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Mr. C. Willard Hayes
REPORT

ON

A GEOLOGICAL RECONNOISSANCE OF CUBA,

MADE UNDER THE DIRECTION OF

GENERAL LEONARD WOOD,

MILITARY GOVERNOR,

BY

Willard Hayes, T. Wayland Vaughan, and Arthur C. Spencer,

GEOLOGISTS.

1901.
Gift of Mr. C. Willard

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General Leonard Wood,

Military Governor of Cuba,

Havana, Cuba.

Sir:

I have the honor to submit herewith a report on a geological reconnaissance of Cuba, made in accordance with your instructions. Both in the field work and in the preparation of the report the economic purpose of the reconnaissance has been constantly kept in mind. Only so much of the general physiography and geology has been included as appeared to be essential to an intelligent comprehension of the economic problems.

Very respectfully,

C. WILLARD HAYES,
Geologist.

INTRODUCTION.

The following official correspondence explains the circumstance under which the reconnaissance of the Island of Cuba was made.

HEADQUARTERS MILITARY GOVERNOR ISLAND OF CUBA.

The Adjutant General,

United States Army,

Havana, February 26, 1901.

Sir:

Mr. David T. Day, Chief of the Division of Mining and Mineral Resources, U. S. Geological Survey, has recently visited Cuba. During his visit he informed me that on formal request to the Department of the Interior, he believed that two Geologists of the United States Geological Survey
would be detailed for work in Cuba, provided their expenses were paid by
the Island government. Mr. Day has just written me that he has arranged
the details and is only waiting my application; therefore, I have the honor
to hereby request the detail of two geologists from the U. S. Geological
Survey and to state that their expenses will be paid from funds of the
Island of Cuba.

It is important that a hasty geological survey of the Island should be
made in order that its principal resources may be known and a statement
thereof published.

Very respectfully,
...

WAR DEPARTMENT.
...

The Honorable,

The Secretary of the Interior.

Sir:

I have the honor to inclose a copy of a letter, dated the 26th ultimo-
from the Military Governor of Cuba, requesting the detail of two geolo-
gists from the United States Geological Survey, for the purpose of making
a hasty survey of the Island of Cuba, and stating that their expenses will
be paid from Insular funds.

In view of the importance of this work, I beg to say that the Department
will be glad if you can find it practicable to comply with this request.

ELIHU ROOT,

Secretary of War.

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY.

Washington, D. C., March 16, 1901.

The Honorable,

The Secretary of the Interior.

Sir:

I beg to acknowledge receipt of your reference on March 9 of a letter
from Major General Wood, Military Governor of Cuba, asking the detail
of two geologists for a geological reconnaissance of Cuba at the expense of
the Island of Cuba.

Compensation for the services of the persons detailed must be included in
amount to be paid by the Island of Cuba, as we are not permitted to
expend any part of our appropriation beyond the limits of the United
States for any purpose.
In accordance with your request for the names of two geologists to be detailed for the services mentioned, I beg to recommend Dr. C. Willard Hayes, in charge, with Mr. T. Wayland Vaughan, to make this investigation. On account of the lateness of the season it is best to send another assistant, and Mr. A. C. Spencer will also be suggested for detail as soon as he can be spared.

Very respectfully,

Your obedient servant,

CHAS. D. WALCOTT,
Director.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY.

Washington D. C. March 16, 1901.

Major General Leonard Wood,
Military Governor.

Havana, Cuba.

Sir:

Your letter of February 26th, to the Adjutant General, has been favorably referred by the Secretary of War to the Secretary of the Interior, whose approval has been given for the geological reconnaissance of Cuba which you wish, provided that in addition to traveling expenses, salaries of the geologists detailed be paid by you. This is necessary, as our appropriations do not permit salaries to be paid in Cuba, and it was a point made in the conversation with you by Dr. Day. Assuming that this is your understanding, I am placing the matter in the hands of Dr. C. Willard Hayes, Geologist, who will leave for Cuba on next Monday with an assistant. He will take this matter up with you and be responsible for the investigation. Another assistant will be sent early in April.

Very respectfully,

CHAS. D. WALCOTT.
Director.

DEPARTMENT OF THE INTERIOR. UNITED STATES GEOLOGICAL SURVEY.

Washington, D. C., March 16, 1901.

Dr. C. Willard Hayes,

Dear Sir:

In accordance with the request of Major General Leonard Wood, Military Governor of Cuba, to the Secretary of War, transmitted through the Secretary of the Interior, you are hereby detailed to report to Major General Wood, at Havana, Cuba, to carry out his instructions for a geological
reconnaissance of the Island of Cuba. You will be accompanied by Mr. T. Wayland Vaughan, and Mr. A. C. Spencer will be detailed to report to you at a later date. The traveling expenses and salaries of yourself and assistants are to be paid for the period of your detail from the funds for the Island of Cuba.

It is expected that this work will occupy you personally for one month, after which it will be continued until the rainy season by your assistants.

Very respectfully,

CHAS. D. WALCOTT,
Director.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY.

Washington, D. C., December 3, 1901.

General Leonard Wood,
Military Governor of Cuba,
Havana, Cuba.

Sir:

I have the honor to submit herewith a report on a geological reconnaissance of Cuba, made in accordance with your instructions. Both in the field work and in the preparation of the report the economic purpose of the reconnaissance has been constantly kept in mind. Only so much of the general physiography and geology has been included as appeared to be essential to an intelligent comprehension of the economic problems.

Very respectfully,

C. WILLARD HAYES,
Geologist.

Itinerary.—Accompanied by Mr. T. Wayland Vaughan, I left Washington March 18, 1901, reaching Havana on the 21st. On the 23d, we left Havana for the Isle of Pines, going on the Government steamer Viking from Batabanó. Three days were spent in making a rapid reconnaissance of such portions of the Island as could be reached in that time. Returning to Havana the next ten days were spent in a trip by rail to Matanzas, and thence with pack train to Cárdenas, Hato Nuevo and Jovellanos: also by rail to Pinar del Río and thence across the mountains to Viñales. From April 11 to the end of the month Mr. Vaughan was engaged in making a reconnaissance of Santa Clara, visiting the principal mineral localities in the central and northern portions of that Province. On May 4 he reached Manzanillo, from which point trips were made to mineral deposits in the vicinity of Portillo and Zarzal. On the 16th he started with pack train for Santiago, going by way of Buecito, Bayamo, Dos Palmas and San Luis, visiting numerous reported mineral localities. He arrived at Santiago May 24.

On April 11 I was joined in Havana by Mr. Arthur C.
Spencer, and we proceeded at once by rail to Cienfuegos and thence by steamer to Santiago. After spending a day at Cobre we started with a pack train into the interior on the 18th, making a careful study of the various manganese deposits in the Cristo district. From San Luís we followed the telegraph trail to Mayari on the north coast and thence returned by the trail which crosses the Sierra de Nipe, arriving at Santiago on the 25th. On the following day I took the steamer for New York.

Mr. Spencer continued the study of the iron, manganese, and copper deposits in the vicinity of Santiago, and between May 7 and 21 made another trip with pack train from Santiago to the north coast some distance to the east of the former route. He also visited Guantánamo.

On June 8 Messrs. Vaughan and Spencer left Santiago by the Havana steamer, stopping part of a day at Baracoa. Mr. Spencer left the steamer at Gibara, while Mr. Vaughan continued on to Havana and on the 19th sailed for New York.

From Gibara Mr. Spencer went by rail to Holguín and spent several days examining mineral deposits in that vicinity. On the 15th he went to Nuevitas and was occupied for 10 days in examining the region between that city and Puerto Príncipe. On the 28th he returned to Havana and a few days later sailed for New York.

From the above brief itinerary it will be seen that both Mr. Vaughan and Mr. Spencer spent between 12 and 13 weeks in the field, while I was on the Island only 5 weeks. The work in May and June was much delayed by heavy rains and extreme heat. Notwithstanding the brief field season and the adverse conditions under which much of the work was necessarily done, the reconnaissance was extended over portions of every province of Cuba, and the Isle of Pines. All of the more important mineral districts were examined with some care and a large proportion of the localities of which we could learn and which promised to have any economic interest were visited.

Authorship of Report.—The preparation of the report on this reconnaissance has been left largely to Messrs. Vaughan and Spencer. In a case of this kind where there has been a constant interchange of ideas and where each member of the party has freely contributed his observations and conclusions to a common fund, it is extremely difficult to assign individual credit and responsibility for various parts of the report. In general, however, Mr. Vaughan has devoted especial attention to the determination of geologic horizons, the discussion of the more strictly scientific questions, such as the geologic history of the Island and a review of the literature pertaining to these questions. He has also written out his notes on the mineral resources of the region which he visited alone (copper and asphaltum of Santa Clara etc.), and has aided in the compilation of literature relating to the economic geology.

Mr. Spencer has devoted his attention chiefly to discussion of the economic geology of the Island, particularly to the geology of the iron, manganese and copper deposits. He has also reviewed most of the economic literature, has determined the igneous
rocks by means of the microscope and has contributed his observations on some of the more purely geological questions discussed.

My own contribution to the report has been chiefly editorial revision, with some sections on physiography, descriptions of a few of the economic mineral deposits, and the chapter on the Isle of Pines.

It has seemedeminently desirable to include in the following report not only the results of our own observations on the economic mineral deposits of the Island, but also a summary of already published information. Numerous accounts of individual deposits or districts have been published, but these are contained in various technical journals and consular reports which are difficult of access. In some cases much better opportunities were afforded other writers for making examinations since the mines were visited by them while in operation and it was possible to gain access to the underground workings. In such cases our own observations have been largely supplemented. Also we were unable to visit all mineral localities on the Island, and in order to make our report comprehensive we have incorporated from other sources the best available information regarding such localities. Practically every paper relating to any phase of Cuban geology has been examined by Messrs. Vaughan and Spencer.

Although the economic purpose of the reconnaissance was kept constantly in mind during the field work, many observations were made bearing on the purely scientific problems. Some of these will be discussed by Mr. Vaughan in a paper which he is preparing for the Bulletin of the Geological Society of America.

Acknowledgments.—Throughout this reconnaissance and in our subsequent office work we have received many courtesies which we wish here to acknowledge. The Military Governor, General Leonard Wood, to whose active interest in the industrial development of the Island the reconnaissance is due, afforded every facility for carrying on the work. Officers of the Army generally, and members of the Insular Government with whom we came in contact, gave us much valuable assistance and information which contributed largely to the success of the reconnaissance. Our thanks are particularly due to the Commandants and Commissary officers of the various army posts who furnished transportation and camping outfit as needed. We are also greatly indebted to Dr. Chas. D. Walcott, Director of the United States Geological Survey, for office facilities afforded us in the preparation of our report.

C. WILLARD HAYES.

GEOGRAPHY.

The Island of Cuba extends in longitude from 74° W. to 84° 59' W., and latitude from 19° 49' N. to 24° 43' N. If Salt Key is included, the coast of the Island reaches to 23° 13'. Its length from Cape Maisí to Cape San Antonio, measured along the curved axis of the Island, is given by R. T. Hill as 730 miles
while its width varies from about 90 miles in the widest portion of Santiago Province to about 20 miles across the Province of Pinar del Río south of Mariel. The area of the Island exclusive of the outlying islands and keys, is estimated at from 40,000 to 43,000 square miles, while the Isle of Pines is given an area of 1,214 square miles and the remaining islands and keys are calculated at 1,358 square miles, making the total area of Cuba between 42,500 and 45,500 square miles. The French geographer, Réclus, gives the area as 45,883 square miles; the Century Atlas, as 41,655 square miles, but it is not stated in the latter whether or not the outlying islands and keys are included.

The coast line of the main island, exclusive of the harbors and minor indentations, has a length of nearly 2,000 miles, but including the sinuosities of the shore and the outlines of the numerous keys, its length is more than 6,800 miles. The northern side of the Island is a broad open curve, the convexity of which is directed toward the north. This curve is interrupted by very few important irregularities. From Cabo Maisí to Punta Icacos in Matanzas Province its trend is northwesterly, while from the latter point it is continued westward in a line which gradually curves toward the south as far as the western extremity of the Island at Cape San Antonio.

The southern coast of Cuba is likewise curved and shows a general parallelism with the northward facing shore. Its irregularities, however, are very noticeable, there being several deep embayments, the largest of which are the Ensenada de Buena Esperanza and Ensenada de Broa, the former located south of the Province of Puerto Príncipe and west of the southwestern extension of Santiago Province, and the latter in the western quarter of the Island. The lesser indentations of the periphery of the Island are features of great interest since they comprise the peculiar landlocked harbors, for which certain of the West Indian Islands and Cuba especially are famous.

The numerous keys which occur at many places within comparatively shoal water around the periphery of Cuba and the Isle of Pines are among the most notable features of the Cuban coast. The aggregate number has been estimated at about 1,300. They are divisible into four distinct groups. The first and principal line of these low islands extends along the northern coast from the vicinity of Nuevitas to Cárdenas, and comprises Cayo Romano, which is divided into two islands by Júcaro Channel and is 74 miles in length, and Cayo Coco, 41 miles in length. The second line of keys occurs from Bahía Honda, west of Havana, to Cabo San Antonio. The third is a large group in the vicinity of the Isle of Pines and the southern shore of the main Island. The fourth group, known as Laberinto de Doce Leguas, extends either in the form of submerged banks or low keys from Tunas de Zaza south of Sancti Spíritus to the mouth of the Río Cauto at the edge of Ensenada de Buena Esperanza.

The Isle of Pines is some 60 miles west of south of Batabanó, the central portion of the island lying directly south of a point
25 miles west of Havana. Its area is given as 1,214 square miles. There are two indentations slightly nearer its southern than its northern coast in its outline. On the east is the Boca de Ciénaga; on the west is the Ensenada de Siguanea. As a marsh extends from one of these indentations to the other, the Isle of Pines may be considered as composed of two islands. That portion north of this marsh is roughly hexagonal in outline; south of the marsh, on the east, is a short point of land narrowing rapidly from a broad base; on the west is a long narrow curved tongue of land at the northwestern extremity of which is Cabo Francés.

**Topography.**

The surface of Cuba may be divided into five topographic provinces, three of which are essentially mountainous, while the other two are of low or moderate relief. The easternmost of these topographic divisions coincides approximately with the Province of Santiago and is for the greater part mountainous. The second, corresponding closely with the Province of Puerto Príncipe, is made up of plains or rolling open country, broken by occasional hills or low mountains, rising above the general level. The third division includes the mountainous and hilly portions of Santa Clara; the fourth comprises the western portion of Santa Clara Province, all of Matanzas and Havana Provinces, and the eastern portion of the Province of Pinar del Río. This low region, like that of Puerto Príncipe, is made up of flat or rolling plains broken by occasional hills several hundred feet in height.

The fifth topographic division, comprising the greater portion of Pinar del Río, is characterized by a prominent range of mountains with its outlying hills and mesas.

The above description of the general topographic features, calling attention to the distribution of mountainous areas at both extremities and in the central portion of the Island, classifies the various topographic divisions in a striking and natural way, but since the low regions extend back into the mountainous areas in the interior and are continued in the form of coastal platforms around the bases of the mountains, the features of the plains can not strictly be said to be confined to any of the divisions distinguished. It is therefore more convenient to describe the topography of the Island without particular regard to the natural topographic divisions.

**Mountains.**

*Province of Santiago.*—The highest mountains in Cuba are situated in the Province of Santiago, where they reach elevations higher than any in the eastern ranges of the United States and are only slightly lower than the highest peaks in Jamaica and Haiti. The mountainous area in this Province is greater than the combined mountainous areas of all the other Provinces of the Island. Its mountains occur in several groups, all composed of
different kinds of rocks and having diverse structures, but more or less closely connected one with another.

The principal range is the Sierra Maestra, extending from Cabo Cruz to the vicinity of the Puerto de Guantánamo, 40 miles east of Santiago Bay. This range is continuous and of fairly uniform altitude, with the exception of a single break in the vicinity of Santiago, where the wide basin which is now partly occupied by Santiago Bay cuts entirely across the main trend of the range. The hills back of Santiago Bay, separating this basin from the drainage of the Río Cauto, correspond in structure to the northern foothills of the main Sierra, east and west of this break. The slopes of the Sierra Maestra are very uniform throughout, being broken only by the cuttings of the evenly spaced arroyos. In the western part of the range the mountains rise abruptly from the depths of the Caribbean Sea, but in the vicinity of the city of Santiago and to the eastward, they are separated from the sea by a narrow coastal plain, which has been locally very much dissected. The streams which traverse it occupy valleys several hundred feet in depth, while the remnants of the plain appear in the tops of the hills.

East of Guantánamo estuary there are mountains which are structurally distinct from the Sierra Maestra, and these continue to Cape Maisí. They rise at first abruptly from the sea, but toward the eastern extremity of the Island are bordered by terraced foothills. Toward the north they are continued across the Island as features of bold relief connecting with the rugged Chichillas at Baracoa and with El Yunque, which lies to the south-west of that town. Extending westward from this eastern mass there are high plateaus and mesas forming the northern side of the great amphitheater which drains into Guantánamo Bay.

The most prominent feature of the northern mountains of Santiago Province to the west of El Yunque is the range of mountains comprising the Sierras Cristal and Nipe. This range extends in a general east and west direction, but is separated into several distinct masses by the northward flowing streams, such as Río Sagua and Río Mayari. The high country to the south of these mountains has the character of a deeply dissected plateau, the highest strata being native limestone. It is supposed that all of the mountains in the eastern part of Cuba have been carved from a high plateau, indications of which are seen in the level summits of El Yunque near Baracoa, and of other flat-topped mountains which have been observed within the drainage of the Mayari and Sagua rivers. The broad flat summits of the Sierra Nipe are also doubtless a remnant of this old plateau.

Below this highest level others are distinguishable as benches or broad plateaus. The two most prominent occur respectively at about 1,500 and 2,000 feet above sea level, according to barometer readings. The highest summits rise perhaps 800 or 1,000 feet higher. The 2,000-foot plateau forms, in the Sierra Nipe alone, an area estimated to be not less than 40 square miles in extent.

Considering the Province of Santiago as a whole, therefore, the
various mountain groups described above form two marginal ranges which merge in the eastern portion of the Province and diverge toward the west. The southern range is the more continuous, while the northern is composed of irregular groups separated by numerous river valleys. Between these divergent ranges is a broad, undulating plain, the famous Cauto valley, which increases in breadth westward and extends to the northern coast between and beyond the diminishing mountain groups of the northern range. Further westward it merges with the more extended plains of Puerto Príncipe.

Province of Santa Clara.—The central mountainous region is situated in the Province of Santa Clara. The Island is here crossed by a belt of mountains and hills, approximately bounded by northeast–southwest lines passing through the cities of Sancti Spiritus and Santa Clara. Four groups may be distinguished. One of these lies southwest of Sancti Spiritus west of the railroad from Tunas de Zaza to Sancti Spiritus, and east of the Rio Agabama or Manati. It is a group of ridges radiating from a short axis having a direction from slightly east of north to south of west. A second group is included between the valleys of the Rio Arinao and Rio Agabama. Its highest peak which is the highest in the central region, is Pico Potrerillo, 2,800 feet in altitude, located seven miles north of Trinidad. The mountains and hills of this group extend northward as far as Manicaragua. A third group, lying to the east and south of the city of Santa Clara, includes the Sierra del Escambray and the Sierra Alta de Agabama. The rounded hills of this region reach an altitude of about 1,000 feet, although a few of the summits may be higher. The last of the four groups consists of a line of hills beginning at a point on the north coast about 25 miles east of Sagua la Grande and extending subparallel to the northern shore of the Island into the Province of Puerto Príncipe. The trend of this range of hills is therefore transverse to the central mountain zone as a whole, but it conforms in direction with the geologic structure of the region. To the east of the city of Santa Clara the hills of the fourth group merge with those in the central portion of the province. The summits in the northern line of hills are not very high and it is probable that there is none above 1,000 feet in altitude. The principal members of the group are the Sierra Morena west of Sagua la Grande, the Lomas de Santa Fé near Camajuaní, the Sierra de Bamburanao near Yaguajay, and Lomas de Sabanas Nuevas south of the last mentioned town.

Province of Pinar del Rio.—The Province of Pinar del Rio, which is the westernmost political division of the Island, is dominated by the Sierra Organos. The main sierra of this range lies just back from the north coast and extends from Mariel westward to the Ensenada Guadiana. West of this bay a line of lower mountains or hills forms the axis of the peninsula to Cape San Antonio, the western extremity of the Island. The sierra is flanked by spurs and more or less isolated foothills and buttes. Southwest of Bahia Honda is the highest peak of the range, the
PLATE II.—Cerro del Sitio, 8 miles south of Santa Clara City.
PLATE VI.—Pan de Matanzas, seen from "El Recreo,"
eight miles northwest of Matanzas.
Pan de Guajaibón, whose altitude has been variously estimated to be from 1,920 to 2,560 feet; the former figures are probably more nearly correct. Between the city of Pinar del Río and Viñales the range is broken up into three parallel ridges, the central one of which is composed of limestone, the other two being composed of slates, schists, and limestones.

Subordinate mountains and hills.—The three mountain groups described above dominate the topography of the Island, but in addition to these highlands there are other less prominent groups of mountains and hills rising above the generally level surfaces in the Provinces of Havana, Matanzas and Puerto Príncipe. These eminences of lower altitude are confined largely to the northern margin of the Island, extending with frequent broad intervals of level plain from Havana eastward to Santiago Province.

A few hills rise from the level plain in the western part of Havana Province. These are the extreme eastern outliers of the Organos Range of Pinar del Río. Other hills lie east and southeast of Havana, being closely connected with a large group northwest of Matanzas which contains one prominent point, the Pan de Matanzas, reaching an altitude of about 1,300 feet. Some hills occur also between Matanzas and Cárdenas and at intervals throughout the northern portion of the Province of Santa Clara. In general, these isolated hills or groups have rounded summits, but their lower slopes are frequently very steep, rising abruptly from the surrounding level plains.

The greater part of Puerto Príncipe is free from hills, the most prominent elevations being in the northeastern portion, where the Sierra de Cubitas contains a few points above 1,000 feet in altitude. To the eastward of this range numerous isolated elevations extend into Santiago, finally merging with the northern range of that Province.

PLAINS.

Aside from the mountains and hills above described the general surface of Cuba is that of a rather low, gently undulating plain. A list of the more important towns in Cuba, with their elevations above sea level, is given in an accompanying appendix. These elevations are also printed on the accompanying maps (figs. 15, 16, 17), and from them its altitude in various portions of the Island may be readily determined.

In Pinar del Río it forms a piedmont plain, which entirely surrounds the mountain range. On the south it has a maximum breadth of 20 miles and ascends gradually from the sea level to the base of the mountains at the rate of about 7 or 8 feet to the mile. Its seaward portion is extremely flat, but as the highland is approached it becomes more undulating and somewhat deeply dissected by stream channels. North of the mountain range the lowland belt is much narrower and also somewhat higher. It does not have a regular slope to sea level but is at least 200 feet high near the coast. It is deeply dissected, so that in places only the level hill tops mark the position of the plain.
The northern and southern piedmont plains of Pinar del Rio unite at the eastern extremity of the Organos Range and extend eastward over the greater part of Havana and Matanzas Provinces and the western part of Santa Clara. Although the divide between northward and southward flowing streams is approximately on the axis of the Island, the plain has a gradual southward slope from near the northern margin. In the vicinity of Havana its elevation is between 300 and 400 feet, and eastward to Cárdenas, wherever it can be recognized, it varies between those limits, that is, the northern edge of the Island appears to have been elevated about 350 feet more than the southern edge. The northward flowing streams have lowered their channels as the land rose and the portion of the plain which they drain has thus become deeply dissected, so that in many places only the level hill tops attest its former extent. The southward flowing streams, on the other hand, have been scarcely at all affected by the elevation and remain generally in very shallow channels. Eastward from Cárdenas the general elevation of the plain is less and it slopes gradually both north and south from the axis of the Island. Considerable areas of the plain are developed among the various mountain groups which occupy the eastern half of Santa Clara Province and beyond these mountains it extends eastward over the greater part of Puerto Principe and into Santiago. In this Province it reaches the northern coast between isolated mountain groups as far east as Nipe Bay and to the southward merges with the Cauto Valley.

From Cabo de Cruz the plain extends along the northern base of the Sierra Maestra to the head of the Cauto Valley. Its elevation near Manzanillo is about 200 feet and it increases to about 630 feet at El Cristo. In the central part of Santiago Province the Rio Cauto and its tributaries have cut channels in the plain from 50 to 200 feet in depth. In the lower part of the valley these channels are sometimes several miles across and are occupied by alluvial plains. They decrease in width toward the east and in the upper part of the valley they are narrow gorges.

Much of this plain, particularly in the central provinces, is underlain by porous limestone, through which surface waters readily find underground passages. Hence large areas are entirely devoid of flowing surface streams. The rain water sinks into the ground as soon as it falls and after flowing long distances underground emerges in bold springs such as that which forms the Almendares River in the vicinity of Havana.

As stated above the plain is largely a plain of erosion and its surface is covered by residual soils. These are mostly derived from the underlying limestones, where they consist of red or black clays having great fertility. Certain portions of the plain, such as that bordering the mountains of Pinar del Rio on the south, are covered with a layer of sand and gravel derived from the adjoining highlands, and their fertility is greatly inferior to the soil derived from the limestone. Similar superficial deposits
occur in the vicinity of Cienfuegos and doubtless in many other portions of the Island where the plain forms a piedmont adjacent to highlands in which siliceous rocks occur.

**DRAINAGE.**

The arrangement of the streams in the greater part of Cuba is extremely simple. Excepting in the southwestern portion of Santiago Province the stream courses are practically all normal to the coast. Owing to the shape of the Island, therefore, none of its streams have any considerable length or volume. There are nearly 200 rivers and large creeks which flow directly into the sea.

The divide between northward and southward flowing streams lies near the axis of the Island, but is generally somewhat nearer the north than the south coast. In Pinar del Río the divide is formed by the crest of the Organos Range. Wherever this range is composite the divide is generally upon the southern crest, that is, the northern portion of the range has been most deeply eroded and the divide has been pushed to the southward of its axis. Throughout the four central provinces, the divide is, for the most part, extremely indefinite, being simply a level plain, on which there is no sharp water-parting. Owing to the southward tilting of the plain the northward flowing streams occupy deeper channels than those flowing to the southern coast. In general the drainage of this central portion of the Island may be described as autogenous—that is, the stream courses are such as would be formed on a gently undulating plain recently raised above sea level. No considerable subsequent adjustments are observed although some of the upper stream courses are adjusted to the geological structure. This is particularly noticeable in the central part of Santa Clara province, where the streams occupy the outcrops of certain soft beds between harder strata on the sides of synclinal folds. A similar adjustment upon the sides of an anticlinal fold is seen in the Yumurí valley near Matanzas.

The drainage of Santiago Province affords some exception to the normal arrangement elsewhere observed. The Cauto River flows through the center of the province in a broad westward pitching syncline. It is therefore a consequent stream, its position being determined by the structure of the underlying strata. Its northern tributaries head upon a low divide similar to that throughout the central provinces, but its southern tributaries head upon the northern slopes of the Sierra Maestra and flow northward directly away from the coast. To the eastward of Santiago de Cuba the streams have courses normal to the coast, although there is less regularity owing to the mountainous character of this region. Many of them cut directly across the edges of upturned strata flowing outward from the center of a syncline. They may be in fact antecedent streams, although their courses have been to some extent adjusted to the structure.
Cuba is noted for its splendid harbors, and nearly every author who has written on the physical aspects of the Island has devoted considerable space to their description. The best harbors, excepting that of Matanzas, are pouch-shaped, possessing a narrow entrance separating a large, nearly circumscribed inland body of water from the sea. The harbors of Havana, Cienfuegos, and Santiago are the most important, and all belong to the same type.

The harbor of Havana possesses between the Morro and Castillo de la Punta a narrow entrance extending east of south. The harbor itself is dumb-bell shaped, arroyos that empty into it determining its outline. The Morro and Fort Cabañas are situated on the northeastern side; Regla with its warehouses and wharves is on a projection on the eastern side; the southern end is shallow, having been filled by sediment brought down by several streams. The city of Havana is situated on the western side, extending south from the Castillo de la Punta to the southern end of the harbor. The water in its channel and central portions is deep enough for the deepest draught vessels, but only shallow draught vessels can be accommodated at the docks.

Careful borings have been made across the entrance to the harbor by the Military Government in connection with the preparation of plans for a sewerage system. The accompanying diagrams show several cross sections of the channel. A point of especial interest is the existence of a once deeper channel now filled with sand in the middle of the present channel. The conclusions which are to be drawn from the presence of this filled channel are important in their bearing upon the origin of the Cuban harbors.

Other important harbors on the northern coast are Bahía Honda, Cabañas and Mariel, in the province of Pinar del Río; Matanzas and Cárdenas, in the province of Matanzas; Nuevitas in the Province of Puerto Príncipe; Gibara, Bahía de Nipe and Baracoa in the province of Santiago. All of these are more or less pouch-shaped excepting those of Matanzas and Cárdenas.

Good harbors are not so abundant on the south coast as on the north. The most easterly one is that of Guantánamo. It is a fairly good pouch-shaped harbor but rather shallow. The next one toward the west is at Santiago, which is one of the finest in the world. There is no noticeable indentation of the coast line excepting in front of the immediate entrance, which is only 180 yards across and is cut in a steep seaward escarpment over 200 feet in height. On the eastern side of the entrance is the Morro, its light-house rising 310 feet above sea level, and about 40 feet above the point of land on which the fort stands. On the western side of the channel the sea scarp is less abrupt and regular, the land rising from the sea in a series of low hills. The Island Cayo Smith lies just within the harbor, to the west of the main channel. On the eastern side are precipitous cliffs rising to a height of 200 or more feet. Cayo
Fig. 1. Plan and cross-section of old filled channel in Havana Harbor.
PLATE XIII.—ENTRANCE TO THE HARBOR OF SANTIAGO, SEEN FROM THE INSIDE, LOOKING SOUTH.
PLATE XIV.—View taken on west side of entrance to the Harbor of Santiago, looking north.
Smith and the high land on either side of the sinuous entrance completely conceal the broad expanse of the harbor proper from the sea. North of Fort Socapa, now in ruins, on the eastern side of the harbor is the narrow entrance to Nispero Bay, a beautiful land-locked harbor deep enough to accommodate the largest man of war, and in which the Military Government has built a dock. The depth of water in the channel and in the greater part of the harbor is sufficient for the largest vessels, but only light-draught vessels can come up to the docks. On the northwestern and northern sides of the harbor the land rises by a succession of terraces from sea level to an elevation of 200 feet, but less abruptly than on the eastern side. It is upon these terraces that the city of Santiago is built.

The harbor of Cienfuegos is very similar to that of Santiago, except that the land on either side of the entrance is not so high.

Other harbors on the south coast, as Manzanillo and Batabanó, are merely open roadsteads, generally shallow and more or less perfectly protected by the numerous sand keys which abound along the coast from Cape Cruz to the western end of the Island.

Various explanations of the pouch-shaped Cuban harbors have been made by several writers. These need not be given here, nor is a complete discussion of the subject in place, but the explanation which appears to us most satisfactory may be briefly stated.

The depressions occupied by the water forming these harbors appear to be due entirely to erosion by streams flowing into the sea during a recent geologic period when the land stood somewhat higher than now. In other words, they are drowned drainage basins. Their peculiar shape, a narrow seaward channel and a broad landward expansion, is due to the relation of hard and soft rocks which generally prevail along the coast. Wherever the conditions are favorable for the growth of corals a fringing reef is built upon whatever rocks happen to be at sea level, and as the land rises or sinks this reef rock forms a veneer of varying thickness upon the seaward land surface. The rocks on which this veneer rests are generally limestones and marls much softer and more easily eroded than coral rock. Hence several small streams, instead of each flowing directly to the sea by its own channel, are diverted to a single narrow channel through the hard coral rock, while they excavate a basin of greater or less extent in the softer rocks back from the coast.

The fact that the land has recently stood at a sufficiently higher level to enable the streams to excavate such basins is proven by the sand-filled channel in the Havana harbor entrance and by borings made near the mouth of Rio San Juan at Santiago, showing that the rock floor lies below the present level of the sea. Doubtless similar filled channels would be discovered in the other harbors of this class if they were properly sounded.

It is interesting to note that at various points along the Cuban coast precisely similar basins are now being excavated which would form pouch-shaped harbors if the land should be slightly
depressed. Several such basins were observed eastward from Santiago. If the coast at Matanzas were to sink thirty feet or more a portion of the Yumurí valley would be flooded, forming a broad basin connected with the sea by a narrow entrance, the present Yumurí gorge.

Terraces.—At numerous points along the Cuban coast there are well marked marine terraces. They are present wherever conditions have been favorable for their development and preservation, as along the north coast generally and along the south coast in Santiago province. From Manzanillo westward to the end of the Island, on its southern side, the terraces are inconspicuous or entirely wanting. A detailed study and description of these terraces would throw much light on the recent geological history of the Island, but for the purposes of this report only a very general statement is required.

To the westward of Havana conditions have been unfavorable for the preservation of terraces. Traces of a coral reef at an elevation of about 150 feet have been observed and another much more recent about 5 feet above tide is generally present. In the vicinity of Havana four terrace levels may be recognized, as follows:

No. 4. Altitude 200 feet, near Ciénaga, contains Upper Oligocene reef corals.
No. 3. Altitude about 100 feet, Fort Cabañas level.
No. 2. Altitude 10—15 feet, Pleistocene coral reef rock.
No. 1. Altitude 4—5 feet, Soborruco, Pleistocene or recent coral reef rock.

Numbers 2 and 1 are only a few yards in width, but the latter is one of the most persistent terraces distinguished around the Island. At Matanzas, on both sides of the bay, and in the Yumurí gorge, at least six terraces may be distinguished, as follows: No. 6. Altitude 400 feet, the shoulder on the sides of the Pan de Matanzas.

No. 5. Altitude 300 feet, Iglesia de Monte Serrato.
No. 4. 200 "  Limonar.
No. 3. 140 "  Cliff summit at Yumurí gorge.
No. 2. 30 "  Pleistocene coral reef.
No. 1. 5—6 "  Soborruco or recent coral reef.

Of these terraces No. 4 is the most extensively developed, forming considerable areas of level plain, as at Limonar, which is about 20 miles from the coast.

At Cárdenas an extensively developed terrace slopes gradually from near sea level to an elevation of 75 feet at its inner landward margin, where there is an abrupt ascent to a high level of 400 feet.

At Nuevitas three terraces are distinguished, the highest 100 feet above sea level, another at 40 feet and a low coastal shelf only a few feet above tide.
At Gibara there are at least four terraces, as follows:

No. 4. Altitude 150—180 feet, extensively developed in and back of the town.
No. 3. Altitude 100 feet, fort level.
No. 2. " 40 " not extensive.
No. 1. " 5—20 " coastal shelf on which most of the town is built.

A fifth level is represented by the flat-topped hills now rising 1,000 or 1,200 feet above sea, some distance back from the coast. These are evidently the remnants of an old peneplain and they probably correspond with the Cuchilla level described by Hill.

At Baracoa three distinct terrace levels are recognized:

No. 3. Altitude about 250 feet.
No. 2. " 90 feet, Castillo level.
No. 1. " 5—6 feet, Soborrucó, containing large masses of recent reef corals; rises to 15 or 25 feet in the town.

Two still higher levels may be recognized in the vicinity of Baracoa, though not properly terraces. One of these is the Cuchilla level, now deeply dissected and represented by the even summit of conical hills which reach elevations of 500 to 600 feet.

The other and highest level is that represented by the summit of El Yunque or the Anvil, which is a flat topped butte with precipitous slopes rising to an elevation of 1,827 feet.

Nowhere on the coast of Cuba are the marine terraces better displayed than along the southern coast of Santiago Province.

At Manzanillo three terraces are distinguished, as follows:

No. 3. Altitude 200 feet, high level plain merging with the Cauto valley.
No. 2. " about 100 feet, bench on which the barracks are located.
No. 1. " 5—20 feet, low bench on which most of the city is built.

These three terraces distinguished at Manzanillo extend southward to Cabo de Cruz.

At Santiago de Cuba no less than eight terraces may be distinguished, although they are not of equal prominence.

Omitting the less important, the three of the best marked occur as follows:

No. 3. Altitude 280 feet, Morro level, contains some reef corals.
No. 2. " 100 feet, Cathedral terrace.
No. 1. " 20 feet, a narrow coastal shelf.

Above terrace No. 3 appear the remnants of a level coastal plain, now deeply dissected. Its altitude is about 400 feet.
Between the Morro and Cathedral levels are three subordinate terraces, at 200, 180 and 140 feet. Also, between Nos. 2 and 1 is a terrace which appears in the northern part of the city with an elevation 60 to 70 feet. About the margins of the harbor, the descent from No. 1 to sea level is made by three benches separated from one another by about 5 feet.

Eastward from Santiago the terraces appear at intervals to the extreme point of the Island, where they are developed in the most striking manner. At least seven distinct levels can be distinguished at Cape Maisí. Three of these are much more strongly developed than the others and probably correspond to the three major terraces of the Santiago region. If so there is a considerable divergence between these terraces toward the east. Thus the distance between terraces 3 and 1 at Manzanillo is 200 feet, at Santiago de Cuba 280 feet, and Cape Maisí, estimated at 600 feet.

GENERAL GEOLOGY.

STRATIGRAPHIC GEOLOGY.

In the following outline it is attempted to give merely a general description of the various geologic formations of the Island. Their most salient lithologic characters and their distribution will be given, but the paleontologic and other evidence upon which the age conclusions are based will be published elsewhere.

Protaxis of the Island. (Serpentine, granite, etc.)—The most ancient rocks in Cuba consist of serpentines, granites, slates, and schists. Slates and schists were seen in small patches in the Province of Santa Clara, some three or four miles south of the city of that name. They were much folded, metamorphosed, and apparently the serpentine had been intruded into them. Outcrops of serpentine occur in every province of the Island. The most westerly occurrence at present known is near Guanajay, in the province of Pinar del Río. In the vicinity of Havana and Guanabacoa are considerable areas. There are large areas northwest of Matanzas between Matanzas and Cárdenas, and east of Cárdenas in the vicinity of Hato Nuevo. Extensive areas also occur in the central portion of the Province of Santa Clara and near the City of Trinidad in its southern portion. It also constitutes the surface formation of large areas in the northern and central portions of the Provinces of Puerto Príncipe and Santiago.

Outcrops of granite were observed at the south end of the harbor of Santiago and south of the city of Santa Clara. A granite porphyry of doubtful age occurs in the Province of Santiago.

These rocks, although of igneous origin, are briefly discussed here because they constitute the basement upon which all of the succeeding geological formations, with the possible exception of some doubtful Paleozoic rocks in the vicinity of Trinidad, have been laid down.

Paleozoic.—Semi-crystalline blue limestones of fine texture
occurrence in the vicinity of Trinidad have been considered as doubtfully of Paleozoic age.

In the Province of Pinar del Río occurring along the axial portion of the Sierra Organos, as for instance at Viñales, is a hard blue limestone, not distinctly crystalline, intersected by small, white veins of calcite. This limestone is the oldest geologic formation revealed in a cross section of the Island taken along a line passing through this place. It occurs at numerous places and, although we do not positively know its age, it may be Paleozoic.

Overlying the above described hard blue limestone, south of Viñales along the road to Pinar del Río, are reddish argillaceous schists, which form two parallel ridges. These schists were evidently derived from the metamorphism of a shale series which contained occasional beds of sandstone and some layers of limestone.

Jurassic?—Strata of Jurassic age have been reported from Cuba and the Isle of Pines since the time of Humboldt. The determination is based upon paleontologic evidence which, when examined critically, proves to be insufficient, and we merely make a note here that limestones occurring in the Provinces of Havana and Pinar del Río have been referred to a Jurassic horizon.

Cretaceous.—Cretaceous formations possess an extensive development in Cuba. In the Province of Havana calcareous strata containing Cretaceous fossils occur at Santiago de los Baños. Lying between the Tertiary limestones and the serpentine protaxis in the vicinity of Havana are glauconitic limestones, somewhat earthy in composition, and magnesian marls, which have been referred by Salterain to the Cretaceous. We consider the age of these beds as doubtful, as neither the paleontologic nor the stratigraphic evidence is sufficient to warrant a positive conclusion.

Occurring below the lowest observed fossiliferous Tertiary horizons in the vicinity of Matanzas are limestones, sandstones, and shales which occupy the same relative stratigraphic position as the supposed Cretaceous of the region near Havana, and may be referable to this geologic period. Cretaceous formations occupy extensive areas in the central portion of the Province of Santa Clara, where such typically Cretaceous fossils as Barrettia, Requienia, etc., were collected. The basement beds consist of an unfossiliferous arkose, composed very largely of material derived from the underlying serpentine and granite. Above these basement beds lies a hard, grayish limestone replete with the remains of organisms characteristic of the Cretaceous period. Formations of the same age occur also in the vicinity of Cienfuegos, and Cretaceous strata of calcareous composition occupy extensive areas in the central portion of the Province of Puerto Principe. Although rocks have been referred to this age in the literature on the province of Santiago, no fossils have as yet been listed, therefore we are in doubt as to the existence of Cretaceous strata in this portion of the Island.

In the Province of Pinar del Río between Viñales and the
city of Pinar del Rio, there is a hard, grayish limestone overlying the schists. No paleontologic evidence as to the age of this limestone was obtained, but from its stratigraphic position and general lithologic character, it is referred provisionally to the Cretaceous period.

**TERTIARY.**

*Eocene.*—The only rocks that we know to be positively of Eocene age in the Island occur in the Province of Santiago, not far from the city of Santiago, where they are associated with manganese ores. This information is furnished us by Mr. Wm. H. Dall, who determined some fossils collected by Mr. Clarence King. Associated with the manganese ores in this province are foraminiferal limestones and foraminiferal green sand marls, which appear to be of Eocene age and are tentatively referred thereto. It is quite probable that the limestones occurring along the northern foot of the Sierra Maestra from Los Negros to Cabo Cruz are also Eocene. Eocene limestones are reported from the province of Santa Clara, particularly the vicinity of Cienfuegos, from the province of Matanzas, near the City of Matanzas, and from the vicinity of Havana. We consider the data upon which the age of these rocks has been determined for these three provinces doubtful; the doubt for the vicinity of Havana being so strong that we feel justified in contradicting the previous age determinations and refer the formations to the Upper Oligocene.

North of the city of Pinar del Rio and along the Rio Santa Fé, just south of the village San José, sandstones underlie the Upper Oligocene limestones. We obtained no paleontologic data by which we could determine the age of this formation, but suggest that it may be of Eocene age.

*Lower Oligocene.*—A yellowish marl composed of the remains of radiolaria has been described by several authors from Baracoa. This material underlies the Upper Oligocene and can probably be referred to Lower Oligocene age.

*Upper Oligocene.*—The limestones and marls of this age are by far the most widespread geologic formation in Cuba. They extend uninterruptedly from the Province of Pinar del Rio to the Province of Santiago. The most westerly locality at which rocks of this age were observed was in the province of Pinar del Rio, some 4 miles north of the city of that name, on the road to Viñales. The material lithologically is either soft limestone or calcareous marl. There is a quarry in yellowish Upper Oligocene limestone at the town of Consolación del Sur, from which place we have obtained a fair collection of fossils through the kindness of the Alcalde of that town. Limestones and marls, with occasional beds of calcareous sands, occur over large areas in the vicinity of Havana, extending from the City toward the west, south, and east.

Limestones and marls, of the same age with some conglomerates, occupy extensive areas around Matanzas and eastward of that city. The gorge of the Yumurí River is cut through rocks
of this age and exposes an excellent section. At this place the river runs nearly east and west through a narrow gorge 500 or 600 feet wide. From its bottom the vertical distance to the top of the highest level through which it is cut is some 450 feet. The gorge itself is about 200 feet in depth. The rocks dip at an angle of about 27 degrees to the southeast, the thickness here exposed being estimated at 600 or 700 feet. The whole section, excepting the lowest 100 feet, at the western end of the gorge, is composed of limestone, more or less impure, with occasional beds of sandstones and conglomerates which occur near the top of the section. Characteristic Upper Oligocene fossils are abundant. We did not collect any Upper Oligocene fossils in the Province of Santa Clara, but we have reason to believe that limestones of this age are extensively developed in its northern and southern portions.

Upper Oligocene yellowish calcareous marl or limestone are found in the vicinity of Nuevitas; also at Baracoa, where they immediately underlie the Pleistocene coastal soborruco. A very great development of marls and limestones, containing large numbers of reef corals, is seen in and around the city of Santiago. The terraces in this city, excepting the lowest soborruco have been cut into Upper Oligocene formations. Upper Oligocene limestones also have an extensive development in the vicinity of Manzanillo.

Miocene and Pliocene.—An extremely interesting fact in the Cuban stratigraphy is that so far as we at present know, there is absolutely no true Miocene on the Island. The Miocene as described by De Castro, Salterain and others is known to be Upper Oligocene. From the evidence now before us, it seems most probable that during Miocene time none of the now existing portions of the Island of Cuba were submerged beneath the ocean.

The data regarding the presence of Pliocene strata are unsatisfactory. The only data on which we could base a conclusion are derived from the notes and collections of Mr. Wm. Palmer. In the western part of Havana, on the Calle Infanta, opposite Castillo de la Punta, Mr. Palmer made a collection of fossils from a quarry in soft white limestone. The bottom of the quarry is about at sea level. According to Palmer the same formation extends to approximately 60 feet above sea level. The fossils obtained from this locality may be Pliocene, though it is probable that they are Pleistocene. The limestone which is being quarried between the Almendares River and Camp Columbia, on the northern side of the road, may be of Pliocene age.

Pleistocene.—Surrounding the greater portion of Cuba, but especially along the northern coast and bordering the southern coast of Santiago from Cape Maisi to Cape Cruz, is a low coastal shelf never exceeding a maximum elevation of 30 or 40 feet. There is beneath this shelf sometimes a lower terrace some five or six feet above the water’s edge. Both of these terraces are composed of elevated coral reef rock. The material is a limestone presenting an extremely rough upper surface, and replete with the
remains of numerous species of corals which are all, so far as examined, at present living in the surrounding Antillean seas. These reefs have been formed and elevated within very late geologic time.

A coating of surface gravel exists over the plain in the Province of Pinar del Río on the south side of the Sierra Orga- nos. The material has been derived from the rocks constituting the mountains and has been distributed through the agencies of streams and floods. It is probably of Pleistocene age.

**IGNEOUS ROCKS.**

The occurrences of serpentine and granite have already been noted in the description of the Protaxis of the Island. Cuba offers a great variety of igneous rocks, ranging in mode of occurrence from deep-seated plutonic intrusions to fragmental volcanics, and in composition from the extremely acid rhyolites and granites to basic diabases and gabbros. The rocks have been named by Mr. Spencer from microscopic examination of thin sections, but no petrographic descriptions of the various specimens collected will be given in this report.

**Acid Rocks.**—Besides the granite, which has previously been mentioned, other acid rocks have been found in the Island. A mass of granite porphyry was seen near Daiquirí on the road to the Magdalena mine, and rhyolite was found 4½ miles southeast of Buecito at Mina Manuel. Volcanic tuffs, probably of rhyolitic nature, were found along the Río Nagua, 12 miles southeast of Zarzal. All of these localities are in the Province of Santiago.

**Syenitic Rocks.**—Syenite was found in the Province of Puerto Príncipe south of Minas, near the copper mines. Syenite porphyry was collected in Santiago Province on the Río Manasas along the telegraph line. Felsite was collected two miles north of Caridad.

**Diorite.**—A mass of diorite occurs near Campo Florida some 14 miles east of Havana and about 2 miles south of the railroad from Havana to Matanzas. This rock is being quarried and used as a road metal on the streets of Havana. Diorite-porphyry and andesite occupy extensive areas in the central portion of Santa Clara Province, especially in the vicinity of the San Ferna- nado copper mines. They also occur abundantly in Santiago Province at Guásimas in the vicinity of Daiquirí, Mina Firmeza, and at Holguín. Andesite occurs near Caridad and four leagues southeast of Zarzal on the Río Nagua, and at a locality 1½ to 1⅔ miles west of the town of Los Negros.

**Diabasic Rocks.**—Diabase was found south of the syenite quarry near Campo Florida, intruded into serpentinite. In the Province of Santa Clara a mass of diabase occurs associated with the copper vein at Mina Santa Rosa, 2¾ miles east of Mina San Fernando. There are several occurrences east of Santa Clara, one 12 miles from the city and the other on the eastern bank of the Río Manajánabo on the road to Camajuaní. In the Province of Santiago a typical fine-grained diabase forms a hill on the
edge of the plain southeast of Zarzal, just at the foot of the mountains. Diabase is found in the same province on the Río Manasas along the telegraph line, and it constitutes the country rock in the river bed east of the Daiquirí mines.

An important occurrence of basalt in Santiago Province is 1\frac{1}{4} miles southeast of Dos Palmas at the mine known as "Impree-vista." This occurrence is more fully described in discussing this copper prospect.

**Gabbros.**—Gabbros were found at several localities within the province of Santa Clara. One is a mile west of Manicaragua, another about 3 miles southwest of Loma Cruz, and a third at Mina Descanso, 23 miles southeast of Santa Clara. Gabbro occurs in the Province of Santiago on the Manasas River along the telegraph line and at Loma Bandera near Mayari.

Diaglage rocks occur as boulders in the bed of the Río Sojo on the road to Mayari, and would doubtless be found in place in the mountains to eastward where this stream heads.

A pyroxene diorite (epi-gabbro) occurs six miles north of Puerto Príncipe City, where it is intrusive into the serpentine. The same kind of rock occurs at Minas copper mines in the Province of Puerto Príncipe.

Excepting the granite and serpentine, all of the igneous rocks studied by us appear to be of Post-Cretaceous age, and some may be quite late Tertiary in age, as Mr. Robert T. Hill reports a dike cutting Tertiary sediments in the vicinity of the water-works at Havana.

**Structural Geology.**

In describing the areal distribution of the geological formations of Cuba it was shown that the oldest rocks, both igneous and sedimentary, occur in a general way along the axis of the Island and that the younger formations outcrop in irregular zones on both sides of this axis. The general structure of the Island is therefore seen to be broadly anticlinal. The opposite sides of the anticlinorium are not of equal extent, the slopes being broader and the dips being gentler and more uniform upon the southern than upon the northern side.

**Pinar del Río.**—In Pinar del Río the anticlinal structure is evident in the metamorphic schists and limestones which form the Organos range. The bedding is generally obliterated by secondary cleavage, but on the southern flank of the range beds of limestone have a steep southerly dip with many minor folds. In the plain south of this range the unaltered Tertiary sediments have a gentle southerly dip resting unconformably on the much older rocks to the north. The same relations were observed by Mr. Wm. Palmer on the northern side of the range. The accompanying section, Pl. XVIII, fig. 1, from Viñales to the south coast, shows only the southern portion of this anticline.

**Havana.**—A section southward from Havana shows a gentle anticline wholly within the Tertiary beds, the older rocks not reaching the surface. A short distance eastward from Havana
the serpentine appears and the structure is more distinctly anticlinal. As shown on the accompanying section, Pl. XVIII, fig. 2, the southern limb is long and gentle while the northern limb is short and contains a number of subordinate folds. The latter are extremely irregular and their axes appear to have no uniform direction.

Matanzas.—West of Matanzas Bay is an elongated dome-shaped uplift. The older rocks, chiefly serpentine, with some slates and limestones, occupy an oval area away from which the younger beds dip on all sides. The lowest of the sedimentary formations contains pebbles derived from the older rocks, showing that they were shore deposits, and it may be that the serpentine was never completely covered by them. The later beds, however, which are largely limestone, probably formed a mantle entirely across the serpentine. Subsequent to their deposition the beds were arched up and then eroded from the top of the dome. The beds which rested directly upon the serpentine, were more easily eroded than the overlying limestone. Hence valleys were formed on the edges of these soft strata leaving the relatively harder serpentine in the center as a mass of hills and the limestone on all sides as an encircling ridge. The Pan de Matanzas is simply a portion of the elevated dome which has not been removed by erosion. The accompanying sketch section, Pl. XVIII, fig. 3, shows the structure of this area. The Pan de Matanzas is introduced in the section although in reality it is several miles west of the line on which this profile is drawn.

Santa Clara.—In Santa Clara the anticlinalorium consists of numerous more or less regular folds or dome-like elevations whose axes have a general east and west direction. These elevations, which bring the underlying serpentines and other old rocks to the surface, extend much further south than elsewhere in the Island.

The occurrences of Cretaceous strata and a variety of igneous rocks in the vicinity of Santa Clara, and especially south of that place, have already been described. In this region the stratified rocks show considerable folding as indicated in the diagram which illustrates the general geologic relations. (Pl. XVIII, fig. 4.)

Granite and serpentine form the lower slopes of the hills, whereas younger intrusive rocks form the higher portions. The Cretaceous limestones occur in the bottom of synclines, while streams, which have adjusted courses, flow between the outcrops of limestone and the harder igneous rocks which form the axes of the anticlines.

Puerto Príncipe.—In Puerto Príncipe the structure is similar to that in Havana and Matanzas, except that the anticline is more nearly symmetrical and the area of basement rocks is broader. The Sierra Cubitas forms the northern rim of the serpentine area and is composed of northward dipping limestones. (See Pl. XVIII, fig. 5.)

Santiago.—The anticlinorium which dominates the structure throughout the five western provinces of Cuba, extends eastward
into Santiago and gives an anticlinal structure to the northern half of the Province. This structure is displayed in the mountains about Holguín and south of Nipe Bay. How far east it extends is not known, but probably it would be detected nearly or quite to the eastern extremity of the Island. South of this anticline in Santiago Province, but not elsewhere, is a broad syncline having a slight pitch to the westward and narrowing eastward. The southern margin of this syncline is formed by the northward dipping strata which rest upon the igneous rocks of the Sierra Maestra. These beds doubtless once extended over the crest of the range throughout its course, as they still do toward its eastern end, where the elevations diminish, but they have been removed by erosion from the higher mountains. Their previous southward extension is, however, only a subject for speculation, since the profound fault, which appears to have determined the present coast line from Cape Maisí to Cape Cruz, has engulfed all the pre-Oligocene formations in the depths of the Caribbean sea.

The broad structural features of this portion of the Island are shown on the accompanying section, Pl. XVIII, fig. 6, which is based entirely on observations made during this reconnaissance. Upon the south, the immediate coast is occupied by modern coral limestone resting upon the eroded surface of igneous rocks which form the lower portion of the southern slope of the Sierra Maestra to the east and west of Santiago. In the Santiago embayment, however, beneath the recent coral rock, there is a series of limestones and marls of late Oligocene age, as shown by the fossils which they contain. The higher portion of the Sierra Maestra is made up of volcanic flows and breccias. These rocks extend across the valley of the Río Cobre, in the vicinity of which they are cut by dikes of igneous rock and also contain bands of interbedded limestones. The nature of this volcanic series may be very clearly seen along the new military road between the villa Boniato and the top of the Sierra Boniato since the recent cuttings have revealed a nearly continuous rock section. The strata exposed from the base of the massive limestone which comes nearly to the top of the mountain on the northern side to the bridge across the Río San Juan have a thickness of about 4,500 feet. This series lies entirely above any of the massive basalts which are intercalated with or intruded into the subjacent strata between this place and the latitude of Cobre or the head of Santiago Bay.

A heavy bed of limestone occurring above the tufts and breccias forms the base of a series of a distinctly different nature, consisting of calcareous sandstones, marls, and limestones in rather thin beds. Fossils are not present in large numbers excepting in a few strata which are largely composed of foraminifera similar to the genus Orbitoides. Opposite the towns of Dos Caminos and San Luis the strata dip gently toward the north but somewhat more rapidly than the slope of the surface, so that in the central portion of the valley the limestone is buried beneath a considerable thickness of the sandstones and marls. In this
central portion of the wide Cauto Valley the strata are gently folded so that with the infrequent exposures it is impossible to follow the structure in detail. For this reason it is impossible to indicate in the geological section the exact position occupied by the beds of coal material occurring in the vicinity of Dos Caminos. It is suspected, however, from what is known of the coal-bearing strata in other parts of the Province that the carbonaceous beds are unconformable with the other strata of the region and occur in isolated basins. It is known that their deposition preceded the folding of the Eocene strata since the beds with which the coal is associated at Mayarí Arriba are very sharply upturned. The character and probable value of this coal are discussed in another portion of this report.

On the north side of the Cauto valley, in the foothills of the northern mountain range, massive limestones also occur. Here they dip southward away from the central core of serpentine. West of the Sierra Nipe they dip toward the west, and may be followed around the nucleus of crystalline rocks, upon the northern side of which their dips are toward the north. Fossil corals of Upper Oligocene age were obtained from these limestones at the point where the telegraph trail between San Luis and Mayarí crosses the Río Sojo.

Along the line of the trail which crosses the Sierra Nipe leading from San Luis to Mayarí, near the line of the section represented in Pl. XVIII, fig. 6, there is a belt of metamorphic and dense igneous rocks between the Oligocene limestone and the serpentine which forms the axis of the Sierra. This series is very poorly exposed but is probably older than the serpentine. Indications of a similar series were observed near the edge of the serpentine on the south side of the Sierra Cristal in the vicinity of Mayarí Arriba.

The main mass of the Sierra Nipe is composed of serpentine, which is shown by the microscope to have originated through the alteration of a rock originally composed largely of bronzite, fragments of which mineral are still frequently to be observed in the otherwise completely altered mass. Since this chemical alteration occurred the serpentine has been intruded by basic igneous rocks comprising gabbro and fine-grained, or dense diabase. These last named rocks occur in such abundance that it is impossible to find any very large area of the serpentine which is not cut at least by small dikes of the later rock, and frequently it is found in very large masses.

On the northern side of the Sierra Nipe the Oligocene limestone reaches an elevation of about 900 feet, dipping northward toward the sea. In the higher exposures the dips are between 10 and 15 degrees, but become less as the coast is approached.

GEOLOGIC HISTORY.

*General Remarks.*—The following account of the geologic history of Cuba is so very deficient that it scarcely deserves the name given in the heading, but it seems desirable that a sum-
mary of what is known upon this subject should be given. In this way the attention of geologists, who may in the future visit the Island, will be called to gaps in our present knowledge and can direct their efforts toward securing the data most needed. Some geologists who have visited Cuba have indulged in what may properly be called geologic speculation. They have drawn conclusions from entirely insufficient data and have given us a history essentially hypothetical, as it lacks the basis of the most essential facts. Some of these attempts at delineating the history will here be criticised in order to point out the weakness of the arguments used.

It should be stated in this place that it will be utterly impossible to know the geological history of Cuba until its paleontology has been thoroughly investigated. In a country in which formations of very different geologic ages are lithologically so similar as often to be indistinguishable, the only means for differentiating them is by their fossils. Sufficient paleontologic work has been done in Cuba to enable us to know much more of the history of the Island than we do, if the specimens collected had been accompanied by proper stratigraphic data. Therefore, any one who contemplates working in the Island is urged to collect as large a series of fossils as is possible, though they may be very poor, and at the same time to work out the stratigraphic relations of each fossiliferous horizon to associated strata, both fossiliferous and non-fossiliferous. We regret that during our stay in the Island we were unable to accomplish as much in these lines as we desired, but as our mission was chiefly to search for occurrences of various kinds of minerals of economic value, we were obliged to pass untouched many problems of stratigraphic geology and the geologic history.

A general description of the physiographic features of the Island has been given, but with the exception of occasional hints, no discussion of that most important phase of the geologic history, called geomorphology, will be undertaken. In the present imperfect state of our knowledge of the stratigraphy and areal geology of the Island, and because of the lack of accurate topographic maps, it would be hazardous in the extreme to attempt to state the times at which most of the various levels were developed, to designate the times during which they were dissected, to write the history of the development of the drainage, etc. This history is the climax of the general geologic history, and requires a detailed knowledge of nearly all phases of the geology before it can be deciphered.

Pre-Cretaceous.—The oldest rocks that we know in Cuba, possibly excepting the schistose limestones of Trinidad, consist of granites and serpentines. The relative age of these rocks to the central mass of limestones in the Province of Pinar del Río has not been determined, but we do know that these oldest igneous rocks were themselves folded, faulted and subjected to other processes of metamorphism, and that subsequent to the changes to which these rocks were subjected the region was uplifted and deeply eroded, before the Cretaceous sedimentation began. No
data are available for determining the geologic period at which the pre-Cretaceous erosion began, but the region had doubtless been standing above the waters of the ocean for a very long interval, since the amount of rock carried away has been manifestly very great. This opinion is justified by the fact that the surface upon which the Cretaceous sediments were deposited appears to have been reduced by erosion to a very low relief, so that the land was a featureless plain when the Cretaceous subsidence began. The time interval required for the accomplishment of this erosion must have been very long, since at the time it began the region is inferred to have been mountainous, because of the complex character and disturbed attitude of the pre-Cretaceous rocks. The granites, diorites and other granular rocks, which appeared at the surface because of this erosion, were originally formed deep within the crust of the earth, and they therefore furnish a reason for believing that this period of erosion was of exceedingly long duration.

Hill, in his "Geology and Physical Geography of Jamaica," (1) has suggested that during Jurassic time the southeastern coast of the United States was connected by a long narrow isthmus, following the line of the Antilles, with the northeastern coast of South America, and states that if the reported Jurassic of the western half of Cuba is correctly determined, the Jurassic land was east of the longitude of Havana. The data here presented indicate that that portion of Cuba including the Province of Santa Clara, and the two more easterly provinces, stood high above sea-level during this period of the earth's history, and lends support to Hill's hypothesis. The data concerning the western provinces are indefinite, but they too probably were high land masses. Hill makes the additional statement, which we heartily endorse: "From Florida to the northeast corner of South America we now have a chain of submerged banks, which constitute the rim of the Gulf and Caribbean basins, and which may or may not represent elements of this ancient Jura-Cretaceous Isthmus,—the same which has been frequently used as data for constructing a hypothetical and impossible Windward bridge during later epochs." (2)

Cretaceous.—The elevation and long period of erosion above described were followed by subsidence, and on the surface of these old rocks the Cretaceous formations were deposited. If these old rocks the Cretaceous formations were deposited. It is very significant that the lowest Cretaceous we were able to discover is composed of an arkose derived in large part from the original igneous mass. The main mass of the strata is composed of limestones, the beds of arkose being confined to the lower part of the formation. Such characteristic fossils as they contain belong to genera similar to those found in the Cretaceous of Jamaica, for example, Radiolites, Barrettia, Requienia, etc. As these genera in Jamaica evidently occur in shallow water or shore

deposits, we should be inclined to adopt the same conclusion for Cuba. During this time the whole of the Island of Cuba was probably submerged beneath the level of the sea. The basis for this conclusion is: The Cretaceous rocks in the Province of Santa Clara, as has been stated previously, occur in the bottoms of synclines and the projected dips appear sufficient to carry the beds over the tops of the dividing anticlinal axes. It is believed, however, that the depth of the Cretaceous sea over the Island probably was never very great.

Eocene.—Because of the lack of accurate paleontologic data the history of the Island during Eocene time is vague, but it is very probable that a large portion of it was submerged during this time. This is certainly true in the Province of Santiago, where Eocene fossils have been collected. During, and possibly previous to, this period volcanic agencies were active in this province, as there are volcanic rocks interbedded with sediments probably of Eocene age. The same forces may have been active in other portions of the Island. The intrusion of diorite porphyries in Santa Clara and other provinces may have taken place then.

Oligocene.—A portion of the Island at least, namely, in the vicinity of Baracoa, was deeply submerged probably during Lower Oligocene time, as is proven by the occurrence of Radiolarian earth beneath the upper Oligocene limestones in the vicinity of Baracoa. Radiolarian oozes are at present being formed on the sea bottom at depths between 2,250 and 4,475 fathoms, average 2,894 fathoms. (1) We can not affirm that these deposits were laid down at so great a depth as these dredgings indicate, but we can feel confident that they were laid down in truly deep water. This does not imply that the whole Island was sunken to abysmal depths.

During Upper Oligocene time very nearly the whole Island was submerged. Previous to this time volcanic agencies had been active throughout a large portion of the Island, as has been noted above. The mountain building in the Province of Santiago had begun before the deposition of Upper Oligocene strata and the Sierra Maestra had already been elevated to a considerable height above the sea level. The Upper Oligocene sea covered the whole of the Island, excepting portions of Santiago Province near its north and south coasts, and occasional high peaks along the axial portion of the provinces to the west. The Province of Santiago was washed on both the north and south sides by the Upper Oligocene sea, and a long arm was sent up the Caño valley and may have connected with the sea at the eastern end. Thus the province was probably divided into two island masses.

Miocene.—Miocene time was one of general uplift, the whole of the Island as we at present know it being elevated above the level of the Ocean's waters. There was folding and uplift during this period, the elevation along the axial line being greater

than at the sides. It is most probable that the folding of the Oligocene strata as seen in the vicinity of Havana, Matanzas, etc., took place during this time. One would infer that the central portion of the Province of Santiago was more highly elevated than the coastal portion, since Upper Oligocene limestones occur in the central portion of that province at considerable higher elevations than along either the north or the south coast. It is furthermore very probable that the terracing of the Oligocene coral reefs, such as are seen in the vicinity of the City of Santiago, was taking place during this time. It should be remarked here that all of the evidence obtained by us goes to show that these are wave-cut terraces. It should be added here that all of the evidence obtained by us goes to shown that these are wave-cut terraces. It should be added here that all of the elevated Pleistocene coral reefs as seen by us and all of those recorded by those whom we consider competent observers, are plastered on the surface of the Upper Oligocene formations, or in some instances upon older geologic formations. This remark will apply to every later coral terrace that has been described, commencing with Cabañas and extending entirely around the Island to the City of Santiago.

Pliocene and Pleistocene.—The existence of marine Pliocene in Cuba has not been proven. It has been intimated in preceding pages that there may be Pliocene in the city of Havana extending some 60 feet above sea level. If this is Pliocene, it would indicate a subsidence during Pliocene time of some 150 to 180 feet. The character of the fauna found by Mr. Palmer in the quarry on Calle Infanta does not indicate a greater depth than 50 to 70 feet for the water in which the limestone was deposited. Subsequent to this deposition there was an elevation which has caused the land to stand some 40 or 50 feet higher than it does at present. This probably took place in early Pleistocene time, and it was probable that at this time the Isle of Pines and Cuba were connected. The former connection with the Isle of Pines and Cuba will be discussed under the geology and geologic history of the latter island. The reason for the belief in this elevation is the existence of an old channel which has been excavated in the central portion of the present channel leading from Havana harbor. There is further evidence of a general elevation obtained from the borings for water some three miles southeast of the city of Santiago. (1) At a depth extending some 70 feet below sea level in the Río San Juan valley apparently stream-carried pebbles were found. This would indicate that the bottom of this valley stood at that time at least 70 or more feet above sea level. Subsequent to this elevation there was a depression amounting to from 40 to 70 feet. There were doubtless other slight oscillations during Pleistocene time, and these may be going on at the present time, though we have no evidence from records of accurately measured monuments established since the Spanish occupation of the Island.

(1) Mr. C. A. Knowlton, engineer in charge of the work, has kindly furnished records of the borings.
Several geologists, including De Castro, Salterain, Rodríguez-Ferrer and J. W. Spencer, have contended that, during Pleistocene time, there was sufficient elevation of this region to secure land connection between Cuba and the continent of North America. The evidence, both paleontologic, biologic and physiographic, on which this conclusion is based has been carefully examined and the opposite conclusion reached, namely, that the possibility of there having been land connection between Cuba and North America at any time since the beginning of the Tertiary is confined to the Oligocene period, and it seems probable that there was no connection during any portion of Cretaceous time.

Résumé.—The geologic history of Cuba, as above briefly outlined, is still further condensed and represented in tabular form below. Since the events are presented in chronologic order, the oldest rocks are placed at the top of the column and the youngest at the bottom.

Table giving a summary of the rock formations and principal events in the geologic history of Cuba.

<table>
<thead>
<tr>
<th>Time</th>
<th>Rocks</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleozoic</td>
<td>{ Serpentine and Granite</td>
<td>Intrusion of igneous rocks into sediments now mostly eroded away.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High uplift and erosion. Land probably connected Florida and northeastern South America.</td>
</tr>
<tr>
<td>Jurassic</td>
<td></td>
<td>Subsidence, probably of the whole Island. Some volcanoes may have been active.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsidence. Active volcanoes, causing interbedding of volcancanic and sedimentary rock. Probably intrusions also.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>{ Hard, grayish limestone,</td>
<td>Deep subsidence of at least portions of the Island.</td>
</tr>
<tr>
<td></td>
<td>underlain by arkose</td>
<td>Submergence of the whole Island excepting occasional peaks and lines of hill along the northern and southern portions of Santiago Province.</td>
</tr>
<tr>
<td>Eocene</td>
<td>{ Limestone,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>glauconitic sands, etc.</td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td>{ Radiolarian</td>
<td></td>
</tr>
<tr>
<td>(a) Lower</td>
<td>earths</td>
<td></td>
</tr>
<tr>
<td>(b) Upper</td>
<td>Limestones, calcareous marls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>some conglomerate</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Rocks</td>
<td>Events</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------------</td>
<td>---------------------------------------------</td>
</tr>
</tbody>
</table>
| Miocene   | ....—Absent.                 | { Elevation, terracing, and folding. Probably some volcanic activity. }
| Pliocene? | { White limestone... }       | { Doubtfully a subsidence of about 200 feet. }
|           | { Elevated coral reefs containing recent species. } | { Subsidence of 80 to 100 feet; then about equal elevation; subsequent subsidence of 40 to 70 feet. }
| Pleistocene |                             | { There may have been minor oscillations. }  |
ECONOMIC GEOLOGY.

METALLIFEROUS MINERALS.

General Considerations.—The noted Cuban geologist, Fernández de Castro, has said that within the Island "The serpentine is the metalliferous terrane par excellence. It contains not only large deposits of copper but also ores of iron and chromium, and also native gold."

This statement was based upon a knowledge of many mineral occurrences in the serpentine and associated igneous rocks, and is certainly true, in that, wherever the serpentine occurs in large areas it is found to afford strong veins of quartz which are usually accompanied to a greater or less extent by metallic minerals. However, the most important producing mines of the Island, both of copper and iron, are found in much younger rocks. The famous but long abandoned copper mines at Cobre, near Santiago de Cuba, are situated in an area of upturned volcanic breccias or tuffs with some intrusions of porphyry; the copper mines at Manicaragua, which were next to the Cobre mines in importance, are in porphyries and granular diorites. However, in Pinar del Rio, Havana, Matanzas, and Puerto Príncipe and Santiago Provinces there have been producing mines located in serpentine as the country rock. The gold mines of the vicinity of Holguin are also in a serpentine region, and it may be said that in its occurrence at intervals throughout the length of the Island, the serpentine offers a good field for prospecting. This probably applies equally well to the comparatively unknown region in Santiago Province, between Nipe Bay and Baracoa, as to the western provinces in which mines have been worked in the past.

The iron ores of the Sierra Maestra are included in the younger volcanic series, though it may be true that their origin is to be connected with geological phenomena of very much earlier date than the intrusions with which they are now associated, as explained elsewhere in this report. There are, however, important occurrences of magnetite in the serpentine, especially in Puerto Príncipe Province, but they have not been made the subject of study. Of similar association are the deposits of chromite or chrome-bearing magnetite which occur in the same region, where they were noted at several points in the course of a very superficial study of the region. Gold certainly occurs in the ser-
pentine area near Holguin and is commonly reported from the region east of Nipe Bay and south of Sagua de Tánamo, but no authentic information is available concerning the importance of the alleged occurrences.

In Cuba manganese ores are of two distinct varieties. In one the metal occurs intimately mixed with magnetite in the serpentine and associated igneous rocks, or in the porphyries which enclose the iron ores of the Sierra Maestra. These are probably original ores. In the other variety the manganese is of secondary origin, and the ores replace calcareous sedimentary rocks. Only the latter ores have thus far been mined.

Occurrences of silver, lead and mercury have been reported in several of the general résumés of the resources of Cuba, but these reports give absolutely no information concerning the supposed deposits beyond the fact of their existence. Denunciations of silver and lead mines are known to have been made in Santiago and Santa Clara Provinces. We were told in the office of the Government Engineer of Mines in Santiago that it was considered very doubtful if any of the discoveries thus far announced would ever prove to be of value. None of those examined during this reconnaissance promise to be of any value.

GOLD.

Historical.—An historical résumé upon the subject of gold in the Island of Cuba is given by La Sagra in his physical history of Cuba, to which we are indebted for the following notes:

It is probable that the exploitation of gold by the Spanish discoverers of the Antilles was limited to the simple washing of sands in which this metal was found. Nevertheless, they were not long in finding profitable mines of gold, the existence of which was divulged by the Indians. Upon the 26th of October, 1510, the Governor of Porto Rico sent to Ferdinand V, king of Spain, gold to the value of 2,645 pesos, and there are notes of other shipments from this Island. Already, at this same epoch, gold had been found in Santo Domingo, and probably also in Cuba, although the actual date of the first shipment from this last island is not known. In a note concerning gold sent from Santo Domingo to Spain in 1512, the statement is made that the shipment comprised a certain amount of gold which had come from Cuba, and in 1514 a letter from Diego Velásquez mentions that he had examined the localities from which gold had been extracted in the Province of Guanabaya, and that he had also obtained gold that had been gathered by the Indians from certain rivers, particularly in the neighborhood of the port of Jaua. These discoveries brought about the demand for the implements necessary for gathering the gold in large quantities, and even at this time the introduction of negroes for the work of mining had already begun. Between the years of 1515 and 1534, according to the records in existence, many consignments of gold were shipped from Cuba to the mother country, the aggregate value amounting to about 260,000 pesos. According to royal regula-
FIG. 2.—Cross-section of auriferous vein, near Guaracabulla, Province of Santa Clara (after de Castro). For explanation of figures see text.
tions one-tenth of the gold extracted by negroes or Spanish, and one-fifth of that collected by the Indians, was due to the throne, but in 1521 the tax upon the natives was cut down to one-tenth of the product, because of their reduced condition, due to a large number of deaths from an epidemic in the preceding year.

Another account of the early exploitation of gold is found in the work of Rodríguez-Ferrer upon the natural history of Cuba, page 549. This author says that the Island of Cuba from the time of its first discovery up to the time of its conquest and colonization became famous not only because of the richness of its gold-bearing sands, but also because of the superior quality of the gold. Some of the older writers upon the Antilles are authority for the statement that Cuba and Santo Domingo alone possessed mines of gold, but the historian Herrera states that gold also occurred in Jamaica and Porto Rico. Herrera also reports that Columbus made note of gold occurring in its matrix at the time of his visit to Santa Catalina in October, 1492. According to the accounts of the Spaniards or natives, the region which they called Cubacán, comprising the region drained by the river Arimao, abounded in sands carrying the precious metal. In the writings of the early historian, Oviedo, an account may be found of ornaments and images inlaid with gold possessed by the Indians. In 1534 the Governor of the Island reported to the empress, during the reign of the Emperor Charles V, that he had visited gold mines in the province of Puerto Príncipe, which had been of considerable value in times past. Diego Velásquez reported that there were eight places in Cuba where gold occurred in large quantities, and that in six of these the inhabitants had no other employment than to collect the precious metal.

In 1868 Manuel Fernández de Castro made a very complete report on the gold mines of Cuba, especially those in Santa Clara province, in the vicinity of Guaracabulla. Describing the mine San Blás, he says the gold occurs sometimes in particles visible with the lens, but in others disseminated in certain veins of serpentine possessing characters difficult to define. There are also dark greenish siliceous veins which probably represent silicification of the serpentine, and are more or less auriferous. At the time the examination was made (about 1860) there were no less than six large shafts or pits which served to exhibit very well the regularity in direction and thickness of the veins. The material thrown out from one of these alone is said to have amounted to between 5,000 and 6,000 cubic varas. The direction of the veins is approximately east and west with variations of not more than ten degrees either way. A drawing illustrating the character of one of the veins is given herewith, accompanied by the notes regarding it made by Señor de Castro.

(1) "No. 1 is a friable chloritic and magnesian rock, impregnated with iron oxide, easily divided into blocks or irregular nodules. As exposed, particles of free gold are quite noticeable.

(1) Translation.
to the unassisted eye. The width of this is about 0.15 metre. Number 2, in contact with the last upon the north side, is of a lighter color, also friable, having the appearance of sand composed of quartz. This contains some gold but it is not perceptible with a lens. Its thickness is .40 metre. The bands marked 3 and 4 are somewhat like number 1, but are sufficiently similar to the country rock marked 5, to indicate that they are merely an altered form of the same. The width of band 4, together does not exceed .25 metre. They contain scarcely any gold. The country rock gives no gold in assay.

"The band marked 6, which has the same appearance as No. 5, has given appreciable quantities of gold in the western part of the mines and in the eastern part contains a larger proportion than No. 1. These two bands are said to merge." The width of bands Nos. 6 and 7 are not given. No. 7 should probably be represented as country rock.

Within a space of 20,000 square varas this observer noted many indications of gold-bearing veins, each having an east and west direction, and appearing in workable width at no less than six distinct points, making it impossible to doubt the existence of veins of considerable extension and regularity, entirely worthy of further exploration with a reasonable hope that its richness would correspond to the surface indications. A large number of samples were collected for assay, representing various portions of the vein, and these gave results varying from nothing up to 7,050 pesos per ton of 2,000 pounds, the average value being $86 per ton.

In 1885 the mines in the vicinity of Holguin were visited by Mr. Ramsden, the former British Consul at Santiago, in company with Mr. Lloyd Owen, an English mining engineer. In his report Mr. Ramsden says that they were much pleased with the appearance of these mines, and judging from the nature of the closing formations and from the quantity of gold found, they are well worthy of development. Soundings were made of the old shafts, and some of the workings were determined to have reached a depth of about 20 metres, which figure does not, however, represent the total depth of the workings, since much debris had doubtless fallen into the shafts. The best information obtainable concerning the value of the ore indicates that it was worth about $17.50 per ton. There are other records, however, to indicate that much of the ore formerly extracted yielded not more than $12.00 per ton.

These mines in the vicinity of Holguin were the subject of a report made in 1885 upon the condition of mining in the Island of Cuba by the Insular Mine Inspector, Lopez de Quintana. He states that there are two localities near Holguin which had been exploited for gold. One of these, about two leagues from the city, showed a vein made up of ochreous clay carrying loose grains of quartz, traversing in a nearly vertical attitude the country rock of serpentine. (1) The vein had been opened at five points and

(1) This is supposed to be the mine near the railroad Aguas Claras, which was visited during this reconnaissance.
was found to have a course about N. 80° E. (magnetic) with a dip of about 80° toward the south.

In these openings the width of the vein was found to be about six inches and to have many ramifications. Developments were not sufficient to prove whether the vein was continuous or a true fissure. Wherever it was opened gold was encountered. Assays of the indurated clay made upon a large scale gave an average result of over six ounces of gold per ton of 2,000 lbs., and tests upon samples sent to London gave a maximum of 32 ounces, and a minimum of 4 ounces per ton of 2,100 lbs.

At the time of this examination the company had two crushers and six mills for pulverizing the ore. In describing the second gold mine mentioned by Quintana, Cia (1) says that on the north side of a hill called Monteverde, in the vicinity of Holguin, about one thousand metres from the base of the hill, is the gold mine Caridad. Its casing is a green rock having the appearance of diorite. In this rock there are ramifications of barite, calc spar and quartz accompanied by gold in grains often perceptible to the naked eye. The ore contains, besides gold, four ounces of silver per ton and is somewhat arsenical. "It is a promising mine and should be explored thoroughly by means of deep shafts."

The account of La Sagra of the early output of gold from the Island is undoubtedly authentic, being founded upon official documents, but of course the amounts of the metal were not large and represented the aggregated product of a large number of mines. It is still an open question in the mind of the writer, whether or not profitable placer deposits may not yet be worked in Cuba after the ground shall have been carefully examined by practical prospectors. It is also possible that valuable veins exist, but evidence is wanting for an unqualified statement that either placers or quartz mines will prove to be of economic importance in the Island.

The recorded observations of de Castro upon geological subjects have been found in the main reliable, and his report upon the gold deposits seems to have been based upon a very thorough study of the regions described, so that it is considered that his qualified favorable opinion of the gold mines of Holguin and of Guaracabulla are to be given considerable weight, as also are the reports of Cia and Quintana.

The gold prospects about Holguin were visited during the reconnaissance (Spencer) and here the general facts were found to be as stated in the quotations given above.

Specimens of placer gold in grains up to a size of a kernel of wheat were obtained from a small arroyo draining the low hill in which the old mines are located at Aguas Claras, near the line of the Nuevitas railroad, about six miles from Puerto Príncipe. The presence of quartz was also noted in the mouths of the shafts, though not in the form of well marked veins. Samples of the quartz containing iron pyrites were assayed and showed only a trace of gold, but a similar sample from a strong vein of

(1) Policarpo Cia: Observaciones geológicas de una gran parte de la Isla de Cuba.
quartz in the neighboring mine at La Guayabal gave one-tenth of an ounce of gold per ton.

A supposed gold mine, known as Mina Descanso, some 23 miles southeast of Santa Clara in the direction of Guaracabulla, was also examined (Vaughan). Two shafts have been sunk on the side of a hill of serpentine and some additional excavations have been made. The serpentine is much fractured and broken, but there was no vein visible at the surface and no evidence of mineralization was seen. One tunnel is driven into the serpentine along the line of a gabbro dike whose strike is north 65° west, standing in a practically perpendicular attitude. No ore was seen on the surface. The information was obtained that ore had been taken from the shafts and shipped to the United States. A small hoisting engine was in place at the time of the inspection, but the workings were entirely inaccessible. Since it was impossible to make an examination of the interior of the shaft or to procure authentic specimens of ore, no opinion can be expressed as to the value of this prospect.

Gold is reported to occur in the vicinity of Mantua in the Province of Pinar del Rio, but no reliable information regarding this region is available.

COPPER.

History.—Copper is said by La Sagra, in his Physical History of Cuba, to have been found by the Spanish conquerors of the greater Antilles, and to have been exploited since the time of the first discoveries. This author made a careful examination of documents in the archives of the Spanish Government, from which he compiled a very complete history of copper mining up to about 1840. The main facts given in what follows have been taken from this work (1), in which the author acknowledges his identedness to an unpublished manuscript by Francisco Ramirez, bearing the date 1802.

In the Antilles the first copper seems to have been mined in Santo Domingo in the first part of the 16th century, and in the year 1505 Ferdinand V sent to the Governor of that island a ship loaded with the necessary instruments for the exploitation of mines, together with seventeen negro slaves.

It was not until about 1530 that the working of the mines in the vicinity of Santiago was agitated, and authority for operating was secured in 1532. The first private owner of copper mines, of which mention has been made, was one Hernando Nuñez, to whom Philip III granted a concession in 1599, and who continued their exploitation with profit until the year 1620, at which time their value was reported by the royal inspector of mines at 33,315 ducats, a figure which covered 150 slaves belonging to the company. During this year the mines were purchased by Juan Eguiluz, who agreed to pay into the royal treasury 2,000 quintals of copper at the value of nine ducats each, for which he

was to have possession of the mines until his death, which took place in the year 1638. At this time he was debtor some 30,000 ducats to Philip IV, and the mines remained inactive until 1648, when the son-in-law of Eguiluz, Francisco Salazar y Acuña, agreed to pay the accumulated debt. He commenced the payment, but, in spite of this, the mines were shut down in 1668 because of the inability of Salazar to complete his obligations.

Work was suspended from this time until 1701, when an emissary was sent to report upon the condition of the property. The account of this officer was very favorable, but no measure was taken for operating either the Cobre mines, or others upon which a report had been made, until 1779, when the heirs of Salazar addressed a petition for permission to open the mines to Charles III, and in 1782 obtained the necessary permission, of which, however, they did not avail themselves. In 1802, when the report of Rumírez was made, the mines were still idle. About this time an English and Spanish Company took up their exploitation, extracting mineral upon a small scale and exporting it to England. The affairs of this company seemed to have made good progress and many franchises were granted them, among others the permission to export the ore and introduce the necessary appliances for ten years free of taxes.

The following are the names of the principal denouncements existing at the time of the report: Charco Hondo, Blanca la Fuente, Lechuzas, Lindran, Madeleena, Aranzibra, Arroyo de las Minas.

It is noted that the latter mine alone had yielded unoxidized ores, and from its name, which is still applied to the stream which passes near the principal mines at Cobre, it is probable that this mine is to be identified with some of those which afterward became of the most importance. Of these mines the one named Lechuzas particularly attracted the attention of Ramirez because of its great richness and because it had been very extensively worked. North of the village of Cobre he describes a hill of about 40 varas in length traversed by a gallery 13 varas high, having a width of about 5 varas. The ore was red oxide and native copper with some blue and green carbonates. Near the excavations of this mine another extensive gallery had been opened from which the same material had been extracted and this was the only opening which had remained intact through the great earthquake of July 11, 1776. All the others had been filled in by débris which had been shaken loose at that time. Nevertheless, after this disaster the women had collected the mineral from the ruins and after roasting it and treating it with water, ground it up between two stones. It was then taken by the men and the metal extracted in a small furnace, the product being afterward remelted and cast in ingots weighing about 25 pounds. The mines were reported as occupying a large area and as being extremely rich. In the soil of the cemetery near the church masses of homogeneous copper were found at a very slight depth, weighing several arrobas (25 pounds).

In the vicinity of Holguín evidence of copper was frequently noted at the surface.
In the province of Puerto Principe an occurrence of copper was reported between two and three miles distant from the coast at Catalina, and another about 40 miles from that town. These two mines had not been exploited to any great extent, but the curé of Catalina had taken from the second a sufficient quantity of the mineral for casting a bell.

La Sagra himself seems to have made a careful examination of certain of the copper prospects of Cobre, and speaks of having interested several American capitalists in the copper deposits in the vicinity of Holguin about the year 1835. He reports the formation, in 1836, of an American company for the exploitation of the copper mines situated in the province of Santa Clara, in the region known as Hoyo de Manicaragua. It is said that in less than one year this company realized profits to the amount of 150,000 pesos. The principal mine of this company was known as San Fernando.

Until 1830 the history of copper mining in Cuba seems to have been that of the Santiago region alone, but about this time the richness of these mines came into such prominence that other regions were searched, with the result that valuable deposits were found at several localities in Santa Clara, Matauzas and Pinar del Rio provinces, as well as in the western portion of Santiago province. The development of the various regions, so far as we have data concerning them, will be given under the more special discussions.

About the year 1828 the Cobre mines seem to have been taken up again and worked in a systematic way, and from this time to 1868 they furnished each year a large amount of ore. It is said that no mineral was shipped which contained less than 18 per cent of metallic copper.

In 1830 an English company, under the name of "Consolidated Mines," obtained mining concessions at Cobre and immediately began extensive operations. This company throughout the period of activity was the principal operator of the mines, but within a few years after its organization several other companies were formed, among which were the "Compañía de Santiago" and the "Sociedad de San José." The properties of these mining companies were located very near those of the Consolidated Company. As late as 1850 a small company called "Económica" established workings adjacent to the older properties.

From the government records and from the papers of the British consular office it is known that all of these companies made good profits up to about 1868, in spite of the difficulties of transporting the ores from Cobre to Santiago Bay. All of the ore, as well as the supplies for the mines, was carried upon the backs of mules and camels, the latter having been imported from Africa especially for service at the mines.

In 1843 a railroad was completed by a Spanish company organized in Havana and the mines were thus connected with the western side of Santiago Bay. Previous to the construction of this railroad, arrangements had been made with the Consoli-
Fig. 3. Sketch map of Santiago and vicinity to show location of mines.
dated Company by which the latter agreed to pay $6.50 (Spanish gold) for every ton of ore hauled to tide water, and $4.00 for each ton of coal, lumber and supplies hauled to the mines. An ironsbound contract was entered into on the part of the mining company to pay these rates under all circumstances, and the railroad company, on their part, agreed that they should never be increased. At the time this arrangement, which was later agreed to by the other mining companies, seemed very advantageous for the producers, and it was not until about 1865 that the reduced value of copper made it impossible to stand the heavy tariff.

About this time an attempt was made to readjust the transportation rates, but the railroad company refused to arbitrate, with the result that charges to the amount of several thousand dollars remained unpaid at the close of the year 1868. These economic complications might have been eventually adjusted had it not been for the outbreak of an insurrection against the Spanish Government in 1858, which resulted in the suspension of all work in the copper mines.

The affairs of "The Consolidated Company" became the subject of litigation, and the railroad company was awarded a considerable sum by the Supreme Court, and since they had no assets they were obliged to mortgage all their property, and later all the holdings of "The Consolidated Company" were transferred to the railroad company in the liquidation of the debt. The mines have remained idle, however, up to the present time. In 1882 an attempt was made by some of the shareholders of the railroad company to reopen the mines. A title to all the properties of "The Consolidated Company" was obtained, a loan of $60,000 was negotiated, and in the latter part of 1883 the work of reconstructing the railroad was begun. This method of taking up the work proved to be ill advised, since the entire sum was expended without completing the railway and without developing the mines at all. On this account the attempt to reopen these valuable properties was a failure, and they remained unproductive, excepting for a small amount of copper recovered from the waters flowing from the mine, until they were taken up after the close of the Spanish-American War by Americans who have acquired the titles of the old companies and who are at present actively engaged in explorations tending to show the advisability of attempting again to operate the mines.

The preliminary operations which have been in progress since the year 1900 have resulted in finding a considerable amount of high grade ore in the portions of the mines above water level, and a considerable amount of copper has been precipitated from water pumped from the old shafts. The companies now controlling the properties find many reasons for supposing that they will be able to put the mines upon a paying basis within a few months.

Cobre Mines.—The copper mines in the vicinity of the village of Cobre are found in a zone of disturbed stratified rocks occurring near the base of the sedimentary series and composed of
fragmental volcanic material, interbedded with flows of lava and also cut by dikes of intrusive rock. These formations have an easterly and westerly trend, and dip away from that portion of the Sierra Maestra which is known as the Sierra Cobre, to the north of which the village of El Cobre is located. The mineral-bearing zone has a width of several hundred feet and a length of between four and five thousand feet. Within an area having these dimensions and in general parallel with its length, there are several strong veins of white quartz, each of which lies within a fairly well defined band of decomposed and mineralized country rock. Between these bleached and mineralized bands the rock shows but little alteration. The general course of the veins is north-northeast and south-southwest with local irregularities in direction and with occasional spurs. The accompanying sketch is taken from notes made between the San José and Hardy shafts and is intended to show the way in which the veins branch.

In their surface exposures the veins exhibit a honeycombed appearance, which is doubtless due to the partial removal of minerals which formerly filled the present cavities of the spongy quartz. At various localities the veins are found to contain large amounts of iron oxide which has had its origin in the oxidation of chalcopyrite ores. These oxides are particularly noticeable in the vicinity of the old shafts and at several places they were observed to pass downward into rich oxide and secondary sulphide ores, which, in turn, doubtless grade downward into the unoxidized pyritic ores. At the time the mines were visited the old surface workings, which had apparently been abandoned since the earliest history of the mines, were being reopened and a good quantity of very rich ore was being found. This tends to show that the abandonment of the mines could not have been due to the fact that the ores were considered to have been exhausted.

From observations made of the exposed portions of the veins at Cobre and from the fragments of ore found on the dumps and in the tailings from the old concentrating works, the conclusion was reached that the ores which were depended upon were pyritic, and while they may have occurred in large masses without admixture of quartz or other material, a large proportion of the material taken from the mine was made up of chalcopyrite occurring throughout quartz masses, and while there is authority for the supposition that no ore carrying less than 18% of copper was shipped from the mines, a good deal of the ore must have been brought to this degree of concentration by means of jigs. The concentration of the ore was originally taken up by an independent company working the waste material from the mines upon a royalty, but later concentrating plants were erected both by the Consolidated Company and by the San José Company, as is attested by heaps of tailings at several points.

The Cobre mines were visited by Professor Ansted, a noted English mining geologist, and a scientific discussion of the occurrence of the ores was published in 1856 in the Journal of the Geo-
Fig. 4. Map of mineral fields of El Cobre (after Ansted).
logical Society of London. (1) This article was based upon extended observations made while the mines were in operation, and therefore contains much information which could not be obtained during our visit. Portions of this report are therefore inserted as more valuable than any description. So far as our own observations go they indicate the entire accuracy of Ansted’s descriptions of the phenomena at Cobre and confirm his conclusions.

"Dimensions of the Lode.—The Cobre lode, as at present known, is limited in its crop to a distance of about a mile, but it probably ranges further to the east. Near the eastern extremity a branch is given off, making an angle of about 30°, and proceeding south-west. At the bifurcation, which is well seen on the steep banks of the Cobre River, both lode and branch are nearly vertical, and the latter is large; but as it proceeds it becomes irregular, and is broken up and intersected by numerous threads and strings. The main lode is cut off to the west by a cross course, after being heaved by several slides of small amount.

"Although the extent of the lode, as known by the crop, extends to 1,800 yards or thereabouts, it is but a small part of this that can be regarded as valuable. The whole workings on the principal vein are limited to a linear extension of 800 yards, and the extreme breadth of the ground, including all the parallel rich branches, is less than 200 yards; so that within a narrow space of about thirty acres are crowded the whole of the ‘plant’ and buildings of two extensive mines, and part of a third, with dressing-floors and ore-heaps on a scale rarely seen (2) as it seldom happens that so much ore has been raised from a single group of lodes of such small extent.

The diagram, fig. 3, marks the limits of the concessions, and thus shows the small extent of surface; but it gives no idea of the crowding that has necessarily resulted from the form of the ground, which is extremely broken, and in many parts precipitous. The section, fig. 4, will, however, assist in giving an idea of these peculiarities.

"Contents of the Lode.—The rich part of the lode is for the most part contained in the precipitous hill on which the old and ruined church stands, and the ground here, at one time the source of litigation amongst three companies, is now entirely undermined. The enclosing ‘country’ of which the shell of this hill is composed—the contents consisting almost entirely of veinstone, formerly largely mixed with red ore (of which nearly a million tons have been removed)—is a confused mass of material scarcely distinguishable from a coarse breccia of the adjacent porphyries, with the exception of some more schistose portions, and of grits met with in descending. This material, identical with that which formed the hill now fissured has no doubt fallen into the cavity

(2) Ansted states that at the time of his visit there were not less than 5,000 tons of dressed ore ready for shipment belonging to the Cobre mine alone.
or rent formed by some subterranean elevatory force. The whole group of lodes may be described as a multitude of yawning cavities, connected with innumerable smaller crevices, having, for the most part, an east and west extension, but crossed by other crevices of the nature of small faults or heaves, all more or less nearly at right angles, and terminated towards the west by one such cross-course, beyond which no ore has yet been found.

"Towards the east, the crevices or veins become gradually of less importance, and pass into a vein containing but little valuable ore, though clearly traceable for some distance at the surface.

"The whole outcrop of the great lode on this hill has been so much disturbed, and there remains so little of the original gossan to examine, that the real characteristics of the gossan and crop can only be made out by close investigation. It would seem, however, beyond a doubt, that the appearances must originally have been very remarkable, consisting of an enormous breadth of ferruginous earthy mineral, much of it of a bright vermilion color, very soft and easily removed, and containing at various depths, down to sixteen or seventeen fathoms, so large a percentage of black oxide of copper in a powdery state that this mineral alone, for a long time, was obtained by simple digging, and sold at a low price to the original proprietors of the Cobre mine. With the black oxide, there was, however, a considerable quantity of red oxide, and of blue and green carbonates, crystals of great beauty having been frequently obtained; whilst, in any hollow space that might exist, or be left after superficial workings, large stalactitic masses of sulphate of copper accumulated. As a specimen lode, however, the Cobre has long ceased to exist, though singularly large and perfect crystals of iron pyrites are still not unfrequently met with, and sulphates might be found in abundance in neglected workings.

"The whole of the ground to the depth above stated (sixteen fathoms) appears to have been largely impregnated with copper; but down to that level, sulphurets of the ordinary kind were either not found or were partly decomposed. This at least appear to be the recollection of those who saw the mine in its early stages, and it is well known that the yield of the ore was then very high, and the supply chiefly oxide.

"Below sixteen fathoms, however, the gossan appears to have terminated, passing down at once into valuable and solid sulphurets, occupying a large breadth of some part or other of the wide space of orey ground which was still traceable and which ranged between what were called the north and south lodes. A section across this part of the lode shows it to consist of three courses of ore, the northernmost of large size, though variable in width, underlying to the south, and especially rich at moderate depth; the middle less regular and less valuable, and diminishing as it goes down, though generally traceable; and the southernmost, smaller and less regular than the northern, but still a steady course of ore, rather improving in depth, and nearly vertical. Between these, not only is the ground generally
mineralized, but pockets and bunches of rich ore have been so often met with, that every part of the space is worth exploring, while many bunches of ore have been found outside the walls both of the north and south courses of ore.

"Heaves and Cross Courses."—The north course of ore has been effected by several small heaves, some of which have not reached the south course. The north course also, about the middle of the rich ground, has apparently possessed the largest and richest branch of ore yet found. All the heaves and cross courses dip west, ranging a little east of north and west of south; and the great north course of ore dipping south, while the south course is vertical, there would thus appear to be a tendency in the gray parts of the lode to unite at a certain depth. Everything seems to show that the various deposits occupy the gaping mouths of a fissure which is of moderate dimensions below, although expanding, and containing much rich ore near the surface.

"Breadth of Orey Ground."—The magnitude of the deposits of ore is often so large, that a breadth of ground amounting to from twenty to forty feet required to be removed, leaving only very small and insufficient arches.

"Timbering on the grandest scale has therefore been resorted to, to prevent accidents; and it is not unusual to see pairs of spars, consisting of trees hewn square and having a section eighteen inches square lashed together, placed to meet at an obtuse angle midway, and strengthened with diagonal bracings, forming a solid construction, like the vaulted roof of a cathedral. Those only who are conversant with the difficulty of introducing such spars into the small shafts of a mine, and handling them underground so as effectually to serve for the purpose intended, and preserve the mine for years without danger or accident, can do justice to the science and engineering that have been brought to bear on this part of the mining operations of the Cobre Company, and it is only a just tribute to the skill and activity of the successive managers (all, I believe, of Cornish experience) to allude to so important a part of the economy of these remarkable mines.

"Mundic."—Within the various parts of the lode are found at intervals, and at all depths, large quantities of mundic or iron pyrites, often highly crystalline. Much of this occurs between the north and south deposits of ore, and, in addition to the masses, and detached crystals, the copper pyrites are not uncommonly so completely coated with this worthless mineral as to render it impossible to estimate their value by the eye. This is the case more in the upper than in the lower levels.

"Veinstone."—The Cobre mine is open at present at the 160fathom level below adit; and, although a fair proportion of reserves exists in the lower levels, it will be readily understood by those accustomed to mining in rich veins, that only a few arches of ground have been allowed to remain in the upper part of the mine. The communications between the different courses of ore at the different depths, and the cross cuts of the lode to north and south, at various points, as well as the appearance of the
lode, where now being removed, are all extremely interesting and instructive. The enclosing country, and the ground between the courses of ore, appear to become more compact and regular in descending, and are occasionally very hard. At the 140-fathom level the lode becomes gypseous, considerable quantities of white alabaster appearing without sensibly affecting the value of the ore; but the veinstone a little below becomes very hard, and in some parts of the lode the ore ceases altogether in the vicinity of the gypsum.

"At the lower levels, the heaves and cross courses appear to have rather more influence than near the surface, at least with regard to the quantity of ore.

"Temperature.—The temperature of the lode in the upper levels is about 90° Fahr., both in the levels themselves, and wherever I could place a thermometer in the rock. At ninety fathoms I noted in one place a temperature of 96°, and in a small neglected working on the south course of ore an exceptional temperature of 101°. At this point, which was not without ventilation, being close to a shaft, the heat was very sensible, but the air did not appear to be tainted with any disagreeable odor. I noticed, however, much iron pyrites thereabouts. Lower down, the air becomes much cooler, and in the 130-fathom level I observed the thermometer to stand at 86° in a small sump near a slide, and at 88° in a hole opened in the rock, not in the ore-y part of the vein. In many parts of the mine, both men and boys work entirely naked, and although, while underground, I did not notice much difference in the temperature, as compared with deep mines in other countries, the subsequent exhaustion was far greater than is usual in temperate climates. The mines and district are by no means unhealthy, although there has often been considerable mortality amongst the white (Cornish) hands, owing to the want of prudence and caution whilst above ground. I was pleased to find a cage provided in the Cobre mine to lift the miners after their work was concluded.

"Recapitulation.—I may now sum up as follows the principal results of my observations on the western or productive part of the Cobre lode.

"1. It includes three courses of ore regarded as distinct, nearly parallel to each other in strike, but gradually approaching as they go down, two of them unusually large and rich, and the third (the middle) of smallest importance, the northernmost (on the foot-wall) being chiefly affected by certain small heaves; but all the ore-y ground terminated by a cross course to the west. The intervals between the three courses of ore are occupied by a conglomerate or breccia, consisting of fragments of decomposing porphyries and greenstone, abounding with lime, passing into a compact whitish green porphyry. Associated with the courses of ore, the veinstone, and the country, are large quantities of iron pyrites, and at a certain considerable depth the veinstone contains gypsum.

"2. Regarding the three courses of ore together as parts of one great lode, nearly 200 yards wide at its crop, this lode may
be described as dipping moderately to the south, as shown in fig. 4, p. 148, the orey portions being chiefly near the hanging-wall and the foot-wall, but extending occasionally and irregularly not only into bunches and strings in the intervening veinstone, but also into the country, both north and south of the lode. The whole of the adjacent rock is also highly mineralized.

3. Not only the lode, but each of the principal courses of ore appears to be well indicated at the surface by a distinct gossan, consisting of spongy quartz and iron oxide of the usual kind, and highly colored clays and marls, immediately beneath or amongst which have been oxides, carbonates, and sulphurets of copper. At greater depth, the yellow ore (a sulphuret of copper and iron) entirely replaces the other metalliferous minerals, the proportion of iron gradually preponderating on going down.

4. The horses, or areas of unproductive ground occurring within the lode and between courses of ore, consist for the most part of porphyry, identical in appearance with rock outside the lode, but generally mineralized with iron and copper pyrites.

5. The metalliferous deposit, obeying the form of the ground, terminates abruptly to the west, where the hill is precipitous, and dies away towards the east. The heaves and cross courses do not carry ore.

The Santiago Lode.—Following the main lode from its chief development towards the east, its outcrop may be traced at intervals until we reach a point where a contra lode or main branch forms a junction with it. This junction is well seen in a natural section formed by the river-banks, and beyond it, towards the east, the outcrop continues remarkably strong, and possesses many points of interest. The contra lode or branch makes an angle of 30° with the main lode, and goes away to the southwest. It is seen at various points, and after about half a mile bifurcates, and is crossed by several small strings and subsidiary lodes, traceable in various directions, and not yet proved to be connected with each other in any important sense. Some of these strings and lodes are of considerable size (measuring underground from three to seven feet) and have shown, either at the surface or at some depth, very good coppery indications, consisting of oxides, carbonates, and rich sulphurets of copper. The gossans of such lodes have generally led down to bunches of unusually rich sulphuret, but no steady and continuous deposit has yet been proved to exist, resembling that found in the Cobre concessions. The country also is here less metamorphosed, calcareous green conglomerates replacing the porphyries, while elvans of porphyry occur amongst the lodes. Generally speaking, in this part of the mineral field the appearance of the lodes when cut underground has not been so satisfactory as might have been expected from the character of the gossans, and whilst the ore obtained has been of the finest quality, the quantity has been too small, and the supply too irregular, to secure a profit on the mining operations carried on.

Besides the group of lodes cropping out to the south of the
Cobre, and connected with the Santiago lode, trials have been made on small gossanary outcrops in the valley of the Cobre, to the north of the lode, and also in the ground to the west. Bunches of ore exist under these crops, but no valuable deposit of copper has been found.

"Conclusion.—The Cobre lode is thus remarkable for its great magnitude and complication, its extraordinary richness, the high degree of mineralization of the surrounding 'country,' the nature of its enclosing rocks, and the combination of metamorphic and mechanically formed rocks, in close contact, and frequent alternation. It possesses the ordinary characteristics of veins only in some respects, and is in others very anomalous. It is situated in a district not much resembling in any point those in which copper is usually found, and the general geology of the surrounding country would hardly indicate so rich and remarkable a deposit as that which has been proved to exist. The study both of the phenomena of the lode and of the surrounding rocks would well repay a longer time than I was able to afford; and I shall be happy if my remarks, by attracting attention, may serve to the further elucidation of the exceptional appearances I have referred to."

Present value of the Cobre deposits.—The question as to whether or not there still remains under ground a sufficient amount of ore to pay for the great expense of unwatering and rehabilitating the mines seems to be a matter of speculation rather than one capable of demonstration. The fact that workings had progressed to a very considerable depth might be thought to indicate that the mines had been developed by following the richest ore bodies, and that all low-grade materials had been left. If this suggestion be accepted it must be supposed that the concentrating plants were kept busy entirely by such low-grade materials as were necessarily removed in reaching the more valuable mineral, so that it seems more likely that considerable low-grade ore must have been mined and concentrated. It does not follow, however, that there may not still remain large amounts of ore that could not then have been worked profitably, but which with the improved appliances of the present day will prove of very great value. From the fact that there are various pieces of new machinery, which were doubtless brought in shortly before the abandonment of the mines, lying where they were unloaded from the cars, it may be reasoned that there was no intention to close operations previous to the political disturbances of 1868. On the other hand, it may be thought that the failure of the mining company to meet their obligations for transportation was an indication that the mines were considered to have been very nearly exhausted; though this failure may well have been due entirely to the then low price of copper.

Records concerning the operations of the Cobre mines are still preserved in the archives of the Cuban Government, and they give a clear idea of the extent of the underground workings at
the time the mines were abandoned. These records are in the form of reports from the Government Mining Engineer and comprise maps and cross-sections which seem to have been very carefully compiled. They are all available to the present holders of the property and will be invaluable to them in their attempt to find and extract the ore which there is much reason to suppose still remains in the mines.

The following table gives the depth of the various shafts:

<table>
<thead>
<tr>
<th>Name</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cristina</td>
<td>835 feet</td>
</tr>
<tr>
<td>Isabelita</td>
<td></td>
</tr>
<tr>
<td>Santuario</td>
<td>892</td>
</tr>
<tr>
<td>San José</td>
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<tr>
<td>San Joaquín</td>
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</tr>
<tr>
<td>San Andrés</td>
<td></td>
</tr>
<tr>
<td>Perseverancia</td>
<td></td>
</tr>
<tr>
<td>Angelita</td>
<td>302</td>
</tr>
</tbody>
</table>

It is understood that the present owners of the Cobre mines have made a careful examination of all the old dumps with a view to saving the mineral which is disseminated through them and it seems not improbable that even the tailings from the jigs which were formerly used may be crushed and reworked with profit. Doubtless the water which comes from the mine will also continue to be worked and if the copper which it contains is completely recovered it will yield a not unimportant revenue.

**OTHER COPPER PROSPECTS IN SANTIAGO PROVINCE.**

*El Caney.*—In the vicinity of El Caney surface indications of copper ore have been found at several places and in the past numerous shafts have been sunk without success in the attempt to find valuable deposits. Some recent explorations have also failed, and from such indications as can be noted upon the surface it seems improbable that any of the prospects which were pointed out to the writer will ever be of any value. The rocks belong to the same general series and to a horizon not very different from that in which the Cobre deposits are found, but the absence of persistent veins of quartz is a distinctly unfavorable feature. Such veins as were seen within two miles of the village cannot be traced for more than a few yards, and could not be expected to carry ore bodies of any importance.

It is understood that there are, in the region between El Caney and Sevilla, several strong quartz veins, some of which show indications of copper. One of these was visited and found to be a well-defined fissure vein containing small amounts of iron pyrites in quite an unweathered state, but no large masses of iron oxide were discovered to indicate that any quantity of the sulphide would be found in depth. This, however, can only be taken as negative evidence and a complete exploration of the vein might reveal valuable deposits of sulphide ore.
In the vicinity of El Caney boulders of amygdaloidal basalt were found lying upon the surface of the ground in several localities and distributed in such a way that they seemed to indicate the presence beneath the soil of masses of similar rock of considerable size. The cavities in this rock were found to be filled with metallic copper, forming in some cases possibly as much as 10% of the entire mass. The character of these ores is, in some respects, not unlike that of a portion of the copper ores of the Lake Superior region, and if the basalts can be proved to be of sufficient extent there is no reason why they could not afford profitable mines.

From what could be learned of the general geology of the region it appears evident that these basalts are lavas intercalated in a series of volcanic tuffs and breccias.

Santa Rosa.—Upon the estate known as Santa Rosa, upon the northern side of the Sierra Maestra, opposite the Juragua mines at Firmeza, metallic copper is found occurring in a basalt similar to that noted near El Caney, and while the locality was visited it was determined that large amounts of basalt occur in the region, it was not possible to conclude to how great an extent they were impregnated by copper, or copper minerals.

Daiquirí.—The porphyry dikes which are found cutting the iron ores in the mines at Firmeza and Daiquirí are occasionally impregnated with chalcopyrite or oxidized minerals of copper derived from it. These occurrences are not of economical importance, but their presence is sufficient to indicate the very general distribution of copper in the Santiago region, and to furnish reason for surmising that all of the vein phenomena have had their origin since the disturbance of the rocks of eastern Cuba which followed the deposition of lower Tertiary stratified rocks.

Zarzal.—Two localities in which there are prospects for copper were examined in the southwestern portion of Santiago Province. The first was five kilometers southeast of Zarzal, which is about 15 miles southeast of Manzanillo. The country rock here consists of volcanic tuffs and decomposed basic porphyries, intersecting which are veins containing on the surface carbonate ores of copper. There are several copper prospects in this immediate vicinity, the best of which was examined. It is a vein two feet wide in somewhat decomposed basic porphyry. It strikes north and south and has a dip of some 45 degrees to the west. Judging from surface indications, as the veins are so narrow, they possess but slight value. There is a possibility, however, that they may be wider below, but on the other hand there is also a possibility that they may become narrower. No work has been done upon these outcrops to discover what quantity of ore is present.

Dos Palmas.—The other copper prospect is 1 1/2 miles southeast of Dos Palmas and is about 12 miles northwest of the village of El Cobre, at Finca la Unión, near the Cauto River. This is an extremely interesting locality. A considerable portion of the surface in this vicinity is underlain by fragmental volcanic brec-
cia, overlying which, and probably in places interbedded with it, is limestone. The ore occurs in a diabase rock, which has been intruded into a shale, along a zone some 70 feet wide following the contact. The copper occurs usually in small veins, largely containing zeolites as vein material. There are copper carbonates, red oxide (cuprite) and native copper. Native copper is found in both the zeolite veins and in the diabase itself. There is undoubtedly a considerable amount of copper ore and at present systematic exploration of the deposit is in progress. The problem to be solved here is whether a sufficient amount of ore occurs in the basalt and the small veins to repay its extraction. Although it can not be stated as a positive fact that the prospect is of value, the indications are that it will be a paying investment.

Gibara and Holguin.—In 1843 Richard C. Taylor read before the American Philosophical Society a paper upon the geology of the region of Gibara and the occurrence of copper and gold in this vicinity. This paper was the result of observations made during the year 1836. From it the following notes have been extracted.

Previous to the year 1830 the existence of copper lodes on the northeast side of Cuba was unknown. They were first discovered during that year in the Savannas of western Santiago Province during an ineffectual search for gold and the denouncement of San Fernando was soon operating as a copper mine. Several others were soon after located and legal possession of them was secured to the proprietors according to the usual Spanish forms by authority of the local government. Among the earliest of these were the mines of San Augustin and Buena Isabel opened in 1835. Stimulated by the success which attended the working of the Cobre mines, the mineral explorations were prosecuted with activity. The principal copper lode at Sabana Vieja was discovered in 1835.

The mineral veins of the Gibara districts are most frequently found in the serpentine, which occurs there in large amount. The lodes wherever examined were found to have regular walls with polished sides or surfaces, and maintained nearly uniform directions and inclinations and are in general parallel among themselves. The prevailing course is about E.N.E. and the average dip about 65 degrees toward the south. The ores comprising within from 50 to 80 feet of the surface are composed of silicates, carbonates, oxides and sulphurets. Native copper is not infrequently found, but does not occur below 39 feet from the surface. In the mine of San Fernando masses of the metal weighing from 10 to 200 pounds are found. The main ore of this mine is, however, a sulphuret of a dark bronze green or bluish gray color mixed with gray and vitreous copper. The richest outcrop of ore noted was that at the San Augustin mine, situated 11 miles from the landing place on the Gibara River. Assays of this ore range between 16 and 51 per cent metallic copper. The shaft by which it was developed had a depth of 46 feet, and the thickness of the vein was three feet. At the Bue-
na Isabela, which is 12 miles from the landing place, three feet of solid ore was observed at a depth of 90 feet, and the mine had been developed by a thousand feet of shafts and tunnels. The mine known as Sabana Vieja is 12 miles from the landing place and about 4½ from the town of Gibara. Within this denouement eight copper lodes have been defined. The course with slight variation is N. 56° E., dipping 60° to 70° to the south. One of these veins upon its outcrop has a width of 30 feet, while another shows 6 feet of colored sulphuret. Still another is 4 or 5 feet between the walls, the ore being rich carbonate and red oxide.

In all 18 copper properties are mentioned by Taylor. In his resumé he says that the field is a very promising one and that the region will certainly add to the abundant resources of the Island at such time as American or English capital might take hold of the development of the mines.

None of the mines mentioned above by Taylor were brought to our notice while in this region, but certain old workings in the immediate neighborhood of Holguin were considered to be practically valueless, since no quartz veins or true fissures were found. There are some strong quartz veins which have been prospected to only a very limited extent, probably for the reason that they do not show upon the surface the same rich sulphides that evidently occurred in some of the places which were opened during the period of interest in the search for copper deposits. One of these veins, occurring two or three miles to the southwest of Holguin, shows a strong outcrop for a distance of not less than 500 feet, and has a maximum width of perhaps 12 feet. A fair quantity of iron oxide is found in the partly porous quartz, and there are some copper stains shown in a small excavation. Doubtless there are other similar quartz veins in the region, and it is considered that they have not been sufficiently investigated to show that they may not be the bearers of valuable bodies of copper ore. The country rock of this region is serpentine cut by dikes of diabase.

**Sagua de Tánamo.**—A note upon a copper-bearing vein located some 10 or 12 miles southwest of Sagua de Tánamo, in the province of Santiago, is found in an article by Pellitero. (1) This prospect is located on Rio Castro about 12 kilometers east of its junction with Rio Sagua. It is a wide vein of copper and iron pyrites carrying 5 per cent of copper.

**Copper in Puerto Príncipe Province.**—The mining of copper in the Province of Puerto Príncipe was at one time an industry of no small importance. Most of the mines which were worked during the early period of activity are situated near the town of Minas, upon the Puerto Príncipe and Nuevitas Railroad, about 27 miles east of the City of Puerto Príncipe.

The rocks of this general region are serpentine diabase, diorite, and porphyritic rocks, related to granite or syenite, but in the vi-

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(1) *Apuntes geológicos referentes al itinerario de Sagua de Tánamo a Santa Catalina de Guantánamo, en la Isla de Cuba, Bol. Comisión del Mapa Geológico de España*, t. XX, p. 97, 1895
cinity of the mines, serpentine and diorite predominate, the for-
mer usually forming the immediate casing of the veins.

The ores are chalcopyrite, occurring with quartz in strongly
marked veins filling true fissures. Several veins of this charac-
ter occur within a zone at one place not less than half a mile in
width, and extending for three miles or more along its northeast-
ern course. Throughout this mineralized belt there are many
old shafts, most of which show evidence of having been produc-
tive to some extent, and several of them certainly yielded large
amounts of ore. The largest mine seems to have been one sit-
uated near the northeastern limit of the mineral belt, and here
there is a large pile of tailings, showing that the ores were con-
centrated previous to being shipped. The distribution of these
old workings would seem to indicate that the mineral occurs in
the veins in the form of ore chutes, or pockets, probably of con-
siderable size. As at Cobre it is an open question whether or
not the deposits were practically exhausted previous to the aban-
donment of the enterprise, but it is probable that only such ore
bodies as were indicated upon the surface outcrops were devel-
oped, and that there was no systematic underground exploration
for hidden ore. On the whole there seems to be a sufficiently
good prospect of finding workable ore in paying quantity to war-
rant the expenditure of several thousand dollars in the exploit-
ation of these deposits. These properties are at present con-
trolled by an American company under the management of Mr.
Henry Adams, of South Bethlehem, Pennsylvania. A shaft has
recently been sunk and some good ore has been taken out by this
tcompany.

There are several other copper localities reported from other
parts of the province, but none of these was visited.

Mr. J. H. Pratt has published some "Notes on the Mineral
Resources of Puerto Principe, Cuba." He examined a prop-
erty about ten miles southeast of Puerto Principe, suppos-
dely a copper mine, known as the "Mysterious Well." His re-
port concerning the value of the property for copper is unfavor-
able, but some gold is present, as well as lead and zinc ores, and
it might pay to have the water pumped out of the shafts and
debris removed so that the old workings can be examined. How-
ever, no definite prediction as to value could be made.

It may be said in regard to the copper deposits of this region,
as of those in Santiago Province, that the presence of strong veins
of quartz is of the first importance in association with the copper-
bearing mineral, and without such quartz veins probably no
deposits of commercial importance will be found, since the basals,
such as sometimes carry copper in the Sierra Maestra
country, are not found in the central provinces of Cuba. (1)

Copper Prospects in Santa Clara Province.—Copper ores are found
at several localities within the Province of Santa Clara, viz.: (1)
at a place known as Mina San Juan de la Maleja, 6 miles north-
east of Santa Clara City; (2) on Finca San Joaquin, which is

429.
about 12 miles west of Manicaragua and about 30 miles northeast of Cienfuegos; (3) at Mina Santa Rosa, 2½ miles further east; (4) a few miles west of Cumanayagua, west of the preceding; (5) in the northern portion of the district of Trinidad, near Guanúa de Miranda; and (6) three prospects near Sancti Spiritus. Only the Mina San Juan de Maleja and the old mines in the vicinity of Finca San Joaquín, Mina San Fernando, etc., and Mina Santa Rosa were examined.

Geologic Age of the Veins.—In discussing the general geology of this region it was stated that the diorite porphyries and other igneous rocks are apparently intruded into Cretaceous strata. Therefore, since the veins examined are in diorite porphyry or andesite, or associated with dikes of fresh basalt or gabbro, it is concluded that the mineralization has taken place since Cretaceous time.

San Juan de Maleja.—This concession is about three miles west of Loma Cruz, and about six miles northeast of Santa Clara City. It is an old prospect, but has been again denounced recently, under the name of Resucitada, by Mariano Medina. The surface of the country in the vicinity of the mine is gently rolling, and is underlain by serpentine and dioritic rocks. The opening for the mine is in an area of gossan which is along the contact of a dike of gabbro. The appearance is similar to what is designated in some parts of the United States as a "blow out." The material is composed of brown and yellow oxide of iron (there may be some hematite also), with considerable quartz and carbonate of copper. Apparently there is a fair amount of carbonate ores but from what was seen they are not in large continuous masses. The transverse section of this body of gossan measures about a hundred feet across.

Considerable tunneling has been done in the mine but no shafts have been sunk, and the ore bodies have not been systematically prospected. We do not therefore as yet know whether sulphide ores will be found at greater depths. Further prospecting, particularly by shaft, will be required before any definite conclusion can be reached concerning the quantity and quality of the ore in this deposit.

Mina Santa Rosa.—This prospect is situated on Finca la Seiba, about 2½ miles west of Mina San Fernando, which is described below. It is upon a vein striking about N. 45° W., and dipping a very steep angle toward the northeast. The footwall of the vein is composed of a feldspathic rock much sheared.

The vein itself is about ten feet wide, is iron stained and contains some carbonate ore, iron pyrites, and some chalcopyrite. To the north of the vein is a zone of much slickensided and brecciated rock, beyond which is a mass of diabase. A tunnel has been excavated in the hillside for a short distance, along the course of the vein, and a shaft has been sunk to a depth of about 14 feet.

Sufficient work has not yet been done to enable one to reach a definite conclusion as to the value of the ore deposit. Since, however, carbonate ore is rather abundant, and there are sulphides
Fig. 5. Map of a portion of Santa Clara Province, showing locations of old copper mines.
at present exposed in small quantities, it would appear that the prospect amply justified further exploration.

*Finea San Joaquin.*—Four distinct mines on this property were visited, namely, San Fernando, Santa Elena, Santa Isabela, and San José. These mines are situated on the north side of Río Arimao, and, as stated above, are about 12 miles west of the town of Manicaragua.

E. G. Spilsberg in his Copper Mines of Santa Clara (1) states that at the time of his inspection of the mines there were six concessions in all. (A concession is 300 metres long and 200 metres wide, the owners having all mineral right within vertical planes extending down from these lines.) Two were known at Santa Rosa, (described above), two as San Fernando, one as Santa Isabela, and one as San José. Mina Santa Helena is not mentioned. San Fernando is only a few hundred yards away from the house of Eulogio Jacomino; Santa Helena is about $\frac{1}{4}$ mile west of San Fernando; Santa Isabela is about $\frac{1}{4}$ mile still further west; while San José is about $\frac{1}{4}$ mile south of the last mentioned.

The first reference in literature to copper mines in this Province, is that published by La Sagra, (2) who says that these mines were first discovered by José Escalante, but who failed to have them properly exploited. These notes apparently apply to what are now called the San Fernando Mines. In 1835 a Mr. Tyson went to Havana for the purpose of investigating these properties. During the next year M. B. Smith and H. Bradford formed a company with the proprietor of the mines for working the mine San Fernando for copper and silver. This is situated in the locality known as Hoyo de Manicaragua in the jurisdiction of Villa Clara. This company had obtained concessions similar to those given the Santiago Company and in less than a year had realized the sum of 150,000 pesos. This fact alone shows that the exploitation was prosecuted on a large scale.

D. T. Ansted inspected the mines and published in 1857 an article entitled "The San Fernando copper lodes near Cienfuegos in Cuba." (3) According to his description considerable work had been done in opening up the mines. He mentions two lodes, the northernmost of which was the more exploited. Ten pits, the deepest 32 fathoms in depth, had been sunk. He states that not less than 10,000 tons of ore had been sent to Cienfuegos. In the year ending July 1st, 1856, about 480 tons of ore, averaging 17 per cent of copper, were shipped to Swansea, Wales; and about 300 tons, supposed to be equally good, were sold to the United States, the total value being $12,000. During that time only ten laborers were employed. Spilsberg, in his report already alluded to, says that in 1868, 3,253 tons of ore were shipped to Swansea, and were sold for £54,446. The average percentage of copper is given as 19.7. Eulogio Jacomino stated that these mines were last worked from 1882 or 1883 to 1885, under the direction of Mr. Tipley, an American engineer, and were then abandoned by

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(1) U. S. Consular Reports, Vol. XII, 1884, pp. 266–270.
(2) Histoire Physique de Cuba, Volume 1, 1842, page 127.
their owners because of the revolution, and confiscated by the Spanish government. Since that time they have not been worked, but have been "denounced" again and are apparently owned by a Havana company, formed in 1885, designated "Sociedad Anónima Industrial; Minas de Cobre San Fernando y Santa Rosa," of which José F. Sta. Eulalia is the President. The land is owned by Eulogio Jacomino.

At the time the mines were visited they were in such a condition that a thorough study of them was not possible. Considerable quantities of ore are still there, but the shafts are partially filled with water, and there are no ropes or ladders by which descent can be made to the old workings. Therefore, it was not possible to make measurements of the thickness of the veins or to obtain other important data.

The country in the vicinity of the mines is hilly, the highest eminences attaining an elevation of about 1,000 feet above sea-level. The declivities are gentle and are usually overgrown with grass. The soil is very fine-grained, though rocky, and makes excellent tobacco land. The two accompanying photographs represent the character of the landscape. The hills shown in the view are composed of diorite.

The general geology is simple, most of the hills being composed of diorite porphyry, with some andesite.

*Mina San Fernando.*—This mine, the most northeasterly of the San Joaquin group, is in a vein, containing much barite, in diorite-porphyry. As Ansted had a better opportunity for making observations than myself, the following is quoted from his paper:

"The lodes are all nearly vertical; but, while the two northernmost dip a little towards the north, the others seem to underlie south. The northern lode is that on which mining operations have been chiefly carried on, and here ten pits were sunk at intervals along a distance of about 800 yards. Most of these pits went down at once at very shallow depths into deposits of rich decomposed ores of copper, through gossan consisting of iron-oxide and quartz, with occasionally a good deal of blende. The ores included blue carbonates of copper, red and black oxides, and purple and yellow sulphurets, besides decomposed carbonates, oxides, and sulphurets. . . ."

"At the time of my visit the lode exposed in the bottom at one point was 35 feet wide, including about 5 feet of 'horse' or barren ground. The hanging-wall was soft and loaded with muncid, which penetrated and impoverished the upper side of the lode. Nearer the foot-wall, the ore consisted of rich yellow sulphuret of great purity. . . ."

So far as recent observations extended they agree with those of Ansted, above recorded, excepting that only small quantities of zinc blende were found. Concerning the blende Spilsberg says: "At the bottom of No. 1 shaft there is evidently a very considerable vein of zinc-blende, mixed with copper pyrite, as evidenced by the piles of ore which were stowed away in the lower portions of the old workings above water level." He further
states that "the old miners, not knowing its value, but having to mine it with the copper, separated it before hoisting the latter to the surface, and piled the blende back in the old workings. I have no doubt but that over 1,500 tons of this rich ore now lie in the dumps and old workings, requiring nothing but a hand-sorting to prepare it for the market."

As it was impossible to go down into the mines for reasons already stated, there was no opportunity to see this ore in any considerable quantity.

The following analysis of specimens of the sulphide ore collected during this reconnoissance was made by Frederic P. Dewey:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>8.36 per cent.</td>
</tr>
<tr>
<td>Iron</td>
<td>57.34 , ,</td>
</tr>
<tr>
<td>Gold</td>
<td>.15 oz. per ton.</td>
</tr>
<tr>
<td>Silver</td>
<td>4.7 , ,</td>
</tr>
<tr>
<td>Lead by qualitative</td>
<td>trace.</td>
</tr>
</tbody>
</table>

Ansted says that some of the ores from this mine contain from 15 to 17 per cent. of copper.

Mina Santa Elena.—The ore is similar to that in San Fernando, pyrites, chalcopyrite and sphalerite. The vein material is largely quartz.

Mina Santa Isabela.—The vein here strikes N. 22 W. in diorite porphyry, the country rock, which shows much fracturing. The surface exposure is poor, but the vein is probably at least 15 feet wide. The surface rock is deeply iron stained, but no ore was seen in it. On the dumps, specimens of both carbonate and sulphide ores were found.

Mina San José.—This mine is located on a vein, the vein material consisting largely of quartz, in diorite porphyry. The ores are sulphides.

Water drawn from the bottom of the shaft at San Fernando is allowed to run through a trough over scrap iron, by which metallic copper is precipitated. The waters draining from the various mines contain much copper in solution, and flow into an arroyo skirting the northwestern side of the hill, where they cause a deposition of salts of copper; the basic sulphate is abundant, around pebbles and larger stones in the stream bed.

This deposit is flocculent, and accumulates rapidly in the dry season, but is readily washed away when the freshets of the rainy season come. Spilsberg estimates that these waters contain very large quantities of copper in solution, and suggests that lime be used as a precipitant, since scrap iron would be too costly. He thinks that a large proportion of the copper now in solution can be utilized in the form of blue vitriol.

The data above given are not sufficient to form the basis of an opinion as to the actual value of the mines. There is copper ore, mostly sulphides (chalcopyrite) of value, and it contains considerable gold and silver; the ore occurs in recognized veins, which are, in some instances at least, of considerable width. The waters coming from the ore bodies contain rather large
quantities of copper. All of these facts indicate that the mines are of value, but no one at present can estimate what quantities of ore can be taken from them. The water in the old workings should be pumped out, and the old excavations cleaned out so as to permit a thorough study of the veins, and it is quite probable that additional prospect shafts must be sunk or that tunnels must be driven, in order to gain the necessary information for determining whether the mines can be operated commercially.

Transportation facilities at present are not good. The nearest railroad is the Cuban Central, and the nearest point on this road is San Juan de los Yeras, some 10 or 12 miles to the north. There is much in need of a railway. The valley of the Rio Arima is very fertile, and there are some hill lands on which tobacco grows well, while other portions are well adapted to stock raising. Therefore, there are special reasons, besides the possibly rich mines, for building a railway from Cienfuegos to Manicaragua.

If furnaces are erected here, the question of fuel must be considered. No deposits of coal of value are known in Cuba, and probably none will be found. There is no timber in the immediate vicinity of the mines, although some is found about three miles distant. It would be necessary to determine whether it would be cheaper to use charcoal for smelting the ores or to import coke for that purpose.

Copper deposits in Matanzas Province.—About eight miles northwest from Matanzas, at an abandoned plantation, named El Recreo, there is a deposit of copper which was somewhat extensively worked many years ago. The copper occupies two or more fissure veins intersecting the serpentinite. The principal vein has been traced and opened at various points for a distance of fourteen hundred feet. It extends in a direction ten degrees east of north and dips at an angle of about eighty degrees to the west. Another vein of similar character has been located, extending nearly at right angles with the main fissure.

Near the surface the ore is chiefly carbonate and the original contents of the vein have been greatly reduced by leaching. In many places the only indication of copper is a slight staining of the gangue minerals from which the ore has been removed. At a distance of fifteen or twenty feet from the surface the ore changes to a heavy black sulphide which is extremely rich, carrying from eighteen to twenty-four per cent of metallic copper. This ore is probably either bornite or cubanite. At this depth the vein throughout the greater portion of its extent is about twenty inches in width, although it shows considerable variation and in some places thins out to a mere streak. Towards its northern end, however, the vein breaks up into a large number of subordinate veins or stringers which are scattered through the rock for a distance of fifty or sixty feet. These stringers are more variable in width than the main vein and it is probable that this portion will be found to contain the largest deposits of the ore.
The work which has been done on this deposit in former times is without much system, the miners having followed the richest and most accessible leads. It is probable that the ore will grow somewhat leaner at a depth slightly below the level of present ground water, but it is certain that the deposit contains a very considerable amount of high grade ore which can be cheaply mined. The gangue minerals are of such a nature that they can be readily removed by simple ore dressing appliances and a high grade product thus obtained. The dressed ore should be worth from fifty to seventy-five dollars per ton, and it is evident that it will bear long transportation to the smelter.

This deposit at El Recreo is the only one in the Matanzas district which has been worked. It is highly probable, however, that this region contains other similar deposits, possibly of equal or even greater value.

At two other points in this same district float copper ore has been noted. At one of these a shallow test shaft has been put down, revealing a vein of considerable width. A small amount of copper is present, but the greater part of the ore has evidently been leached out, leaving a porous rock which the miners call "cinder." The surface indications at this point appear to be even better than at El Recreo, and it is at least probable that a valuable deposit of copper sulphide may be found at a moderate depth.

In conclusion, it appears that an area seven or eight miles in width and fifteen or twenty in length, lying northwest of Matanzas, affords excellent promise of yielding valuable deposits of copper ore, and merits thorough prospecting.

Copper in Provinces of Havana and Pinar del Río.—Indefinite reports concerning the presence of deposits of copper in these two provinces have come to us, but we have not visited them ourselves nor obtained definite accounts of them from the literature. Rodríguez Ferrer (1) mentions copper ore from the Vuelta Abajo, but does not give the locality whence it came. Manuel Fernández de Castro (2) mentions mines of copper in the vicinity of Mantua, Pinar del Río.

LEAD.

Wm. J. Clark in his Commercial Cuba, (3) page 417, gives the following information concerning lead mines in Cuba:

Loma de Gato Mines.—These are situated about twenty-five miles west of the city (Santiago) and five miles from the coast. They are known as "Washington" and "Jehovah." The work done thus far has uncovered an ore vein about twenty inches wide at the top, containing lead, zinc, and a little gold. The following is an analysis of the ore:

(1) Naturaleza de la Grandiosa Isla de Cuba, p. 573.
(3) New York, Charles Scribner's Sons, 1898.
<table>
<thead>
<tr>
<th></th>
<th>Per Cent.</th>
<th>Oz. per Ton.</th>
<th>Per Cent.</th>
<th>Oz. per Ton.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead........</td>
<td>46</td>
<td></td>
<td>46.60</td>
<td></td>
</tr>
<tr>
<td>Zinc.........</td>
<td>14.34</td>
<td></td>
<td>12.50</td>
<td></td>
</tr>
<tr>
<td>Silver......</td>
<td></td>
<td>19</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Gold........</td>
<td></td>
<td>3/100</td>
<td></td>
<td>8/100</td>
</tr>
</tbody>
</table>

Various American promoters have endeavored to capitalize this property, but without success, and probably no development has yet been made.

*Tres Corrales.*—This mine is said to be rich in argentiferous galena, but has not been thoroughly investigated.

*Zarzal.*—A small galiniferous prospect was inspected 12 miles southeast of Zarzal. It is a narrow vein in volcanic rocks, and promised to be of no value, though occasional fair specimens of ore can be obtained.

**Manganese.**

*History.*—The mining of manganese in Santiago Province dates from about 1887, in which year, according to the report of Mr. Ramsden, the British Vice-Consul of Santiago, contracts were made by local miners to furnish high grade manganese ores. However, up to the time of the report no actual shipments had been made. In a report by the same official in 1892, (1) it is stated that 50 tons of picked ore were sold in 1887 in the United States, at $100 per ton. In 1888 the same parties shipped 1,298 tons, and up to January, 1890, 1,175 tons more, making a total of 2,471 tons up to that date. This ore was extracted from the Margarita and Avispero mines, now comprised in the Boston group. This company failed at the beginning of 1890, after which some of the mine owners began to work the properties themselves, or leased them to others desirous of taking out the ore upon royalties varying from $1.75 per ton. The shipments for 1890 amounted to 21,810 tons, but in 1891 a reduction in the value of the ore caused the output to fall off to 9,487 tons.

In August, 1895, the American Consul, T. F. Hyatt, reported that the Ponupó Mining Company had dispatched to the United States their first shipment of 500 tons of manganese ore. This company had constructed about a mile and a half of railway connecting the terminus of the branch of the Sabanilla and Maroto Railway, by which they were enabled to ship their product to the City of Santiago. This mine was, however, obliged to shut down shortly after being opened because of the activity of the insurgent forces in the region, but mining was resumed in 1898, and has been carried on up to the present time. At the time of the report of Consul Ramsden, there were in the neighborhood of Santiago 88 denouncements of manganese ore, covering an area of 4,015 hectares.

*Occurrences of the Manganese Ores.*—The only deposits of man-

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(1) Foreign Office, Her Majesty's Government: Diplomatic and Consular Reports of the trade and finance, Annual Series No. 1132, 1892, and report for the year 1891 on the trade, agriculture, mining, and so forth, St. Jago de Cuba.
ganese in the Island of Cuba which have been generally known are located in the Province of Santiago, where the principal occurrences are found in a belt lying back of the Sierra Maestra, and extending from the vicinity of Guantánamo upon the east to Manzanillo upon the west. Throughout this region the ores occur at intervals, and there is strong evidence for believing that they lie usually at the same geological horizon, a fact which, if true, is of the greatest importance to those who may be in search of the mineral.

It is commonly said of manganese ores that in their occurrence they are generally of a pocketed nature, by which it is meant that the ores are found in limited masses surrounded by unproductive country rock, as opposed to the usual occurrence of other minerals in veins, as in the case of gold, silver, and lead, or in beds as in the case of coal and certain iron ores. This mode of occurrence is the one found in the deposits of Santiago Province. The ore bodies usually occur upon a hill or knoll, from the top of which they may extend down upon the sides.

The ores comprise the minerals manganite, pyrolusite and wad, mixed in various proportions, and they are associated almost without exception with yellowish or brown jasper or "bayate," as it is locally called. The rocks in which the deposits are found are of a sedimentary nature and comprise limestone almost completely made up of the shells of foraminifera and sandstones composed of greensand and which also contain many shells of foraminifera. In many places, as at the Boston, Isabelita, and Ponoipo mines, the evidence is complete that the manganese minerals have been brought to the position they now occupy by circulating waters and that they have replaced both the sandstone and the limestone. Also, in other places, as for instance in the Los Negros group of mines situated south of Bayamo, the ore occurs in small pockets in a massive non-fossiliferous limestone in such a way that it is evidently also a replacement of the rock. Frequently, as illustrated in the accompanying figure, the ore occurs in bands or layers interstratified with layers of unmineralized rock, and comprises from 10 per cent. to perhaps 80 per cent. of the entire mass. It is supposed that these occurrences illustrate stages in the process of replacement, and that had the mineralizing influences continued the substitution might eventually have become complete.

A very noticeable and important feature of the manganese mines is the association of hard jasper or "bayate" with the ores. This substance, which is a form of silica, occurs either in large masses around which the richest bodies of ore lie, or in the form of nodules distributed through, or as veinlets penetrating the ore. In some instances it seems that the small veins of jasper have been introduced since the formation of the metallic mineral, since they seem to replace the ore, but in other cases it appears that the ore replaces the siliceous material. From the mode of occurrence it is judged that the jasper and the ore are of contemporaneous origin and were formed through the action of hot springs.
The presence of the jasper adds very greatly to the expense of mining, and because of the irregularity of its occurrence, renders the estimation of the value of the ore bodies almost impossible. Jasper is very resistant to the effects of weathering and it usually covers the surface of the ground in the vicinity of the manganese deposits. It is owing to this fact that the ores are usually found upon slight eminences and its presence in the soil in large amounts may be taken as an indication that the conditions are favorable for the occurrence of ore. In several places where the manganese deposits were studied with some care, it was found that they occur along the central portion of structural arches in the stratified rocks with which they are associated.

This mode of occurrence is suggestive of their having been deposited by ascending solutions; and together with the fact that the jasper is probably a hot spring deposit warrants the supposition that the ores were formed by the action of hot water having its origin at a considerable depth below the surface of the earth upon certain beds of calcareous rocks particularly suited by their composition to being replaced by the chemical constituents held in solution.

Besides the ores which occupy the central belt in the drainage of the Rio Cauto, others are reported to occur in the same region as the valuable iron ores along the seaward side of the Sierra Maestra. These are probably of a distinct origin from the interior deposits, and related to the magnetites of the southern coast of the Province, but their relations have not been studied. One of these localities is near the abandoned workings of the Sigua Iron Company, about 25 miles east of Santiago. Another group is located close to the small port of Macío, about 35 miles to the west of Santiago, and still another near the small bay of Portillo, about 80 miles west of Santiago. These ores are said to exist in large amounts, but their analysis shows a percentage of silica which will probably prevent their ever being put upon the market.

*Mines at Ponupó.*—These mines are located about 1½ miles southeast of La Maya, at which point a standard gauge track built for the transportation of the ores connects with the terminus of the Sabanilla and Maroto Railway. The geological formations in the vicinity are composed of shales, marls, limestones, and calcareous sandstones composed in part of glaucornite. The beds are gently folded and the ore deposits are located in the center of an anticlinal fold. The mines have been opened along the upper slopes of a knoll, which owes its prominence to the large amount of bayate or jasper associated with the ore and which covers the top of the hill. The occurrence of the bayate is somewhat irregular. In the central portion of the productive area it is present in very large masses and has pockets of ore lying next to it and running out from it into the adjacent sandstones. At a greater distance from the center of the hill the bayate occurs in smaller masses and as a rule subordinate in amount to the ore, which is disseminated through a decomposed and friable rock. However, the quantity of jasper
FIG. 6.—SKETCH SHOWING OCCURRENCE OF MANGANESE ORE AT PONUPO MINE

1. Decomposed green-sands.
2. Jasper, "Bayate."
3. Ore (heavy black).
sometimes renders the mineral so siliceous as to make it unfit for shipment.

A careful examination of the Ponupo deposit shows that both the bayate and oxides of manganese have been deposited as replacements of limestone or of calcareous sandstones which resemble greensands or glauconite sandstones. The association of these siliceous materials with those of a metallic nature is so intimate that it appears in some cases as though the ore had been deposited subsequent to the bayate and that it had in part replaced the siliceous material. In other cases it seems as though the jasper has the nature of a replacing substance and that it had been brought in after the formation of the ore.

The accompanying drawing, figure 6, taken from a sketch made upon the ground, illustrates the manner in which the ore occurs disseminated through the decomposed sandstone and its relation to a bed of limestone made up almost entirely of foraminifera. This stratum of limestone appears to mark the upper limit of strata in which the ore deposits occur. It is of particular interest since the limestones of the central portion of Santiago Province are rarely fossiliferous, and a similar bed of limestone, made up of foraminifera, has been found associated with several of the manganese occurrences which have been seen, and it lies immediately above the strata in which the ores are found.

Up to June, 1901, the output of the Ponupo mines had amounted to about 60,000 tons, and while from the nature of the deposits it is impossible to give any accurate estimate of the ore still available, it seems probable that considerable mineral will still be found adjacent to the present workings; and as the company is also prospecting other deposits in the neighborhood, it is not improbable that other bodies of ore of sufficient size to be worked will be discovered.

Isabelita Mine.—The Manganese denouncement known as the Isabelita is located about two and a half miles east of the town of Cristo and less than half a mile from the railway which has recently been built to the neighboring Boston mines. The country rock is similar to that at Ponupo, though the beds are so greatly decomposed that their true nature could not have been determined excepting by comparison with the rocks in which the ore occurs in the other mines of the vicinity. Here as at Ponupo the ore is associated with bayate occurring in such a way that it appears to replace the substance of the sandstones. The largest masses of ore are found next to the bayate and frequently have the appearance of well defined more or less vertical veins, though in some cases it may be made out that the masses of siliceous material are entirely surrounded by irregular deposits of the manganese from a few inches to several feet in thickness. Gash-veins of the ore are also found within the masses of bayate. Adjacent to the bayate the sandstones contain large amounts of manganese in the form of botryoidal masses from less than an inch to several inches in diameter. These nodules are distributed along the well marked planes of strati-
fication and frequently become merged into continuous layers. With them there are occasional pieces of jasper having the same botryoidal form. In one case a band of the decomposed sandstone not less than 15 feet in thickness, and impregnated with ore, was traced to a distance of 25 feet from a large mass of jasper. It was estimated that not less than 50 per cent. of the rock was composed of high grade ore which could be easily separated by means of a concentrator. A sketch to indicate the mode of occurrence is given in figure 7.

At the Isabelita mine there are within a radius of perhaps 150 feet, not less than six outcrops of jasper in masses of large size and not connected upon the surface. Each of these has been dug about to a considerable extent, and in every case indications of ore have been found, but only one of them has ever been developed into what may be called a mine. From the extent of the workings in this locality, it is probable that not less than ten or fifteen thousand tons of ore have been taken out, and there is every indication that there is a good deal of ore yet to be uncovered.

The Isabelita mine has been idle for several years, except during the past summer, when some work was being done to ascertain its value with a view of connecting it with the railway from Cristo to the Boston mines. If the concentration of the manganese at the latter place should prove a success the Isabelita property will prove to be of great value, but it will almost certainly furnish more than sufficient high grade ore to pay for the development which is being done.

Boston Mines.—The properties known as the Boston Manganese mines are located nearly south of the Isabelita, and between 2½ and 3 miles from Cristo, to which point a railroad for transporting the product has recently been completed. At the time of our visit several thousand tons of high grade ore had been prepared for shipment and the company was intending to erect a plant for concentrating the large amount of low grade ores which have been developed, both by the former owners of the mines in their search for ores of sufficiently high analyses to stand the expense of hauling to Cristo, and also by their own work, prosecuted expressly with the intention of discovering the amount of lean ores which could be counted available. This work has been so satisfactory to the owners that they have felt themselves justified in building 2½ miles of railway and in arranging for the erection of a large concentrating plant.

The nature of the enclosing rocks and the character of the ore deposits at this place are identical with those at Ponupo and at Isabelita mines. A thin band of limestone made up entirely of the shells of foraminifera marks the upper limit of the ore, and being exposed at several places in the vicinity serves to show the fact that the jasper and manganese oxide occupied the arch of a rather broad anticline in the sedimentary rocks. Along the axis of this fold the ores have been discovered and opened at several points. They occur both in juxtaposition to the masses of jasper and in the form of impregnations in decomposed sandstone. The occurrence is illustrated in fig. 8.
FIG. 7.—Sketch section in cutting on the southwest side of Isabelita mine. Scale 24 feet to 1 inch.

1. Surface soil.
2. Green-sand with bands of manganese.
3. Layer of manganese nodules and kidneys.
4. Lenses of jasper, ("bayate").
5. Green-sand with jasper lenses.
7. Ore bodies.
FIG. 8.—Diagram illustrating the occurrence of manganese at the Boston and Ponupo Mines.
1. Decomposed greensand.
2. Foraminiferal limestone.
The original nature of these strata can be better observed at this point than in any other place which was visited. They have a peculiar mottled appearance and generally a green cast, though they frequently contain blotches of red clayey material, having the appearance of some zeolite mineral. They contain large numbers of foraminifera and are probably glauconitic and comparable to certain so-called greensands which are very prominent in the coastal region of the Eastern and Southern United States.

From what was seen of this property it is considered that in the event of the successful operation of the concentrating plant which it is intended to erect, a sufficient supply of ore will be found for its operation for a considerable period. The mines will doubtless also furnish a good amount of high-grade ore, which will require no preparation for market.

San Nicolás.—On the north side of the Rio Guaninicum and less than a mile distant from a point upon the railway of the Compañía de Cuba known as San Nicolás, 10 or 12 miles a little west of north from San Luis, there is a prominent hill composed of jasper or bayate. The amount of jasper at this point is very great and it seems probable, in view of the proximity to the railway, that adequate prospecting, which has not yet been attempted, will show the presence of a commercially important deposit of manganese. At present nothing can be said except that the arroyos which drain the hill exhibit a very large amount of high-grade manganese ore in the form of loose boulders.

At a distance of only a few hundred feet from the railroad line, just west of San Nicolás, between the track and the river, a thin band of foraminiferal limestone is exposed. Underneath it there are decomposed sandstones similar to the glauconitic rocks described at the Boston and Ponupo mines.

The strike of the strata in this vicinity is NNE, and the dip is 20 or 30 degrees toward the south. In the decomposed greensand there is a considerable amount of disseminated manganese in nodules, but no jasper was noted. This manganese occupies a bed not less than six feet in thickness and has been opened at two points along the strike at a distance of about 1,200 feet from one another. From this fact it seems probable that the intervening region which has not been prospected is also impregnated along the same horizon and it is possible that a careful exploitation of this deposit might develop a sufficient amount of ore suited for concentration to pay for opening it upon a commercial scale. It would have to be mined underground, but would probably be quite regular in its occurrence as a bedded deposit. The limestone mentioned would form an exceptionally good roof, so that safety in mining would be easily attained. The proximity to the railroad would make the cost of putting the ore upon the market not excessive.

In the vicinity of Cristo manganese mines have been operated in the past, and some recent work has been done in the attempt to prove the value of the deposits. Several of them were seen and it is known that they are of the same general mode of occur-
rence as the deposits described, but while no accurate estimate
of their value could be made it seems that upon the whole the
deposits which occur south of the range of hills known as Sierra
Boniato will not warrant the expenditure of capital for their
exploitation upon any extended scale. However, their proximity
to transportation may render them of value in some instances,
though it must be urged that in each instance careful prospecting
must be done before spending any money for the equipment neces-
sary for working a large mine.

Southwestern Santiago Province.—In the vicinity of the town of
Portillo, some 50 to 60 miles south of Manzanillo, a fair number
of denouncements of manganese prospects have been made.
Mr. Vaughan made a journey into the Portillo district for the
purpose of examining the reported prospects. One six miles
northwest of Portillo was visited. At this place a small amount
of impure manganese was found occurring in a pocket in the
impure limestone. The amount of material was small and there
were no indications of larger quantities being present in that
locality. According to the guide to this locality the other pros-
spects in the same general vicinity contained only small quantities
of ore, so they were not visited. It is reported to us that there
is more ore to be found in the vicinity of Ensenada Mora, 13 or
14 miles further west. We are unable to state whether this
report is reliable or not.

In the vicinity of the town of Bueycito, about 30 miles north
of east of Manzanillo, are five denouncements of manganese prop-
erties. One of these, known as Mina Manuel, 4½ miles south
of above mentioned village, and situated on the east side of the
Buey River, where it emerges from the mountains, was examin-
ed with some care. The country rock consists of limestone and
some chert and rhyolite. The ore occurs both as replacement of
limestone and as an impregnation of breccia. The manganese
ore occurs over a fairly large area and in places it is of good
quality. A very large amount of it, however, is low grade, and
probably would not repay working even with concentrators.
The Costa Mine, which is situated on the next hill east of Man-
nuel, across a small ravine, was also examined. The mode of
occurrence of the ore is the same as in the preceding mine.
Some of the manganese ore is very pure, is fibrous and some-
times botryoidal. In all, four prospect pits on this property
were examined. There is a considerable quantity of ore, but it
is frequently impure, being an impregnation of a breccia. This
mine might be worked in a modest way so as to necessitate no
great expenditure for machinery, and sufficient quantities of ore
probably could be taken out to warrant the investment of moder-
ate sums of money, but it does not promise to possess any
great value.

In the vicinity of Los Negros two mines were examined, the
more important one being Mina San Antonio. The ore at this
mine occurs in pockets as replacement of limestone. This is an
intensely interesting locality, as it shows the mode of segregation
of the ores. The masses of manganese in the limestone range from
small stringers in the limestone, or partial replacements of limestone through masses the size of a man’s fist, to masses many feet in diameter. The ore is very pure, containing between 50 and 60 per cent. of metallic manganese. It frequently occurs in botryoidal form and shows on the fractured surface a fibrous structure. The difficulty to be encountered in working these deposits is, the ore does not occur in large continuous bodies, but is pocketed—there is no means of predicting the size of the pocket; from what was seen, the conclusion was reached that probably none of the ore bodies are large. It is probable, however, that the ore in this mine can be worked to advantage if it is done on a small scale, not necessitating any great expenditure of money for machinery, provided transportation facilities are good. At present Los Negros is not near any line of railway, but it is quite probable that as the country is opened up, railroad lines will become accessible.

**Future of the Manganese Industry.**—As to the outlook regarding the future of the manganese industry, it may be said in general that there are many localities in the central portion of Santiago Province where a good deal of first-class ore exists; but the life of any single mine is likely to be short. It is estimated from the records of the industry in the past, that the total available high grade ore in any one deposit can not be expected to greatly exceed 100,000 tons; though if the concentrating plant now practically completed at the Boston Mines near Cristo is successful in treating the low grade ores, the industry will be placed upon an entirely new and more favorable basis than at present. Should the concentration of the ores prove a failure manganese mining upon a large scale should not be attempted, and with the present low price which the ores command, it appears that only such deposits as are conveniently situated in regard to easy lines of transportation can be worked at all. Even these should be opened on a modest scale, without large expenditure of capital for permanent mining equipment.

**Iron.**

**General Remarks.**—The mining of iron ore is at present the most important mineral industry in the Island of Cuba. (1) With the exception of a short interval after the American intervention in 1898, operations have been continuous since 1884. The deposits which have been worked up to the present time are confined to the seaward slopes of the Sierra Maestra in Santiago Province.

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(1) Upon this subject see:
The ores are commercially known as hard hematites; mineralogically, however, they are almost pure magnites, with a possible excess of Fe₂O₃. The percentage of iron ranges from 60 to 72 per cent. and both sulphur and phosphoric acid are very low, so that the ores are particularly well suited for the Bessemer process.

In undertaking a careful study of the ore bodies revealed in the extensive workings of the Juraguá and Spanish–American Companies', mines it was hoped that some general law of occurrence would be revealed which would afford a basis for the further exploitation of the deposits. No such law was discovered, however, and though the mode of occurrence was definitely determined, it was found to be such that the position of ore bodies and their extent can never be determined, excepting by a careful magnetic survey. Each body of ore is separated from all others by masses of barren rock in such an irregular way that the distance between adjacent ore bodies may be very small or large, just as the ore may occur in small or large masses. While the ore bodies are very irregularly distributed within the productive belt, the ore-bearing zone has a definite trend along the seaward side of the Sierra Maestra which parallels the southern coast of Santiago Province. This trend, as will presently appear, is expressive of certain general geological features of the region.

Iron ores are now being mined at only three localities, although they are known to occur in large quantities at several other places along the seaboard both to the east and west of Santiago. (See sketch map, figure 1.) The mines of the Cuban Steel Ore Company are located at Guama, some thirty-five miles west of Santiago Bay, and still west of these, large deposits are known on the Rio La Plata, and others have been located between them and Santiago. East of Santiago the largest occurrences are at Sevilla, Firmenza, Daiquirí, Berraco, and Sigma, five, nine, eighteen, twenty-one and twenty-five miles east of Santiago respectively.

Of these localities only the first four of the eastern group were visited, and nearly all the data were collected at the mines of the Juraguá Company at Firmenza, and those of the Spanish–American Company at Daiquirí and Berraco.

History.—The following historical statement in regard to the production of iron ore from this region is taken from "Industrial Cuba," by Mr. Robert P. Porter, formerly Special Commissioner for the United States to Cuba and Porto Rico. The data given may all be found in various reports to the State Department by the U. S. Consular Agents, (1) and in the British Consular Reports.

The mining districts of Cuba are confined almost exclusively to the mountainous or eastern end of the Island, and so far the province of Santiago is the chief producer. Its leading product is iron ore, mined principally by American companies with American corporations. The first real

iron-mining in Cuba began about 1884, when 21,798 tons were shipped to the United States. This was the first Cuban iron ore received in this country, and was about one-twenty-third of the total iron ore importation. In 1897 we received 397,173 tons of Cuban ore, which was three-fourths of the ore imported. During the years 1884–1897 we received 3,401,077 tons of Cuban ore.

The ore is a brown hematite, in large quantities, easy to work, of excellent quality, about sixty-two per cent. iron, and is especially adapted for the making of Bessemer steel. Though there are many mining properties, three American companies, the Juragá Iron Company, the Spanish-American Iron Company and the Sigua Iron Company, do all the business. The Juragá does far more than all the others. Its shipments to the United States in 1897 were 244,317 (5,932 tons, in addition, to Nova Scotia) to 152,356 tons by the Spanish-American Company, which made its first shipment in 1895, and none by the Sigua Company, which has shipped, in all, 21,533 tons. The Sigua began operations in 1892, the Spanish-American in 1885, and the Juragá in 1884. In 1897, the Spanish-American Company shipped 51,537 tons to foreign countries; bringing its total output for the year up to 203,893 tons.

Although iron ore of the best quality outcrops in many places on the estates once devoted to coffee on the southern slope of the coast range, it was not until the year 1881 that the first claim was located, or denounced. Since then more than a hundred locations have been denounced in this range (the Sierra Maestra), both to the east and the west of the city of Santiago de Cuba. Of these denouncements the most important, and in fact the only ones that have ever been worked, are to the east of the city, covering a distance of twenty odd miles along the range, a few miles in from the coast. The deposit is not continuous, but there are numerous separate deposits along this distance; some of them very extensive.

In order to encourage the mining of this ore, the Crown of Spain issued, on the 17th of April, 1883, a royal decree to the following effect: That for the period of twenty years from that date, the mining companies should be free from all tax on the surface area of all claims of iron or combustibles; that ores of all classes should be free from all export taxes; that coal brought in by mining companies for use in their work should be free from all import taxes; that combustibles and iron ore should be exempted from the three per cent tax on raw materials; that mining and metallurgical companies should be free from all other impost; that for a period of five years the mining companies should be exempt from the payment of duties on all machinery or materials required for working and transporting the ore; that vessels entering in ballast and sailing with ore should pay a duty of five cents per ton navigation dues, and that vessels entering with cargo destined for the mining companies should pay $1.30 per ton navigation and port dues on all such cargo, and on the remainder of the cargo as per general tariff.

Under this charter the Juragá Iron Company, Limited, opened mines in Firmeza, laid a railroad twenty miles long from that point to La Cruz in Santiago Bay, where fine docks and piers were built, and in 1884 shipped the first cargo of iron ore from Cuba. The company has a fine fleet of iron steamers. The mines of this company were extensively and successfully worked, and, encouraged by this, the Spanish-American Company and the Sigua Company purchased mines to the east of the Juragá properties and at once began the work of developing them.

The Spanish-American Iron Company, incorporated under the laws of West Virginia, and owned entirely by American citizens, built four miles of standard-gauge railroad from its mines to Daiquirí Bay, about sixteen miles east of the harbor of Santiago de Cuba. Here the company constructed a steel ore-dock of 3,000 tons capacity, a landing-pier, buoys, moorings, and other harbour improvements at a cost $500,000. The work of preparing this harbor delayed the opening of the mines for shipment, and it was not until May, 1895, that the first cargo was cleared.

The Sigua Iron Company built a standard-gauge road nine miles long from its mines to Sigua Bay, and there constructed a breakwater and a wooden ore-dock. This company during the first two years of operation shipped 21,863 tons. Later the mines were closed, and during the war
between Spain and the Cubans the dock, roundhouse, locomotives, and buildings of the company at Sigua Bay were entirely destroyed in the course of an engagement between the Spanish and the Cuban forces.

“The Spanish-American Iron Company and the Juragua Iron Company remained in operation during the entire war between Spain and Cuba, and although located at the extreme outpost of Spanish troops, with Cuban forces in the immediate vicinity, maintained throughout a strict neutrality, and continued shipping ore until they were closed by order of the Spanish authorities, after the declaration of war between the United States and Spain.

“The three companies, which are the only ones that have ever operated mines in the province, represent an investment of American capital of about $8,000,000, and the two still operating have paid into the Treasury of the United States more than $2,000,000 in import duties on iron ore.

“It is interesting to note that none of the mines are worked underground. The ore outcrops on the sidehills, and the mining is in the nature of quarrying.”

The following table, compiled from data furnished by the officers of the two principal mines, is substituted for the table given by Mr. Porter:

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ECONOMIC DATA ON IRON MINES.

The iron mines of Santiago have been made the subject of a report to the Military Government, by Chas. M. Dobson, E. M. The following facts taken from this report will serve to show present equipment and methods of working the properties of the Juragua Iron Company, the Spanish-American Iron Company, the Sigua Iron Company and the Cuban Steel Ore Company.

Mines of the Juraguá Company, Limited.—The mines of the Juraguá Company are located at Firmeza, about 18 miles east of Santiago and 3 miles northeast of Siboney.
The present main workings, known as the East Mine, faces the south, has been, and is, worked in concave form, in an arc of 115 degrees. A line drawn from the termination of the arc measures 900 feet in length and 350 feet in width at the "belly," and 180 feet in height. This open working exposes the terminations of what were immense ore bodies, which have been depleted to such an extent as to leave perhaps not more than 180,000 tons in sight and probable.

The West Mine and West Mine No. 1, situated on Abundancia Hill, lying to the west of Suborence Hill, are practically exhausted. The same may be said of the other old workings. Some ore is exposed, but the economy of mining this ore is precluded by the cost of removing the enclosing débris and unmineralized rock. The ore in sight from all sources and probable, is estimated not to exceed 225,000 tons, or at the present output, the life of the mine will be about sixteen months.

The Northeast Mine is located on Reforma Hill. This mine is in its infancy of development, showing the top of a lens of ore of unknown extent, but probably not of great size, since a body of limestone on one side, and an intrusion of decomposed syenite on the other, appear to cut the ore out.

The shipping port for the Juraguá mines is at La Cruz on Santiago Bay, from whence steamers transport the ore to Baltimore, Md., consigned to the Pennsylvania Steel Company and Bethlehem Iron Works. There are eighteen miles of railroad connecting the mines at Firmeza with the high grade steel dock at La Cruz, via Siboney, besides two miles of switches and sidings, the total estimated cost of which is $185,000. This railroad construction includes five iron bridges and one wooden trestle. Rolling stock comprises 17 locomotives and 1,296 ore cars of 7 tons capacity each, or 90 cubic feet.

The wharf has no ore pockets, vessels loading directly from mine cars by movable chutes. Time of loading vessel of 3,500 tons capacity, 20 to 24 hours.

At the time of the Spanish-American War, the temporary buildings of all kinds numbered 920, but of this number sixty-six at Siboney were burned by order of the United States Military authorities, because they were supposed to be infected with yellow fever. At Siboney are located a first-class iron foundry, car repair shops, etc.

Total area of company's land, 800 acres. Total investment, $4,500,000.

In all of the mines the quarry system is employed, the product is conveyed from the West Mine by 30 inch gauge railroad by locomotives, and dumped into cars running on a gravity tramway 975 feet in length, the vertical height of which is 280 feet. The cars of this tramway are automatic dumping and discharge into the seven ton ore cars of the trunk road. All other mines are operated by a 36 inch gauge railroad, with switches into the workings. Formerly high grade switches were run into the workings, but these grades being on the ore bodies, have been removed in order to mine the ore upon which they were located.
The estimated gross production of these mines since their opening in 1884 is nearly 4,000,000 tons. Since the Spanish-American War and at the present time, the shipments of ore average 15,000 tons per month. The cost of production here is controlled largely by climatic conditions, but a fair average can be stated as follows:

Cost of mining, per ton........................................ $ 0.87
Railroad transportation, per ton (to coast)............ .515
Cost of freight by steamer, per ton................. 1.25
Cost of import duty, per ton......................... .40
Cost of royalty, per ton................................. .05

Total.............................................. $ 3.085

It will be noted that steamship freight ($1.25 per ton) is low. The reason for this is, that the Pennsylvania Steel Company have been large owners of the steamships transporting the ore, the same corporation being interested in the Juragua Company.

Mines of the Spanish-American Iron Company.—Operations on these mines commenced in 1889, when construction on the railroad was simultaneously commenced, and completed in 1892. These operations were continuous from the first given date till 1895, when the first shipment of ore was made. It is stated that over $1,000,000 were expended in preparatory work during this period. Regular shipments have been continuous since, with the exception of four months during the Spanish-American War. The most systematic methods are in force in the operation of these mines. The organization of economical methods both in mining and transportation of materials is remarkable in its perfection. Gravity is utilized at every available point, the topography of the locality lending itself in a large measure to the project of economy in this respect. Value of mining equipment, $200,000. Total area of property owned by this company, 2,895.4 acres.

Daiquirí is a sub-port of entry of Santiago de Cuba. It has a Custom House, an Inspector of Customs, a United States health officer and a post office. It is an open roadstead fifteen to sixteen miles east of the Morro Castle at the entrance to Santiago Bay. It is the port of this company, and here are located a large iron ore pier, with storage pockets to hold 3,000 tons of ore, and also a low grade wharf for merchandise. The harbor is partly sheltered from winds by a promontory to the east, and vessels can load nearly all the year. It has been found that there are about five days in the year, generally in the autumn, when vessels cannot load on account of wind and sea. There is a regular pilot stationed at Daiquirí and pilotage is compulsory. Fresh water pipes run to the iron pier and to the low grade merchandise wharf, for furnishing water to vessels.

The Daiquirí mines at present employ 600 men, and could easily find work for double that number if men could be obtained. There is no need of any one desiring employment in this district remaining idle,
The main workings, or those from which the larger part of the ore has been extracted, are confined to a hill known as Lola Hill, situated about seven kilometers from the ocean, in the foothills about seven kilometers from the ocean, in the southeast of the Sierra Maestra. The altitude of this hill at the summit is 1,025 feet. There extends from the southeast face of the hill, in an arc of 180 degrees toward the west, and continuing to the northwest reverse of the hill, a massive lens of hematite ore, practically free from deleterious matter. From this ore body one million tons of high grade Bessemer ore have been mined and shipped.

The ore body on the northwest side of Lola Hill (Magdalena Mine) is mixed hematite and magnetite, in proportions of 66 per cent. magnetite; 34 per cent. hematite. On the southerly face little magnetite is found. (1)

Along the contour of the hill at an arc of 180 degrees, and in the direction aforedescribed, four benches or tiers have been cut, each tier exposing faces of ore; each tier or bench being about forty feet in height and forty feet in width. These tiers are worked simultaneously, and the ore conveyed by locomotives along a narrow gauge railroad to ore pockets at the head of an inclined gravity tramway.

The ore body maintains an average width of 150 feet from the face of its periphery to what may be termed its hanging wall. This condition has been proven to a depth of 200 feet by open workings. At the southeast base of these operations in the Lola Mine, a shaft has been sunk which develops the continuity of the lens to an additional depth of 50 feet, bottoming in ore. This development added to the workings above the floor of the mine shows a continuous body of ore 250 feet in height.

The life of the mine at this point, beyond the ore developed and in sight, cannot be estimated with any reliability, as the volume of the deposit is unknown. Only exploration by shafts and tunnels or core drills can determine this. It is fair to say, however, that it will take many years to exhaust the ore in sight and prospective, at the present rate of production. An approximate estimate of ore in sight and developed, calculated on a comparative cubical basis of the amount extracted, will probably amount to six-tenths, assuming the amount extracted to have been four-tenths.

Extensive preparations are being made by this company to operate other deposits in the immediate vicinity. The Providencia Mine, situated in the San Rafael claim, located on Providencia Hill, is the newest of this company's mines. An inclined tramway has been constructed and the ore body exposed, which, although smaller than the Lola and the Magdalena, is a very promising deposit.

Providencia Hill is situated one mile in a southeasterly direction from Lola Hill. The openings expose a lenticular mass of hematite of unknown volume. The altitude of the apex of this

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(1) While studying the ore at Daiquiri I made many tests with the magnet and found no ore that were not strongly attracted by it. A. C. S.
ore body is 1,050 feet. The trend of the edge of the ore outcrops is north 12 degrees east. The hill is heavily timbered with small mahogany, jaguey and other hard woods. A track has been extended from the main ore pockets or chutes at the base of the Lola Hill to the base of Providencia Hill, and the improvements in opening up this new mine have cost $20,000.

Other mining possessions of this company are known as the Barcelona, the Fausto Group, three miles south of Sigua, which includes Fausto 1st, Fausto 2d, Falconera Bufera and three fractional claims.

The Berraco group consists of the Ave María, Trinidad, California and Nueva Caridad mines. A railroad survey is complete from Daiquirí to the new mines, connecting with the main line, to the seaboard. Length of the new line seven miles.

In the markets of the United States the ore mined at these and other mines of this district is subject to fluctuation.

At the present time (January, 1901) it is worth a fraction over seven cents per unit of iron contents, but has been as low as four cents per unit. There is an import tax of forty cents per ton on these ores into the United States, thirty-eight cents per ton of which is allowed as a bonus to the United States exporter of the manufactured production from these ores.

Steam shovels are used to remove the alluvial soil and débris covering the apex of the ore bodies. For the removal of the ore the ordinary methods of hand and steam drilling and blasting with dynamite and black powder are employed. The whole operation is one of quarrying and is not mining in the ordinary sense of the word.

Narrow gauge fantailed railroad tracks are laid in the excavations and the ore loaded on pitcars and conveyed by donkey locomotives to ore pockets at the head of two balanced gravity tramways 1400 feet in length. The vertical height of the mine pockets at the head of the tramways is about 400 feet above the discharge pockets at the standard gauge railroad track below. The tram cars are self-dumping into the ore pockets, from which railroad cars having a capacity of 24 tons each receive their load. The ore is then conveyed over a standard gauge railroad six kilometers in length, in trains of about 400 tons each, to ore pockets at the seaboard. These pockets have a combined storage capacity of 700 tons. The steel dock has a capacity of 3,000 tons and at it vessels drawing 24 feet can load.

Besides, there is direct connection by switches and "Ys" from the reserve pockets, which have a capacity of 4,000 tons.

Some representative analyses are appended.

Average of four levels in Lola Mine:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>62.29</td>
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<tr>
<td>Phos.</td>
<td>0.036</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.082</td>
</tr>
<tr>
<td>Copper</td>
<td>trace</td>
</tr>
</tbody>
</table>
Average of 12 samples from second level in Lola mine:

- Iron: 65.92
- Phos: .0218
- Sulphur: .030
- Copper: .33

Average of 132 samples from mines at Daiquiri:

- Iron: 63.07
- Phos: .0305
- Sulphur: .454
- Copper: .129

Analysis of Average Sample, 1896:

- Metallic Iron: 63.050 per cent.
- Metallic Manganese: .062
- Metallic Copper: .016
- Metallic Titanium: .007
- Sulphur: .048
- Phosphorus: .025
- Alumina: .821
- Lime: .890
- Magnesia: .259
- Silica: 7.585

Average moisture in ore in natural condition, 71%.

Analysis of Average Sample, 1897:

- Metallic Iron: 63.100 per cent.
- Metallic Manganese: .097
- Metallic Copper: .056
- Sulphur: .072
- Phosphorus: .029
- Alumina: .712
- Lime: 1.060
- Magnesia: .381
- Silica: 7.225

Average moisture in ore in natural condition, 75%.

*Mines of the Sigua Iron Company, Limited.*—The mines of the Sigua Iron Company are located on the south side of the Sierra Maestra several miles back from the seaport of Sigua, about 33 miles east of Morro Castle. They are connected with Sigua by a railroad about 12 miles in length, which was built in 1891. The first ore was shipped in 1892, but operations were suspended in 1893.

The buildings and pier at Sigua were practically destroyed during the insurrection of 1897, but the buildings at the mines are in good condition; they are nearly fifty in number. Nearly all the trestles and bridges on the railroad have been burned, and the grade is in very poor condition.

From a personal examination it was concluded that the greater part of the ore that was shipped by the Sigua Company was derived from surface float. In the neighborhood of 60 tunnels,
having in some cases a length of 40 feet, were driven in the
search for ore bodies, but none of demonstrated importance seem
to have been developed. Recently parties have made some open-
ings which show masses of ore about 20 feet in thickness, and
with further development these may prove to be of value.

It is estimated that explorations to demonstrate the value
or worthlessness of the Sigua mines would cost not less than
$100,000 or $150,000.

The Mines of the Cuba Steel Ore Company.—These mines are sit-
uated at Guamá, 37 miles (by sea) and 72 miles (by trail) west
of Santiago de Cuba. The town of Guamá is connected with the
seaport known as Chirivico by a standard gauge railroad, and is
about midway between Chirivico and the mine locations. The
railroad was built for the purpose of transporting ore from these
mine locations to the seacoast. At Chirivico there are two
wharves, one a steel ore dock 1,000 feet in length adapted for the
purpose of loading vessels at all tides. The other wharf is of low
grade and is used as a landing for light draught vessels leased
by the company for direct communication with Santiago. The
approach to the ore dock is by means of a viaduct 500 feet long
built on steel towers, and the dock extends 500 feet into the sea.
The latter is built upon creosoted piles, and is a masterly piece
of steel frame construction. Both dock and viaduct were built
by the Pennsylvania Steel Company under a private contract
with the Cuban Ore Company, said to be on a basis of 10% of
cost. The former concern supplied their own skilled labor and
the estimated cost is close to $150,000.

The railroad between the dock and the mines is six miles in
length, and is laid with steel rails weighing 80 lbs. to the yard;
its heaviest grade does not exceed 2 1/2%. There are four trestles
aggregating 640 feet in length and three iron bridges, the largest
of which crosses the Guamá River with three spans. It is esti-
ated that the construction of this road cost $65,000 per mile.
The equipment consists at the present time of two 80 ton
Baldwin engines, one 55 ton Baldwin engine, two 8 ton 30 inch
gauge engines and one hundred ore cars of 40 tons capacity
each. This property is all on the ground and in operation. The
road is the best equipped and the finest piece of railroad work
in the Island of Cuba.

The "Victoria" mine is situated one mile from the terminus
of the standard gauge railroad. It has an elevation of about 700
feet above the pockets, into which it is proposed to convey the
ore to a point 265 feet below by means of an inclined plane 900
feet in length. From this point it is to be carried by a narrow
gauge railroad system around the graded contour of a mountain
distance of one and a quarter miles. Thence it will be lowered
by means of another incline to the main track, 365 feet below.

The Cuban Steel Ore Company has acquired in fee simple the
title to 1,500 acres of land in the vicinity of the mines, but the
mining rights are owned by Mr. F. Bacardi of Santiago, to
whom a royalty of ten cents per ton is paid.

At Guamá there is a town of about 30 houses, and at Chiri-
FIG. 9.—Diagramatic geologic section through iron ore zone from the South Coast to the Sierra Maestra.

1. Diorite.
2. Diorite-porphyry.
3. Iron ore and enclosing schists.
4. Basalt, tuffs, and limestone breccia.
5. Coarse, acid, volcanic breccias.
vico there are 20 more, all the property of the company. They include offices, dwellings, barracks, store-houses, machine shops and engine sheds. There is a telephone from the mines to Santiago. The company is reported to have expended between $1,250,000 and $1,750,000 in developing this property.

The amount of ore in the Guamá region is certainly very great, but it is not yet proved beyond a doubt that the different ore bodies are of the size to make the enterprise of mining them a commercial success.

The analyses of the ores show them to be of equal value with those of the other mines of the Santiago region. The above extracts from Mr. Dobson's report give a fair idea of the commercial aspects of these iron ore deposits, as well as the present condition of development and equipment of the mines. As it was impossible during the recent reconnoissance for members of our party to visit all of the deposits, special study was given to those which it was believed would throw most light on the origin and geological relations of the ores and also develop the best method of future prospecting.

Geological Relations.—The coast from Siboney to Sigua is bordered by a line of hills which, although cut through at intervals by stream valleys, forms a barrier between the sea and a region of lowland in front of the foothills of the Sierra Maestra. The tops of these hills and their seaward slope is covered by a thin veneer of recent coral limestone, evidently deposited during a period of gradual uplift of the land. The landward slope and much of the adjacent country is occupied by a coarse-grained quartz diorite, which is well exposed beneath the limestone at the Playa where the ore docks of the Daiquirí mines are located. Back of this belt of diorite, which has a width of about three miles, and covering the low ground back of the coastal barrier as well as the lower foothills of the Sierra Maestra, there is a zone characterized by intrusive masses of porphyry. Near the southern edge of this zone, the porphyry occurs in the form of extremely irregular dikes and these dikes become larger and more numerous in the higher foothills to the north. It is within these foothills that the iron ore occurs. Above them the slopes of the Sierra Maestra are composed of bedded volcanic rocks with a few intercalated beds of limestone or limestone breccia. The lower flows are of a basaltic nature, but some of the uppermost are rhyolitic, while upon the top of the mountain the massive rocks are overlaid by rhyolitic breccias, which constitute the base of a series of fragmental volcanic rocks occupying the northern slope of the range. These features are indicated in the accompanying diagram (figure 9), which represents also the general geology and structure of the Sierra Maestra from Cabo Cruz to the vicinity of Guantánamo Bay.

Description and Origin of the Iron Ores.—The iron-bearing rocks occupy a zone along the foothills or upon the southern slopes of the mountains, between a belt of granular diorite on the south and a series of volcanic flows on the north. In the mines at Firmeza the ores are associated with hornblende and epidote
schists, and crystalline limestone or marble. All these rocks and the associated iron ores as well are penetrated in a very irregular way by dikes or stocks of the same porphyry that cuts the diorite, and they are thus broken up into irregular blocks. The relations between the ore and the metamorphic rocks is such that the origin of the former is probably to be connected with the chemical changes to which the latter were subjected at the time of their metamorphism, though there are some facts which point to the possibility that the magnetites may be of magnetic origin. The porphyry alone, of the two varieties of igneous rock, has been seen in contact with the schists and ores, and the nature of the schist inclusions in the porphyry shows definitely that its laminated structure is of earlier origin than the date of the porphyry intrusion. It is possible, however, that the ores have originated within the schists and limestones from contact metamorphism due to the diorite, but no data are available to prove or disprove this suggestion, as all the relations observed would as naturally occur if the ore had originated entirely previous to the intrusion.

In the few cases where schist and ore were seen in contact there is rather rapid gradation from the one into the other; and quite beyond the limits of what could be designated lean ore, there are segregations of magnetite and epidote which have the appearance of being secondary in the hornblende schist, as illustrated in figure 10, taken from a sketch made while studying the "East Mine" at Firmeza.

Evidence against the origin of the ore as the result of differentiation from the porphyry during the period of its cooling and at the same time against its origin as the result of contact metamorphism due to the porphyry is seen in the clear cut surfaces where the porphyry and ore come in contact, and in the narrow dikes of porphyry cutting the ore, and proving the subsequent intrusion of the porphyry.

The relations of the ore in the "Northeast Mine" of the Jurguá Company is illustrated in figure 11. At this place the magnetite seems to be an intrusive dike cutting across a mass of crystalline limestone into which it sends a short apophysis. Specimens collected along the periphery of the invading arm show a rather rapid gradation from the pure magnetite to the marble, leaving a doubt as to whether the ore is a replacement of the limestone or is, as it appears, the result of igneous intrusion. If the latter supposition is correct two alternatives remain; one, that the ore is a replacement of some igneous rock; the other, that it represents an extreme basic differentiation of an igneous magma. In the latter case its occurrence in the form of a dike is of extreme interest, since hitherto it seems that iron ores of original igneous origin have only been found associated with the gabbroic magmas from which they have been differentiated. The absence of any true gabbros in this region is perhaps an a priori reason for doubting the origin suggested, but the diorites approach gabbros in their composition, showing even some of the structural features characteristic of gabbros, as, for instance,
FIG. 10.—Magnetite and epidote near ore body in East Mine, Firmeza.

Fig. 11.—Section through small ore body in North East Mine of Juraguá Company.

a. Magnetite.
b. Selvage impregnated with chalcopyrite.
c. White marble belonging to the schist series.
d. Fine-grained porphyry.
FIG. 12—Working face of Lola Mine, showing general relations of ore-body to enclosing porphyry.
FIG. 13.—GENERALIZED VERTICAL PROJECTION OF MAGDALENA ORE-BODY AT DAQUIRI, TO ILLUSTRATE INTRUSION OF IGNEOUS ROCK.
a poecilitic arrangement of constituent minerals. Magnetite, occurring in the form of dikes cutting a country rock of metamorphosed calcareous nature, was again observed in the trial workings at Berraco, and here the indications are strongly suggestive of an intrusive origin. The age relations of the porphyry dikes, shown in the illustration (figure 11), is corroborated by the similar features brought out in the following discussion of the Lola and Magdalena ore bodies.

In the mines at Daiquirí there are but small amounts of schist and no limestone, the ore in this locality occurring enclosed in the porphyry unaccompanied by these rocks. Dikes of the porphyry also penetrate the magnetite and cross from one side of the ore bodies to the other. The narrow dikes are sometimes handed along the contacts with the ore, through rapid cooling during the injection of the molten rock. These penetrating dikes are of the same rock and continuous with the surrounding porphyry, the only difference being a greater density; a fact which proves beyond all doubt the subsequent origin of the porphyry. These features are illustrated in the diagrams representing the ore bodies in the Lola and Magdalena mines, figures 12 and 13, in which the clear-cut contacts of the ore and porphyry are not at all exaggerated, since there is in these mines absolutely no gradation between the ore and country rock.

The suggestion that the magnetite may have resulted from magmatic differentiation of the lava from which the porphyry was derived is precluded by the late intrusion of the porphyry. If it is of metamorphic origin it may be connected, as already suggested, with the diorite intrusion, though from the known occurrence, in other parts of Cuba, of magnetic iron ores which are of a magmatic origin it is possible that the Santiago ores have been formed in the same way.

An interesting feature of the iron mines is the occurrence of copper pyrites in the form of impregnations of the narrow dikes of porphyry of the ore itself. In the locality illustrated in figure 4, there is a well-defined fissure between the magnetite and the marble, filled with copper pyrites, which is also disseminated in the magnetite adjacent to the fissure. None of these veins has yielded any important amount of copper ore.

From observations made by the writer in other parts of the island it seems probable that the schist series, in which the ores occur, can be correlated with other metamorphic rocks which are older than the serpentines, by which they are intruded and which underlie all of the unmetamorphosed sedimentary rocks of Cuba. The eruption of the diorite and porphyry occurred at a period previous to the Oligocene Tertiary, as shown by fossils of that age in the strata, which are younger than the igneous rocks, and which occur upon the northern slope of the Sierra Maestra.

The quantities of igneous material in the ore belt are so great that in the portion of the earth's crust which has been revealed by erosion the mass of the invading rock now surpasses that of the enclosing formation. It is perhaps not outside of the truth
to say that the schists have more of the nature of inclusions in the intruded porphyry than that they exist in the form of a matrix. See figure 9. No more striking example could be offered of the immensity of the telluric forces involved in the processes of igneous intrusion. A mass of many million tons weight floated upward by the bouyant effect of molten rock in motion from the interior toward the surface of the earth, is the only conception which adequately accounts for the mode of occurrence of the ore bodies of the Magdalena and Lola mines at Daiquirí; while, though less strikingly shown, at Firmeza it is likely that the masses of schist, marble and ore have been likewise actually suspended in the molten lava.

Upon the theory proposed it is necessary to suppose that the ore bodies of the metamorphic series were originally widely distributed and of immense size, and that the ore bodies which are now found adjacent to one another, though separated by dikes or stocks of porphyry, were formerly parts of one mass. It is certainly true that the Lola and Magdalena ore bodies were united previous to the igneous intrusion, and here the two large masses of magnetite are subdivided by dikes of medium or narrow width, showing upon a smaller scale the same relations as are exhibited by the larger masses of igneous rock. The extreme irregularity of the ore bodies within the productive zone has been the natural and unavoidable outcome of the invasion of the ore-bearing formations by igneous rock injected from below.

The original locations of the productive iron mines of the Santiago region were determined by means of the large quantities of surface ore which were found at various localities in the mineral belt. Some of these were so conspicuous that they led to very extravagant ideas on the part of the discoverers and also to overvaluation by several experts who examined the properties. Nevertheless, their development has been in the main successful and the actual significance of the surface indications can now be very closely determined. The Spanish-American Iron Company in recently opening the Ferraco Mines have made very complete underground explorations to determine the actual amount of ore available, and have found sufficient ore to warrant the construction of more than six miles of railroad to gain an outlet to their docks at Daiquirí. The superficial portion of one of these ore bodies was opened by trial pits about 15 feet in depth and was estimated by the writer to cover a hill-top approximately 150 feet square, figures which would give, according to a very rough calculation, not less than 100,000 tons of ore lying directly upon the surface of the ground.

Future explorations by the rule of thumb methods hitherto employed, can hardly prove of equal success in the future, and it is the writer's belief that careful magnetic surveys should be made of the various iron-bearing regions with a view to locating large ore bodies not indicated upon the surface, and thus prolonging the otherwise rather limited life of these important mines.

Iron Ores Outside of the Sierra Maestra.—The presence of mag-
netite and related ores in bodies of good size has been noted in various parts of Cuba within the areas covered by massive igneous rocks. Disturbance of the magnetic needle is frequently encountered by surveyors, and this phenomenon may be attributed to the presence of ores containing iron. Practically no study has been given to these occurrences, so that no idea can be formed of their prospective value. It is only known that such ores are quite widely distributed; they are entirely undeveloped, though recently some efforts have been made to exploit certain deposits occurring northwest of the city of Puerto Principe in the vicinity of the Sierra Cubitas. It is understood that the engineers who have examined the properties have made a favorable report and it is hoped that they will soon be developed.

It is probable that the magnetites of Puerto Principe Province are of magmatic origin, that is, that they have been formed as a result of segregation of iron oxide from deep-seated igneous rocks while in a molten state. Since they have not been seen it cannot be stated that this actually is their origin, but the mode in which the chrome-iron ores occur in the same general region shows them to be associated in such a way with rather basic diorites or gabbros intrusive in serpentine, that they must be considered as having originated together with, and as a part of, the invading igneous rocks.

It is probable that the same origin is to be attributed to the magnetites which have been encountered in the vicinity of Matanzas and Santa Clara. The Matanzas ore is a natural lodestone which appears to form a definite vein in serpentine country rock near the contact with the overlying beds of limestone. No excavations have been made to develop the deposit, so that no definite idea could be obtained of the amount of ore available; but the abundance of float ore along the outcrop indicates that it is continuous for several hundred feet along its length, and if the width is as great as appears from the surface indications, it could doubtless be mined with profit. The ore could be worked in open pits with a small amount of stripping and the deposit could be reached by a narrow gauge railway or surface tram without any great difficulty.

Occupying the general region between Nipe Bay and Moa Bay and somewhat back from the northern coast there is a region reaching a general elevation of from 1,500 to 2,000 feet, and occupied by serpentines and other igneous rocks. Upon the top of this sierra there are many large areas which are practically level, and these are always covered by a thick mantle of red clay which contains a large proportion of iron ore in the form of spherical pellets. Locally this material entirely replaces the clay, and the separate particles are cemented together by ferruginous materials, making a spongy mass of brown iron ore. Similar occurrences of shot and massive ore were noted upon the tops of certain hills lying to the north of the city of Puerto Principe, and following the general trend of the Sierra Cubitas. The rock in this vicinity is also serpentine, and the ores have identical characteristics with those of the region mentioned above.
Analyses were made from samples of these residual ores collected near Río Seco along the trail between Mayari and San Luis.

**ANALYSES OF FOUR CUBAN ORES.** (1)

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<th>1</th>
<th>2</th>
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<th>4</th>
</tr>
</thead>
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<tr>
<td>Silica</td>
<td>2.62</td>
<td>2.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>trace</td>
<td>present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Iron ore from Sierra Nipe near trail crossing of Río Naranjo, about 10 miles from Mayari, Santiago Province.
2. Iron ore from Sierra Nipe near Río Seco, Santiago Province.
3. Magnetic iron ore about 6 miles northwest of Matanzas.
4. Manganese ore. Strickland and Shafer's mine near line of Cuba Central Railroad, west of Ingenio Santa Ana, Santiago Province.

These residual ores are locally known as "tierra de perdigones," or "moco de herrero," signifying shot-soil and blacksmith's waste, either of which term is a very apt designation. Rodríguez Ferrer is authority for the statement that hydrated oxide of iron in the form of pellets in the soil occurs at various points in the Island. (2) The following localities are mentioned: Province of Pinar del Río, between Consolación del Sur and Candelaria; Matanzas Province, in the Sierra Morena, between Cárdenas and Sagna la Grande; Loma Iman near the city of Puerto Príncipe, and Monte Líbano north of Guantánamo, Santiago Province. The amount of these ores in various parts of the island is certainly very large and it seems not improbable that they may eventually find a market in the United States in cases where they are situated near a sufficient supply of running water for washing them free from the clay with which they are mixed.

**CHROMIUM.**

The fact that ores of chromium were present in Cuba has been noted in the geological papers of de Castro, but no specific data have been discovered concerning their value or mode of occurrence, with the exception of certain deposits occurring near Moa Bay on the northern coast of Santiago Province.

At this place there is reported to be a large amount of chromo-

(1) Analyses by L. M. Tolman, Washington, D. C.
bearing iron ore lying upon the surface of the ground, and though no samples have been seen it is likely that the mode of occurrence is similar to that of the so-called *tierra de perdigones* which is elsewhere found in large quantities, as noted in the discussion of the ores of manganese. An analysis of this ore is given by Consul Ramsden in his report to the British Government for 1892.

*Analysis of Chrome Iron Ore from the Moa Mines (1).*

<table>
<thead>
<tr>
<th>Component</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic iron</td>
<td>43.43%</td>
</tr>
<tr>
<td>Titanium oxide</td>
<td>4.09%</td>
</tr>
<tr>
<td>Silica</td>
<td>4.19%</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.21%</td>
</tr>
<tr>
<td>Chromic oxide</td>
<td>15.31%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.024%</td>
</tr>
</tbody>
</table>

This analysis has been referred to the Wilson Aluminum Company of New York who are users of chromium ores for the preparation of chromium steel by means of the electrical furnace. It was the opinion of their experts that the content of chromium was too low to allow of its use.

Other deposits of chromium in the form of chromite were observed in the Province of Puerto Príncipe. These occur in association with gabbro rocks cutting serpentine and there can be but little doubt that they have had their origin as segregations from the rock magmas with which they are found. Three localities were noted, the most promising of which is within one mile of the town of Minas on the Nuevitas and Puerto Príncipe Railway. A specimen picked up on the surface at this place was analyzed by Frederic P. Dewey, and found to contain 56.28% of chromium, showing an ore of high grade.

The mode of occurrence of the chromite renders very likely the probability that there are still other similar occurrences in the same general region, since there are large tracts over which the same favorable geological conditions prevail.

It is thought that commercially valuable deposits of chrome ore will some time be developed in this vicinity, and it is more than probable that a careful study of the areas of serpentine and associated igneous rocks in the island will reveal other occurrences quite widely distributed.

NON-METALLIC MINERAL PRODUCTS.

BITUMEN.

Asphalt and Mineral Tar.—The occurrence of mineral pitch or asphalt (1) in the Island of Cuba has been known since the time of the Conquest. In the general history of the Antilles by Oviedo, published in 1835, mention is made of a spring of pitch near the coast in the Province of Puerto Príncipe. This material was used with an admixture of grease for coating the hulls of vessels. The same author mentions the occurrence of pitch upon the shores of Havana Bay, where it was also used for a similar purpose. The presence of this mineral was noted by Humboldt, who visited the Island in 1803, and it was mentioned both in the personal narrative of his voyage and in his essay upon the Island of Cuba. It is probable that Humboldt visited some of the localities which have since become prominent as asphalt mines in the vicinity of Havana. He reports that it occurs in the serpentine rocks in the form of fissure veins. He observed also some fluid bituminous material of the nature of petroleum running out of fissures in the same rock. In 1828 La Sagra published in "Anales de Ciencias, Agricultura, Comercio y Artes," a journal formerly printed in Havana, a somewhat extended account of the occurrence of asphalt in the vicinity of Havana, and though this article has not come into our hands the general report comprised in the great work of La Sagra upon the natural history of the Island shows that the wide distribution of bituminous materials was well known at the time its author was in Cuba. Reference has also been found to a memoir on the bituminous deposits by one Navarro, published in 1829, and another by Moisant, in 1857, entitled "Memoria sobre los productos bituminosos de la Isla de Cuba." Neither of these papers, however, has come into our hands. Previous to 1837, the asphalt mines in the vicinity of Havana were visited by the geologist R. C. Taylor, and the results of his studies were published in two papers in which the material is described as bituminous coal. (2)

(1) We follow the definition given by F. V. Greene in his "Asphalt and its uses," as we can see no logical basis for the one given by Malo. Amer. Inst. Min. Eng., Trans., Vol. XVII, pp. 355-373, 1889.


Later, however, in speaking of the same localities in his Statistics of Coal, published in 1848, this author indicates that the mineral is not coal, since it occurs in a true fissure, not lying within the stratification of sedimentary rocks.

Since the publication of these notes, bitumen ranging in character from the solid form of glance pitch to that of mineral tar has been found in every province of the Island. In the following account we have given not only our own observations but have compiled such information as could be gleaned from a somewhat extensive literature. In the following discussion the deposits are treated by provinces, beginning at the west with Pinar del Río.

Province of Pinar del Río.—The most westerly locality known to us is that of Santa Elena, at Bahía Honda, which district contains unworked deposits of asphaltum of great brilliancy and purity. Asphaltum is also reported to be very abundant in the Vuelta Abajo.

The next more easterly localities are in the general vicinity of Mariel. Salterain gives the following description of these occurrences: (1)

"The mines in the same province (Pinar del Río), entitled 'Rodas Concepción' and 'Magdalena,' belonging to Don Ramón Balsinde, as well as the sugar plantations 'Cañas' and 'Tomasita,' on which these are located, at the head of the extensive Bay of Mariel. These are mines worked under the open sky, upon masses of asphalt, notable for their dimensions, especially the mine 'Magdalena' of the plantation 'Tomasita,' which measures, in the part already laid bare by the works, 12 meters of thickness, more than 100 in length, and 15 to 12 meters in depth. This mass lies in the direction of west-southwest to east-northeast, and is probably a continuation of the other two mines situated on the neighboring plantation of Cañas.

"The quantity of mineral obtained in these mines amounts to 1,000 to 1,300 tons a year, which is partly consumed on the same estate of señor Balsinde, as fuel, and the production of gas for lighting purposes.'"

Mr. Wm. Palmer says that on the rough exposed surface of the reef at Mariel are patches of asphaltum from one inch to six or eight inches in diameter, and rarely more than half an inch thick. They occur always in the higher portion of the rock between cavities and appear to have been drawn out by the heat of the sun.

One mile south of Mariel Bay is a deposit of asphaltum which has been quarried to a depth of about 50 feet. Several wagon loads were taken to the barracks of Guanajay. It is barely possible that this locality corresponds to one of the two mines above described. Mr. Palmer states that there are other occurrences of asphalt eight or ten miles to the southwest. The specimen brought by Mr. Palmer is a brownish, impure, solid asphalt.

Near the town of Banes, between Mariel and Havana, are two other mines known as "San José" and "Constancia," which are

the property of Mr. Henry L. Crawford. These mines have never been worked extensively, and according to Salterain the production scarcely reached 400 tons during the two years preceding 1883.

Province of Havana.—There were several asphalt mines operated in days gone by in this province. R. C. Taylor made a study of some of these mines and published articles, already referred to, upon them. Subsequently Salterain, in this article in the Consular Reports, described other mines. As the information contained in these reports will probably be of value to those seeking information on Cuban asphalts we have decided to copy their descriptions.

The following extract is taken from Taylor's Statistics of Coal (1).

Casualidad Mine.—Situated six miles from the city of Guanabacoa, three leagues from Havana, and two miles from the sea or place of embarkation, in a region of metamorphic and magnesian rocks, of which the most prevalent are serpentines, diorites, and euphotides, accompanied by veins of quartz, chalcedony, and often of copper, occurs the substance denominated chapapote. Instead of a coal seam in the formation appropriate to that mineral, which we had been invited to inspect, we saw in the midst of these stratified rocks, true wedge-formed veins, where they appear at the surface, but enlarging downwards to the breadth or thickness of several feet. The strike of the Casualidad vein is nearly north and south, conforming to the local range of stratification, although the general range is nearly east and west, following the direction of the Island. At the point excavated by the workmen, the vein was laid bare, to the width and depth of near forty feet, each way; its character being for that space fully developed, or sufficiently so to enable a plan and section to be constructed. At the outcrop the vein is scarcely a foot thick, but at the depth of thirty feet is enlarged to nine feet, descending nearly vertically. Thus, at the rate at which it continued to increase, in the short depth proved, it was anticipated the mass beneath must acquire enormous magnitude. Several lateral branches pass upwards from the main vein, both in its vertical and longitudinal section, all apparently ramifying from a voluminous mass below. Strictly speaking, the solid bitumen was in no case enclosed between walls, but seemed rather to occupy fissures in the ancient rocks, and cavities larger than we could venture to speculate upon. The outcrop was easily traced about two hundred to three hundred yards, but beyond this no effort had been made to prove the vein.

Miserably inadequate as was the system adopted for the extraction of this coal, we could not but infer that an enormous amount of this substance might very cheaply be obtained. Under the management then going on, all the water, as well as the materials, was hoisted up by hand, in small vessels, and conveyed to a distance by a gang of negroes; economy in labor being in no re-

spect consulted, and no kind of machinery, not even a windlass or wheelbarrow, was employed in the so-called mine.

"In regard to the arrangement of the matter of the vein itself, we noted that the asphaltum was disposed in horizontal laminae, whatever might be the inclination of the veins or branches; thus essentially differing from the usual character of coal seams, whose lamination is always parallel to the direction of the strata.

"An analysis was made by T. G. Clemson; the result is as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>34.97</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>63.00</td>
</tr>
<tr>
<td>Ashes or cinder</td>
<td>2.03</td>
</tr>
</tbody>
</table>

100.00

"Specific gravity, in three different specimens, 1.142, 1.189, 1.197. Streak—dark, powder brown.

"Externally it is of a deep jet-black; having the horizontal surface of the laminae covered with curious conchoidal markings, like the impress of a seal upon black wax. These impressions are marked with concentric, or rather with eccentric rings, not unlike the lines of growth on the flat valves or upper shells of some bivalves. They vary greatly in diameter, from only half an inch to a foot.

"A considerable quantity of this coal or asphalt we found excavated and stored; some of which had been employed by the smiths and workers of iron in Havana. From various causes, we understand that the mine has been prosecuted very feebly, and latterly has not been in operation; nor do the proprietors appear to have a ready market for the material."

The following notes concerning the mine Prosperidad, six miles from Havana on the road to Tapaste, were taken by Taylor (1) from an article published in the Diario de la Havana during the year 1842 by M. Costales.

"The substance here denominated bituminous coal is of the two varieties to which we have alluded, and is developed to a surprising extent. Two shafts have been sunk here, forty-five yards apart. In the principal one of these, the coal or chapapote was reached at the depth of seven yards, and contained therein to the depth of forty yards—the bottom of the shaft. From the four sides of this shaft four straight exploratory galleries have been conducted, in opposite directions, thirty yards in length; in all which space the mass of bitumen continues horizontally, and without any interruption. At the bottom of the shaft, or of the forty yards above mentioned, instead of sinking further in the chapapote, the miners proceeded to bore perpendicularly down, about thirteen yards more; always in coal. At four hundred yards from the principal shaft, a third pit has been sunk, which reaches the coal at the depth of fourteen yards.

(1) Loc. cit. p. 245.
The results of the exploration are these: In the small space indicated, a body of coal, asphaltum, or solid bitumen, is thus far proved to be one hundred and eighty feet in surface or horizontal extent; that is to say, and it is to be understood, so far only as had been bored without reaching the bottom. The mass is spoken of as almost horizontal; but its true form can not satisfactorily be ascertained from the foregoing data, and, moreover, the position of the stratified rocks is stated to be almost vertical.

According to the report of an English engineer, this is one of the most extraordinary mines in the world. By his account, which, however, is not particularly intelligible, the upper part was highly charged with bitumen, and was convertible into good coke. The lower portion consisted of an improved quality, being, as he thinks, less bituminous and much more compact. A railroad, we understand, has, of late, been constructed from the mine to the port.''

Salterain furnishes the following notes regarding asphalt mines in the province:

"In the Province of Havana are the mines (1) 'Santa Teresa,' 'Jesus del Potosí' and "Santa Rosa." The first is situated in the town of Las Minas, near the Bahía Railroad. It was worked by a company until 1862 by means of wells and galleries to the depth of 86 meters. Its bed consisted of a vein of excellent mineral in the serpentine formation, but whether it became exhausted, or whether proper search was not made, or from some other cause, the mine has been completely abandoned.

"Those called 'Jesus del Potosí' and 'Santa Rosa,' the property of Messrs. Clym and Gómez, border on and are located in a place called "Las Chumbas," half a league south of the station of Campo Florida, on the above-mentioned railroad and on the shores of the river Bacuranao."

"The mass or masses of asphalt taken from them are placed between the Cretaceous marl and the serpentine rocks which are found on the north, their direction being from southeast to northwest, with an approximate width of 5 to 6 meters, and extremely deep. This asphalt is quite impure, owing to the earthy matter which it contains; but, on the other hand, to the mixture of the said earthy substance is owing, without doubt, its more advantageous application as combustible in grates and retorts for the elaboration of gas, as is evidenced by various experiments made for the purpose, as also for street pavements, etc.

"The slight nature of the preparatory works hitherto established, and the necessity for others which, though not properly belonging to the mines, were indispensable to their proper working, account for the fact that no more than 500 to 700 tons have been extracted during the present year; but it is safe to say that a bed, at once abundant and easily worked, exists; besides which, one of the most indispensable conditions for cheap transporta-

tion is assumed, namely, its proximity to the railroad station of Campo Florida, distant some 15 miles from Havana.

Viscous asphalt was seen exuding along the joint planes in the syenite rock being quarried about 1½ miles southeast of Campo Florida, when that locality was visited during this reconnaissance.

At present there is one asphalt mine being operated in the Province of Havana. The mine known as Angela Elmira is located about five miles from the town of Bejucal, and is owned by the West Indies Company, whose offices are in New York, and of which Mr. Charles F. Wiebusch is Treasurer. Work was begun in December, 1900, and the first shipment to the States was made in January, 1901, since which time there have been regular shipments, the entire output being distributed in the United States. This was an old mine operated previous to the last war of insurrection. It was closed down by the Spanish authorities, according to report, and after the establishment of peace the property was procured by the present owners and work was resumed.

The material occurs as a body of very considerable size in limestone. It is hard asphalt, with from 70 to 72 per cent. of bitumen, which is composed of about half and half of so-called "asphaltene" and "petrolene." The above data and the following analysis were furnished us by Mr. Wiebusch.

*Analysis of Asphalt from Mine Angela Elmira.*

By Dr. L. Saarbach

In 100 parts.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture and volatile at 60° C.</td>
<td>2.4</td>
</tr>
<tr>
<td>Petrolene</td>
<td>34.6</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td>38.1</td>
</tr>
<tr>
<td>Non-bituminous organic matter</td>
<td>5.4</td>
</tr>
<tr>
<td>Silica</td>
<td>10.2</td>
</tr>
<tr>
<td>Oxides of iron and aluminum</td>
<td>4.9</td>
</tr>
<tr>
<td>Lime</td>
<td>1.7</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.2</td>
</tr>
<tr>
<td>Sulphur in mineral combination</td>
<td>2.4</td>
</tr>
<tr>
<td>Alkalies and undetermined</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Province of Matanzas.—Nine or ten miles northwest of Matanzas (about one mile east of north of the property known as El Recreo, now owned by Captain L. H. Mattair, U. S. A.) there is an occurrence of asphalt on the north side of a hill. The asphalt oozes out in liquid form and impregnates the surface sands and gravel, cementing them into a kind of puddingstone. It also accumulates in small quantities in some ditches which have been dug here for the purpose of testing the yield. There is no great amount of the asphalt escaping to the surface, although the yield might be materially increased by sinking a shaft on the fissure. It exudes apparently from small fissures in the serpentine near its contact with a hard blue limestone, the serpentine forming the hill above and the limestone lying on its
lower flank. The latter rock has no perceptible odor of asphalt or petroleum, and therefore probably has no association with the origin of the bituminous material.

Another reported occurrence of asphalt is in the vicinity of Guamacaro between the towns of Limonar and Cárdenas. This locality was not visited nor have we been able to obtain any descriptions of the occurrences.

J. L. Hance (1) has published a rather detailed account of the asphalt deposits in Cárdenas Bay and the following extracts are here reproduced:

"The asphalt deposits in this consular district (Cárdenas, Cuba) are nearly all submarine and situated in the bay of Cárdenas. It is not known that any scientific examination into their source has been made. This territory, being of limestone formation, has very extensive subterranean passages. On each side of the city are undergrown streams of fresh water of such magnitude that they are generally described here as rivers. They are the source of the supply of potable water for the city, and they provide all the water consumed in the numerous sugar boiling establishments and other manufacturing enterprises of the place. As the mines in the bay are slowly, but continually, resupplied with asphalt, it seems very probable that the source of this product is inland, and its course to the bay is through these subterranean passages. As no thorough search has been made in the bay for the asphalt, there is a great likelihood of the discovery of deposits other than those which are now known.

"As regards inland deposits, I am informed by a gentleman residing here, whose character is perfectly trustworthy, that he has discovered one within 15 miles of a railroad station, with good facilities for the construction and operation of a road and for the delivery of the product at a shipping port. This deposit is capable of yielding from 1,000 to 5,000 tons annually at slight expense and for many years, owing to the replenishment which is continually in progress. This deposit produces also an oil which has been burned in common kerosene oil lamps with good results.

"The deposits in the bay from which asphalt has been taken are four in number and of two grades. No. 1 is in the western part of the bay, and produces a very fine grade of practically pure asphalt, used in the United States for the manufacture of varnish. I have myself seen a serviceable varnish made by the simple process of dissolving this quality of asphalt in turpentine. Asphalt has been taken from this deposit in large quantities for the last twenty-one years. Recently, however, the work has not made rapid progress, owing to the frequent caving in of the sides of the shaft, which is from 80 to 125 feet in depth—varying according to the rapidity with which the asphalt is removed and replenished. A long iron bar, with a pointed end, is raised by a winch on board the lighter and allowed to fall so that its own weight detaches portions of the asphalt, which is about as friable

PLATE XX.—View at Mina Hamel, near Hato Nuevo.
PLATE XXI.—Quarry in "Cantera" limestone, between Rio Almendares and Camp Columbia, near Havana.
as cannel coal, and has much of its appearance. The gloss, however, is more brilliant. |After a sufficient quantity has been detached, a common scoop net is sent down and filled by a diver—not in a diving suit. The average quantity obtained is from a ton to a ton and a half daily. The price for this grade, delivered in New York, ranges from $80 to $125 per ton of 2,240 pounds.

"The other three mines are of a lower grade, the product being used chiefly for paving purposes, but occasionally for roofing materials. No. 2 is northeast of Cay Coupe. No work has been done there since the hurricane of 1888, which caused the shaft to be filled up with silt. Previous to that time several cargoes were taken from the deposit. Nos. 3 and 4 contain asphalt of the same grade as No. 2, and adapted for the same purposes. No. 3 is situated at the mouth of the River La Palma, about 20 miles from Cárdenas. It is in the same condition as No. 2. No. 4 is situated near Diana Cay, 15 miles from the city of Cárdenas, and is the largest of all. It is called the "Constancia Mine," and is owned by persons residing at Cárdenas. It has been under operation for more than twenty years. Probably 20,000 tons have been taken from it, and it appears practically to be inexhaustible. Vessels of from 150 to 200 tons have been moored over the deposit, and have been loaded by the joint labor of their own crews and the crew of the lighter usually engaged in this labor. The depth of water is about 12 feet. As there are several wells of no considerable depth, the facilities for procuring the asphalt are abundant. The deposit is inclosed within a circumference of about 150 feet, and the asphalt seems to be continually renewed in every part of this space. In 1882, an American vessel took on board, in the manner I have just described, over 300 tons in the space of three weeks.

"That the deposit of asphalt in the bay can be profitably worked as at present with methods seriously lacking in economy, suggests very strongly that considerable profit can be derived from the introduction of efficient machinery; the advantage would undoubtedly be increased in the case of easily accessible mines in the interior."

Near what was formerly the town of Sabanilla de la Palma, about 30 miles east of Cárdenas and some four of five miles west of Hato Nuevo, on the north side of the railroad, is the well of J. B. Hamel. This well is sunk to a depth of about 80 feet in serpentine rock and into it oozes a thick mineral tar. The material is drawn out by hand power, bucket and windlass being used. The output is about 20 barrels per day. In the vicinity of this well are two others, one about 100 yards further east, and the other about 200 yards to the west. The mode of occurrence of the material is the same. No area of limestone was discovered associated with the asphalt, but fragments were struck in the well. About a mile southwest of Mina Hamel and about 100 yards north of the railroad, is another area of natural tar wells or springs; one well is said to be 60 feet deep. Malthe has extended from it over a considerable portion of the immediately surrounding surface.
This area of mineral tar occurs within a shallow topographic basin. There are hills occurring on both the north and south sides, rising to 75 or 100 feet above the included depression. The elevation at Mina Hamel is probably not more than 25 or 30 feet. One hole in this vicinity, according to H. E. Peckham, (1) was fired during the last insurrection, and burned for four months until a heavy rain finally put it out. At present the ground for 70 or 80 feet around this hole is covered with coke. The well itself is full of rain-water, upon which floats masses of vegetation stuck together with bitumen that comes from below. A pole shoved down into the water eight or nine feet meets resistance in a soft yielding material, and if this can be brought to the surface it will be seen to be the same as that in the neighborhood. Peckham, in his article referred to, mentions several other localities. One is a tar hole near Santa Catalina plantation, some five kilometers north of east from Recreo. He refers also to the locality north of the hill on the north side of Mina Hamel, on the Victoria plantation.

In the same province, at scarcely a kilometer from the northern coast, there exists a deposit of bituminous shale impregnated with asphaltum of a high degree of purity and in great abundance, whose workings, though favored by facilities of transportation, have also been abandoned.

Province of Santa Clara.—Asphalt is reported from a fair number of localities in this Province. A considerable proportion of the data here included are taken from letters to Hon. Adam Badeau, Consul General at Havana in the years 1882 and 1883. (2) The most northwesterly locality in the province is about 15 miles northwest of Santa Clara in the direction of Sagua la Grande, near a plantation known as Indio. We have no precise data concerning the mode of occurrence or nature of this material, but we know that it is more or less liquid; whether it is a maltha or one of the more liquid petroleum's is not stated.

About nine miles northeast of Santa Clara is a mine of asphalt known as Santa Eloisa, which is being worked at present. The deposit fills a cavity in serpentine rock and has been penetrated to a depth of about 20 meters; it is about 40 meters wide and the length is not known. The material is a hard glance pitch and is used in the city of Santa Clara in the manufacture of gas. We are informed that some of the material is shipped, but to what place is unknown to us. The material is easy to mine as it needs no timbering, the roof is firm and pillars of asphalt which are left are all the support that is necessary. We are informed that this mine is owned by Juan Eulasia. The following analysis was made by Mr. Frederic P. Dewey. It is unfortunate that it was not expressed in terms of "petroleo" and "asphaltene" instead of being given as volatile matter and fixed carbon. Probably the volatile matter can be reckoned as being mostly "petroleo" and the fixed carbon will all belong to what is known as "asphaltene."

Analysis of Asphalt from Mina Santa Eloisa, Cuba.

By Frederic P. Dewey.

Moisture .................. 1.28 %
Volatile Matter ............ 45.43 %
Fixed Carbon ............... 31.75 %
Ash ......................... 21.54 %

100.00 %

There are several deposits in the vicinity of Camajuaní, about 18 miles from Santa Clara in the direction of San Juan de los Remedios. This material is more or less liquid but we do not definitely know its nature. There is another deposit of solid asphaltum three miles from Ranchuelo and 12 yards from the Sagua River. It belongs to Diego G. Abreu. We have no specific information concerning this occurrence. Two undeveloped asphalt mines are reported to be on the sugar plantation of San Antonio, owned by a man named Flagué and located about 30 miles from the town of Sagua la Grande, a railroad running through the place. Another occurrence of asphalt is reported east of Sancti Spiritus near the boundary between Santa Clara and the Province of Puerto Príncipe.

The Province of Puerto Príncipe.—In the introductory remarks on asphaltum and mineral tar it is stated that deposits of this material in the Province of Puerto Príncipe have been known for many years, but we possess no specific data concerning them. Mr. José G. Fuentes, in a letter addressed to Hon. Ramon O. Williams, (1) makes the following notes, furnished him by Mr. José Martínez:

"In Jatibonico there are four asphaltum mines, located on both sides of the River Jatibonico, in the jurisdiction of Puerto Príncipe (Morón) and Sancti-Spiritus; but they are not known in either province, because the little that has been extracted from them has been exported through Caibarien. They are close to the jurisdiction of Remedios, toward Mayajigua. On one side of the river there is a bed of asphaltum, in the jurisdiction of Morón, and in another in the same river; and toward the other side of the river, in the jurisdiction of Sancti-Spiritus, there are two others; these have never been worked, and have, indeed, only lately been opened.

"One of the beds, the one in Morón, is liquid and can be easily ignited. It is known by the name of 'Mal Nombre.' The one that offers most advantages from its abundance and quality is the one in the river; it has a beautiful color.

"The one in Morón is situated on the estate of Encarnación Leyba; the one in the river on the property of Mrs. Rita Marín; and of the two in Sancti-Spiritus, one is on the estate of Mr. N. Legón, and the other on that of Mr. José Oropesa.

"Mr. Francisco de la Calzada had these mines denounced to

the Government and obtained possession of them, but in order to avoid argument with the owners of the ground he paid them $50 a year for each caballería (33½ acres) where asphaltum was found. The said Calzada died some three years ago, and ever since the mines are almost uncared for, and even he had very little profit out of them. He brought a pump that was never set to work, being part of it in Mayajigua and the other part in Jatibonico.

"The asphaltum was taken out by means of picks and crowbars, for it was really never mined, being only worked on the surface. From the mines the asphaltum was conveyed on mules' backs as far as the road to Mayajigua, or rather to the hill of 'Los Angeles' (3 miles) and from there in carts to Rosa María (6 miles), where there is a railroad named 'Sagua and El Estero Real' (4½ miles).

"The cost of the asphaltum, from the mines to El Estero Real, is $12 per ton, but it could be done for $10 if there was anybody who would work up the mines. From El Estero Real to Caibarién or Cayo Francés the conveyance is done in lighter at $1.50. It is easier to go to Cayo Francés, as the winds are more favorable. The cost of working the mines is not known, neither the yearly yield, because, as already stated, the work done has been merely a trial.

"From the mines to El Estero Real on the coast, it is 13½ miles, and from there to Cayo Francés or Caibarién, 15 or 16 miles.

"The little asphaltum that was taken out by Calzada was sent to the United States, where it obtained a prize at the Exposition at Philadelphia.

"The market value cannot be told, as what the cost would be of extracting the mineral is not known.

"This is the only asphaltum in the place."

Province of Santiago.—The only data concerning asphalt in this province are furnished us by Mr. M. J. Martínez, of Havana. There is a deposit of solid asphalt, a glance of pitch found near Puerto Padre. This locality may be reached by going six miles south from Puerto Padre, to Ingenio San Manuel. From the latter place about two miles southwest to La Farola crossroads, thence south about one-quarter of a mile, where the asphalt is seen outcropping along the left-hand side of road. So far as we know no work has ever been done on this deposit.

General Remarks on the Mode of Occurrence of the Asphalt.—From the foregoing descriptions it is seen that all of the deposits of asphalt concerning which we have specific information occur as veins, pockets, or exuding in the form of springs, usually in serpentine rock, but occasionally in limestone. None of the material is now found in its original rock, it having come into its present position from elsewhere. It is not at present possible to state from what rock this material has been derived or to give the original place of its occurrence. It must have been derived from organic matter, which could have furnished the necessary ingredients for petroleum, as it is now believed that asphalt and mineral tar are simply residual products from mineral oils.
Commercial Value of the Deposits.—The data which have here been presented show that the bituminous substances, asphalt and mineral tar, occur from place to place in every province of Cuba. In some localities there is promise of fairly large quantities. Much of the material can undoubtedly be used in the manufacture of varnish and insulating purposes, but the practicability of its use for other purposes is at present a somewhat undecided question. Apparently in the glance pitch the proportion of "asphaltene" is too high, so the material does not possess sufficient cementing qualities to be of value for paving, roofing, or asphalt cement. Some of the material evidently possesses large amounts of "petrolene," but whether it is in stable chemical combination must be determined. It is suggested that the glance pitches which contain large proportions of "asphaltene" might be mixed with maltha, which contains a large proportion of "petrolene." In undertaking any commercial handling of the Cuban asphalts and maltha there should first be an extremely careful examination of the deposits to determine the quantity that probably can be procured. If it is proven that a property possesses a sufficient quantity of material, then it should be chemically studied with great care to determine the precise uses to which it can be put. Therefore, although we consider these bituminous substances as offering an inviting field for the investment of capital, it is suggested that any company which contemplates making such an investment should proceed with the very greatest care.

PETROLEUM.

The existence of petroleum in Cuba has been known for many years. R. C. Taylor in his Statistics of Coal, (1) makes some general remarks on the occurrence of such substances in the Island. He does not separate maltha from the more liquid mineral oils, so we are not able to distinguish precisely what he meant.

The only occurrences of petroleum of which we have positive reports are in the provinces of Matanzas and Santa Clara. Saltarin, (2) in his article on "Asphalt and Bituminous Oil in the Island of Cuba," states that there is a mine of bituminous oil in the district of Lagunillas, Province of Matanzas, there or four leagues southwest of Cárdenas. "Its yield has not been great during the last few years, not reaching more than 70 liters daily, which flow from the sides and bottom of a well 35 meters in depth; but there is now a company preparing a preliminary boring in the hope of increasing the yield. This oil contains a great quantity of the bituminous element, and requires one or two classifications for the extraction of petroleum, the principal object proposed by the company referred to." This locality apparently is the one described by Peckham in his article on the

(1) Phila., 1848, pp. 246-247.
(2) U. S. Consular Reports, Vol., X., 1883, p. 75.
"Bituminous deposits" situated at the south and east of Cárdenas," Cuba. (1) Peckham states that several wells have been bored on the plantation formerly owned by a man named Alvarez and associates. It has been about five years since anything has been done here. While drilling a well some 78 feet deep, for water, a black thick oil was found rendering the water unfit for drinking purposes. A second well was sunk somewhat further to the west. There was some oil in this well but the water was potable, and was used. Alvarez conceived the idea of drilling a well for mineral oil. An engineer and the necessary machinery was secured and a well, No. 3, was drilled. A large hole was put down to a depth of about 25 feet, and a two inch pipe was driven down 500 feet, at which depth oil was obtained. From this well 100,000 gallons were pumped out but the well would yield no more. An unsuccessful attempt was made to drill this well deeper, in the hope of procuring more oil. An attempt was made to drill another well but this also proved a failure. Further plans were being made for additional drillings when the last war between Spain and Cuban insurgents broke out. The refineries of Alvarez were burned and nothing has been done since.

In the western portion of the Province of Santa Clara is a naphtha well known as Mina Motembo. Salterain (2) has given the history, which we copy below, of the borings made here:

"Nevertheless, the works accomplished and the discovery of deposits of naphtha oil in the mine called 'San Juan,' situated in the province of Santa Clara, district of San José de los Ramos, hacienda 'Motembo,' distant more than three leagues north of the railroad station, San José de los Ramos, and about as far from the coast, are of great importance and worthy of special mention.

"For some time attention had been directed to the fact that at many points of this locality hydrocarburated gas was escaping, and with the object of investigating the circumstances Don Manuel del Cueto obtained the requisite permission from the government general, and in the year 1880 established a boring. After several attempts, which were ineffectual because of his little experience in this class of operations, he discovered. August 18, 1881, at the depth of 95 meters, a deposit of naphtha oil of extraordinary purity, which yielded some 25 gallons daily. Its special characteristics are that it is colorless, transparent as the clearest water, easily inflamable, and leaves no sensible residue after its complete combustion; its density is 0.754, it boils at a temperature of 85°, and dissolves asphaltum and resinous matter, and, in fine, possesses the characteristics of a naphtha of the rarest and most exceptional limpidity and purity.

"In the hope of obtaining greater quantities of the oil the boring was continued, and at the depth of 748 meters another deposit of the same substance was discovered with a yield of 250 gallons daily.

"This yield, however, soon diminishing, it was determined to continue the boring; but the operation unfortunately had to be discontinued at the depth of 300 meters, and at a time when the escape of gas was greatest, on account of the cable used for drawing up the oil, and up to the present time it has been impossible to extricate it.

"Such is the present condition of this interesting mine, but it is intended to make other borings at points where, owing to the analogous conditions, it is presumed that new deposits exist and where a favorable result is anticipated."

The locality in which these wells were bored was examined by Mr. Vaughan. The wells were bored in the bottom of a shallow topographic basin and penetrated rock which is largely of volcanic origin. A portion of a well core consisted very largely of volcanic glass and other volcanic material. In the hills surrounding this basin are masses of serpentine. At present the only use being made of the naphtha is for the household purposes of a family living near by. The naphtha is piped from one well to this house, and, as it is very volatile, it is used for furnishing artificial light and in cooking. The pressure is very slight. No gas or oil is emitted from the second well.

There is a reported occurrence of one of the light petroleums from a place some three or four miles west of Santa Clara. This place was visited and a filled up well, at present only some three or four feet in depth, was seen. There was no evidence of the existence of petroleum at that place.

Dr. H. N. Stokes of the United States Geological Survey examined a petroleum from Santa Clara, and has published an elaborate analysis of it (1). The following is extracted from this article:

"At Santa Clara, Cuba, there is a spring known as the Sandalwood Spring, from which issues with the water a certain amount of petroleum, which, from its peculiar odor, is called 'sandalina,' or sandalwood oil, although it more closely resembles the odor of cedar. The oil is collected from the surface of the water, and used as illuminating oil and for other purposes without being refined. About two litres of this oil were sent to the laboratory of the U. S. Geological Survey by Mr. C. W. Cunningham, and it examination gave the results described below.

"The oil, which its about as viscous as strong sulphuric acid, is somewhat turbid from suspended water, but when dried over calcium chloride it is perfectly transparent, amber colored, and shows the merest trace of bluish-green fluoresence. Its odor, as above mentioned, is agreeable, and in no way suggestive of even refined American petroleums, but rather of cedar wood. The specific gravity at 33/33° is 0.901.

* * * * *

"The results obtained may be thus summed up: Sandalina is characterized by its peculiar odor, suggesting cedar wood; by

the almost total absence of bodies other than hydrocarbons and by the comparative absence of such of these as boil below 230° and above 330° C., these being 3.3 and 11.3 per cent. respectively. "Paraffin wax is absent, other paraffins, if present, probably only in subordinate quantity.

"Unsaturated fatty hydrocarbons do not amount to more than 1 per cent.

"Naphthenes are present in large quantity, and probably make up the bulk of the oil. In this respect it is allied to the Russian petroleums.

"Naphthene or petroleum acids are formed and may be separated in notable quantity even in a rapidly conducted oxidation with chromic acid. The final products of oxidation are carbonic acid, acetic acid, with traces of higher homologues, and water. Small quantities of acetone were also obtained."

Besides these occurrences of petroleum vague rumors have come to us of the existence of similar oils in the Province of Santiago near the towns of Manzanillo and Guisa, but we have been unable to find confirmatory evidence of these reports, although Mr. Vaughan spent some time in studying the geology in that portion of Santiago Province.

COAL.

The occurrence of coal in Santiago Province.—The records of the Department of Mines at Santiago show that mining claims for coal lands have been denounced in three widely separated places in the province, in the valley of the Guaninicum near the Sabanilla and Maroto Railroad, at Mayarí Arriba, and in the vicinity of Baracoa. Specimens from all of these places, and also from the vicinity of Gibara, have been examined and found to be for the most part very impure. Specimens from the upper part of the Mayarí River, however, showed a coal of apparently good quality, having a cubical and somewhat conchoidal fracture, jet black color, being free from sulphur and not soiling the hands. A visit was made to this locality, where the nature of the series of rocks in which the coal occurs was well exhibited and the character of the deposits sufficiently well determined to show the strong probability that they are by no means of any economic importance.

The coal occurs at several horizons in a series of coarse sandstones and shales, all of which are more or less filled with fragments of vegetable matter. In some cases there are masses of carbonaceous material, from a few inches to a foot in length, within the sandstone itself, but the more important accumulations are found between the beds of sandstone and the strata of shale which are found underneath. These layers are, however, very inconstant and have the nature of small lenses occurring at intervals along the same horizons rather than of constant seams. The greatest thickness reported to have been discovered, so far as I could learn, was not over two or three feet, and within a few yards the coal diminishes from this maximum to less than six inches in thickness. Two analyses of the Mayarí coal made by Frederic P. Dewey of Washington, D. C., are as follows:
Analyses of two samples of coal.

<table>
<thead>
<tr>
<th></th>
<th>No. 1</th>
<th>No. 2</th>
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</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>10.48</td>
<td>13.68</td>
</tr>
<tr>
<td>Volatile combustible</td>
<td>42.70</td>
<td>49.92</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>34.82</td>
<td>35.53</td>
</tr>
<tr>
<td>Ash</td>
<td>12.00</td>
<td>2.87</td>
</tr>
</tbody>
</table>

100.00       100.00

Sulphur       1.32       0.50

Color of ash red in both cases.
Character of coke powdery.

We were unable to visit the locality of the coal in the vicinity of Gibara, but one of three samples submitted to us by parties interested was of good quality, and if the presence of such coal, in a vein above three and a half feet in thickness and of continuous occurrence, could be demonstrated, it would be of undoubted value because of its proximity to the coast and to proposed railroad lines. The geological age of the Cuban coals is still undetermined, though they are either Cretaceous or Tertiary, with the probability in favor of the former.

Doubtless there are many other localities than those noted at which the coal-bearing formations occur, and it may yet prove that there are deposits of true coal which will be of economic importance in the future, though from what has been thus far seen it is more likely that the mineral occurs in small basins rather than in continuous deposits extending over considerable areas.

**ASBESTOS.**

The occurrence of asbestos has been reported from various places in the northern part of Santiago Province, and while many samples were seen, nothing of commercial importance came to our notice, and, indeed, the nature of the rocks in the region from which the asbestos always comes makes it improbable that valuable deposits will be discovered. These rocks are serpentines which have been very much crushed by dynamic action.

**SALT IN CUBA.**

The Tertiary rocks of Cuba have been noted as saliferous at several points. In the vicinity of Santiago de Cuba there are beds of marl exposed in the cuttings of the Juraguá Iron Company's Railroad which are quite salty to the taste. Salt springs are reported in the vicinity of Bayamo, also in Santiago Province. In the vicinity of Nuevitas, Puerto Príncipe Province, salt springs are very common, and I am informed that borings made
by the U. S. Army in attempting to secure artesian water at
Nuevitas encountered salt water at various depths.

Mathew (1) reports that "The low hills upon which Cienfue-
gos is built, are composed of soft yellow rocks in beds inclined
to the southward, at an angle of about thirty degrees. Water
taken from wells sunk in this rock is strongly brackish and
bitter."

From the geological relations of these occurrences there is
reason to suppose that salt will be found very generally in many
parts of the Island where its presence is not now a matter of
record.

We understand that in places along the shore there are large
accumulations of salt in tidal pools. The high tide or winds fill
the pools with sea water, which is subsequently evaporated by
the heat of the sun, leaving a considerable accumulation of salt.
These accumulations going on through considerable time at last
become of commercial value.

**STRUCTURAL MATERIALS.**

*Building Stone.*—The several geological formations which occur
on the Island of Cuba furnish some stone suitable for building
purposes, though not in great variety or of the best quality.

In Pinar del Rio the hard blue limestone which forms the
axis of the Organos Range would doubtless make an extremely
durable building material if it could be quarried and dressed
cheaply. Its extreme hardness and fineness of grain render it
capable of taking a high polish and it may therefore be found
suitable for ornamental work. Its dark color might fit it for
use in connection with the white marble of the Isle of Pines as
floor tiling. Very large masses of this limestone admirably sit-
uated for economical quarrying were observed in the vicinity
of Vinales.

Extensive beds of soft Tertiary limestone, white, yellow or
gray in color, are found in every province of Cuba. The local
name for this material is "Cantera." It is so soft in the quarry
that it can be readily cut out and dressed into blocks of any
desired size and shape with an ordinary axe. On exposure to
the air it hardens to some extent, but always remains more or
less friable. By reason of the ease with which the cantera is
quarried and dressed it has been employed quite extensively in
the construction of dwellings and other buildings.

In some places Tertiary limestones of better quality than the
cantera are quarried, notably in the vicinity of Havana by the
Cuba Quarry Company. In Santa Clara Province, between San
Fernando and San Juan de los Yeras, is a hard whitish limestone
suitable for building purposes. In the vicinity of Santiago a
limestone is obtained which has a very pleasing grayish color
and is fairly durable. This is being used in the construction of
the new city school house.

As a more careful search is made for building stone under the stimulus of increasing demand, an abundance of stone for local needs will doubtless be found in nearly all parts of the Island.

Lime and Cement.—Much of the Tertiary limestone of the Island is nearly pure carbonate of lime and is extensively used in the manufacture of quicklime. There are no large establishments for this manufacture, but numerous small kilns supply local demands. The lime makes an excellent mortar, as is shown by its condition in many of the old Spanish buildings in Havana and elsewhere. It is quite probable that among the marly beds associated with the purer limestones some might be found having the composition requisite for making a natural cement. Only a careful examination of the limestone formations and numerous chemical analyses, both of which are beyond the scope of a reconnoissance, would definitely determine this question.

Portland cement is being manufactured at one point on the Island. A modern plant with rotary kiln has been erected by Belgian capitalists on the Rio Almendares near Havana. The lime is obtained from beds of rather pure Tertiary limestone quarried near the works. The required silica and alumina are obtained by adding the necessary amount of residual red clay, also obtained in the immediate vicinity. No analyses of the constituent materials or the resulting cement are available. Also no test of the cement were obtained, so that it is impossible to make any statement regarding its quality. It would appear that a better clay might probably be found for this purpose than that which is being used. The latter probably contains an excess of alumina and iron and is deficient in silica.

Many localities might be found on the Island equally or better adapted for cement manufacture than that in the vicinity of Havana. Lime of the required purity may be obtained at almost any point, but clay having the proper composition is less generally distributed. An important element in cost of manufacture is fuel, and since this must be imported, the available sites for cement plants are restricted to the immediate vicinity of the seaports.

Clays.—No attempt was made during the reconnoissance to study the clays of Cuba, and no publications on the subject are known to us.

A large part of the Island's surface is covered by a mantle of red clay, mostly residual, derived from the underlying limestones. This is utilized to some extent for the manufacture of brick and roofing tile. Some large brick plants are operated in the vicinity of Havana, but in general the establishments are small and the methods primitive. Away from the larger cities the demand is chiefly for tile, since this is practically the only kind of roofing used except thatch. No clays suitable for pottery or for the better class of structural products are known, although such deposits may very easily have escaped our attention.

Sand.—Since a large proportion of the surface of Cuba is occupied either by calcareous or basic magnesian rocks, neither of
which contain quartz, there is little if any good sand found on
the Island. The occasional beaches are made up chiefly of finely
comminuted fragments of shells and coral or other limestone.
This may be used for certain purposes, although it is generally
inferior to sharp quartz sand, such as occurs abundantly on the
Isle of Pines.

Road Metal.—Limestone is extensively used in Cuba for macad-
amizing roads, but as it wears out quickly under heavy traffic
it is not satisfactory. The question of getting good road metal
for use in the city of Havana has given the engineering author-
ities there considerable trouble. At last the question seems to
have been satisfactorily solved by the opening of a quarry of
Diorite about 1½ miles southeast of Campo Florido, which is
12 miles from Havana on the railroad to Matanzas. There is an
abundance of this material and it is in fairly fresh condition.
In a letter from Mr. C. E. McDowell, the general Superintend
ent, we are informed that the Insular Government has made a contract
for 20,000 tons of stone. He writes that the use of the stone on
the streets has effected improvement which is already apparent.

Besides syenite there are other igneous rocks which will make
good road metal. There are quantities of andesite and diorite-
porphyry in Santa Clara and Santiago Province. With railroad
facilities for the shipment of this material when quarried, it
could be advantageously used at many points. There are, besides
these rocks, basalts and other igneous rocks which can probably
be used to advantage in highway construction.

The following records of tests on Cuba road material were
kindly furnished us by Hon. James Wilson, Secretary of Agri-
culture.
PLATE XXIV.—Eastern Cliff, Sierra de los Caballos, Isle of Pines.
PLATE XXV.—Eastern Cliff, Sierra de los Caballos, old Marble quarry, Isle of Pines.
Character of material, Rock.
Name, Andesite.
Specific gravity, 2.7.
Weight of cubic foot, 168.8.
Pounds of water absorbed by a cubic foot, 2.2.
Department's coefficient of wear, 86.5.
Per cent of wear, 2.7.
French coefficient of wear, 15.2.
Cementing value, 337.
Recementing value, 124.
Sent, Nov. 26, 1901.

HIGHEST AND LOWEST RESULTS OBTAINED UP TO THE PRESENT DATE ON ANDESITE:

<table>
<thead>
<tr>
<th></th>
<th>Lowest</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of cubic foot</td>
<td>187.5</td>
<td>162.5</td>
</tr>
<tr>
<td>Pounds of water absorbed per cubic foot</td>
<td>1.9</td>
<td>.1</td>
</tr>
<tr>
<td>Department coefficient of wear</td>
<td>84.0</td>
<td>48.0</td>
</tr>
<tr>
<td>Per cent of wear</td>
<td>10.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Cementing value</td>
<td>.14</td>
<td>.3</td>
</tr>
</tbody>
</table>

Remarks.—As can be seen from the above figures, this rock gives a higher cementing value and resistance to wear than any rock of its class tested in this laboratory. The cementing value is excellent. It is admirably suited for any but very heavy city traffic. If used on lightly traveled country roads, a liberal covering of screenings should be used (\( \frac{3}{4} '' \)).
Chemical and mineral composition of sample of road material from Cienfuegos, Cuba.

Character of material, volcanic rock.
Name, Andesite.
Essential minerals, Feldspar (labradorite), 40 per cent.
Accessory minerals, Magnetite 5 per cent, apatite 1 per cent.
Secondary minerals, Chlorite 20 per cent, quartz 15 per cent, altered glass 15 per cent, epidote 2 per cent, calcite 2 per cent.
Soluble in hydrochloric acid, CaCO₃ 2 per cent.
Insoluble in hydrochloric acid, SiO₂ 58.96 per cent, Al₂O₃ 20 per cent, Fe₂O₃ 3.75 per cent, MgO 3.30 per cent, CaO 5.38 per cent, Na₂O 4.25 per cent, K₂O 1.37 per cent; loss on ignition 1.66 per cent. Total 98.67 per cent.
Remarks.—The original iron-bearing silicates of the rock, such as augite and possibly hornblende, are wholly replaced by chlorite and epidote with some calcite. The feldspar is partly altered to chlorite and epidote. Quartz occurs, as infiltration product, in the interstitial spaces and vesicular cavities of the ground mass. Owing to the highly weathered condition of the rock, the texture is probably loosened, although the original toughness would be in a measure restored by the secondary quartz acting as cement.
## ABRASION TEST.

<table>
<thead>
<tr>
<th></th>
<th>MATERIAL USED IN TEST.</th>
<th>SIZES OF MATERIAL AFTER TEST.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2\frac{1}{2}-1\frac{1}{4}</td>
<td>2\frac{1}{2}-1\frac{1}{4}</td>
</tr>
<tr>
<td>Inches</td>
<td>6.31-3.18</td>
<td>6.31-3.18</td>
</tr>
<tr>
<td>Centimeters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight in ounces</td>
<td>176.00</td>
<td>171.3</td>
</tr>
<tr>
<td>Weight in grams</td>
<td>5000.00</td>
<td>4865.2</td>
</tr>
<tr>
<td>Number of pieces</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Per cent.</td>
<td>100.00</td>
<td>97.3</td>
</tr>
</tbody>
</table>

Test No.: 402. Character of material: Rock.
Locality: Cienfuegos, Cuba.
Date of test: November 13, 1901. Department's coefficient of wear: 86.5
Made by French coefficient of wear: 15.2
Remarks: Percentage of wear: 2.7
Character of material, Rock.
Name, Diorite.
Specific gravity, 2.8.
Weight of cubic foot, 175.
Pounds of water absorbed by a cubic foot, .7.
Department's coefficient of wear, 82.3.
Per cent of wear, 3.5.
French coefficient of wear, 11.7.
Cementing value, 137.
Re-cementing value 88.
Sent, November 26, 1901.

HIGHEST AND LOWEST RESULTS OBTAINED UP TO THE PRESENT DATE
ON DIORITE.

<table>
<thead>
<tr>
<th></th>
<th>Highest</th>
<th>Lowest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of cubic foot</td>
<td>187.5</td>
<td>162.5</td>
</tr>
<tr>
<td>Pounds of water absorbed per cubic foot</td>
<td>1.9</td>
<td>.1</td>
</tr>
<tr>
<td>Department coefficient of wear</td>
<td>84.1</td>
<td>48.0</td>
</tr>
<tr>
<td>Per cent of wear</td>
<td>10.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Cementing value</td>
<td>14</td>
<td>.3</td>
</tr>
</tbody>
</table>

Remarks.—This rock is best suited for suburban and highway traffic, and if properly maintained, should give good results even under urban traffic. Its cementing value is the highest yet obtained for diorite.

CHEMICAL AND MINERAL COMPOSITION OF SAMPLE OF ROAD MATERIAL
FROM CAMPO FLORIDO, CUBA.

Character of material, Plutonic rock. Name, Diorite.
Essential minerals, Feldspar (andesine) 60 %, hornblende 15 %, quartz 15 %.
Accessory minerals, Magnetite and apatite 1 %.
Secondary minerals, Pyrite 5 %, Chlorite 2 %, Kaolin 2 %.
Soluble in hydrochloric acid.
Insoluble in hydrochloric acid, SiO₂ 55.93 %, Al₂O₃ 17.70 %, FeO₃ 8.79 %, CaO 8.11 %, MgO 5.90 %, K₂O 0.85 %, Na₂O 2.13 %, Loss in ignition 1.26 %. Total 100.67 %.

Remarks.—Rock is moderately coarse grained and has an even granular structure. It is but slightly weathered. The hornblende is somewhat chloritized, and the basic central portions of the feldspar crystals are partially altered to kaolin.
# Abrasion Test

**Sample No. 472.**

<table>
<thead>
<tr>
<th></th>
<th>Material Used in Test</th>
<th>Sizes of Material After Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
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<td>$\frac{1}{16} - \frac{1}{100}$</td>
</tr>
<tr>
<td>Centimeters</td>
<td>$6.31 - 3.18$</td>
<td>$\frac{1}{16} - .025$</td>
</tr>
<tr>
<td>Weight in ounces</td>
<td>176.00</td>
<td>.2</td>
</tr>
<tr>
<td>Weight in grams</td>
<td>5000.00</td>
<td>6.4</td>
</tr>
<tr>
<td>Number of pieces</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Per cent</td>
<td>100.00</td>
<td>96.5</td>
</tr>
</tbody>
</table>

Test No. 403. Character of material: Rock.
Locality: Campo Florida, Cuba.
Date of test: November 13, 1901.
Made by.

**Remarks:**

Department's coefficient of wear: 82.3.
French coefficient of wear; 11.7.
Percentage of wear: 3.5.
Character of material, Rock.
Name, Marble.
Specific gravity, 2.7.
Weight of cubic foot, 165.6.
Pounds of water absorbed by a cubic foot, 1.0.
Department's coefficient of wear, 79.5.
Per cent of wear, 4.1.
French coefficient of wear, 10.1.
Cementing value, 90.
Re-cementing value, 18.
Sent, Nov. 26, 1901.

Highest and lowest results obtained up to the present date on Marble.

<table>
<thead>
<tr>
<th></th>
<th>Highest</th>
<th>Lowest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of cubic foot</td>
<td>165.6</td>
<td>165.6</td>
</tr>
<tr>
<td>Pounds of water absorbed per cubic foot</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Department coefficient of wear</td>
<td>79.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Per cent of wear</td>
<td>17.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Cementing value</td>
<td>90</td>
<td>0</td>
</tr>
</tbody>
</table>

Remarks.—The resistance to wear of this rock is remarkably high for marble, and its cementing value is good. It should give excellent results on any but heavy traffic roads.

Chemical and mineral composition of sample of road material from Dr. F. Kohly, Habana, Cuba.

Character of material, sedimentary rock.
Name, marble.
Essential minerals: calcite 96.35 per cent, dolomite 2.63 per cent.
Accessory minerals: quartz 1 per cent, decomposed volcanic ash 0.26 per cent.
Secondary minerals.
Soluble in hydrochloric acid, CaCO₃ 97.78 per cent; MgCO₃ 1.20 per cent.
Insoluble in hydrochloric acid, SiO₂ 1 per cent, volcanic material 0.26 per cent.

Remarks.—Rock is a very compact, fine grained marble, containing in general no impurities. The analysis was made from material slightly fissured and discolored.
### ABRASION TEST.

**Sample No. 473.**

<table>
<thead>
<tr>
<th>Material Used in Test</th>
<th>Sizes of Material After Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td>21/4-11/4</td>
</tr>
<tr>
<td>Centimeters</td>
<td>6.31-3.18</td>
</tr>
<tr>
<td>Weight in ounces</td>
<td>176.00</td>
</tr>
<tr>
<td>Weight in grams</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Number of pieces</td>
<td>58</td>
</tr>
<tr>
<td>Per cent</td>
<td>100.0</td>
</tr>
</tbody>
</table>

- All under 1/16
- 1/16-1/100
- .16-.025

- All detritus

---

Test No. 404. Character of material: Rock.
Locality: Havana, Cuba.
Date of test: Nov. 13, 1901.
Made by.

**Remarks:**

- Department's coefficient of wear: 75.5.
- French coefficient of wear: 10.1.
- Percentage of wear: 4.1.
A general description of the outline of the Isle of Pines and its division into practically two islands by a morass extending across it somewhat south of its median portion, has been given in discussing the geography of Cuba. As our work on this island was confined to its northern portion, we shall not attempt a description of that part south of the ciénaga.

**TOPOGRAPHY.**

The topography of the Isle of Pines is comparatively simple. It consists essentially of a level plain above which rise numerous isolated ridges. The plain itself consists of three distinct elements: (1) A low coastal fringe, (2) elevated terraces, (3) interior plain.

(1) The coastal fringe varies in width from nothing up to four or five miles. It consists of beach sand and mangrove swamps and corresponds in all particulars to the numerous keys which lie north of the Island. Its elevation is from tide level up to ten or fifteen feet above tide. It is practically continuous about the Island except at two points on the north shore where prominent headlands extend into the sea, and along the south shore of the Island, where a heavy surf prevails and the coast is receding by reason of marine erosion.

(2) In the vicinity of Nueva Gerona and probably elsewhere on the Island a distinct sea-cut terrace is observed at an elevation of about fifty feet above tide. This is not sharply separated from the low coastal fringe, but its upper limit is very distinct, particularly where it touches the base of the ridges. Here wave-cut cliffs are commonly found and clearly indicate the origin of the terrace.

(3) By far the larger portion of the Island’s surface is made up of a nearly level plain, whose general elevation is between seventy-five and a hundred and twenty-five feet above tide. This plain has evidently been developed by sub-aerial erosion and no evidence was discovered to indicate that it has ever been covered by the sea. Considerable portions of this plain are almost perfectly level, while elsewhere its surface is gently undulating, the undulations rarely reaching more than thirty feet in height.

The streams, which are not numerous, flow in broad shallow depressions with very gentle slopes. Their channels are sharply cut, from 5 to 15 feet in depth and having a width proportionate to the size of the stream. These channels are said to be entirely filled when the streams are in flood. All of the stream channels observed are rock cut and have no flood plains. The streams reach tide level some distance from the coast and their lower portions are generally deep. Nueva Gerona is about 4 miles from the mouth of Rio de las Casas, which is navigable for small sailing craft and for the steamer which runs between Cuba and the Isle of Pines. It has ample water for much larger boats and would form a fairly good harbor except for the bar at its
mouth, on which there is only 4 or 5 feet of water. The Rio de Santa Fe on the east and the Rio de los Indios on the west coast have similar deep channels near their mouths, tide water extending from 6 to 10 miles inland. Doubtless other streams which were not examined have a similar character.

Rising abruptly from the plain above described are several isolated ridges. The most important of these are the Sierra de las Casas and Sierra de Caballos, on either side of Nueva Gerona, Sierra de la Daguilla, in the south-east portion of the Island, and the Sierra de Canada, in the western portion. These ridges are due entirely to differential erosion, being composed of more resisting rocks than those which underlie the surrounding plain. The change of the slope at their base is always abrupt, and in case of the ridges near Nueva Gerona this is accentuated by the wave-cut cliffs already mentioned. The contour of these ridges depends upon the character of the underlying rocks. In case the latter are schists, the outlines are rather smooth, but where the ridges are composed of marble, their outlines are quite rugged and the slopes are often precipitous. The Sierra de las Casas appears to be a single ridge although a deep gap nearly bisects it. On the south of this gap vertical cliffs rise several feet in height. The Sierra de Caballos is made up of three ridges, each two or three miles in length, separated by narrow gaps at the level of the surrounding plain. These ridges are not exactly in line, their axes being almost exactly north and south while the axis of the range as a whole is a few degrees east of north. This arrangement is doubtless due to the structure—probably to a system of diagonal faults—but the time at our disposal did not suffice for the working out of these details. Both sierras as well as Sierra Pequeña have bold, precipitous, rugged faces on the west and much more gentle, even slopes on the east. This also is directly connected with their structure. The ridges are formed by steeply dipping, massive beds of marble, and the rugged slopes are formed by the broken edges of these beds, while the smooth slopes coincide with the dip of the beds.

No opportunity was afforded for examining the surface south of the morass which crosses the Island from east to west. As seen from the summit of La Daguilla, this portion of the Island appears to be very similar to the northern part, except that it has fewer elevations rising above the level plain, only a single one being observed near the eastern coast.

**ROCK FORMATIONS.**

The following rock formations are differentiated in the Isle of Pines:

(1) Recent Alluvium.—This consists of beaches and and swamp deposits, which form the coastal fringe and rise but a few feet above sea level. It is composed almost entirely of quartz sand, generally gray from admixture of a small amount of some dark mineral and organic matter. There are also some reddish yellow
and gray sandy clays and some ferruginous gravels associated with the beech sand.

(2) Mal Pais Gravel.—This formation covers by far the larger part of the Island. It consists of quartz gravel, the pebbles varying from small sand grains up to two inches in diameter. The smaller pebbles from half an inch to three-quarters of an inch in diameter, are moderately well rounded and their surfaces are well polished. The larger pebbles are quite angular, although their surfaces are also frequently polished. The gravel is always deeply stained with iron and manganese, giving it a dark red or black color. It is also frequently cemented by iron into a ferruginous conglomerate, which often occurs in large boulders at the surface. The iron has not merely stained the surface of the pebbles, but has thoroughly penetrated them, giving them a red color and frequently a metallic lustre throughout. The thickness of the gravel is difficult to determine, but it probably varies from a few inches to a dozen feet. It forms the surface of the broad gentle swells which characterize the interior plain, while in the intervening depressions it is generally covered by a few inches of gray sandy loam. From the distribution and peculiar character of this gravel it is inferred that its origin is residual, and that it has never been transported any considerable distance. The rounding and polishing of the pebbles is considered to be the result of a torrential rain-fall on a surface very imperfectly protected by vegetation. The fact that only the smaller pebbles, which can be readily moved by rain, are rounded, while the larger ones are angular, is conclusive proof that the gravel has never been subjected to wave action or transported any distance by running water.

(3) Gerona Marble.—The ridges on either side of Nueva Gerona are composed of crystalline marble. It is probable also that the same material forms the Sierra Pequeña parallel to the Sierra Caballos and a few miles to the eastward; also, judging from the topography of the Sierra de Canada which was only seen at a distance. This marble is everywhere thoroughly crystalline, retaining no trace, so far as observed of the organisms which it may originally have held. The greater portion is rather coarsely crystalline, although there are some beds of fine white strata marble. The color varies from pure white to dark gray, and in some cases there is a strongly marked banding.

Owing to the thoroughly crystalline character of this rock, no evidence was obtained throwing light on its probable age. It can, however, scarcely be younger than paleozoic. In certain beds the impurities of the original limestone have recrystallized to form certain silicate minerals, chiefly fibrous hornblende. No exact measurements could be made to determine the thickness of this marble, but it was estimated to be not less than two thousand feet.

(4) Santa Fe Schist.—Associated with the Gerona marble and to some extent interbedding with it is a great mass of crystalline quartz-mica-schist. It rarely reaches the surface except in water courses, being nearly everywhere covered by the mal pais
PLATE XXIX.—Palmetto savana, southeast of Santa Fé, Isle of Pines.
Fig. 14. Sketch section from east to west through Nueva Gerona, Isle of Pines. a, Gerona marble. b, Santa Fé schist. c, Mal País gravel.
gravel. Wherever it reaches the surface it is deeply weathered to a soft yellowish, micaceous sand. In addition to the quartz and mica, some portions of the schist also contain numerous garnets, and a thoroughly disseminated black mineral, which is taken to be manganese. The more siliceous portions of the schist are banded and resemble a gneiss. The schist contains numerous veins of quartz, from several feet in thickness down to mere stringers. It is evident that these quartz veins and the siliceous bands and grains of the schist are the sources of the mal pais gravel and of the extensive deposits of beach sand surrounding the Island. Some portions of the schist are highly siliceous, forming essentially a quartzite. In the Cerro Signanea this has been extensively fractured and re-cemented by iron and quartz. It is thus rendered more resistant than other portions of the schist and forms a series of hills.

*Daguilla Diorite Schist.*—This is a dark grained rock which has been observed only in the Cerro Daguilla, although the same rock doubtless occurs elsewhere in the Island. It is evidently an intrusive basic rock, probably a diorite which has been rendered schistose along with the inclosing formations. It is extremely tough and compact, presenting a high degree of resistance to erosion. Some portions of the rock are rather massive, the schistose structure being most highly developed along the margin of the intrusive mass.

**STRUCTURE.**

The Gerona marble and Santa Fe schist are of sedimentary origin, having been originally limestone, sandstone and shale. These materials, however, have been almost entirely re-crystallized, so that in the schist all the original bedding is entirely obliterated, as well as the minor bedding of the marble. In the latter, however, the major bedding planes can be detected when observed in large masses. The Sierras de Casas and de Caballos are monoclinal ridges with easterly dips of twenty-five to thirty-five degrees and probably separated by a fault. The Sierra Pequeña appears to be a third faulted block outcropping to the eastward of the other two and parallel with them. The probable structure of this portion of the Island is indicated by the accompanying sketch, (fig. 14), which extends east and west through Nueva Gerona.

Wherever observed, the foliation of the Santa Fe schist strikes about north and south and generally dips steeply towards the east. In general, therefore, it appears that the structure of the Island consists essentially of a series of sharp faulted folds with north and south strike and steep easterly dips.

**GEOLoGIC HISTORY.**

So far as it has been made out by our brief study the later geologic history of the Island is singularly simple. Its rocks are old, probably Paleozoic, and at some remote period while still deep-
ly buried they were completely metamorphosed, the limestones converted into marble and the other sedimentary rocks as well as some intrusive rocks into schist. For a long time the Island has occupied very nearly its present position with reference to sea level—long enough for much of its surface to be worn down by subaerial erosion to a flat plain. Marine erosion has also been active and the Island has doubtless decreased in size through this agency. A slight oscillation in level has taken place in very recent time. There was an elevation, probably 100 feet or less, which persisted long enough for the streams to deepen their channels backward a few miles from the coast, but not long enough for them to accomplish any marked dissection of the old interior plain. There was then a depression, possibly equal to about half the previous elevation, so that the Island now stands some 50 feet higher than it did during the preceding long cycle in which the interior plain was formed.

The Isle of Pines is separated from Cuba by about 60 miles of sea so shallow that an elevation of less than 50 feet would establish land connection between the two, which was doubtless the condition prevailing during a part of the Pleistocene time. Yet the geologic histories of the two islands have almost nothing in common. The great depressions evidenced by extensive Cretaceous and Oligocene formations in Cuba did not affect the smaller island, nor do the equally great elevations marked by un-conformities and absence of Miocene and Pliocene in Cuba appear to have extended this far south. Further, there appears to have been no connection between the forces which produced the metamorphism in the older rocks in the two islands, for the structural axes in the Isle of Pines are almost exactly at right angles to those in Pinar del Río, the nearest part of Cuba.

MINERAL RESOURCES.

Marble.—The most important mineral resource of the Isle of Pines, so far as known, is marble. As indicated above, this rock forms two ridges, about two miles apart, which extend in a north and south direction on either side of Nueva Gerona. It presents considerable variety in texture, varying from a coarse grained rock made up of interlocking calcite crystals, which average an eighth of an inch in diameter, to a fine grained, even textured stone suitable for statuary purposes. Both the coarse and fine grained stone appears to be remarkably free from cracks or flaws, and slabs of any desired dimension could doubtless be obtained from it. The beds are from five to twenty feet in thickness, so that the size of the block to be quarried would be limited only by the purpose for which it was to be employed. The conditions for quarrying are exceptionally favorable. The ridges rise abruptly from a level plain and are almost entirely free of vegetation and soil. No stripping or other dead work would be required and the stone could be utilized from the surface of the quarry. It would doubtless be desired, if quarries were opened, to work on the bedding, although the rock generally presents no cleavage or other structure which would make this necessary.
The beds are generally sufficiently thick so that channeling machinery could be used and the rock worked in horizontal courses, if desired. The marble varies in color from pure white to dark gray, both extremes of color being observed in rock of various texture.

This marble was formerly quarried at a point about four miles from Nueva Gerona, on the eastern side of the Sierra de Caballos. A complete plant for sawing it into tiling was at one time in operation at this point, but no work has been done here for the past forty years and the machinery and buildings are in ruins.

**Manganese.**—Certain portions of the Santa Fe schist contain a large amount of disseminated manganese. In some places, as at Santa Fe and in the valley of the Río Mal País, this manganese has become concentrated, forming deposits of unknown extent, which may some time become valuable. The mineral presents considerable variety, from hard, concretionary masses to soft mud, which is now accumulating in sluggish streams and swamps. Thorough prospecting would be necessary to determine the quantity and quality of this mineral. Under present conditions it is not probable that it would prove profitable to mine.

**Iron Ore.**—In the Cerro de la Siguanea, and probably elsewhere on the Island, siliceous schist containing veins of very pure brown hematite are found. Masses of this ore are scattered over the surface in considerable abundance, but no veins of workable size were observed, the largest being only a few inches thick. In some cases the rock has been thoroughly shattered and the fragments recemented by iron oxide. The sandstone weathers out, leaving a surface composed of these veinlets of iron ore, but the material within would be too siliceous to be used. While no deposits of iron ore commercially valuable were discovered, the indications are favorable for the existence of such deposits, especially in the western portion of the Island. Only thorough prospecting can determine whether or not such deposits exist.

**Road Material.**—The Mal País gravel constitutes an excellent and abundant road material distributed through the greater portion of the Island. Wherever this gravel forms the surface, an excellent road can be made simply by ditching and crowning the surface. In the depressions and in the coastal fringe it would be necessary to transport the gravel a short distance from the higher land adjacent. The Daguilla diorite is admirably adapted for macadam and would form a smooth and very durable roadway.

**Sand.**—Wherever beaches occur about the northern portion of the Island, they are made up of sharp, white quartz sand. This would form an excellent sand for building purposes and for making artificial stone. It is also adapted for marble cutting and has been successfully used for this purpose.

**Clay.**—The terraces in the vicinity of Nueva Gerona at an altitude of fifty feet above the tide, are covered with red and gray sandy clay, and this has been utilized to a small extent for manufacturing brick and tiles. It is probable that with proper manipulation, a fairly good quality of brick could be made from this clay, although it is probably too sandy for the best grades.
APPENDIX.

ELEVATIONS ALONG RAILWAY LINES IN CUBA.

Unless it is stated that the elevations have been determined by aneroid barometer readings, they were furnished by the officials of the railway companies.

ELEVATIONS FROM HAVANA TO PINAR DEL RIO ALONG THE WESTERN RAILWAY OF HAVANA.

<table>
<thead>
<tr>
<th>Station</th>
<th>Feet</th>
<th>Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cristina Station, Havana Bench-mark</td>
<td>8.85</td>
<td>2.73</td>
</tr>
<tr>
<td>Pinos</td>
<td>161</td>
<td>48.95</td>
</tr>
<tr>
<td>Arroyo Naranjo</td>
<td>227</td>
<td>69.29</td>
</tr>
<tr>
<td>Calabazar</td>
<td>160</td>
<td>48.48</td>
</tr>
<tr>
<td>Rancho Boyeros</td>
<td>217</td>
<td>66.09</td>
</tr>
<tr>
<td>Santiago de las Vegas</td>
<td>272</td>
<td>82.98</td>
</tr>
<tr>
<td>Rincón</td>
<td>267</td>
<td>81.39</td>
</tr>
<tr>
<td>Salud</td>
<td>185</td>
<td>56.54</td>
</tr>
<tr>
<td>Gabriel</td>
<td>78</td>
<td>23.92</td>
</tr>
<tr>
<td>Guáira</td>
<td>52</td>
<td>16.00</td>
</tr>
<tr>
<td>Alquízar</td>
<td>51</td>
<td>15.59</td>
</tr>
<tr>
<td>Dagame</td>
<td>92</td>
<td>27.95</td>
</tr>
<tr>
<td>Cañas</td>
<td>97</td>
<td>29.69</td>
</tr>
<tr>
<td>Artemisa</td>
<td>75</td>
<td>22.85</td>
</tr>
<tr>
<td>Mangas</td>
<td>77</td>
<td>23.32</td>
</tr>
<tr>
<td>Punta Brava</td>
<td>74</td>
<td>22.60</td>
</tr>
<tr>
<td>Candelaria</td>
<td>135</td>
<td>41.06</td>
</tr>
<tr>
<td>San Cristóbal</td>
<td>118</td>
<td>36.00</td>
</tr>
<tr>
<td>Taco-Taco</td>
<td>98</td>
<td>29.75</td>
</tr>
<tr>
<td>Los Palacios</td>
<td>98</td>
<td>29.80</td>
</tr>
<tr>
<td>Paso Real</td>
<td>79</td>
<td>24.14</td>
</tr>
<tr>
<td>Herradura</td>
<td>114</td>
<td>34.72</td>
</tr>
<tr>
<td>Consolación del Sur</td>
<td>113</td>
<td>34.37</td>
</tr>
<tr>
<td>Puerta de Golpe</td>
<td>65</td>
<td>19.96</td>
</tr>
<tr>
<td>Las Ovas</td>
<td>61</td>
<td>18.55</td>
</tr>
<tr>
<td>Pinar del Río (rails)</td>
<td>96</td>
<td>30.60</td>
</tr>
<tr>
<td>Bench-mark, end of platform, Pinar del Río</td>
<td>103</td>
<td>31.32</td>
</tr>
</tbody>
</table>
Fig. 15. Map showing alignment of the Western Railway of Havana from Havana to Pinar del Río, with stations and their elevations in feet above sea level.
ELEVATIONS ALONG THE UNITED RAILWAYS OF HAVANA FROM HAVANA (REGLA) TO JOVELLANOS, DETERMINED BY ANEROID BAROMETER READINGS.

Regla ........................................ about .... Feet.
Minas ........................................ 120 
Campo Florido .......................... 60 
Jaruco .................................... 340 
Bainoa .................................... 290 
Aguacate ................................ 320 
Empalme .................................. 350 
Seiba Mocha ................................ 190 
Matanzas ................................... 
Gelpí ........................................ 153 
Guanábana (1) .......................... 261 
Limonar .................................... 200 
Coliseo ................................... 250 
Coliseo ................................... 250 
Jovellanos (1) ..................... 99

ELEVATIONS FROM MATANZAS TO VENERO, ALONG THE LINE OF THE MATANZAS RAILROAD COMPANY.

<table>
<thead>
<tr>
<th>Location</th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matanzas</td>
<td>153</td>
<td>46.505</td>
</tr>
<tr>
<td>Gelpí</td>
<td>261</td>
<td>79.489</td>
</tr>
<tr>
<td>Guanábana</td>
<td>352</td>
<td>107.318</td>
</tr>
<tr>
<td>Sidra</td>
<td>390</td>
<td>118.883</td>
</tr>
<tr>
<td>Union</td>
<td>165</td>
<td>50.388</td>
</tr>
<tr>
<td>Bolondrón</td>
<td>157</td>
<td>47.993</td>
</tr>
<tr>
<td>Güira</td>
<td>122</td>
<td>37.203</td>
</tr>
<tr>
<td>Navaljas</td>
<td>51</td>
<td>15.417</td>
</tr>
<tr>
<td>Corral Falso</td>
<td>60</td>
<td>18.224</td>
</tr>
<tr>
<td>Isabel</td>
<td>60</td>
<td>18.244</td>
</tr>
<tr>
<td>Cuevitas</td>
<td>98</td>
<td>29.897</td>
</tr>
<tr>
<td>Baró</td>
<td>97</td>
<td>29 709</td>
</tr>
<tr>
<td>Guareiras</td>
<td>124</td>
<td>37.922</td>
</tr>
<tr>
<td>Carrillo</td>
<td>176</td>
<td>53.626</td>
</tr>
<tr>
<td>Cumanayagua</td>
<td>112</td>
<td>34.258</td>
</tr>
<tr>
<td>Venero</td>
<td>179</td>
<td>54.622</td>
</tr>
</tbody>
</table>

ELEVATIONS ALONG THE CÁRDENAS AND JUCARO RAILWAY

From Cárdenas to Santa Clara.

<table>
<thead>
<tr>
<th>Location</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cárdenas</td>
<td>91</td>
</tr>
<tr>
<td>Contreras</td>
<td>99</td>
</tr>
<tr>
<td>Jovellanos</td>
<td>65</td>
</tr>
<tr>
<td>Quintana</td>
<td>67</td>
</tr>
</tbody>
</table>

(1) Elevations from railroad profiles.
<table>
<thead>
<tr>
<th>Location</th>
<th>Elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colón</td>
<td>138</td>
</tr>
<tr>
<td>Macagua</td>
<td>229</td>
</tr>
<tr>
<td>San Pedro</td>
<td>about 230</td>
</tr>
<tr>
<td>Alvarez</td>
<td>260</td>
</tr>
<tr>
<td>Mordazo</td>
<td>240</td>
</tr>
<tr>
<td>Manacas</td>
<td>190</td>
</tr>
<tr>
<td>Santo Domingo</td>
<td>170</td>
</tr>
<tr>
<td>Jicotea</td>
<td>240</td>
</tr>
<tr>
<td>Esperanza</td>
<td>310</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>360</td>
</tr>
</tbody>
</table>

Elevations from San Pedro to Santa Clara, inclusive, aneroid barometer readings.

**From Recreo to San José.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreo</td>
<td>57</td>
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**Elevations from Conchas to Cienfuegos, Cuban Railway. Determined by aneroid barometer.**

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Fig. 17. Map showing alignment of the Puerto Príncipe and Nuevitas Railroad, from Puerto Príncipe to Nuevitas.
ELEVATIONS ALONG THE PUERTO PRINCIPE AND NUEVITAS RAILROAD FOR EVERY KILOMETER FROM PUERTO PRINCIPE TO NUEVITAS.

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### ELEVATIONS ALONG THE SABANILLA AND MOROTO RAILWAY.

From Santiago de Cuba to San Luis.

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Santiago (rails) .......... 3.4 Feet.
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Boniato ................... 289 »
San Vicente ............... 425 »
Dos Bocas ................ 475 »
Cristo .................... 640 »
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**From Cristo to La Maya.**

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