loma Pesada and the eastern foot of Loma Peguera and at the eastern foot of the prominent ridge, northeast of the Río Leonora, that extends northward from Loma Siete Cabezas. This member has been mapped for a distance of slightly over 24 kilometers along the strike. The width of outcrop ranges from 0.3 kilometer at the northern end of the district to 1.3 kilometers at the southern end. The thickness is estimated to range from 200 to 600 meters.

The sedimentary tuff is a light greenish-gray, fine-grained rock. Much of it has weathered to a buff-colored clay, and it breaks into rather small fragments; consequently it makes poor outcrops. Over most of the area the tuff is massive and devoid of structure. At several localities, however, conglomeratic layers were found, and in other places the tuff is laminated. In the bed of the Río Leonora, 1.9 kilometers south of Maimón, outcrops of the sedimentary tuff contain angular rock fragments as much as a centimeter or more in diameter that stand out on the weathered surface. A similar but darker tuff is exposed at an altitude of 315 meters in a small northeastward-flowing creek on the east slope of the ridge northeast of the Río Leonora, 6.0 kilometers southeast of Maimón.

The sedimentary tuff is laminated immediately adjacent to the greenstone contact seen in the bed of a northeastward-flowing stream at an altitude of 175 meters on the east slope of Loma Peguera, 3.2 kilometers northwest of Maimón. The bands are light to dark gray and only a centimeter or two thick.

A study of the tuff under the microscope shows it to be remarkably uniform in texture and mineral composition. In general it consists of banded, cloudy matter, irresolvable under the microscope even with high magnification, and apparently is fine clastic material or triturated glass. Vesicular glass fragments were found in a thin section of a specimen from an outcrop in the Río Leonora, and bits of feldspar and, more rarely, quartz are present in the relatively coarser bands. No dark minerals nor vestiges of dark minerals have been found except a few scattered, somewhat altered augite grains that are associated with the glass fragments. Secondary minerals are abundant, especially fine-grained cloudy epidote; less commonly chlorite, sericite, and biotite and rarely calcite are found in abundance. Several thin sections show quartz veinlets. Although glass fragments are common at least in one thin section, shards and crescentic fragments that are commonly associated with volcanic ash were not found.

The rock evidently is detrital in origin. Its uniformly fine texture, its banded or laminated character in places, and the general absence of ferromagnesian minerals all suggest that the rock is a sediment probably derived from the weathering and erosion of latitic or andesitic rock. It is therefore classed tentatively as a sedimentary tuff.

GREENSTONE

The greenstone is the most distinctive of the Cretaceous (?) rocks. It is easily recognized and therefore is the best horizon marker in the strata above the limestone. It crops out in a discontinuous band along numerous small hills northwest and southeast of Caribe and along the east slope of Loma Peguera, and it forms the crest and steeper northeastern slopes of the prominent ridge northeast of the Río Leonora. It supports a junglelike cover of hardwood trees, which along most or all of the upper contact on Loma Peguera stand out in contrast to the pine and fan-palm vegetation covering the ultramafic mass. Northwest of the village of Caribe the greenstone lies between the lower and upper tuffs, but southeast of Caribe it lies between the lower tuff and the sill-like mass of ultramafic rocks.

The greenstone has been mapped for a distance of slightly over 22 kilometers along the strike. Moreover, greenstone that may belong to the same unit was observed near the summit on the west slope of the ridge connecting Loma Siete Cabezas and Loma Mogote, 8.5 kilometers south-southeast of the southernmost point to which the lower sedimentary tuff-greenstone contact was mapped. Like the lower tuff, the greenstone has a greater width of outcrop at the south and thins toward the north, at one place apparently pinching out completely. Although the thickness of the greenstone may be as great as 500 meters, in general it is probably less than 200 meters.

The greenstone is speckled, dark, greenish to grayish, and moderately coarse to fine grained. Under the hand lens it is seen to be made up principally of greenish hornblende and whitish plagioclase. Gneissic structure is locally developed and is well shown at an outcrop in the bed of the Río Leonora immediately adjacent to the contact with the ultramafic mass, where the gneissic banding strikes N. 60° W. and dips 55° W. It is characteristically cut by many small veinlets of feldspar.

Under the microscope the typical greenstone is seen to be composed essentially of secondary minerals, and alteration has obliterated the original texture of the rock. Pale-brown to green pleochroic hornblende, some of it in sheaves and radial groups, is the most abundant mineral. Altered feldspar and chlorite are less common. Some of the altered feldspar has clear borders but cloudy cores, giving the grains a skeletonized appearance. Epidote and zoisite are minor secondary minerals.

The relation of the greenstone to the underlying and overlying tuff is not clearly revealed, but in the absence of positive evidence that the greenstone is intrusive, it is tentatively regarded as a flow. Though the comparatively coarse grain of much of this rock would be consistent with its intrusion as a sill, the gneissic texture that occurs locally and the recrystallization of the rock that has obliterated its primary texture lessen the value of its grain as a criterion. Nowhere were greenstone dikes found, nor were crosscutting relations observed between the greenstone and the tuffs. Furthermore, no evidence was found to indicate that the greenstone follows a zone of weakness within the tuffs. Its persistence over a long distance within such a uniform mass without crosscutting to another stratigraphic horizon is not characteristic of intrusions. The structural relation of the greenstone to the upper tuff was largely obliterated by the intrusion of ultramafic rock along their contact.

UPPER SEDIMENTARY TUFF

The upper sedimentary tuff crops out in two separate areas: (1) in a wide zone on the southwest side of the ultramafic mass of rocks along the north end of the main ridge of Loma Siete Cabezas and the lower slopes and western foothills of Loma Mala and Loma Peguera and (2) in a narrow, discontinuous zone on the northeast side of the ultramafic rocks northwest of the village of Caribe, where it forms several small hills, and the lower northeastern slopes of Loma Caribe. In the southern and larger area of outcrop it ranges in width from 2 to

3.2 kilometers. In the smaller area, northwest of Caribe, the width of the outcrop averages only 400 meters, but part of the tuff here has probably been obliterated by a longitudinal fault, as explained on page 339. Because of observed variations in the width of its outcrop, the thickness of the upper sedimentary tuff cannot be accurately determined, but its thickness in the southern area is approximately 2,500 meters.

The upper tuff, like the lower, is light gray to pale greenish gray, very fine grained, and compact. In general it also is devoid of any structure; the mineral grains are too small to be identified in the hand specimen. It is free from cleavage but apparently full of small fractures that cause the rock to break into small, irregular pieces.

Interbedded with the upper sedimentary tuff are some quartzite and schist lenses, which are well exposed in the bed of a small creek draining to the southwest from Loma Mala at a point 2½ kilometers northeast of Piedra Blanca. On the southwest slope of Loma Mala, about 2.2 kilometers northeast of Piedra Blanca, boulders as much as 1 meter in diameter of a reddish, siliceous rock resembling jasper are scattered over an area several acres in extent; these boulders are cut by irregular stringers and veinlets of milky quartz and manganese oxide. As this rock was nowhere found in place, its relation to the tuff could not be determined, but its local concentration here indicates its derivation from a lens in the upper tuff. Locally the upper sedimentary tuff is cut by veinlets of secondary quartz that serve to distinguish it from the lower tuff, particularly in the area where the two are adjacent.

Under the microscope the upper tuff is seen to be similar to the lower. The primary material composing the rock consists of a dark, cloudy aggregate, indeterminable under the microscope. Embedded in it are rock fragments consisting of glassy as well as microgranular volcanic rocks, bits of feldspar, and—locally—fragments of augite. It has been replaced to varying degrees by secondary minerals. Unlike the lower, the upper tuff contains hornblende as an abundant, and in some thin sections the most abundant, secondary mineral. Other secondary minerals are epidote, zoisite, chlorite, and minor amounts of calcite.

AGE

The sedimentary tuffs and greenstone, like the sericite schist, are considered to be of Cretaceous (?) age, probably Upper Cretaceous.

TERTIARY(?) VOLCANIC ROCKS

DISTRIBUTION AND CHARACTER

A series of volcanic rocks rests unconformably on the chert on La Trinchera and, in at least one place in the northeastern part of the district, on slates belonging to the adjacent limestone. These volcanic rocks are well exposed on the northern slopes of La Trinchera and on a number of low hills that extend to the northeast edge of the mapped area and beyond.

Though the volcanic rocks have not been differentiated in mapping, tuffs, breccias, and flows of latite, rhyolite, and andesite have been recognized at various localities. The oldest of these is a latite forming outliers west and southwest of El Plantano and an irregular border around the main mass of the volcanic rocks to the east. It is the only effusive rock with which the chert was seen in direct contact.

The large, elongate hill in the northeast corner of the mapped area, trending southeast from El Mamey, is composed principally of rhyolitic rocks with conspicuous quartz phenocrysts. Reddish-gray to purplish andesitic rocks are exposed on the long, northeastward-trending spur on the north flank of La Trinchera on the east side of the Arroyo Melgar. Most of the volcanic rocks seen are fragmental, chiefly tuff and breccia; agglomerate, if present, forms only a minor part. The restricted distribution and the small size of the rock fragments indicate that their source is outside the mapped area.

RELATIONS TO ADJACENT ROCKS

The unconformable relations of the volcanic rocks to the chert and limestone have been described. The mantle of volcanic rocks on both the chert and limestone shows further that the chert in prevolcanic time was faulted into its present relative position and that any formations on top of the chert were removed by erosion. Field relations show, also, that the volcanic rocks were extruded on a surface having considerable relief. They are exposed on top of the chert at higher altitudes on the upper northern slopes of La Trinchera than on the lower slopes, where they lie at increasingly lower altitudes. A small patch of the volcanic rocks is exposed on the south bank of the Río Yuna half a kilometer west of El Plantano. Due south of El Plantano chert forms a low ridge between two higher ridges formed by the volcanic rocks. The local vertical range in distribution of the volcanic rocks shows that the prevolcanic topography had a relief of more than 400 meters, and it is probable that the area at the time of the volcanism was as rugged as it is today.

AGE

Except for the alluvial deposits, the undifferentiated volcanic rocks are the youngest in the district. Their fresh appearance, compared to that of the Cretaceous (?) volcanic rocks, and their angular discordance with the westward-dipping formations of known Cretaceous or probable Cretaceous age indicate that they are certainly younger than

Cretaceous. As the upper age limit is unknown, the volcanic rocks are tentatively considered Tertiary.

QUATERNARY ALLUVIUM

Large areas of alluvial material, covered by grassy savannas, palms, or jungle growth, form the floors of the broader valley bottoms and extend fingerlike branches up tributary streams. In some of the larger valleys, such as those of the Río Yuboa and the Río Yuna, the alluvium is probably very thick, but in many of the tributary valleys it forms a relatively thin mantle. All the streams are now in the process of down cutting, and most of them, possibly with the one exception of the Río Yuna, have exposed bedrock at various points along their courses.

Several ages of alluvial material can be identified in the Maimón-Hatillo district, but time did not permit the mapping of the various terraces. In the vicinity of Piedra Blanca is an area covered by high-level fluviatile deposits on both banks of the Río Maimón and on the west bank of the Arroyo Juan Manuel. These deposits form a mantle over the flat tops and gentle slopes of low, broad ridges. They occur at elevations of 5 to 45 meters above stream level. A great deal of the material is composed of well-rounded boulders of a coarse-grained igneous rock, possibly diorite or gabbro. These deposits extend down the Río Maimón almost as far as the contact between the sedimentary tuff and the ultramafic mass.

In the vicinity of Maimón a terrace, in outline roughly corresponding to the 100-meter contour (see map, pl. 19) and approximately 5 meters high, is covered at widely scattered localities with small pellets of iron and manganese oxides as much as a centimeter or slightly more in diameter. This terrace deposit forms a thin mantle over the sericite schist formation; streams that cut the mantle all expose schist at various points in their beds.

The recent alluvium forms only narrow bands along the present courses of the streams.

INTRUSIVE IGNEOUS ROCKS

GENERAL STATEMENT

The intrusive igneous rocks include a sill-like mass of ultramafic rocks, three stocks of syenite, and a mass of hornblende schist and related rocks that were probably derived from a quartz diorite or quartz monzonite. The ultramafic mass is intruded between the greenstone and the upper sedimentary tuff, except in the northern part of the area on Loma Caribe where it lies between the upper sedimentary tuff and a small mass of hornblende gneiss. The stocks of syenite are intruded into the upper part of the limestone, into the lower part of the sericite schist, or at the contact between the two. The hornblende schist is exposed in two widely separated areas, the larger mass in the southwest corner of the mapped area, where it is in contact with the upper sedimentary tuff, and the smaller mass on the southwest side of Loma Caribe, where it is in contact with the ultramafic rocks. Only a small part of the formation is within the mapped area, and its mode of occurrence and relation to the adjacent rocks are obscure.

The relative order of intrusion of the igneous rocks has not been determined. Nowhere in the district are the intrusions in contact with one another except on Loma Caribe, where a small mass of hornblende schist is adjacent to ultramafic rocks. Judging from the age relations between ultramafic and more felsic rocks in general, it is probable that the ultramafic rocks in the district are older than either the syenite or hornblende schist. The mode of occurrence of the hornblende schist is too uncertain to warrant any speculation as to its relative age compared with the syenite.

The intrusion of the igneous rocks was probably postdeformation in time, as is suggested by their alinement with the structure of the region. Since the major period of deformation of the invaded rocks is believed to have occurred during very late Cretaceous time, the time of intrusion is tentatively assigned to the late Cretaceous or early Tertiary. Until more definite information becomes available on the geology of the Cordillera Central, a more exact age assignment cannot be made.

ULTRAMAFIC ROCKS

DISTRIBUTION

The mass of ultramafic rocks occupies an area of almost 50 square kilometers in the western portion of the district. It forms the major part of Loma Caribe, Loma Peguera, Loma Mala, and an unnamed hill east of the main ridge of Loma Siete Cabezas. This intrusive mass has been mapped for a distance of 25 kilometers along its trend, but it continues both to the north and to the south of the mapped area. Its width at right angles to the long axis of the body ranges from 1.5 to 4.7 kilometers, probably averaging 2.5 kilometers.

The ultramafic rocks are of special interest because associated with them are nickel deposits and a lateritic soil cover, both of which are described in this report.

CHARACTER

The mass of ultramafic rocks consists partly of dunite (composed almost entirely of olivine) and partly of saxonite (composed of olivine with 10 to 40 percent enstatite, the orthorhombic pyroxene). Apparently all gradations between the two rocks exist even in the same area. The variability of the mass was recognized in the field, but it was considered impractical, during the allotted time, to attempt to map the rocks separately. This ultramafic mass has been referred to as serpentine (Cooke and Ross, 1921, pp. 52, 231), but only a small portion of it actually is serpentine, which on the whole is limited to a fine network of fractures that cut the rock and to larger areas along shear zones. Nowhere was a large mass of serpentine found.

Both the dunite and the saxonite are dark green on fresh surfaces; in weathered outcrops they are brownish green. Most of the saxonite is porphyritic, and the enstatite phenocrysts are easily recognized. On weathered surfaces the saxonite is readily identified by its pitted surface, which owes its unevenness to the greater resistance of enstatite to weathering as compared with olivine.

Dunite was recognized only in the area north of the Río Maimón, where the nickel deposits are found. These deposits are best exposed on the southeast slopes of Loma Caribe and Loma Peguera. Neither nickel deposits nor the quartz-boxwork float so typical of the nickel deposits in the Dominican Republic, as well as of similar deposits in other parts of the world, were found south of the Río Maimón, where only saxonite is present.

OCCURRENCE

The ultramafic rocks form a sill-like mass, the greater part of which, within the mapped area, has been intruded between the greenstone and the upper sedimentary tuff of Cretaceous (?) age. Only on Loma Caribe, in the northern part of the area, does it leave the greenstone contact, and there it is intruded along the upper contact of the upper sedimentary tuff. Its emplacement at different stratigraphic horizons shows it to be an intrusion and not a flow. Its intrusive character is also clearly shown by its relation to the greenstone. The contact between the ultramafic rocks and the greenstone everywhere is indefinite, consisting of a zone of mixed rock 100 meters or more wide, in which greenstone inclusions are thickly scattered through the ultramafic rocks. It was no doubt one of these inclusions that Cooke and Ross (1921, pp. 52, 231) saw in a prospect pit on "Loma Pegado, a hill about 4 kilometers southwest of Maimón," and which they interpreted as a dike of hornblende diabase. Such zones of mixed rock are especially well displayed in the small ridge northwest of El Verde and in the ultramafic rocks south of the Río Maimón. Along the Río Leonora inclusions of greenstone up to 30 meters long and 10 meters wide were encountered from the greenstone contact to within a kilometer of the contact between the ultramafic mass and the upper sedimentary tuff. Many of the inclusions have serpentinized borders. The possibility that the inclusions of greenstone in the ultramafic rocks might be in-faulted blocks was considered until the many thousands of all sizes seen at all levels in the intrusion rendered that interpretation untenable. Apparently the greenstone has been sheared and shattered along a longitudinal fault (pp. 339–340) and has formed a spongelike channel for the intrusion of the ultramafic magma.

At the margins of the intrusion, east of the zone of mixed rock, the ultramafic rocks also form dikes in the greenstone. On top of the ridge 1.6 kilometers south-southwest of Maimón, about 150 meters southwest of the summit (altitude, 317 meters), an ultramafic dike averaging 3 meters in width was seen in the greenstone nearly half a kilometer northeast of the greenstone-ultramafic contact. The dikes of the ultramafic rocks in the greenstone, the zone of mixed rock at the contact, and the crosscutting relation of the ultramafic mass to the upper sedimentary tuff leave no doubt that the ultramafic mass is an intrusion and not a flow.

SODIC SYENITE

DISTRIBUTION

Three stocks of syenite occur within the limits of the mapped area. The largest of these stocks occupies approximately 5 square kilometers east of the main ridge of Loma Aguardo, forming its eastern slope and foothills, and is referred to as the Aguardo stock. At its southern end it crosses the ridge connecting Loma Aguardo and Loma Mogote. Two apophyses that lie on each side of a hill of white marbleized limestone, known locally as La Búcara, extend northwestward from the main central mass of syenite, one beyond the northern border of the mapped area. Another exposure of syenite lies 0.7 kilometer southeast of the Aguardo stock. It forms a small conical peak along the main ridge of Loma Mogote and is designated the Mogote stock. It is a small subcircular body with a diameter of slightly over 300 meters and is located alongside a thick lens of limestone in the sericite schist. It may be connected along the east slope of the ridge with the Aguardo stock. The third stock, exposed in the valley of the Arroyo Margarita and in its main tributary to the southeast, is designated the Margarita stock. It extends from the creek southeastward across an irregular ridge that trends eastward from Loma de la Mina. The Margarita stock underlies an area of slightly more than 2 square kilometers.

All three stocks are intruded into the lower part of the sericite schist or at the contact between the schist and the underlying limestone. Their intrusion along a rather definite stratigraphic horizon implies that their emplacement was guided by bedding and contacts, although cross faults may have exerted some influence.

CHARACTER

The syenite presents some minor megascopic variations in appearance, but in general it is similar in all outcrops seen. The typical color of the fresh syenite is greenish gray to dark gray; on weathered surfaces it is buff to rusty brown. It is essentially fine-grained, but in the center of the Aguardo stock it is coarser-grained than along the margin. Although it is nonporphyritic, local concentration of mica gives the rock a pseudoporphyritic texture. The recognizable minerals are light-gray feldspar, mica, and other mafic minerals that cannot be identified under a hand lens.

A study of the syenite under the microscope shows it to consist typically of a fine-grained granitoid aggregate composed chiefly of albitized orthoclase and subordinate amounts of oligoclase, augite, hornblende, and quartz. Minor accessory constituents are apatite and magnetite. All the minerals of the syenite have suffered more or less replacement, which varies in degree and kind in the different stocks and even in the same stock. The orthoclase has been extensively replaced by albite, but the degree of replacement varies in the different grains. The oligoclase is most commonly cloudy, and in the syenite from the Aguardo and Mogote stocks it is much sericitized. It is commonly bordered by clear orthoclase and albite that are in marked contrast to the cloudy core. The augite has been partly replaced by hornblende and chlorite. Hornblende also forms disseminated grains but has been largely replaced by secondary green biotite, chlorite, and small amounts of epidote. Only part of the chlorite is secondary after hornblende and biotite. Much of it forms irregular, scalloped, and triangular grains and bunches interstitial to the feldspar, as well as irregular veinlets cutting the syenite, and it is undoubtedly a direct precipitate from solution.

The chief primary difference between the syenites lies in their ferromagnesian minerals. In the syenite of the Aguardo and Mogote stocks both augite and hornblende are present, but in the Margarita stock only hornblende was found—and only in minor amounts. The Margarita stock is much shattered and brecciated along microscopic shear zones. Along the fractures and shear zones biotite, epidote, and chlorite have been deposited and form abundant irregular clusters and ramifying veinlets. In the syenite of the Aguardo and Mogote stocks biotite and epidote are far less common. Sericite is a common alteration product of the feldspar in the syenite of the Aguardo and Mogote stocks but is only sparsely distributed in the syenite of the Margarita stock.

SUMMARY AND CLASSIFICATION

Study of the syenite under the microscope shows that it differs somewhat in the different stocks and even in the same stock. Some differences are primary, but others are due to alteration of the syenite and some are a result of differences in degree of alteration, thus producing different facies of syenite. The primary minerals in all the stocks consisted chiefly of orthoclase and subordinate amounts of oligoclase and ferromagnesian minerals. The Aguardo and Mogote stocks are composed essentially of augite-hornblende syenite, whereas the Margarita stock is composed of hornblende syenite. Subsequent extensive albitization, chiefly of the orthoclase, modified the primary syenite. The different facies thus formed, together with their primary differences, might warrant a subdivision of the syenite, but because of their essential similarity they are all classified as sodic syenite in this report.

HORNBLENDE SCHIST AND RELATED ROCKS

To the southwest of the upper sedimentary tuff of Cretaceous(?) age and in an apparent stratigraphic position above the tuff lies a large mass of hornblende-bearing rocks that vary in texture and mineral composition from schist to gneiss and enclose a small irregular body of hornblendite. All these hornblende-rich rocks are believed to represent metamorphosed facies of the same original rock, probably a quartz diorite or quartz monzonite. The relation between the hornblende-bearing rocks and the other formations in the district is not clear, but it is thought that the metamorphism took place at depth and that the schist was brought to its present position by movement along a fault.

DISTRIBUTION

The hornblende schist is exposed in two areas in the district. The larger exposure is in the southwest corner of the mapped area, where the schist crops out on a number of low hills and ridges that extend from Sonador to Piedra Blanca along the Carreterra Duarte. It was mapped to a maximum width of 1.9 kilometers, but the western contact is outside the mapped area. The second exposure, separated from the first by a wide expanse of alluvium, lies in a low foothill at the southwest edge of Loma Caribe. It crops out in a rather small, irregularly shaped mass in contact with the ultramafic intrusive.

CHARACTER

The hornblende schist is the most highly foliated rock in the district, although the degree of foliation varies in alternate bands, some of the bands being clearly gneissic. The schist in the main mass in the southwest corner of the mapped area is pale green to black and has a metallic sheen. Hornblende is easily recognized. On weathered surfaces it is greenish gray, and where the intercrystallized feldspar in the gneissic bands becomes distinguishable it is somewhat speckled. Under the microscope the most highly foliated bands are seen to consist almost entirely of pleochroic green to bluish-green hornblende with minor amounts of quartz, plagioclase (in part untwinned), chlorite, epidote, zoisite, and rutile. The less foliated bands consist of layers of sheared and granulated quartz and plagioclase in a subparallel arrangement, which alternate with layers consisting chiefly of hornblende. Epidote, zoisite, chlorite, and rutile are accessory minerals.

The rock in the small mass on the southwest side of Loma Caribe is less foliated on the whole than that in the main mass just discussed and is essentially a gneiss. Under the microscope it is seen to consist chiefly of hornblende with a few small, irregular, cloudy areas that probably consist largely of feldspar, as shown by faint twinning bands in some areas. Other cloudy areas consist of aggregates of fine-grained material of low birefrigence, probably quartz and feldspar, with some zoisite. The accessory minerals include epidote, zoisite, and chlorite, which are either disseminated or occur in small veinlets.

HORNBLENDITE MASS ENCLOSED

An irregular, somewhat elongate mass of hornblendite is exposed on a hill 1½ kilometers west of Piedra Blanca, occupying approximately the middle of the mapped band of hornblende schist. It grades into the hornblende schist, and its boundary as drawn on the geologic map is necessarily somewhat arbitrary.

The hornblendite consists of an aggregate of coarse hornblende crystals in random orientation, with an accessory amount of interstitial material forming less than 20 percent of the mass. The hornblende crystals show considerable variation in size. They reach a maximum length of about 35 millimeters but more commonly are 6 to 12 millimeters in length. The interstitial material is gray and fine-grained. Quartz and small crystals of hornblende can be recognized in it under a hand lens. On exposed surfaces the interstitial material is weathered away, leaving the coarse hornblende crystals in relief.

Under the microscope the coarse hornblende is seen to be a pale-green variety. It is in part replaced by a secondary mineral, probably augite, which gives it a mottled appearance. The interstitial material consists of quartz grains that enclose smaller, well-formed crystals of hornblende, augite, epidote, and zoisite.

ORIGIN OF HORNBLENDE SCHIST AND HORNBLENDITE

The hornblende schist and the hornblendite are probably genetically related, but their origin and their relation to the other formations in the district are obscure. The original rock from which the schist and gneiss were derived appears to have been a granitic rock, probably of the composition of quartz diorite or quartz monzonite, as is indicated by the sheared and granulated bands of quartz and feldspar still present in the gneiss and in some bands of the schist. The secondary introduction of the hornblende is clearly demonstrated by its parallel arrangement and its freedom from the shearing and crushing that have affected the quartz and feldspar. Neither quartz monzonite nor quartz diorite has been found in the area mapped, but Gabb (1873, p. 138) reported a mass of granitic rocks a short distance up the Río Maimón to the southwest of the schist, and it is probable that the schist marks the altered border of this mass.

The great abundance of hornblende in the schist and its rare occurrence in the adjacent upper sedimentary tuff formation can hardly be accounted for merely by differences in the composition of the original rock. It seems likely that the schist formed at a depth considerably below its present location and was subsequently faulted into its present position from a deep-seated position. This hypothesis is given credence by the occurrence of brecciated schist along the contact with the upper sedimentary tuff, which is well exposed on the south bank of the Río Maimón just east of the highway at Piedra Blanca. A thin section of the breccia shows the fragments to consist of sheared and granulated granitic rock of the composition of a quartz monzonite or quartz diorite, in part replaced by hornblende and cemented by epidote. The hornblende crystals have been truncated sharply at the edge of the breccia fragments and are clearly earlier than the brecciation.

There are two possible interpretations of the origin of the hornblendite mass. It may have been formed by further metamorphism of the schist, or it may represent an intrusion of a basic magma that could also have been the source of the hornblende-depositing solutions. The gradational contact of this irregular body with the schist and the similar mineral composition of the schist support the belief that the hornblendite was derived from the schist locally by extreme alteration. Until more information becomes available regarding the geology of the adjacent area to the west, further speculation on this problem is not warranted.

STRUCTURE

The brief description of the structure here presented is limited to that of the known Cretaceous and probable Cretaceous rocks, which underlie more than 90 percent of the area. They are both folded and faulted. The structure of the undifferentiated Tertiary(?) volcanic rocks in the extreme northeastern part of the mapped area was not determinable because of their restricted distribution and their unconformable relations with the Cretaceous rocks.

FOLDS

DESCRIPTION

The rocks of known Cretaceous and probable Cretaceous age within the area mapped are mainly homoclinal in structure (pl. 19). In general they strike northwest and dip to the southwest. They probably form part of the west limb of a regional southeastward-plunging anticline, as may be inferred from the attitude of the cleavage in the sericite schist in its relation to the bedding. Only scattered observations on strike and dip of bedding were obtainable; the great thickness and essential uniformity of the formations made it impossible to determine many details of the structure. Such determinations as could be made suggest that the average trend of the formations is about N. 50° W., which conforms to the general strike of the strata shown by their areal distribution. The scattered observations on the dip of the formations range from 13° to 55° W., with easterly dips shown here and there by some beds in the upper sedimentary tuff south of the Río Maimón. Faulting probably accounts for the easterly dips.

In contrast to the bedding, the cleavage of the sericite schist of the area in general strikes N. 20° W. and dips steeply westward; thus it is notably discordant with the strike and dip of the bedding. According to the usual interpretation of similar features elsewhere (Leith, 1923, pp. 176–185), the relations between bedding and cleavage in the Maimón-Hatillo area conform to those on the southwest limb of an anticline plunging to the southeast. Also, as the plane of cleavage in general is parallel to the axis of the fold, it is inferred that the axis of the anticline in the Maimón-Hatillo area strikes about N. 20° W. and dips steeply westward.

The extent of the anticline could not be determined, as the greater part of it is outside the mapped area. Brief reconnaissance east of the mapped area along the highway from Sabana de la Mar to Hato Mayor and to the south shows that the Cretaceous and Cretaceous(?) formations exposed there strike northeast and dip to the southeast, thus conforming to the general picture of a large regional anticline. It is not known, however, whether the rocks exposed there form part of the same structure present in the mapped area, and until data regarding the area immediately east of that mapped become available, further speculation is not warranted.

AGE

Folding was effected prior to the deposition of the Tertiary(?) volcanic rocks in the northeastern part of the mapped area, but lack of data to determine their age precisely prevents assigning a definite age to the folding. However, the principal period of folding is tentatively referred to Laramide time. This conclusion accords with findings in other parts of the country by C. P. Ross and D. J. Varnes (personal communication), as a result of recent reconnaissance work, and with findings in Haiti (Woodring et al., 1924, p. 351). The scope of this paper is such, however, that no conclusions are drawn here as to the period of most intensive folding for the island as a whole.

FAULTS

GENERAL STATEMENT

Faulting apparently played a less conspicuous part than folding in the structural picture of the district but is probably more prevalent than is indicated by the map (pl. 19). No doubt there are many faults with moderate displacement that are difficult to recognize because of the great thickness of some of the formations and the absence in them of reliable horizon markers. Thus the recognition of faults in the sericite schist and in the upper sedimentary tuff is practically impossible, and relatively few faults are shown in the area underlain by them. Broad expanses of alluvium in the larger valleys and the junglelike growth of vegetation over a large part of the region so thoroughly conceal the underlying formations that only faults of large displacement revealed by obviously discordant stratigraphic relations have been recognized and mapped there. Also, faults may have been obliterated by the intrusion of the sill-like mass of the ultramafic rocks. Data to determine the relative age of the faults likewise are meager. However, faulting probably occurred in several periods. In the following description, therefore, the faults are treated in groups according to the formations affected. Both longitudinal and transverse faults are present.

FAULTS BOUNDING THE CHERT

The chert which forms La Trinchera is bounded along its southern and western margins by a group of faults, or a fault zone, along which it has moved upward so as to lie across the strike of the limestone. Along the southern margin of the chert the fault can be traced in an irregular course along the northeast bank of the Arroyo Margarita and the lower southern slopes of La Trinchera for a distance of about 8 kilometers. About a kilometer north of Hatillo it passes underneath the alluvium, and here it either curves northward or is intersected by a north-northeastward-trending fault along the west side of the chert. About a kilometer west of the settlement of El Plantano, near the northern part of the mapped area, it passes underneath an outlier of the Tertiary (?) volcanic rocks and Quaternary alluvium.

The irregular contact of the chert with other formations indicates that the fault along which it was emplaced is complex and also that it has been cut by several cross faults. Two cross faults of northerly trend are implied by the discordant position of the sericite schist east of Los Cacaos. Farther east, about 1½ kilometers west of the eastern edge of the mapped area, the presence of cross faults is even more clearly shown by the block of limestone on the north side of the main fault. None of the cross faults could be traced for more than relatively short distances along their strike.

Nowhere was the direction of dip of the main fault zone clearly indicated, and the character of the fault, whether normal or thrust, is not shown. Near its southeast end—that is, southeast of the limestone block on its north side—the trace of the main fault curves to the northeast where it crosses a spur on the lower slope of La Trinchera. This effect of topography on the trace of the fault suggests a dip to the southwest and the relation of a normal fault, but present information is too meager to reach any definite conclusion regarding its attitude. Neither has the amount of displacement along the fault been determined. Where the sericite schist has been brought into contact with the chert, the displacement at least exceeds the thickness of the limestone, which has been estimated to be greater than 400 meters. In other places the displacement is less, but lack of information regarding the stratigraphic position of the chert, its thickness, and its attitude precludes any reliable estimate of the magnitude of the faulting.

FAULTS IN THE GREENSTONE AND ADJACENT FORMATIONS

The greenstone, which is relatively thin and easily recognized in the field, has served as an excellent horizon marker to record the degree of deformation of the rocks above the limestone. The deformation of the greenstone implies corresponding movements in adjacent strata and also is indicated in part by the lower sedimentary tuff. The great thickness and uniformity of the sericite schist, as well as the extensive alluvial cover in critical areas, have prevented the recognition of the effects of deformation there, whereas its effects in the overlying formations are obscured by the intrusion of the ultramafic mass.

The greenstone has been cut by two major and numerous minor transverse faults into a number of blocks that have been rotated and bent in several directions. A strike fault is indicated at the upper contact of the greenstone, but it was probably obliterated by the intrusion of the ultramafic mass. The southernmost of the two major transverse faults is clearly indicated along the valley of the Río Maimón, where the fault cuts the greenstone and lower sedimentary tuff. The immediate displacement shown by the greenstone on opposite banks of the river is small, probably less than 0.2 kilometer, but the over-all displacement, including the apparent bending of the greenstone south of the river, is about 1 kilometer. To the northeast of the lower sedimentary tuff, in the area underlain by the sericite schist, the fault is concealed beneath alluvium. Still farther northeast, where this fault intersects the strike-fault zone that bounds the chert on La Trinchera along the southwest side, rock exposures are too poor to permit interpretation of the structure with assurance. Beyond this fault zone and a short distance northwest of its projected course, the fault is approximately in line with the fault zone along the northwest side of the chert.

Southwest of the greenstone exposures along the Río Maimón the transverse fault apparently dies out. Although its southwest extension is suggested by sheared and serpentinized ultramafic rock, which is well exposed along the trail on the northwest bank of the Río Maimón, there is no appreciable offset of the lower contact of upper sedimentary tuff along the projected strike of the fault. The absence of any such offset may be accounted for either by (1) its termination against the strike fault obliterated by the ultramafic intrusion or (2) absorption of the transverse fault movement by the ultramafic mass.

Another major transverse fault with an over-all displacement of approximately 1 to 1.5 kilometers occurs along the northwest end of Loma Peguera, but information beyond the mere fact of its presence is meager and its extent to the northeast and southwest of the greenstone exposure was not determined. The sharp turn in the course of the Río Yuna and the abrupt thinning of the ultramafic mass northwest of Loma Peguera indicate that the fault lies essentially near the northwest margin of the broad ultramafic mass forming Loma Peguera, but the broad alluvium-filled valley has concealed the position and character of the fault.

The greenstone is also cut by many minor transverse faults. The amount of their displacement ranges from 100 to 200 meters, and the direction of the displacement differs from fault to fault. Their large number, together with the abundance of greenstone inclusions in the ultramafic rocks (p. 329), indicates that the greenstone was intensely shattered and displaced along numerous faults ranging from mere slips to faults of appreciable magnitude. Only the more significant of these faults are shown on the map.

The time relations between the transverse faulting and the intrusion of the ultramafic rocks are somewhat obscure, but both preintrusion and postintrusion faulting are indicated. That movement occurred in postintrusion time is clearly shown by many of the smaller transverse faults northwest of Hato Viejo and El Verde where the ultramafic rocks form part of some of the small fault blocks. In many places the transverse faults can be traced into sheared and serpentinized ultramafic rocks that are probably best seen along the trail on the north side of the Río Maimón. Evidence showing preintrusion transverse faulting is scanty and less definite. Significant, however, are the bulge of the ultramafic mass on Loma Peguera between the two major transverse faults and, especially, the abrupt thinning of the ultramafic mass northwest of Loma Peguera, which suggest the influence of these faults on the shape of the intrusion and imply their existence prior to the intrusion. From the available data, the writers believe that the most important period of movement occurred prior to the intrusion of the ultramafic rocks but that faulting continued during and after their intrusion.

STRIKE FAULT IN THE UPPER SEDIMENTARY TUFF

The presence of a former strike fault along which the ultramafic mass was intruded has already been mentioned (p. 329); it is more fully discussed here. Its presence southeast of the Río Maimón is inferred from the abnormal dips of the upper sedimentary tuff and the large number of greenstone inclusions in the ultramafic rocks.

Southeast of the Río Maimón the upper sedimentary tuff dips northeastward, whereas northwest of the Río Maimón and elsewhere in the district the regional dip is to the southwest. The discordant structural relations thus shown, the emplacement of the ultramafic mass between the greenstone and the upper sedimentary tuff, and the large number of greenstone inclusions in the ultramafic mass suggest that the upper sedimentary tuff here forms a fault block that has been tilted to the northeast.

Northwest of the Río Maimón a large part of the critical area is covered with extensive alluvial deposits, so that evidence of the extension of the strike fault there is less definite. Locally, as to the southeast of the Río Maimón, the ultramafic rocks contain abundant greenstone inclusions, suggesting that the greenstone was brecciated prior to or during the period of ultramafic intrusion. Throughout the greater part of the mapped area the ultramafic mass was emplaced between the greenstone and the overlying upper sedimentary tuff, but on Loma Caribe in the northwest corner of the mapped area the ultramafic mass lies between the upper sedimentary tuff, which is greatly reduced in thickness, and a small mass of the hornblende schist. This change in the stratigraphic position of the ultramafic mass from the lower to the upper contact of the upper sedimentary tuff shows that the ultramafic mass cuts across this unit, but whether at a low angle along a strike fault or a sharp angle along the transverse fault bounding the northwest end of Loma Peguera, northwest of which it may follow bedding, is not clear. Data are inadequate within the area mapped to determine the reasons for the thinning of the upper sedimentary tuff. Just north of the mapped area the greenstone and, very probably, the upper sedimentary tuff turn sharply eastward from their normal northwesterly course, but the adjacent contact of the ultramafic mass appears to continue in its normal northwesterly course. These relations would indicate that much of the sedimentary tuff has been eliminated by a strike fault that transgresses the upper sedimentary tuff. Much of the original fault zone has undoubtedly been obliterated by the intrusion of the ultramafic mass, but collectively the geologic features both to the southeast and northwest of the Río Maimón favor the conclusion that a strike fault formed the channel along which the ultramafic magma was intruded.

STRIKE FAULT ALONG THE CONTACT BETWEEN THE UPPER SEDIMENTARY TUFF AND HORNBLENDE SCHIST

The brecciated character of the hornblende schist found at the contact with the upper sedimentary tuff on the south bank of the Río Maimón (p. 334) shows that this is a fault. Exposures along the contact, however, are sporadic and so poor that its nature was determinable in only a few places. The straight line of this contact supports the tentative conclusion that the hornblende schist owes its present position to faulting.

AGE OF FAULTING

Neither the age of the faulting relative to that of the folding nor its actual geologic age is known. The faulting is assumed to be in part contemporaneous with the folding and in part probably younger.

GEOLOGIC HISTORY

As it has been impossible to fix the age of several of the formations, this outline of the geologic history of the mapped area is incomplete and tentative. The oldest rock in the district apparently is the chert. Much remains to be learned about its origin, but it is thought to be at least in part sedimentary. Its age, except for the probability of its being older than the limestone of Cretaceous age, has not been determined.

The earliest dated geologic record is given by the limestone, and it shows that during part of Cretaceous time, probably late Lower Cretaceous, the Maimón-Hatillo district was covered by shallow marine waters. Massive limestone reefs were built up by reef-forming pelecypods such as caprinids. In depressions between the reefs some argillaceous sediments were deposited. Toward the end of the period of deposition of the massive reef limestone, the clastic sediments that are now in the form of mudstone, particularly in the valley of the Río Tocoa, were deposited. Although the sea was shallow, a great thickness of limestone was deposited, indicating that deposition of limestone lasted a long time and that subsidence kept pace with deposition.

During a later period, probably in Upper Cretaceous time, volcanism broke out on a grand scale and thousands of feet of volcanic breccias with minor flows and tuffaceous sediments accumulated in the area. However, coarse agglomerates are absent in the district, and it is inferred that the centers of volcanism were located beyond the borders of the mapped area, probably somewhere to the south.

Evidence is lacking, in general, regarding the conditions under which the volcanic rocks were laid down. The lower part of the thick volcanic deposit represented by the sericite schist has interbedded lenses of limestone, conglomerate, and quartzite, which suggest that at least some of the volcanic detritus was water-laid, probably in shallow water that fluctuated somewhat in depth. Although the tuffaceous sediments carry no known interbedded marine deposits, they appear to be well sorted, and this sorting—together with their fine-grained texture—implies that they also are water-laid. However, it is inferred from the thick and widespread greenstone flow interbedded with the tuffaceous sediments in this stratigraphic unit that at times the area emerged.

Toward the end of Cretaceous time, or in the time span generally assigned to the Laramide Revolution, orogenic movements were initiated, but their magnitude is not known. The region was compressed in a northeast-southwest direction, and the rocks were tilted to the southwest and probably faulted. It was during this period of tectonic activity that the chert forming La Trinchera was faulted upward. The major tectonic movements were followed or accompanied by the intrusion of the ultramafic rocks, the syenite stocks, and the dioritic or monzonitic stock now represented by the hornblende schist. After emplacement of the igneous rocks hydrothermal solutions invaded the adjacent country rocks, metamorphosed the limestone, and culminated in the deposition of iron and copper minerals at favorable places.

During early Tertiary time there followed a long period of erosion. It is probable that the Río Yuna and the other major streams were developed at this time. After erosion had dissected the area, probably into a topography with considerable relief, volcanic eruptions again took place, evidently during an undetermined part of Tertiary time, and the pyroclastic rocks in the northeastern part of the district were extruded.

During late Tertiary and lasting into Recent time there has been another long period of erosion accompanied by minor fluctuations in the elevation of the area. During this time most of the alluvial material exposed in the district was deposited. The ultramafic mass underwent a long period of weathering during which the lateritic and nickeliferous blanket of weathered material was formed over certain parts of the area. That Recent tectonic movements have caused slight elevation of the area is evidenced by the fact that all the streams are cutting down into earlier alluvium.

MINERAL DEPOSITS

The Maimón-Hatillo district contains widespread deposits of iron and nickel and small deposits of copper, cobalt, chromium, and manganese (pl. 19). Although these deposits have been known for many years, there has been no commercial production. Most of the deposits have had only a cursory exploration, and prospecting has been limited to shallow pits, cuts, and one tunnel. Of the known deposits those of iron and nickel offer some possibility of exploitation, but their value cannot be accurately appraised until they have been systematically and thoroughly explored. The copper and cobalt deposits appear to be of minor importance, and the deposits of manganese and chromium, as far as is known, are only of geologic interest.

IRON

Iron is found in the district in two types of deposits: (1) magnetite deposits in the eastern part of the district and (2) laterite deposits, derived from the weathering of the ultramafic rocks and greenstone, in the western part.

MAGNETITE DEPOSITS

DISTRIBUTION

Twelve deposits of magnetite are known in the district and are shown on the accompanying map (pl. 19). Most of them lie within a narrow tract, roughly 25 kilometers long and up to 17 kilometers wide, extending from Sabana Grande on the northwest to the divide between the Arroyo Margarita and La Laguna on the southeast. Nine of the deposits are in the area underlain by the limestone or by the adjacent sericite schist, two are on the chert, and one is in the area underlain by syenite. Seven of the deposits are in the vicinity of the Aguardo syenite stock. Of these seven, one is in the limestone at the northwest base of La Búcara; one is in sericite schist near the syenite contact south-southwest of Loma Manteca; another small deposit lies entirely within the area of outcrop of the syenite, northwest of the last-mentioned deposit; and four, including the largest deposit in the district, are in the limestone around the edges of Loma Manteca (pl. 19).

An eighth deposit, isolated from the others, lies at the crest of the main ridge of Loma Mogote at the contact between the sericite schist, a large limestone lens in the schist, and the southern edge of the small Mogote syenite stock. This deposit may be the one referred to by Brinsmade (1918, pp. 356–358) as the Loma del Gallo deposit.

A ninth deposit, the most accessible, is on the middle of three little limestone hills that are alined in a northerly direction on the southeast bank of the Río Yuna near the village of Hatillo. This deposit is the "Loadstone Mountain" of Schomburgk (1853, pp. 738–740), the "Iron Mountain" of Gabb (1871, pp. 141–142), the Sabana de

Hatillo deposit of Brinsmade (1918, p. 358), and the deposit near Hatillo described by Ross (1921, p. 229). No intrusive rock is exposed at the surface near this deposit; however, Brinsmade (1918, p. 358), who dug 14 pits into the red clay soil in which magnetite boulders are embedded, reported that the clay grades downward into "decomposed porphyry" at a depth of several meters. Meyerhoff (personal communication, August 2, 1948), who did considerable trenching and test pitting at the Hatillo deposit, states: "The Hatillo deposit does not consist of boulders, but of a solid body of ore."

One other occurrence in the limestone is between the headwaters of the Arroyo Margarita and La Laguna in a saddle on the ridge trending eastward from Loma de la Mina. This deposit, which lies between steep limestone walls, is traversed by the Hatillo-La Laguna trail for a distance of over 500 meters. According to Brinsmade (1918, p. 358), it is situated along a porphyry dike. However, the writers saw no evidence of the presence of this dike.

Two small magnetite deposits lie in the area underlain by the chert on La Trinchera. The first of these is 1.6 kilometers northeast of Hatillo at an altitude of 280 meters; the second, which is possibly the one referred to by Brinsmade as the Arroyo Piedra Iman deposit, is in a small alluvial valley crossed by the unfinished Cotui-Piedra Blanca road, about 2.5 kilometers by road southwest of El Plantano.

Two other deposits (not shown on the map), the first about half a kilometer southeast of the Arroyo Piedra Iman deposit and the second in the Margarita Valley about a kilometer southeast of the block-faulted limestone hill, were pointed out by local guides as being similar to the other iron deposits but on examination proved to consist of spongy limonite.

Another occurrence deserving mention is outside the Maimón-Hatillo district; it lies along a trail about 100 meters northeast of the Cotui-Piedra Blanca road and 2¼ kilometers by road southwest of Cotui. At this locality a few magnetite boulders are scattered over a small area underlain by an andesite porphyry that probably belongs to the Tertiary(?) volcanic rocks.

Locally magnetite was found in veinlets and stringers in the country rock, but it is of no commercial interest. A few hundred meters southwest of the deposit, in the schist at the south edge of the Aguardo syenite stock south-southwest of Loma Manteca, there is an outcrop of jasper about 25 meters long and 10 meters wide cut by numerous stringers and bands of hematite associated with a small amount of magnetite. Some of these stringers are paper thin, and others range in thickness up to 2 centimeters. Northeast of Los Cacaos there are veinlets of magnetite in fractured chert adjacent to a fault.

OCCURRENCE

The visible magnetite deposits of the Maimón-Hatillo district are residual boulder deposits consisting of subangular pieces of magnetite from a few centimeters up to 2 meters across embedded in residual soil. Commonly the pieces are pitted, suggesting that the more soluble associated minerals have been leached out, leaving the insoluble iron oxide. The boulders are composed of both magnetite and hematite intimately intergrown. In any single deposit highly magnetic fragments occur together with some that are very slightly magnetic. The ratio of hematite to magnetite in the Hatillo deposit, according to analyses published by Brinsmade (1918, p. 358) and given in table 1, ranges from 0.71 to 1.09; a piece of float (table 1, sample 15) is almost pure hematite.

The magnetite boulder deposits are scattered discontinuously over an area 25 kilometers long, suggesting that the boulders were derived locally from the weathering and erosion of lenses or irregular masses and veinlets of magnetite in the country rock. They do not represent an alluvial deposit, for they are distributed on slopes as well as in the valleys and range in altitude from approximately 100 meters at Hatillo in the Río Yuna Valley to about 380 meters on Loma Mogote. Some of the magnetite deposits are in areas in which the limestone has become crystalline, although no lime silicates were found that would indicate that the iron deposits are metamorphic in type. In the deposit southeast of Sabana Grande magnetite occurs in boulders of marbleized limestone. Similar boulders were seen in the Arroyo Margarita, and Ross (1921, p. 229) found recrystallized limestone south of Hatillo. The association of the magnetite deposits chiefly with the limestone near the syenite stocks and the mild metamorphic effects shown by some limestone near the magnetite deposits suggest that the primary iron deposits are genetically related to the syenite and were deposited at favorable places following the intrusion of the syenite.

GRADE OF ORE

The chemical analyses of 20 samples of the magnetite (table 1) show a range from 65.21 percent to 69.23 percent iron, averaging 67.97 percent. The low phosphorus content of the analyzed samples is notable, ranging from 0.01 to 0.12 percent and averaging 0.045 percent. All other constituents, except insoluble material, amount to less than 1 percent. These samples are of weathered material from which most of the impurities undoubtedly have been leached, and predictions regarding the purity and grade of any unaltered magnetite that might be found in depth are not warranted. It seems safe to conclude, however, that the magnetite is of high quality and will compare favorably with similar ores mined in other parts of the world.

TABLE 1.—*Analyses of magnetite from Maimón-Hatillo district, Dominican Republic*

[Samples 1–9 after Meyerhoff (unpublished report); samples 10–15 after Brinsmade. Samples 16–20 analyzed by F. S. Grimaldi, U. S. Geological Survey]

Sample No.	Fe	Fe_2O_3	FeO	Mn	MnO	S	P	SiO_2	Al_2O_3	CaO	Insoluble	H_2O	TiO_2	Cr_2O_3	V_2O_3	Total	$Fe.Fe_2O_4$	[1] Fe_2O_3	Ratio, Fe_2O_3 to $Fe.Fe_2O_4$
1 [2]	68. 28			0. 15		0. 03	0. 05	2. 02	1. 05	0. 40			0. 05						
2 [2]	69. 10			. 22		. 02	. 02	1. 43	. 42	. 15			. 03						
3 [2]	68. 45			. 13		. 02	. 04	1. 43	1. 03	. 10			. 10						
4 [2]	69. 00			. 19		. 01	. 05	1. 27	. 59	. 20			. 03						
5 [2]	68. 60			. 19		. 04	. 07	1. 53	. 75	. 25			. 04						
6 [2]	68 90			. 19		. 02	. 04	1. 29	. 22	. 20			. 05						
7 [2]	68. 40			. 16		. 07	. 03	. 89	. 34	. 20			. 03						
8 [2]	68. 50			. 18		. 01	. 02	1. 39	. 27	. 30			. 03						
9 [2]	67. 75			. 16		. 02	. 03	1. 54	. 40	. 20			. 04						
10 [2]	67. 59	79. 11	15. 94		0. 33	. 034	. 040			. 80	1. 90	0. 30				98. 454	51. 43	43. 63	0. 85
11 [2]	67. 25	80. 68	14. 52		. 20	. 027	. 059			. 60	1. 80	. 80				98. 686	46. 84	48. 36	1. 04
12 [2]	68. 15	81. 96	14. 27		. 10	. 020	. 053			. 40	2. 00	. 50				99. 303	46. 03	50. 20	1. 09
13 [2]	67. 49	77. 82	17. 22		. 30	. 027	. 050			. 60	1. 60	. 60				98. 217	55. 55	39. 49	. 71
14 [2]	69. 02	80. 11	17. 22		. 30	. 020	. 035			. 40	1. 70	. 60				100. 385	55. 55	41. 78	. 75
15 [3]	67. 05	93. 32	2. 44		. 20	. 048	. 041			. 30	1. 60	. 80				99. 249	7. 87	87. 89	11. 17
16 [2]	69. 23						. 04						. 05	0. 05	(4)				
17 [5]	65. 79						. 01						. 90	. 01	(4)				
18 [6]	67. 69						. 07						. 05	. 04	(4)				
19 [6]	65. 21						. 12						. 06	. 04	(4)				
20 [7]	67. 91						. 03						. 08	. 04	(4)				

[1] Calculated by authors.
[2] Magnetite from Hatillo deposit.
[3] Magnetite float in road 2 miles north of Hatillo deposit.
[4] Less than 0.01 percent.
[5] Magnetite from west side of La Trinchera.
[6] Magnetite from deposit 3 kilometers southeast of Sabana Grande.
[7] Magnetite from Loma Mogote.

RESERVES

Reliable estimates of the quantity of minable ore cannot be made at the present time because the magnetite deposits are discontinuous and the exposures poor. The only deposits seen by the writers were surface deposits covering an estimated total of 35 to 40 acres. Lenses of magnetite in place reported by Meyerhoff (unpublished report) were not observed because the trenches and test pits that had exposed them had slumped and caved. Thus the writers are unable to make any estimate of the possible occurrence of subsurface deposits. A survey by dip needle, magnetometer, or other geophysical methods should be undertaken to obtain information as to possible concentrated deposits in depth as well as possible primary deposits.

RECOMMENDATIONS

The magnetite deposits, although the surface showings are relatively small, contain high-quality, low-phosphorus lump ore that can be easily mined. The deposits are in a narrow belt that should be thoroughly prospected. The most favorable area for detailed exploration is the vicinity of Loma Manteca, around which lie four of the residual magnetite boulder deposits, one of them perhaps the largest in the district.

LATERITIC IRON DEPOSITS

The weathering, under tropical conditions, of the ultramafic mass and the greenstone in the western part of the district has resulted in the formation of a brick-red lateritic soil layer coextensive with these rocks. Erosion has removed much of this material, and in most places the laterite is a thin veneer, half a meter or less in thickness. Locally, however, on benches or the flat tops of ridges, the laterite forms a layer of a nickeliferous, limonitic, and siliceous material of appreciable though unknown thickness that may be worthy of further prospecting. This blanket of lateritic soil is similar to that found in several places in Cuba, where it is of similar origin and is mined on a large scale.

The largest single deposit of laterite is on top of Loma Caribe at its north end, where the brick-red soil fills a saucer-shaped depression about a square kilometer in areal extent, drained at its eastern side by a small arroyo. The depth of the laterite at this locality was not determined but is thought to be greater than at any other locality in the district. A small deposit occurs on a flat bench on the northeast corner of Loma Peguera, northwest of Hato Viejo. Other scattered patches of lateritic soil are distributed over the broad top of Loma Peguera and along the lower southern slopes of this hill. At lower elevations the laterite deposits include soil wash derived from the upper slopes.

Partial analyses of lateritic material made in the Chemical Laboratory of the Geological Survey (table 2) show the iron content to range from 22.66 percent in the pellets and nodules scattered over the surface on top of Loma Peguera and from which the matrix has been eroded away to 38.36 and 37.65 percent, respectively, in the lateritic soil on the northeast end of Loma Peguera and on the north end of Loma Caribe. The iron content of the lateritic soil compares favorably with similar lateritic iron in Cuba. In Cuba (Leith and Mead, 1912, p. 91), it was found that the percentage of iron tends to increase somewhat below the surface and "to maintain its average grade, or better it, toward the bottom." It is probable that similar relations will be found in the lateritic deposits in the Maimón-Hatillo district. Nickel and chromium also are present in the lateritic soil in the district and in quantities comparable to those in Cuba.

TABLE 2.—*Partial analyses of lateritic iron, Maimón-Hatillo district, Dominican Republic*

[F. S. Grimaldi, analyst]

Sample No.	Description and location	Fe	CoO	MnO	TiO_2	Cr_2O_3	V_2O_3	NiO
1	Pellets and nodules up to 2 centimeters in diameter from southeast end of crest of Loma Peguera.	22.66	0.08	0.63	0.09	0.50	(1)	0.30
2	Lateritic soil on bench on northeast end of Loma Peguera, northwest of Hato Viejo.	38.36				2.35		1.20
3	Lateritic soil on broad bench on north end of Loma Caribe.	37.65	None			2.16		.78

[1] Less than 0.01.

At present data are not available to compute the tonnage of the iron-rich laterite in the Maimón-Hatillo district. A soil-auger survey of the laterite deposits will be necessary to obtain this information. The mountainous terrain occupied by the ultramafic rocks from which the laterite was derived, however, precludes the possibility of finding a large acreage of laterite of commercial grade.

NICKEL

OCCURRENCE

Nickel in the Maimón-Hatillo district occurs (1) as a minor constituent in the lateritic mantle on the top of and grading into the ultramafic rocks and (2) in quartz boxwork in irregular veins in the ultramafic rocks and either as veins or irregular masses in the laterite. The nickeliferous laterite has already been described and is considered here only in its relation to the quartz-boxwork deposits and their origin.

The quartz boxwork forms a coarse honeycomb in which the interstices are filled with garnierite, a green, hydrous nickel magnesium silicate, and deweylite, a whitish hydrous magnesium silicate that grades into garnierite. In places altered dunite, partly or wholly weathered to a spongy, yellowish to brownish, limonitic material, fills the interstices. The septa or partitions of the boxwork, which range in thickness from thin films to partitions several centimeters thick, consist of white quartz and, rarely, chalcedony. In outcrops and loose boulders scattered over the surface the interstitial filling of silicates has weathered away, leaving an open boxwork of the quartz, locally stained yellowish to brownish by iron oxide. The resistant character of the quartz boxwork forms a protective surface cover for the soft garnierite commonly found inside. Because of this association of garnierite with the characteristic quartz boxwork, boulders of quartz boxwork serve as an excellent guide in locating probable nickel deposits of this type.

The boxwork deposits and the nickeliferous laterite in the Maimón-Hatillo district are associated with dunite and closely related saxonite in which the enstatite crystals are not abundant. South of the Río Maimón the ultramafic mass, covering an area of about 13 square kilometers, appears to consist entirely of saxonite with conspicuous phenocrysts of enstatite; here neither garnierite nor the characteristic quartz boxwork has been found. North of the Río Maimón, where both dunite and saxonite are present, the quartz-garnierite boxwork deposits have a sporadic distribution.

DISTRIBUTION

The quartz-garnierite veins are exposed only in the relatively fresh ultramafic rocks on slopes, where erosion has removed any lateritic mantle that formerly may have been present. Along the flat-topped ridges and on the gentle lower slopes where the lateritic mantle has not been subject to excessive erosion, boulders of quartz boxwork are scattered over the surface and, probably, embedded in the laterite. Whether these boulders represent a layer of boxwork more or less uniformly distributed over the weathered ultramafic rocks or were derived from veinlike bodies in fissures or shear zones is not clear from field observations. Quartz-garnierite boxwork veins are exposed on the south slope of Loma Peguera, and boulders of the boxwork are sparsely scattered over other parts of Loma Peguera and parts of Loma Caribe and are especially common on the southeast slope of Loma Caribe.

LOMA PEGUERA

Boxwork veins on the south slope of Loma Peguera are best exposed in two trenches, which are reported to have been dug early in 1939 by German engineers prospecting for nickel. The first of the prospects is at an altitude of about 200 meters at the base of a rather steep slope in a little valley near the southeast end of Loma Peguera, 0.6 kilometer northwest of the Río Maimón and 3 kilometers southwest of the village of Maimón. This prospect consists of two trenches cut on the same vein, the upper one about 20 meters long and 3 to 5 meters deep and the lower one about 10 meters long and 2 to 4 meters deep. At one point in the lower cut the boxwork is approximately 15 centimeters wide and is filled with pale-green garnierite (slightly darker when wet). An analysis of this vein in the Chemical Laboratory of the Geological Survey, represented by sample 1 in table 3, shows it to contain 2.78 percent NiO. In the upper cut the garnierite is a bright apple green, though it lies at almost the same depth below the surface of the ground as that sampled in the lower cut. An analysis of the vein in the upper cut represented by sample 2 in table 3 shows it to contain 8.55 percent NiO. Because of the surface debris this vein could not be traced beyond the cuts, but it probably continues for some distance in both directions.

The second prospect is on the ridge that trends southward from the summit of Loma Peguera; it is at an altitude of about 590 meters and about 550 meters south of the summit. A single trench, about 12 meters long, exposes an irregular quartz-garnierite boxwork vein in partly weathered dunite to a depth of 3 to 4 meters and a width of slightly over 1 meter. An analysis of a composite sample picked from the dump of the prospect (table 3, sample 3) shows it to contain 2.76 percent NiO.

TABLE 3.—*Nickel content of samples of quartz-garnierite boxwork on Loma Peguera, Loma Caribe, and Loma Mala, Maimón-Hatillo district, Dominican Republic*

[F. S. Grimaldi, analyst]

Sample No.	Description and location	NiO (percent)	CoO (percent)
1	Sample from boxwork vein 15 centimeters wide in lower cut of prospect 1 at southeast end of Loma Peguera, near base of mountain.	2.78	(1)
2	Sample from boxwork vein 12 centimeters wide in upper cut of prospect 1, 10 to 15 meters from sample 1.	8.55	(1)
3	Sample of boxwork from dump of prospect 2 on top of ridge trending southward from Loma Peguera, 0.55 kilometer south of summit at altitude of about 590 meters.	2.76	
4	Composite sample from scattered boulders of boxwork collected over several acres at altitude of 260 to 280 meters on slope of Loma Caribe, east-northeast of summ	1.35	(1)
5	Channel sample 10 meters long from east wall of small adit at southeast end of Loma Caribe, near base of mountain. Mostly weathered peridotite.	1.35	0.01
6	Composite sample of saxonite from top of Loma Mala	.43	.01

[1] Less than 0.01.

Boxwork veins also crop out along a faint trail that descends the ridge from the second prospect to the sawmill on the north bank of the Río Maimón (p. 313). Their exposure is poor and their extent was not determined. Quartz-boxwork boulders are scattered over the flat-topped ridges of Loma Peguera, particularly in the area 1 kilometer to 2 kilometers east-northeast of the summit (altitude, 688 meters on map). Sporadically distributed boulders were seen, also, on other parts of Loma Peguera, notably in the vicinity of Hato Viejo and along the prominent ridge that extends northward toward Loma Caribe.

LOMA CARIBE

The only information regarding the deposits of Loma Caribe was gained from the study and sampling of surface material and from a short adit on the southeast side of the hill. Many large boulders of quartz boxwork as much as 6 feet in diameter are scattered over the laterite-covered surface. Most of the boulders are loose, but some may be in place. All the quartz boxwork examined contained garnierite in various amounts.

On the southeast slope of Loma Caribe at an altitude of 260 to 280 meters, about half a kilometer east-northeast of the summit and immediately to the west and northwest of the adit, boulders of quartz boxwork with garnierite are especially common on a gentle slope over an area of several acres. The source of these boulders is uncertain. The adit is driven in altered and fractured ultramafic rock that is thoroughly weathered to a soft, brownish, and apparently highly ferruginous mass, but no quartz boxwork was found in place and no garnierite was visible. The absence of veins in the adit indictes either that the boulders of boxwork on the surface are float from a vein higher on the slope or that they represent a former blanket deposit now largely destroyed.

A partial analysis of a composite sample collected from boxwork boulders scattered over the surface, as well as a channel sample 10 meters long of the weathered material taken along the east wall of the adit, shows that they both contain 1.35 percent NiO (table 3, samples 4 and 5). The appreciable content of nickel both in the boxwork and in the weathered mantle of ultramafic rocks indicates that the deposit on the southeast slope of Loma Caribe is one of the largest in the district.

A few boulders of quartz boxwork were seen, also, on the eastern and northern slopes of Loma Caribe, but their sparse distribution and erratic character afford little information on which to base any reliable estimate of the extent or character of these deposits. Although erosion has stripped away most of the lateritic mantle on the eastern slopes of Loma Caribe, no boxwork was found in place. This fact, together with the sparse distribution of the boxwork boulders, suggests that prospects of finding a promising nickel deposit here are remote. On the northern end of Loma Caribe, sporadically distributed boulders of boxwork occur along the margin of the lateritic mantle preserved on a topographic bench. A partial analysis of the laterite collected at the surface shows it to contain 0.78 percent NiO.

Taking into consideration the close association of quartz boxwork and laterite, as well as the origin, to be discussed, of the nickel silicate deposits, it is not improbable that both scattered boxwork deposits and somewhat enriched nickeliferous laterite may be found a short distance below the surface.

ORIGIN

The occurrence of nickel in the Maimón-Hatillo district, both in the lateritic blanket and in quartz-boxwork veins, and the close association of these deposits with the ultramafic rocks point unmistakably to the derivation of the nickel deposits as a product of weathering of the ultramafic rocks. An analysis of a composite sample of the ultramafic rock collected on top of Loma Mala shows it to contain 0.43 percent NiO. The nickel in the secondary deposits apparently owes its enrichment to the leaching of the more soluble constituents of the ultramafic rocks and, in part, to solution of the nickel from the upper, more weathered material and its redeposition in the lower part of the weathered zone. The relation of the irregular quartz-boxwork veins and the scattered boxwork boulders to the lateritic zone is not clear from the evidence the writers were able to obtain. However, the local concentration of the nickel in the quartz-boxwork veins in the relatively fresh ultramafic rocks implies that the veins probably formed below the lateritic mantle and occupy fissures or shear zones that afforded more rapid circulation of ground water and permitted the solutions to converge locally and redeposit the nickel leached out of the overlying lateritic blanket.

In 1942 W. T. Pecora and S. W. Hobbs (1942) described a similar occurrence of nickel near Riddle, Oreg. They showed that the nickel deposit is a layered blanket that rests upon unserpentinized peridotite, particularly on terraces, flats, and gentle mountain slopes. They recognized three main layers of the blanket: a top layer of brick-red soil, a thick, yellow, limonitic intermediate layer with some quartz-garnierite boxwork, and a root layer of quartz-garnierite boxwork in nearly fresh peridotite bedrock. They also showed that the nickel content of the garnierite is highest near the top of the intermediate layer and that it lessens gradually toward the base of the root layer.

The nickel deposits of the Maimón-Hatillo district appear to be similar in arrangement to the Riddle deposit. The relation of the blanket to terraces and gentle slopes, however, is not evident in the district. If the veins exposed on the southwest side of Loma Peguera, which range in altitude from 200 to 600 meters, represent the roots of a lateritic mantle that rested on a flat or terrace, they imply that the garnierite-quartz veins have a vertical extent of at least 400 meters. Data are not available to check the vertical extent of the garnierite veins, but in general the veins are believed to be shallow and it seems probable that at least in places they formed on slopes.

COMMERCIAL POSSIBILITIES

The nickel deposits are insufficiently exposed at the present time to attempt an estimate of the probable tonnage, and additional sampling is needed to determine their general grade. Such information can be obtained only by a program of trenching and test pitting in favorable localities, supplemented by further prospecting by means of churn drill or soil auger. Such a program probably would reveal a considerable tonnage of material carrying from 1 to 3 percent nickel, but whether or not deposits of such a grade warrant further exploration must necessarily depend on the successful metallurgical treatment of low-grade nickel silicate ore.

Four favorable areas where such a program of exploration might be carried out to best advantage, listed in the order of their occurrence from north to south, are as follows:

1. The laterite deposit preserved on the topographic bench at the north end of Loma Caribe. Boulders of quartz boxwork are scattered along the edges of this bench. Trenching, test pitting, or churn drilling should be employed, together with sampling, to discover the distribution and extent of any concealed boxwork and also the thickness and grade of the lateritic mantle.
2. The topographic benches and gentle slopes along the southeast slope of Loma Caribe. This area should be trenched and sampled to determine the distribution and grade of the boxwork and churn-drilled in favorable places to determine the thickness and grade of the nickeliferous laterite.
3. The laterite deposit, containing some quartz-garnierite boxwork, along the flat-topped main ridge of Loma Peguera northeast of the summit. Test pitting and trenching should show the distribution of this material and determine whether additional work is warranted.
4. The veins along the southeast slope of Loma Peguera. Trenching should be undertaken to determine the distribution of the veins and churn drilling of the favorable veins to determine their vertical extent.

COBALT

A cobalt-bearing variety of psilomelane was found on a small brush-covered topographic bench, 3 to 4 acres in areal extent, at the southeast end of Loma Caribe at an altitude of about 175 meters. It has been exposed in a number of shallow pits where it occurs in lumps as much as 10 centimeters in diameter embedded in laterite. It is black, with a distinct bluish cast, and most of the lumps are coated with yellowish-red limonite. Associated with it in the laterite are spheroidally weathered boulders of quartz gabbro a foot or more in diameter.

The origin of the cobaltiferous psilomelane is uncertain. The apparent absence of the cobaltiferous psilomelane in other parts of the laterite suggests a genetic relationship with the gabbro boulders, but a final conclusion must await the determination of the origin of the gabbro boulders.

A partial analysis of a composite sample, made in the Chemical Laboratory of the Geological Survey by F. S. Grimaldi, gave the following results: MnO, 25.26 percent; CoO, 4.44 percent; NiO, 2.50 percent.

At the time the writers were in the field the cobalt content of the psilomelane was not appreciated; hence the extent of the deposit was not determined other than to note that it was small and of no commercial value as a source of manganese.

COPPER

A copper deposit is exposed on Loma de la Mina a little over 4 kilometers southeast of Hatillo. It occurs on a topographic bench on one of the main spurs of this mountain, about 0.7 kilometer north of the summit at an altitude of about 400 meters. It is accessible with difficulty and was reached by following a little trail up an arroyo along the west contact of the triangular area of limestone on the north slope of the mountain to a small plantation at an altitude of 320 meters. From there a trail was cut by machete.

The country rock of the copper deposit consists of sericite schist, but limestone, probably part of a fault block, crops out only 250 meters to the northeast and syenite about a kilometer to the east. The schist has been sheared and in places is iron-stained. It contains numerous stringers of quartz as much as a few centimeters thick.

Copper occurs as blue azurite and green malachite, both basic cupric carbonates, which form films and plates along the cleavage planes of the schist. Pieces of azurite and malachite as much as 3 centimeters thick and 8 centimeters long are weathered out on the surface. Other evidence of mineralization consists of a few fragments of gossan scattered over the surface. A pocket of white kaolin was found in one of the pits, but its exposure was too poor to determine its extent and relation to the schist and copper minerals.

The copper deposit has been prospected by shallow trenches and pits over an area roughly 250 meters long and 150 meters wide. Some of the pits are 25 meters across and 10 meters deep. All have caved considerably. At the northeast end of the prospected area there is a large dump 75 meters in diameter and 10 to 15 meters thick. At the west side are several small heaps of crushed slag, evidence of attempts by the early prospectors to smelt the ore.

No record is available as to whether ore was ever mined in quantity. A small dump of azurite and malachite was found on the north bank of the Río Tocoa, 3.3 kilometers due south of Loma de la Mina. No pit could be found, and slag among the fragments suggests that this material was carried here by the early Spanish prospectors. The presence of this dump on the bank of the river, however, suggests that small quantities of ore may have been mined and shipped. An analysis of one piece of slag in the Chemical Laboratory of the Geological Survey by F. S. Grimaldi shows it to contain 3 percent copper but no gold.

The commercial value of the deposit on Loma de la Mina cannot be appraised, since the prospecting is too shallow to reveal critical data. As far as is known, the prospecting did not extend below the oxidized zone. No remnants of sulfides were found with the oxidized minerals. The relative abundance of copper carbonates at the surface in this area of high relief and abundant rainfall, as well as the proximity of this deposit to the Margarita syenite stock, are factors that favor the presence of an ore body beneath the oxidized zone and warrant further exploration in this area. It is recommended that either diamond drilling be undertaken along the northwest slope of Loma de la Mina or an adit be driven near the base of the mountain 100 to 200 meters below the crest.

MANGANESE

In the Maimón-Hatillo district manganese occurs in three distinct types of deposits: (1) stringers of manganese oxide in jasper, (2) pellets of manganese oxide in alluvium, and (3) cobaltiferous psilomelane in laterite. None of these deposits is considered to be of commercial value as a source of manganese. They are therefore mentioned only as a matter of record. The cobaltiferous psilomelane has already been described and is not considered further.

STRINGERS OF MANGANESE OXIDE IN JASPER

Stringers of manganese oxide occur in boulders of jasper that are scattered over an area of several acres on a low ridge on the southwest slope of Loma Mala. The deposit is located about 2.2 kilometers northeast of Piedra Blanca and half a kilometer east of the Piedra Blanca-Maimón trail. Nowhere was jasper found in place. The boulders probably were derived from a lens of jasper in the upper sedimentary tuff. The stringers of manganese oxide range from films to veinlets 3 centimeters thick. The reddish-brown jasper breaks along fractures that are filled with manganese oxide, giving the appearance in places of solid pieces of manganese oxide. However, a close examination of such pieces of jasper shows that they are merely coated with manganese oxide and that the amount of manganese is too small for it to be commercially important.

PELLETS OF MANGANESE OXIDE

Pellets of manganese oxide were found at several places in the upper 10 to 15 centimeters of alluvium on the upper terraces in the area underlain by the sericite schist. Such pellets were noted as being especially common in the upper alluvium along the trail southwest of Maimón. They consist of concentric layers, are spherical to nodular in shape, and are as much as 3 centimeters in diameter. An analysis of a composite sample collected along the Piedra Blanca-Maimón trail, 0.6 kilometer southwest of Maimón, shows the pellets to contain 13.95 percent MnO and 0.13 percent CoO.

These deposits have no commercial value, as they are small and scattered and the grade of the pellets is low.

CHROMIUM

Chromite ($FeCr_2O_4$) is present in several areas underlain by ultramafic rocks on Loma Peguera and Loma Caribe. On Loma Peguera it occurs in granular lumps as much as 3 centimeters in diameter scattered through the laterite overlying the ultramafic rocks. Two pits, now caved and almost completely obliterated, have been dug on top of Loma Peguera 600 and 1,200 meters, respectively, east-northeast of the summit. Several pieces of chromite were collected from the dumps, and a partial analysis by F. S. Grimaldi gave the following results: Cr_2O_3, 61.58 percent; Fe, 18.86 percent; Co, 0.03 percent; and NiO, 0.09 percent.

A chromite deposit on a low ridge near the southeast end of Loma Caribe was prospected by German engineers in 1939. It is reported that they shipped about 50 tons of material in small lots to Germany. The workings consist of several shallow cuts, a pit 15 by 30 meters across and 6 meters deep, and an adit about 30 meters long that connects with the bottom of the pit. Chromite is exposed only in the pit. It occurs as disseminated grains and aggregates in thoroughly weathered rock that was tentatively determined as pegmatitic material. Under the microscope the pegmatitic material is seen to be thoroughly altered to serpentine. A sample of chromite collected from the dump of the pit was analyzed by F. S. Grimaldi and gave the following results: Cr_2O_3, 46.01 percent; Fe, 12.28 percent; Co, 0.02 percent; NiO 0.09 percent; and U_2O_3, none.

Although the chromite of the district is sufficiently pure to constitute a high-grade ore, the known deposits are too small to warrant exploitation.

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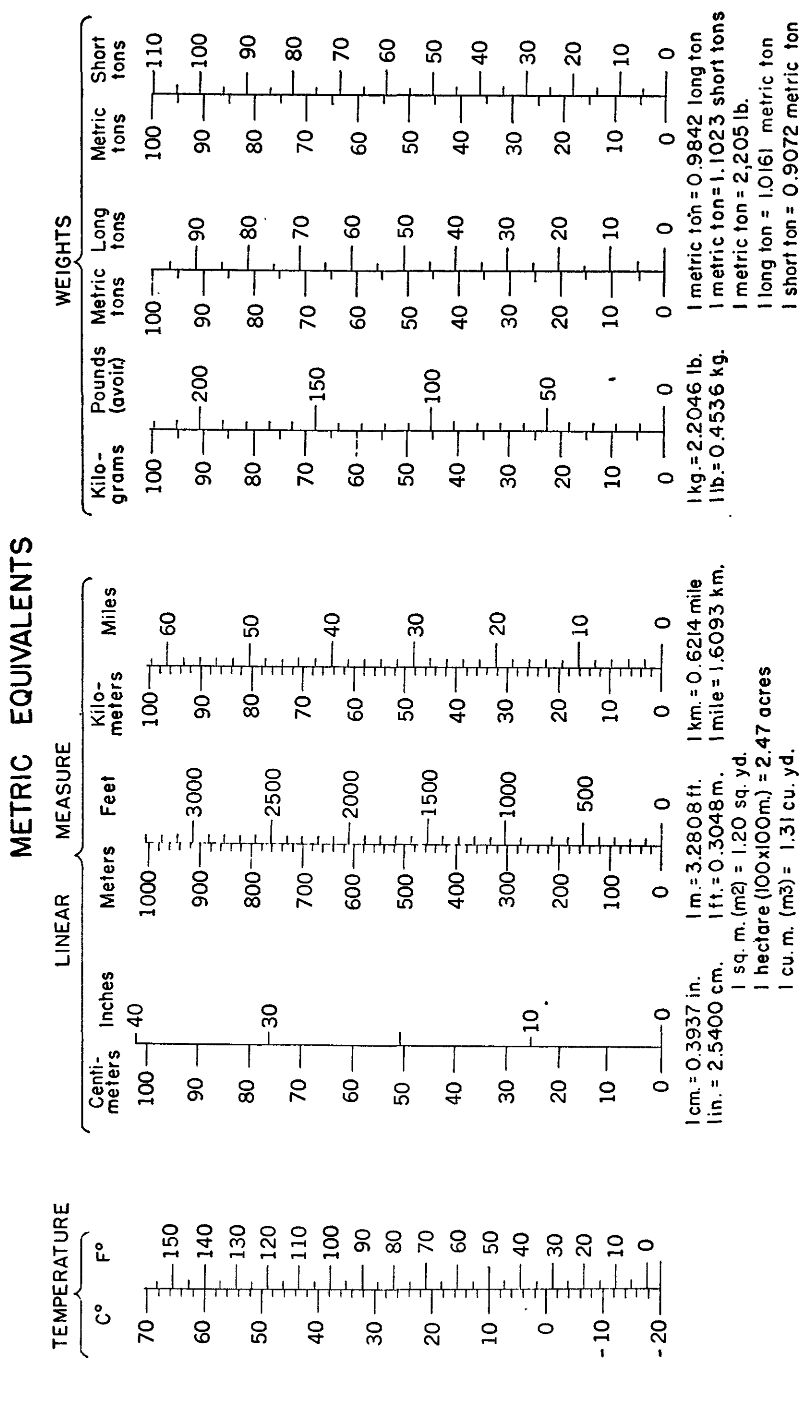
METRIC EQUIVALENTS
TEMPERATURE
C° F°
LINEAR MEASURE
Centi- meters Inches
Meters Feet
Kilo- meters Miles
1 cm. = 0.3937 in.
1 in. = 2.5400 cm.
1 m. = 3.2808 ft.
1 ft. = 0.3048 m.
1 km. = 0.6214 mile
1 mile = 1.6093 km.
1 sq. m. (m2) = 1.20 sq. yd.
1 hectare (100x100m.) = 2.47 acres
1 cu. m. (m3) = 1.31 cu. yd.
WEIGHTS
Kilo- grams Pounds (avoir.)
Metric tons Long tons
Metric tons Short tons
1 kg. = 2.2046 lb.
1 lb. = 0.4536 kg.
1 metric ton = 0.9842 long ton
1 metric ton = 1.1023 short tons
1 metric ton = 2,205 lb.
1 long ton = 1.0161 metric ton
1 short ton = 0.9072 metric ton

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