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MANGANESE DEPOSITS OF CUBA

BY

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CONTENTS

ILLUSTRATIONS

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ABSTRACT

This preliminary report on the manganese deposits of Cuba is based on brief examinations of 168 deposits made during the winter of 1940-41. The report describes the geologic setting and classification of the deposits, and discusses their origin. It describes individual mines only insofar as they provide typical examples of the ore deposits.

Manganese has been found in every Province of Cuba, but the deposits that have been most productive and that contain the largest known reserves are in Oriente Province. The Oriente deposits lie in a broad zone about the Sierra Maestra, which consists largely of Eocene volcanic rocks and limestone; with few exceptions they are either bedrock deposits in the Eocene rocks or the superficial accumulations known as granzon.

The bedrock deposits are mainly either in tuff or in limestone. Their manganese minerals are mostly the oxides pyrolusite, psilomelane, and manganite. Much "bayate", or jasper, is associated with the ores, and zeolites are locally abundant. The manganese is thought to have been deposited by warm springs, which were active during the last stages of the Eocene volcanism that centered in the Sierra Maestra. Textural features show that the manganese oxides were in part deposited in open spaces—conduits of the spring waters and pore spaces in the rocks--and in part by replacement of the rocks. Some of the deposits are bedded and appear to be primary accumulations of manganese oxides, presumably derived from spring waters discharged into the sea. The lithologic character of these bedded ores indicates that they were deposited contemporaneously with the associated sedimentary rocks.

The granzon ore consists of nodules or pellets of the manganese oxides found in soil or subsoil near the outcrops of the bedrock deposits. It is not concentrated in streams as gravel, but appears to be most abundant in nearly level areas or playas where surface water stands intermittently or runs off slowly.

From 1888 to 1940, the Cuban deposits yielded a total of 1,237,858 long tons of manganese ore, valued at $21,386,706. The 1941 production was expected to be about 225,000 tons, and the known reserves are sufficient to maintain this rate of production for several years, providing the present high prices are maintained. Production could be increased by opening and improving roads and by introducing efficient mining and milling equipment.

INTRODUCTION

An investigation of the manganese deposits of Cuba was carried on for 5 months during the winter of 1940-41 by the Geological Survey, United States Department of the Interior. The work was sponsored by the United States Department of State and was made possible by the cooperation of the Cuban Government. Mr. Antonio Calvache, Mining Engineer Consultant for the Cuban Ministry of Agriculture, accompanied the writer throughout the study, and his knowledge of the deposits, together with his familiarity with the country and the people, greatly facilitated the work. It would be a pleasure to acknowledge each one of the many other enjoyable associations made in the course of the work, but a list of all the persons from whom courtesies and cooperation were received would be too long to publish here.

During the investigation, 168 manganese properties and groups of properties were briefly examined. The short time available did not allow the writer to map any deposit in detail nor to make an extensive study of the general geology. This paper is, therefore, in the nature of a progress report, for it is hoped that the geologic studies in the mineralized region will be continued.

The distribution of the principal districts is shown on the accompanying index map (pl. 21).

GENERAL GEOLOGY

Most of the manganese ore produced in Cuba has come from Oriente Province, which also contains most of the known reserves. Deposits are known throughout the area that lies in the southern part of Oriente and west of Guantanamo, on both the northern and southern slopes of the Sierra Maestra; others lie north and northeast of Santiago de Cuba, and there are small bodies north and east of Holguin. In Pinar del Rio Province, manganese deposits have been found in the lowlands both north and south of the Organ Mountains; the best deposits so far developed lie along the northern base of the mountains between Bahia Honda and Los Acosta. In Las Villas (Santa Clara) Province, a little ore has been developed in the north near Amaro and on the southern coast near Trinidad. Deposits on the Isla de Pinos also were examined, but they have been so little prospected that it is impossible to evaluate them. The best material seen on the island was in the eastern part, near Santa Fe. There are said to be undeveloped deposits in the Provinces of Camaguey, Mantanzas, and Habana.

Oriente Province

The Sierra Maestra, which extends along the southern coast of Oriente Province, rises abruptly from the Bartlett deep to a maximum altitude of about 6,560 feet at Pico Turquino. The range is composed largely of Eocene volcanic rocks and limestones dipping in general to the north. Along its southern base there are intrusive rocks (the Sierra Maestra batholith), the prevolcanic Vinent formation, and older metamorphic rocks. The Vinent formation, which is either Cretaceous [1] or Eocene [2] in age, consists of quartzite, conglomerate, breccia, lava flows, and limestones, and is intruded by granodiorite and other differentiates of Eocene age.[3]

The major structure of Oriente, as Hayes, Vaughan, and Spencer first pointed out, is a broad syncline with the long axis trending nearly east. The strata dip northward from the Sierra Maestra at progressively lower angles, and in the northern part of the Province the dips are southward. The synclinal structure

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1/ Taber, Stephen, Sierra Maestra of Cuba, part of the northern rim of the Bartlett Trough: Geol. Soc. America Bull., vol. 45, pp. 575-576, 1934.
Singewald, J. T., Jr., and Miller, B. L., The genesis and relations of the Daiquiri and Firmeza iron-ore deposits, Cuba: Am. Inst. Min. Met. Eng. Trans., vol. 53, p. 74, 1916.

2/ Schuchert, Charles, Historical geology of the Antillean-Caribbean region, or the lands bordering the Gulf of Mexico and the Caribbean Sea, p. 493, John Wiley & Sons, 1935.

3/ Taber, Stephen, op. cit., pp. 575-576, 591-593.

is complicated by numerous minor folds and faults, and reversals of dip are rather common. In the north the beds are in contact with extensive serpentine masses. The correlation of beds is complicated by the abrupt changes in character and the irregular distribution of the volcanic debris.

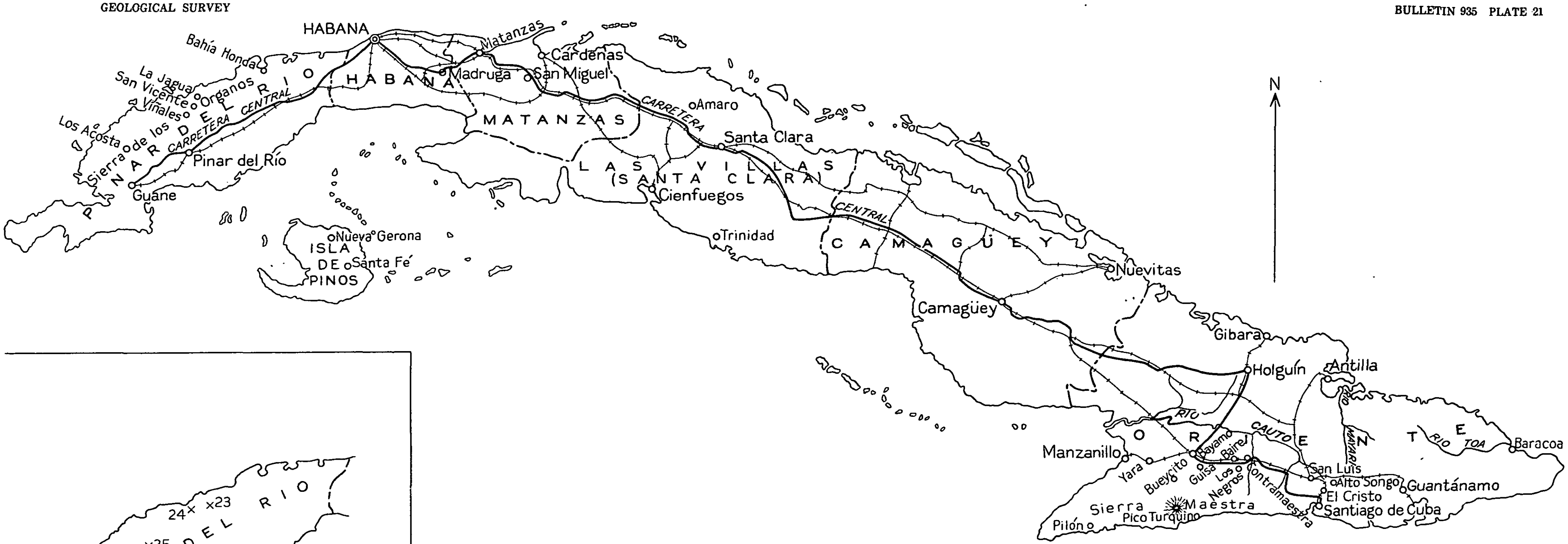
The manganese-bearing rocks of southern and central Oriente are upper Eocene volcanics interbedded with limestones. The volcanics consist principally of water-laid basaltic tuffs and agglomerates, although in the main Sierra Maestra there are flows and dikes, some of which are basaltic and some of which are rhyolitic. A basal conglomerate and accumulations of reworked shaly volcanic rocks, probably of Oligocene age,[4] overlie the Eocene volcanics.

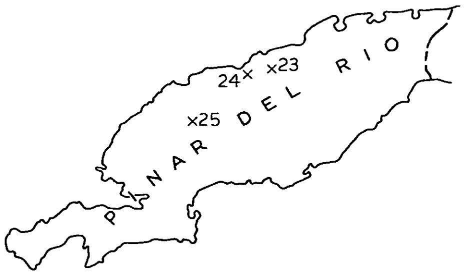
The basaltic volcanic tuff is generally somewhat altered, and contains devitrified glass and ash, quartz, feldspar, olivine, amphibole, pyroxene, and fragments of extraneous rocks, particularly limestone. Chlorite and both red and brown iron oxides are abundant in the highly altered facies, and locally manganese oxides, magnetite, cryptocrystalline silica, zeolites, calcite, and minor alteration products are developed. The texture of the tuff differs greatly from place to place. Near the northern base of the range, the rocks are predominantly fine-grained water-laid tuffs with little coarse debris and very few flows. Farther north the volcanic character of the rocks is obscure, for the tuffs grade into fine-grained shaly and limy beds, locally interlayered with sandstones. The source of much of the volcanic debris is apparently near the core of the Sierra Maestra, where flows, dikes, and coarse breccias are most abundant.

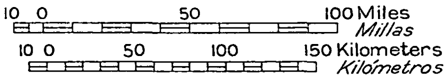
4/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., Report on a geological reconnaissance of Cuba: In Civil report of Brig. Gen. Leonard Wood, Military Governor of Cuba, for 1901. Also 4th Spanish edition, Direc. Montes, Minas y Aguas, Habana, Cuba, 1938.

Taber, Stephen, op. cit., pp. 567-620.

Lewis, J. W., Geology of Cuba: Am. Assoc. Petroleum Geologists Bull., vol. 16, pp. 533-555, 1932.



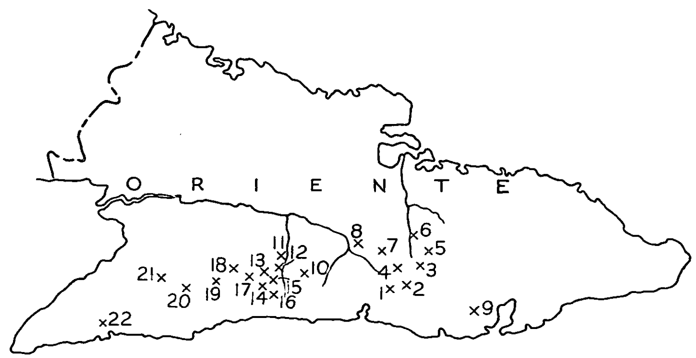




MANGANESE DISTRICTS

DISTRITOS DE MANGANESE

1. El Cristo (Quinto, Isabelita)
2. Ponupo
3. Sabanilla
4. Jutinicu
5. Valle de Manganeso
6. El Iris
7. Esperansita
8. Abundancia
9. Sigua
10. Manacas
11. La Estrella, Mafo
12. La Yeya
13. Antonio
14. Pozo Prieto
15. El Tony-La Gaceta
16. La Unica
17. Charco Redondo
18. Guisa
19. El Cádiz
20. Bueycito
21. Tamayo
22. Ponupo Manacal
23. La Cuca
24. Maceo
25. Los Acosta-Francisco



INDEX MAP OF CUBA AND LOCATION OF CUBAN MANGANESE DISTRICTS
MAPA DE CUBA INDICANDO LOS DISTRITOS DE MANGANESO

The limestone, which is locally dolomitic, is a dense gray or cream-colored rock. It is generally thin-bedded, but in places it is massive. Foraminifera of Eocene age are found in many places,[5] but no detailed study or correlation of the strata has ever been made.

Pinar del Rio Province

In Pinar del Rio most of the manganese deposits are in the shaly San Cayetano formation, but there are small bodies in the massive Vinales limestone, which forms the bulk of the picturesque Organ Mountains.

Fossils embedded in a black carbonaceous shale in the San Cayetano formation were found at a shaft at La Gloria, a manganese prospect that lies about halfway between San Vincente and La Jagua and about a kilometer east of the road. These fossils were determined by J. B. Reeside and R. W. Imlay to be perisphincted ammonites of Upper Jurassic age. This confirms Dickerson and Butt [6] in their assignment of the San Cayetano formation to a Jurassic age. The Vinales limestone lies in isolated patches on the San Cayetano formation. According to Dickerson and Butt, the Vinales is younger than the San Cayetano and rests unconformably upon it, but other geologists think that the Vinales is older than the San Cayetano [7] and have suggested that the Vinales bodies may be remnants of a plate thrust over the San Cayetano.[8]

5/ Cushman, J. A., The American species of Orthophragmina and Lepidocyclina: U. S. Geol. Survey Prof. Paper 125, pp. 39-105, 1920.

6/ Dickerson, R. E., and Butt, W. H., Cuban Jurassic: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 116-118, 1935.

De Golyer, E., The geology of Cuban petroleum deposits: Am. Assoc. Petroleum Geologists Bull., vol. 2, pp. 136-148, 1918.

7/ Metcalf, R. J., Discussion of Cuban Jurassic: Am. Assoc. Petroleum Geologists Bull., vol. 16, pp. 553-554, 1932.

8/ Palmer, R. H., personal communication 1941.

Las Villas Province and Isla de Pinos

The general geology of Las Villas (Santa Clara) Province near the manganese districts has been described briefly by Rutten [9] and by Thiadens, [10] and descriptions of the Isla de Pinos have been published by Hayes [11] and by Llaguno. [12] The rocks of Las Villas and of the Isla de Pinos are principally schists, shales, and limestones similar to the formations of Pinar del Rio and Habana [13] Provinces.

ECONOMIC GEOLOGY

Mineralogy

Manganese minerals.--Manganese ores of both chemical and metallurgical grades are mined in Cuba, but metallurgical ores are by far the more abundant. The two types occur together, and as they cannot be distinguished with certainty in the field no effort was made to study them separately.

The ores in general seem to be simple in composition. The principal ore minerals are pyrolusite (MnO_2), psilomelane ($MnO_2.Mn_2O_3$) containing up to about 5 percent barium, and manganite ($Mn_2O_3.H_2O$). Other minerals of little or no economic value that occur in the deposits are the silicates braunite ($3\ Mn_2O_3.MnSiO_3$) and orientite ($4CaO.2Mn_2O_3.5SiO_2.4H_2O$) and the gray, brown, or black, vitreous, amorphous or cryptocrystalline material included under the name of neotocite. Piedmontite, a manganese-bearing epidote, is associated with manganese oxides

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9/ Rutten, M. G., Geologia de la parte Norte de la Provincia de Santa Clara (Traduccion por los Sres. E. V. Perez y Jorge Brodermann): Direc. Montes, Minas y Aguas, Cuba, Bull. 16, pp. 5-55, 1938.
10/ Thiadens, A. A., Geologia de la parte Sur de la Provincia de Santa Clara (Traduccion por los Sres. E. V. Perez y Jorge Brodermann): Direc. Montes, Minas y Aguas, Cuba, Bull. 18, pp. 5-56, 1939.
11/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., pp. 112-117, 1901.
12/ Llaguno y de Cardenas, Pablo, La Isla de Pinos, pequeño bosquejo historico de las Isla y sus aguas medico medicinales: Habana. No date given.
13/ Brodermann, Jorge, Determinacion geologica de la Cuenca de Vento: Revista de la Sociedad Cubano de Ingenieros, vol. 34, pp. 272-315, 1940.

from Sigua, Oriente, and from a deposit near the city of Camaguey. A sample of oxide ore from the Lucrecia prospect near Amaro, Las Villás, contains 0.25 percent cobalt,[14] and prompts the suggestion that the ores should be tested for small quantities of metals, particularly cobalt and tungsten, that might be recovered as salable byproducts.

The manganese oxides range in color from brilliant silver gray to sooty black. The hardness of the ore varies widely; much of it is soft, but some specimens will scratch steel. The ore is commonly friable, botryoidal, powdery, or fibrous, and is exceedingly porous.

Other minerals.--Brown, red, and in a few places gray or black "bayate" or jasper (cryptocrystalline silica) is a common companion of the manganese ores, particularly those in tuff beds. In the ores associated with limestone in the Los Negros-Charco Redondo-Guisa areas in Oriente, jasper is commonly present in small nodules or pockets, but in general it is much less abundant in these ores than in the ores associated with tuff. The jasper is commonly associated with faults and forms the crests of arches and domes, from which the beds dip away in all directions. As the jasper weathers and disintegrates less readily than the enclosing tuffs, limestones, and shales, the larger bodies crop out as knobs or hills, and fragments of it are conspicuously scattered over the surface. The best ore near the domes is commonly covered with a rubble of jasper and with other surface debris, because it is in the softer tuff beds next to the jasper. In many of the domes, manganese-bearing veinlets and pockets are found in the jasper, and locally these are mined. The domes are numerous in the El Cristo-Alto Songo region, Oriente, where they include such well-known deposits as the Ponupo (2),[15] Isabelita (1), Sabanilla (3), and Jutinicu (4).

14/ Analysis by Michael Fleischer, Geological Survey, United States Department of the Interior.

15/ Numbers in parentheses refer to those used on the map (pl. 21).

In other deposits of Oriente, such as Abundancia (8) and Ponupo Manacal (22), the jasper is concentrated in irregular masses along faults, and the manganese ore is richest next to jasper and decreases in grade away from it. In Pinar del Rio, gray or black jasper resembling chert forms beds, generally less than 6 inches thick, or nodules distributed parallel to the bedding. This material seems to be most abundant near manganese deposits, although it is also present elsewhere. In Las Villas Province near Amaro, manganese oxides cement white or light-gray chert fragments in a breccia zone along a limestone-schist contact.

The jasper is commonly cut by veinlets of manganese oxides, but in some places manganese oxides are cut by veinlets of jasper. This is interpreted to mean that the jasper and manganese oxides were deposited in part concomitantly from the same solution. As pointed out by Spencer,[16] the fact that jasper and manganese oxides are concentrated along the tops of arches and domes indicates that they probably were derived from ascending solutions.

Many ores contain abundant zeolites. Larsen [17] found analcite, heulandite (?), and laumontite (?), and Hewett [18] found, in addition to analcite and laumontite, coarsely crystalline pectolite and chabazite in veinlets crosscutting the manganese oxides of the Bueycito ores. The zeolites, particularly where they are coarsely crystalline, are thought to have been deposited from warm water, as a result of hydrothermal action that continued after the deposition of the manganese oxides.

Black calcite, the color of which is caused by finely divided particles of manganese oxides, is widespread. Rhodochrosite, if present at all, is exceedingly rare.

16/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., p. 64.
17/ Larsen, E. S., in Burchard, E. F., Manganese-ore deposits in Cuba: Am. Inst. Min. Met. Eng. Trans., vol. 63, p. 60, 1920.
18/ Hewett, D. F., personal communication, 1941.

The manganese silicates bementite and neotocite are widespread, occurring in small quantity in many deposits, but there are many deposits in which they have not been found.

Unoxidized pyrite is associated with manganese oxides in several mines, such as the Ponupo.

The presence of chlorite and possibly glauconite causes many tuff beds in Oriente to be bright green. The green color is strikingly conspicuous in the beds a few inches below ore, though it is also present elsewhere in the tuffs.

Most manganese deposits are bordered or overlain by red tuffs and limestones, and the miners commonly associate red coloration with the presence of manganese oxides nearby. Similar red rocks occur, however, at many places where no manganese deposit is known nearby. The red rocks near the deposits may have been formed at about the same time and by the same solutions as the manganese oxides, but they are of questionable value as an aid to prospecting because they resemble the products of ordinary weathering.

Classification of the deposits

Ore deposits may be classified in various ways, depending on what is known concerning them and the purpose to be served by the classification. If the purpose is to interpret genesis, much information concerning the minerals and their relations, as well as their geologic environment, is needed. If, however, the purpose is to facilitate exploitation, emphasis may be placed upon outstanding elements of form and rock environment. The present study has yielded considerable information about the geologic environment and the form and mineralogy of the manganese deposits, but the deposits have not yet been studied with sufficient thoroughness to permit the formulation of a comprehensive genetic scheme. At this time, therefore, it seems advisable to present a classification of the deposits based primarily upon rock environment together with some consideration of the form of the workable deposits of manganese oxides.

Most of the manganese deposits fall into three principal classes:

1. Deposits in tuff. Examples: The mines near El Cristo (1) and the Bueycito mines (20), Oriente.
2. Deposits in limestone. Examples: La Unica mine (16) and Charco Redondo mine (17), Oriente.
3. Granzon, or surficial layers of manganiferous granules and pellets in soil. Examples: La Gaceta mine (15), Oriente, and La Cuca mine (23), Pinar del Rio.

Some deposits do not properly fit into any one of the three main classes, and they are, for convenience, described together as "miscellaneous deposits."

Deposits in tuff.--The deposits in tuff are the most abundant in Oriente, and they occur throughout the mineralized area of that Province. These deposits consist of grains, nodules, pockets, and veinlets of manganese oxides irregularly distributed through beds of altered tuff. Their form is essentially tabular. In many of the ore bodies the matrix is soft, soapy, pinkish or reddish material, described by Larsen [19] as kaolinite (?), with some of the zeolites analcite, heulandite (?), and laumontite and some calcite. At such properties as the Quinto pit (1) and the Ponupo (2) mine, Oriente, entire beds up to 20 feet or more in thickness are mined over considerable areas, but most of the bodies are locally lenticular or of irregular shapes. In most beds the ore grades laterally into low-grade mineralized tuff, but some contacts between ore and the enclosing tuff are abrupt, and there the rocks within about a foot of the ore are almost free of manganese oxide. The tops and bottoms of ore-bearing beds are sharply defined undulating or plane surfaces. In a few places the ore bodies are limited by faults or slips.

19/ Larsen, E. S., in Burchard, E. F., op. cit.

The deposits in tuff are larger and of more uniform composition, in general, than those in other environments, and consequently they have yielded most of the manganese produced in Cuba.

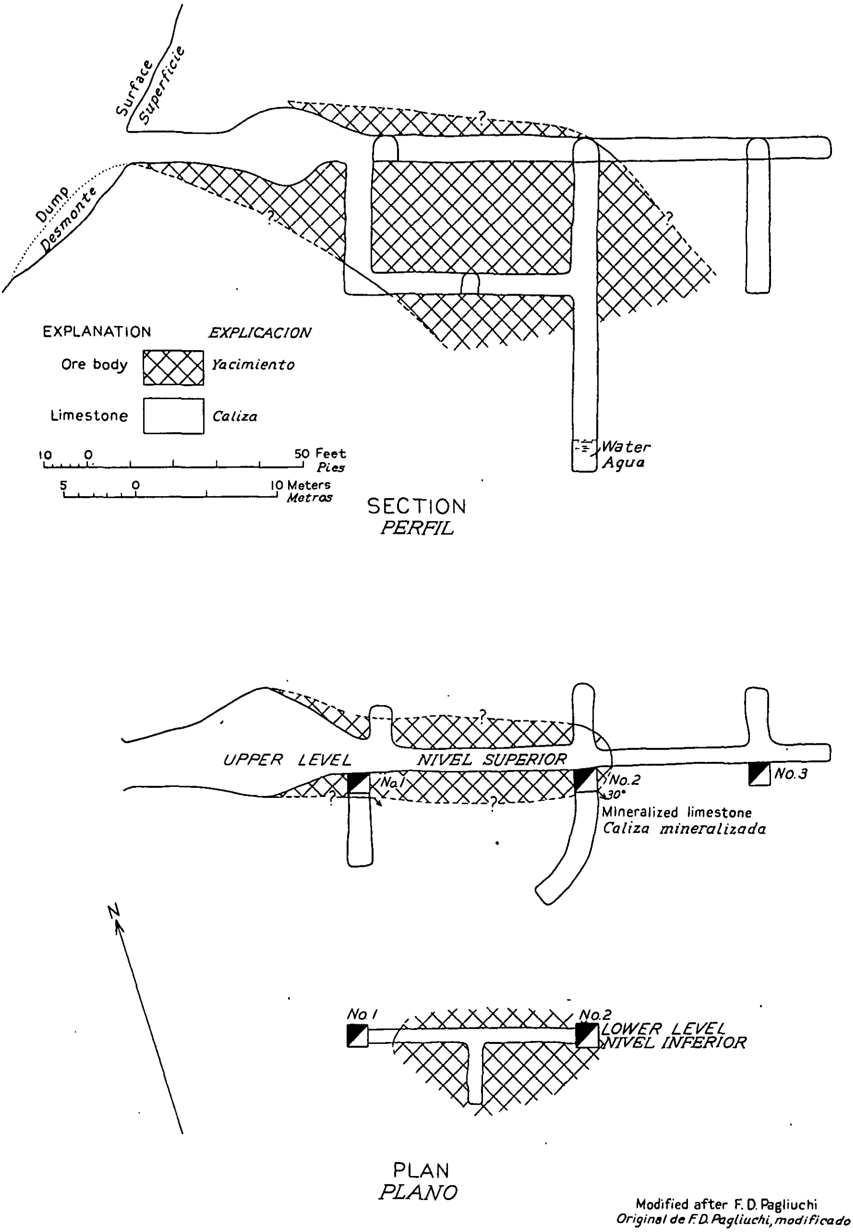


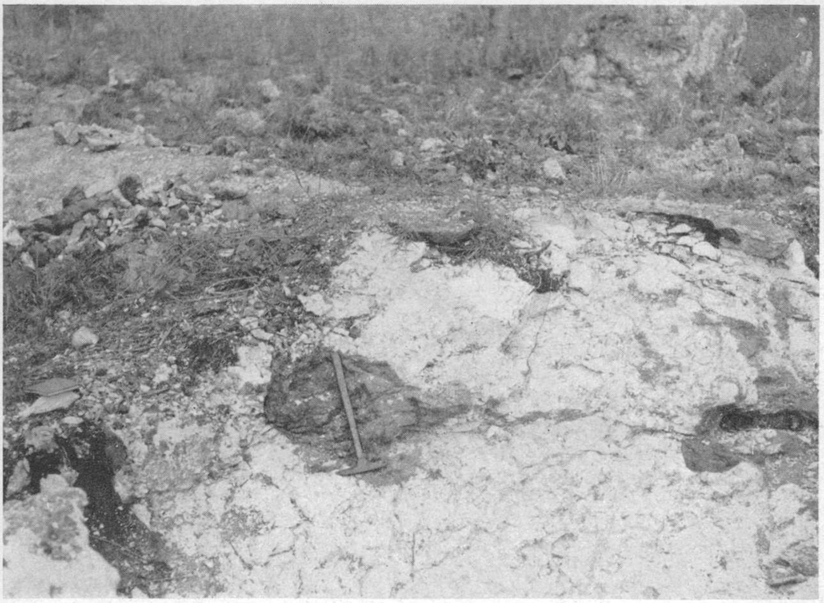
Figure 7.—Plan and section of La Unica mine, Oriente, Cuba.

Deposits in limestone.--The deposits in limestone occur chiefly in Oriente, on the northern flank of the Sierra Maestra between Contramaestra and Guisa, but similar deposits have been prospected in Pinar del Rio and near Trinidad in Las Villas. A few ore bodies such as that mined at La Unica (16) (see fig. 7) are large, well-defined lenses, but generally the limestone contains irregularly distributed stringers of manganese oxides together with pockets or small lenses of ore formed where the stringers widen or coalesce (pl. 22, A). In some places, manganese oxide stringers cement limestone breccia; in other places, fragments of manganese oxides in broken veinlets and in groups of broken fibers are cemented by limestone (pl. 22, B). At the Charco Redondo (17), Oriente, and other nearby deposits, layers of manganese oxides up to 4 feet thick lie between limestone beds. These oxide layers contain a few inclusions of tuff and other materials, and some of them are remarkably continuous. At Charco Redondo a bed 6 inches to 2 feet thick has been traced by means of trenches and pits for more than a mile along the strike.

Except for a few large lenses, some of which contain 25,000 tons or more of ore apiece, the manganese oxide bodies in limestone are small, and few yield more than 100 tons of ore.

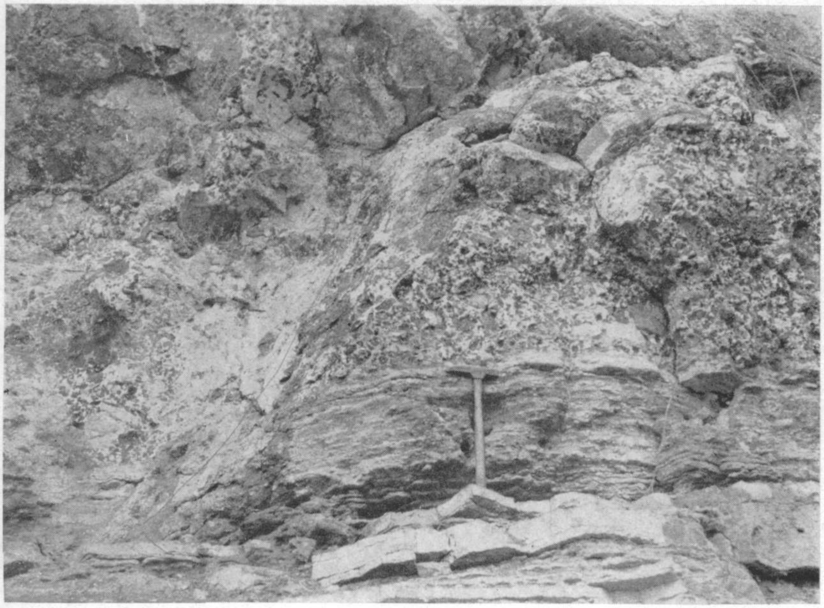
Granzon.--Granzon is a term applied to ore consisting of nodules or pellets of manganese oxide in soil or subsoil. These pellets, most of which are less than an inch in diameter, are generally made up of concentric layers of oxides (pl. 23, A). To have commercial value they usually should make up more than 10 percent of the bulk of the soil. The best granzon ore is free from pebbles and from nodules of minerals other than manganese oxides, so that it yields a high-grade concentrate when washed. In some localities, particularly in Pinar del Rio, the granzon contains iron oxides and the manganese-rich pellets grade into pellets of iron oxides without manganese that are very similar to them in appearance. For this reason, careful sampling of granzon ores in advance of mining is necessary.

Granzon is found throughout the manganese-bearing region of Cuba, principally near the outcrops of other kinds of ore. It



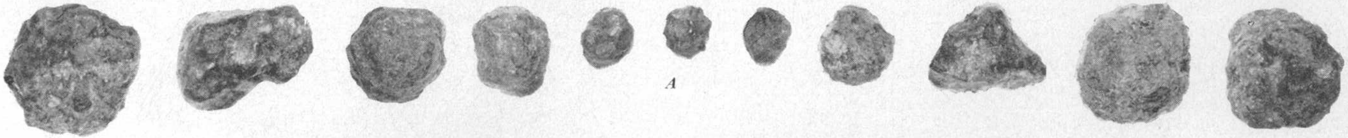
A. MANGANESE OXIDE POCKET IN LIMESTONE, EL TONY PROSPECT, ORIENTE, CUBA.

The hammer handle is 18 inches long.

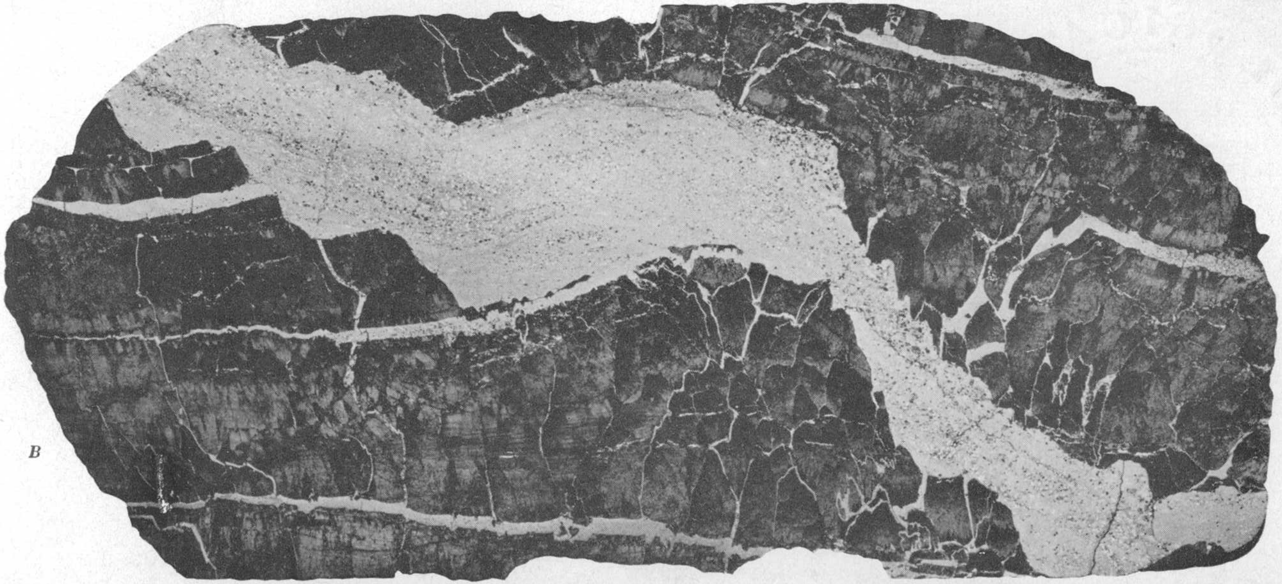


B. MANGANESE OXIDE FRAGMENTS IN LIMESTONE, CHARCO REDONDO MINE, ORIENTE, CUBA.

The hammer is on a layer of solid manganese oxides.



A



B

A. GRANZON FROM LA CUCA MINE, PINAR DEL RIO, CUBA.
B. VEINLETS OF TUFF IN MANGANESEE OXIDES, CHARCO REDONDO MINE, ORIENTE, CUBA.

is not concentrated in streams as gravel but appears to be mostly mixed with soils at or near the surface in nearly level areas, or in playas where surface water stands intermittently or runs off slowly. In some deposits in Pinar del Rio and the Isla de Pinos, manganese oxide pellets are cemented together into cobbles or boulders which, if numerous, may be strewn over the surface.

Most individual granzon deposits yield less than 1,000 tons of concentrate, although some bodies, such as the one at La Cuca mine (23), Pinar del Rio, are estimated to contain more than 50,000 tons. The ore is easily recovered with a small capital outlay, and the concentrates are of better grade than the other varieties of ore. For these reasons, granzon is much sought and is commonly the ore first mined in a district.

Miscellaneous deposits.--The surface outcrops of a few mineralized bodies, particularly in Pinar del Rio, are marked by soft black powder or black soil, but not by granzon. In Pinar del Rio, and to a lesser extent in Oriente, layers of fine-grained, compact, high-silica, manganese-bearing rock are found, commonly parallel to the bedding. As such rock requires expensive beneficiation, these lodes have been little explored. Many are less than a foot wide, and many would be relatively costly to mine because of their steep dip. The ores in the Maceo prospect (24), near Vinales, Pinar del Rio, and similar properties consist largely of manganese silicates with small amounts of manganese oxides; other bodies, such as those near Bahia Honda in Pinar del Rio and near Sigua (9) in Oriente, contain some silicates but appear to be mainly fine-grained mixtures of manganese oxides and silica. Some of the siliceous deposits, such as those near Bahia Honda, contain patches of low-silica oxides that are large enough to be worth exploring.

At the Esperansita prospect (7), about 16 miles north of San Luis, Oriente, fragments of manganese oxides are scattered irregularly through a bed of conglomerate 20 to 30 feet thick, and at some places in this conglomerate the matrix also consists in part of manganese oxides.

At the Antonio mine (13), near Los Negros, Oriente, manganese oxides partly fill caves in limestone, and cave deposits in limestone are known in other localities.

Relation to bedding

In many tuff deposits the layers of manganese oxide, though apparently parallel to the bedding, actually are inclined at a small angle to it. The tuff is replaced by the manganese oxides, as is shown by corroded remnants of rock and by relict structures and textures in the ores. In the same deposits, however, fragments of veinlets or of crystal groups lie with their long axes parallel to bedding planes. This mode of occurrence is interpreted to mean that some manganese oxide was deposited with the tuff, but that manganese-rich solutions continued to circulate through the beds after sedimentary accumulation stopped. Evidence that the manganese oxides were deposited before the tuff was consolidated can be seen at the Charco Redondo mine (17), where there are small veinlets of tuff in manganese oxides (pl. 23, B).

Many of the manganese deposits are at or near contacts between tuff beds, or between tuff and schist or limestone. Some deposits, for example La Estrella mine (see fig. 8) and La Yeya mine (12) (see pl. 24), are in the tuff, whereas others, such as El Cadiz (19) near Guisa, Oriente, are in both tuff and limestone. Some of the manganese-bearing layers in limestone have a limy matrix, others contain small quantities of tuff and pinkish zeolites, and nodules of brown jasper. There is every gradation from the bedded ores in limestone to the characteristic ores in tuff. Manganese ores are so generally concentrated along contacts of tuff and limestone and near the bottoms of the limestone beds as to indicate that in places the carbonate caused the deposition of manganese oxide.

The bedded ores also show features that indicate contemporaneous deposition of manganese oxides and limestone. At Charco Redondo sharks teeth occur in clay seams in the ore, and similar teeth are reported from deposits near Guisa. At Charco Redondo a bed of manganese oxide and impure limestone contains undeformed rods that suggest worm burrows, and rhythmically banded

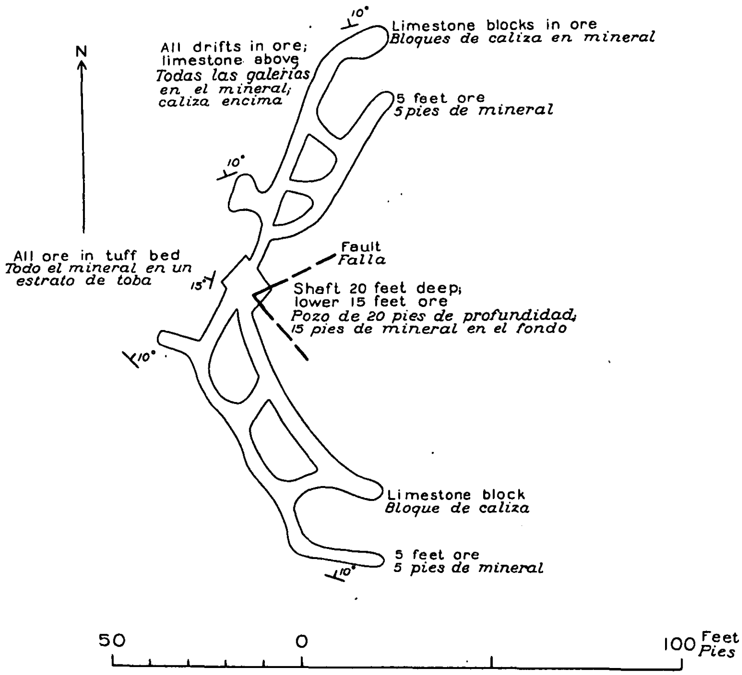


Figure 8.--Plan of La Estrella mine, Mafo, Oriente, Cuba.

nodules and layers are common. These and similar deposits appear to be primary accumulations of manganese oxides in a limy ooze on the bottom of a shallow sea floor.

At Charco Redondo a limestone that overlies a bed of solid ore contains, near its base, many fragments of manganese oxides and a few pieces of volcanic rocks. No evidence of faulting was seen in the well-exposed contact zone (pl. 22, B). The material strongly resembles an intraformational conglomerate containing fragments from the underlying bed of ore. Similar conglomerate has also been noted in the Guisa area.

Thin persistent beds of oxides are common in the limestones of the Los Negros, Charco Redondo, and Guisa areas. At Charco Redondo, one such bed with a maximum thickness of 2 feet in its middle part has been followed along its outcrop for more than a mile. It thins out in both directions to about 6 inches. Such a bed probably formed as a sediment on the sea floor, the manganese being contributed by spring waters.

Relation to faults

Faults are abundant throughout the mineralized areas, and have evidently acted as conduits for ascending solutions. In some mines the best ore occurs along faults or fault zones (see fig. 9), but in other deposits, such as that of the Sultana ore body at Ponupo (2), there is no convincing evidence that the ore bodies are related to faults. Most of the faults, however, are of small displacement, and many die out in the nearby overlying and underlying beds.

Origin of the bedrock deposits

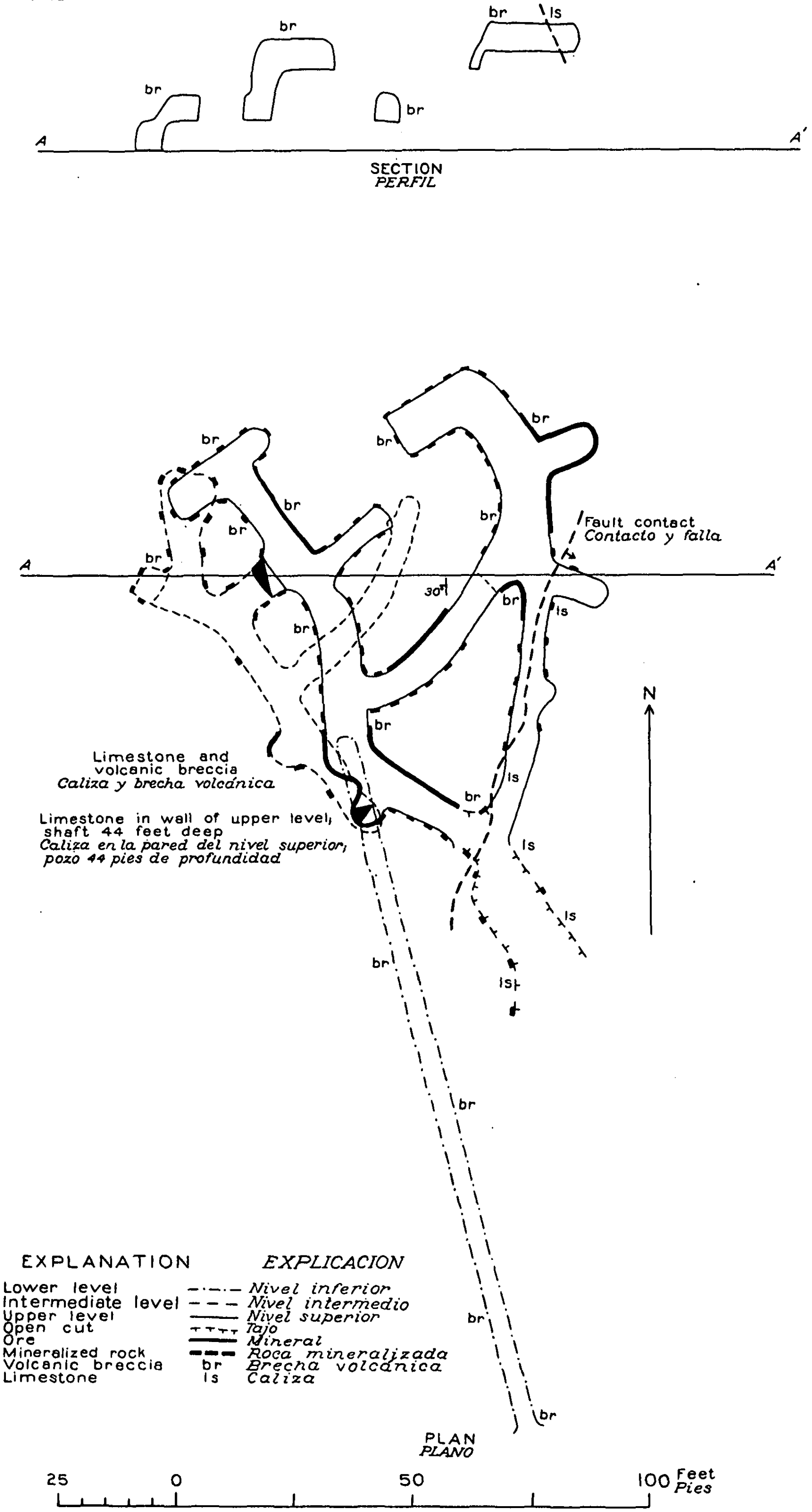
Spencer,[20] who first studied the Cuban deposits, thought that most of the oxides were of hydrothermal origin. He said:

> This mode of occurrence (along arches)[21] is suggestive of their (manganese ores) 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.

In general, St. Clair [22] agrees with Spencer. He says:

> The ores were deposited by ascending warm solutions approaching the hot spring type.* * *The theory that manganese oxides formed the primary ore* * *eliminates the difficulty presented by the complete absence of carbonates* * *and by the

20/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., p. 65.
21/ Parenthetical words inserted by the writer.
22/ St. Clair, David, unpublished memorandum, dated May 1, 1941.



PLAN AND SECTION OF LA YEYA MINE, ORIENTE, CUBA

PLANO Y PERFIL DE LA MINA LA YEYA, ORIENTE, CUBA existence of primary pyrite and zeolite in close connection with the ore.

Norcross [23/] considered the ore to be hydrothermal. He said:

> Manganese mineralization in Oriente Province is of regional character and probably had its inception in hydrothermal activity incidental to this intrusive epoch (the intrusion of the Sierra Maestra granodiorite batholith).

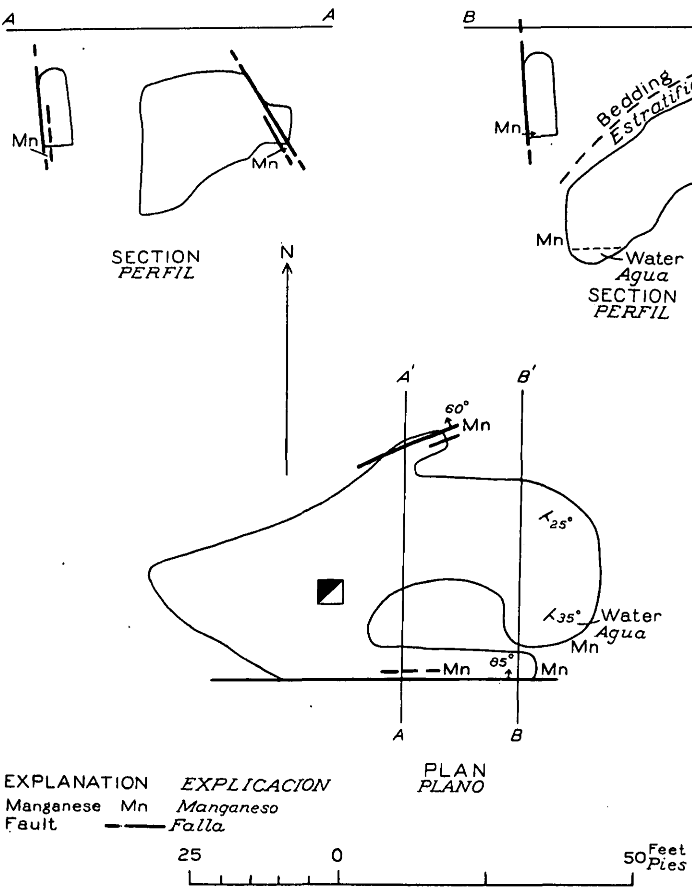


Figure 9.--Plan and sections of the Manuel stope No. 5 A, Bueycito mines, Oriente, Cuba.

Hewett [24/] considers that such deposits as the bedded oxides of Charco Redondo are sedimentary in origin, but he believes that all of the hydrous silicates, zeolites, and silica in the region are products of widespread hydrothermal activity, and

23/ Norcross, F. S., Jr., Development of the low-grade manganese ores of Cuba: Am. Inst. Min. Met. Eng. Tech. Pub. 1188, p. 3, 1940.
24/ Hewett, D. F., personal communication, 1941.

that some of the manganese oxides also were deposited by hot waters.

Burchard [25] in 1920 suggested that

> The proximity of volcanic rocks to the manganese-bearing areas in Oriente Province, and the broader structural relations of the region suggest the possibility that the manganese was derived from volcanic rocks of the Sierra Maestra, transported by artesian waters and deposited, together with silica as masses of manganiferous jasper in joints, fissures, and cavities in the limestone and other rocks in the local anticlines of the basin, as well as along the beds of the more porous tuff.

The small deposits of manganese oxides discovered in recent years near the crest of the Sierra Maestra are difficult to explain as products of circulating artesian waters related to the present topography.

The deposits have none of the characteristics of superficial accumulations of manganese oxides concentrated by weathering. Cuba is subjected to alternating seasons of heavy rainfall and drought, and much of the land is deeply weathered. Under such conditions superficial concentration by ordinary weathering processes should be expected. Such deposits, however, are unusual. Granzon and soft black powdery soil derived from nearby bedrock deposits are widely distributed, but accumulations of residual manganese oxides derived, like bauxite and lateritic iron ores, from the decomposition of large rock masses are unknown.

In the best-exposed deposits, moreover, such as those near El Cristo, no evidence of enrichment related to the present surface has been recognized below the few feet of granzon on the outcrop. At the Quinto pit, beds 10 to 20 feet thick have been explored to a depth of more than 300 feet, or for about 1,200 feet down the dip. The thickness, grade, and character of these beds do not change appreciably with depth.

Pyrite is found near several ore bodies, both above and below them. The presence of unaltered pyrite in porous beds

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25/ Burchard, E. F., op. cit., pp. 56-57.

directly overlying manganese oxides indicates that ordinary processes of oxidation have not been active since the formation of the pyrite.

The deposits of manganese oxides in caves which are found at several places in the limestone area may or may not be residual. At the Antonio mine (13), near Los Negros, stalactites of calcium carbonate project through layered accumulations of manganese oxides which, together with a few thin beds of red or brown clay, partly fill the cave. As the limestones are extremely cavernous and surface waters move rapidly and easily through them, some of the cave deposits are thought to be residual. On the other hand, deposits that appear to be cave fillings directly overlie and seem to grade into ores typical of the deposits in tuff. As ascending warm waters would take advantage of any open channels, it is possible that some of the manganese in the caves was deposited from circulating warm waters.

It is concluded that the manganese of the deposits of Oriente, excluding the granzon, was derived from warm springs. It is believed that the warm waters rising along conduits deposited manganese oxides at favorable places along the conduits and in adjacent porous beds, partly by direct deposition in openings and partly by replacement of tuff or limestone; it is also believed that warm water reaching the sea deposited manganese oxides as a primary sediment. Deposition is thought to have taken place during the last stages of the Sierra Maestra volcanic activity, in late Eocene and possibly early Oligocene times. The largest deposits were formed in a broad zone around the center of greatest volcanic activity. The ultimate source of the manganese is not known.

Although this explanation is advanced particularly for the deposits of Oriente, a similar origin is considered to be likely for the deposits in Pinar del Rio and Las Villas Provinces. The deposits in other areas are so imperfectly known that no definite conclusions regarding their origin are warranted.

Production of manganese ore 1/ from Cuba

Year	Long tons 2/	Value 2/
1888-1896	3/ 77,228	$695,393
1897	4/ 6,992	81,126
1898	1,600	8,026
1899	16,359	221,785
1900	20,582	259,348
1901	21,627	307,084
1902	36,294	285,571
1903	17,721	111,670
1904	16,239	80,974
1905	6,489	35,049
1906	11,701	117,050
1907	30,006	262,847
1908	1,469	13,489
1909	2,950	11,800
1910	2	26
1911	0	0
1912	0	0
1913	0	0
1914	0	0
1915	5,141	69,453
1916	30,563	514,184
1917	44,511	612,413
1918	82,974	2,751,193
1919	35,320	1,433,202
1920	8,247	266,744
1921	34	679
1922	12,568	89,677
1923	9,062	137,016
1924	23,065	347,874
1925	12,747	253,315
1926	14,112	224,523
1927	8,976	141,836
1928	3,180	60,402
1929	2,667	32,654
1930	2,071	32,317
1931	3,804	5/ 19,891
1932	6,749	111,770
1933	28,257	430,906
1934	63,743	965,610
1935	43,955	700,493
1936	37,912	521,809
1937	122,937	2,185,800
1938	131,422	2,242,425
1939	105,936	1,689,547
1940	130,646	3,059,735
Total	1,237,858	21,386,706

1/ Ore containing 35 percent or more manganese.
2/ Figures from the Bureau of Foreign and Domestic Commerce.
3/ Exports from Cuba.
4/ Imports into the United States from Cuba.
5/ This is the figure recorded, but it seems low.

Production

Prior to January 1, 1941, Cuba had produced, according to the best available records, 1,237,858 tons of manganese ore, containing 35 percent or more of manganese and having a value of $21,386,706. Nearly all this ore was mined in Oriente Province. The preceding table gives the production by years.

Economic factors

Manganese mining in Cuba has in the past been more or less irregular--when prices rose the mines were opened and when prices dropped the mines were abandoned. With a few exceptions the mines are owned and operated by individuals and small companies with little capital, and even owners with ample capital have been loath to make large investments because of the uncertain future of the industry. Many efforts, a few adequately financed, have been made to establish the industry on a permanent basis; but all these have failed, principally because of the low grade and pockety nature of the ore, high costs of mining and transportation, and lack of a cheap method to improve the grade of the ores. The recently developed open-pit mining methods and the flotation and nodulizing plant of the Cuban Mining Co. at El Cristo will, it is hoped, form a stabilized basis for expanding the industry. With the exception of the Cuban Mining Co. and a very few others, the mines producing Cuban manganese are mining at high cost and generally with a low margin of profit, and only if drastic reduction in cost can be effected at these mines will it be possible for them to operate during normal times.

The first need of the mining regions is improved transportation. Many mines are connected with the Central Highway or the railroad only by trails and unimproved roads that are poor when dry and impassable when wet. Ore is hauled from many properties on muleback, a costly and unsatisfactory method because production is limited by the number of mules available and the state of the weather. Thus there is urgent need of well-drained and graded roads, passable for trucks in wet and dry weather. Transportation is handicapped, moreover, by high freight rates and irregular railroad and boat services.

Method of mining.--Except for the large bodies of low-grade ore which are being extracted systematically, the manganese deposits are being mined from small holes and irregular workings. As most of the deposits are irregular and pockety, this practice of following the ore is wise; many long adits and deep shafts have been driven in vain attempts to cut ore in depth. Mining machinery is expensive, and even second-hand equipment is hard to get; miners, therefore, with a few exceptions, have no other mining equipment than picks, shovels, and wheelbarrows, and where hoisting is necessary, buckets and windlasses. Loading and storage bins are practically unknown. The ore is generally moved by hand several times before it reaches the railroad, and each time the friable ore is moved, much is lost in fines. Also, as the ore is very porous, it absorbs and retains water whenever stored in the open during rainy weather.

Method of concentration.--Most of the ore, of whatever kind, must be concentrated. This is generally done by the slow process of hand-sorting: the ore is dumped on the ground, the larger pieces are broken with small hammers, and the high-grade material is picked out and piled at one side or put into sacks. Several mines use inexpensive log washers to remove clay from soft ores and granzon, and where water is plentiful this method seems to give good results, though the fines are generally lost. During the dry season some granzon is recovered by dumping soil and pellets on a $\frac{1}{4}$-inch screen, where they are dry-scrubbed by hand with wire brushes until the pellets are clean. At a few properties, efforts are made to concentrate ore by jigging, but such operations are all handicapped by old and inadequate equipment and by lack of trained personnel. The modern flotation and nodulizing plant of the Cuban Mining Co., designed to handle about 1,200 tons a day, has recently been described.[26]

Future of the deposits

It was estimated that Cuba would produce in 1941 about 225,000 tons of ore containing 38 percent of manganese or better, including sintered fines from the Cuban Mining Co. plant. Sufficient ore is available to maintain present production for years if present high prices are maintained. Production could readily be increased by opening roads into favorable but at present inaccessible regions, such as Pozo Prieto, south of Baire, and Valle de Manganeso, northeast of Alto Songo.

26/ Norcross, F. S., Jr., Development of the low-grade manganese ores of Cuba: Am. Inst. Min. Met. Eng. Tech. Pub. 1188, 1940.

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