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MANGANESE DEPOSITS IN PART OF THE SIERRA MAESTRA, CUBA

BY

C. F. PARK, JR., AND M. W. COX

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By C. F. Park, Jr., and M. W. Cox

ABSTRACT

Manganese deposits are widely distributed in the rolling foothills north of the Sierra Maestra, Oriente Province, Cuba. The area is underlain by thick volcanic formations, principally tuffs and agglomerates, which are capped by middle or upper Eocene limestone. The rocks are gently folded along westward-trending axes and are broken by numerous faults. The principal faults trend nearly east-west, parallel to the axes of the folds, and there are many small north-south faults. Manganese deposits occur in both the volcanic rocks and the limestones at and near their contacts, especially where the contacts are cut by fractures. The deposits were formed at or near the surface, by warm waters thought to have been associated with the late stages of the Sierra Maestra volcanism.

Pyrolusite and psilomelane are the most common manganese minerals in the deposits, though other oxides and silicates are present. Calcite, jasper, and zeolites are the most abundant gangue minerals. Ore, to be salable, must contain 40 percent or more of manganese, and most ore must be hand-picked or otherwise concentrated in order to reach this grade.

The production from the Sierra Maestra in 1941 was between 75,000 and 90,000 tons of ore, carrying 40 percent or more of manganese, out of a total Cuban production of about 250,000 tons. Known reserves are estimated at 300,000 tons that averages more than 40 percent manganese and at least 1,500,000 tons of rock that contains more than 20 percent manganese and more than 20 percent silica. Present production can be maintained or increased for several years.

Many of the mines in the region are described.

INTRODUCTION

The manganese deposits of Cuba have recently received considerable attention because of their great value to the steel industry of the United States during the war period when more distant sources are cut off. Study of these deposits by the Geological Survey, United States Department of the Interior, began in November 1940, under a program financed by the United States Department of State and with the consent and cooperation

of the Cuban Government. During the first season, from November 1940 to May 1941, a reconnaissance of most of the known deposits was made, and its results were summarized in a brief preliminary report.1/ The second season began early in December 1941, and continued through September 1942. The present report is a summary of the results obtained in the 1941-42 field season, during which time individual mines were studied and mapped in detail. Mapping was confined to deposits in the northern foothills of the Sierra Maestra west of Santiago de Cuba, and to Sigua and Gran Piedra, east of Santiago (fig. 15). No descriptions of the well-known deposits of Cristo 2/ or of other deposits north of Santiago de Cuba and along the southern coast of Oriente are included here. The study is being continued, and this paper, like the earlier one, is in the nature of a progress report.

It is a pleasure to acknowledge the willing cooperation of all the mine owners and operators in the region. Mr. Antonio Calvache, Consultant of the Cuban Ministry of Agriculture, has helped in many ways, and his son, Guido Calvache, was employed as recorder to assist with the plane-table mapping. F. C. Calkins and T. A. Hendricks have read the manuscript and have offered much constructive criticism.

The section of the Sierra Maestra that contains the bulk of the manganese deposits is in the rolling foothills at the northern base of the range (fig. 16 and pl. 51). It lies between Bueycito on the west and Santiago on the east, and includes the Bueycito, Guisa, Charco Redondo, Los Negros, and Manacas districts and part of El Cobre district. The region is well drained by northward-flowing rivers, which include, from west to east, the Buey, Yao, Mabay, Bayamo, Guama, Guisa, Cautillo, Mogote, Contramaestre, Caney, and Cauto Rivers. Most of the Cobre district lies on the north side of the Santiago basin and is drained by the Paradas River, which flows south into Santiago Bay. East of Santiago manganese deposits are in the drainage area of the Bacanao River in the high Sierra Maestra. Ample water is available in most mines for mining and milling purposes. In a few areas of sinkhole topography, such as the Pozo Prieto district, water is scarce and ore must be hauled several miles to a stream for washing.

Production and reserves

Cuba produced, in the years from 1888 to 1940 inclusive, some 1,237,858 long tons of ore, which contained on the average more than 35 percent of manganese and which had a total value of about $21,386,706.3/ In 1941, Cuba produced 251,385 metric tons—about 250,000 long tons—valued at $6,510,131. Most of the past production has been from the Province of Oriente, but the amount yielded by the Sierra Maestra district is not known. Of the 250,000 long tons of ore produced in 1941, the Sierra Maestra yielded between 75,000 and 90,000 long tons averaging above 40 percent manganese. It is estimated that the tonnage will be somewhat reduced in 1942, because of marketing difficulties.

1/ Park, C. F., Jr., Preliminary report on Cuban manganese deposits: U. S. Geol. Survey Bull. 935-B, 1942.

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

3/ Figures from the Bureau of Foreign and Domestic Commerce.

AERIAL VIEW OF TYPICAL SIERRA MAESTRA FOOTHILLS.

Junction of Bayamo and Guama Rivers. Courtesy U. S. Army

Present ore reserves in the Sierra Maestra are estimated to be sufficient to yield about 300,000 tons of concentrates con-

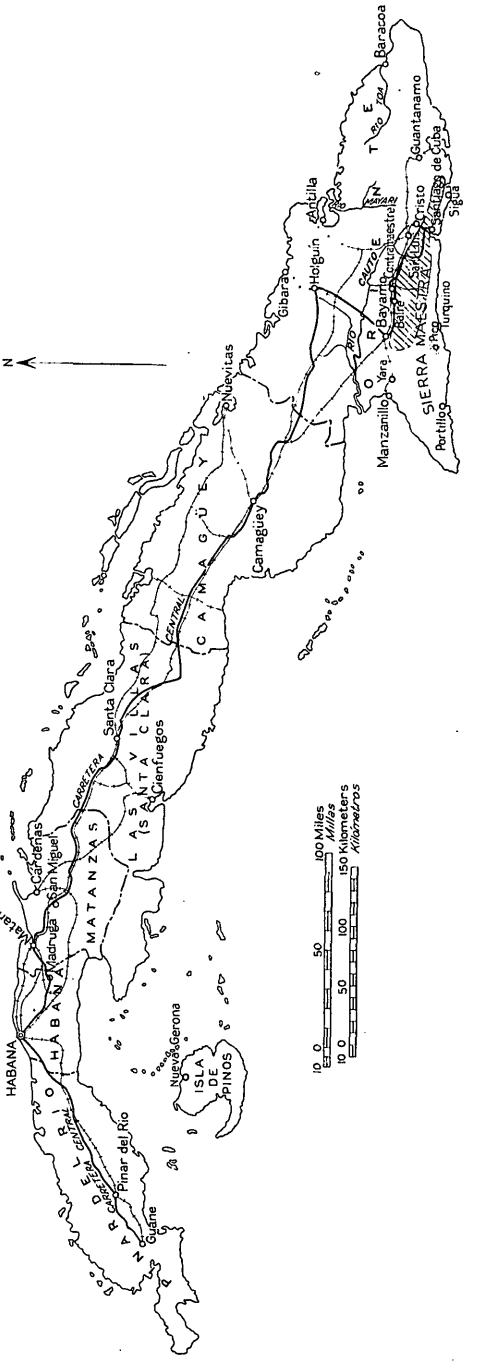

Figure 15.--Index map of Cuba showing location of manganese district studied in 1941-42.

taining 40 to 45 percent manganese. Much favorable land is unexplored and it seems likely that ample reserves are present

to maintain or increase present production for several years at least. The reserves of high-silica ore at Sigua and Gran Piedra are over 1,500,000 tons, but the deposits cannot now be worked without improved concentration methods except along the outcrops and high-grade pockets.

Mining methods

A few improvements in mining methods, such as the installation of small compressors and the use of jackhammers, has been made at several mines during the past year, but they are a mere beginning. Hand steel, pick, shovel, and wheelbarrow are still the standard implements, even in the larger ore bodies where systematic mining is possible. Such commonplace inexpensive conveniences as ore chutes, mine cars, small hoists, and storage and loading bins are practically unknown.

Mining is generally done through many small shallow shafts and adits rather than through one or several haulageways. The stopes are irregular gopher holes that can be kept open only by leaving many large pillars; timber is seldom used, and the whole appears to be a wasteful, expensive process. Much ore is literally worn out in being moved by hand at least three or four times; the best ores are friable, and the percentage of fines, which have a low sale value, increases each time the ore is moved.

Trained mine operators are badly needed at several properties, for most of the local personnel has had little or no mine experience other than in the Cuban manganese properties and chromite pits, neither of which have been operated extensively underground.

In many mines the daily yield is about half a ton of ore per man. Mining costs probably average between $5 and $10 per ton, and at most properties 25 to 50 tons of ore a day is considered to be a large production; and yet at several mines, such as those at Manacas and at Taratana, the production could readily be stepped up to 100 tons a day or more and mining costs could be lowered to $1 or $2 a ton.

Transportation

The problem of transporting ore from the mines to the railroad has been one of the most perplexing economic problems, but the situation has improved somewhat during the past year. All of the principal producing areas are accessible by truck during the dry season, though some, such as Cádiz, south of Guisa, are reached by long roundabout routes. Slow but continuous maintenance work on the worst stretches of roads by the mining companies has had results, and several mines, such as Taratana and Yeya, can be reached at almost any time. Grading and ballasting the worst roads, such as that between Manacas and Ramón, would facilitate production, and would save considerable wear and tear on tires and equipment.

Present practice at many mines, notably La Unica, is to pile ore during the wetter seasons and haul only in the dry season. With this system mines which use power equipment are often shut down in wet weather, owing to lack of gasoline and other essential supplies. Many of the smaller and more remote mines rely on mules for moving ore, but this makes the freight

cost high and the production is restricted by the number of mules available.

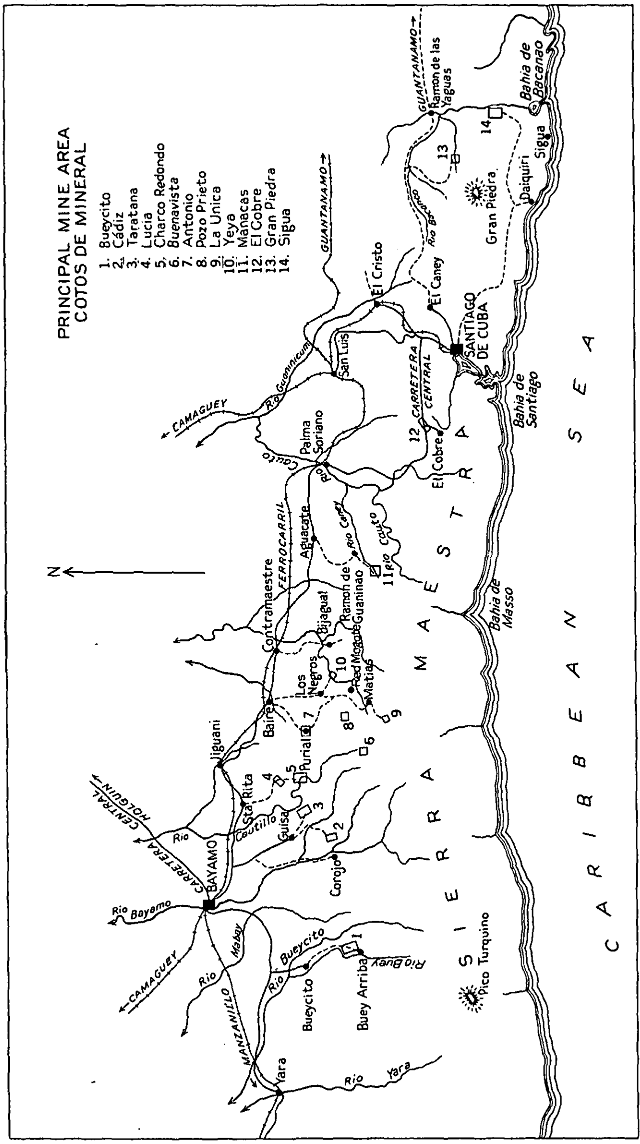

Figure 16.--Sierra Maestra manganese district showing location of mines mapped.

Milling methods

Until about a year ago most concentration was done by hand or with a few simple log washers, but recently several plants containing improved log washers, trommels, and jigs have been

installed, and the consequent improvement in technique has resulted in considerably more efficient recovery. Unfortunately some hard ores in limestone, such as those of La Unica, are apparently not readily amenable to this method of treatment, and hand cobbing remains the cheapest and best way of improving the grade of such ores.

GEOLOGY

The Survey's work during 1941-42 was devoted primarily to detailed mine examination and mapping of widely scattered deposits, and, as a result, very little information on the regional geology was obtained. The local stratigraphy and structure of the individual deposits is best described in connection with the mines, and this general section is therefore limited to a few remarks of regional interest.

Stratigraphy

The rocks near the Sierra Maestra manganese deposits consist of interbedded volcanic rocks and limestones. The volcanics are principally andesitic to basaltic tuffs, which grade into agglomerates and fine-grained limy tuffs, although a few flows, dikes, and irregular intrusive bodies are recognized. The tuffs, which are generally green or brown, contain devitrified glass, quartz, olivine, feldspars, amphiboles, pyroxenes, and extraneous rocks, especially limestone. Much of the tuff is altered and contains abundant chlorite, kaolinite, quartz, iron oxides, zeolites, calcite, and other decomposition products. The volcanic rocks do not contain many fossils, but the limestones which immediately overlie them and are interbedded with them are of upper Eocene age. The thickness of the volcanics is unknown but must be several thousand feet.

The limestones are dense, gray or cream-colored rocks, in places dolomitic and locally crystalline. Algal heads and conglomerates which seem to indicate local unconformity are widely developed near the bases of the beds, especially near the mineralized areas. At some mines, such as La Unica, the limestone is massive and is practically devoid of bedding planes; elsewhere, as at Charco Redondo, it is thin-bedded and platy. The limestone weathers into a jagged pitted surface, and in the Pozo Prieto region large deep sink holes are developed in it (pl. 52). Orbitoidal foraminifera of upper Eocene age 4/ are abundant in the limestone. The limestones range in thickness from a few feet to several hundred feet, but complete sections have not been measured. The limestone-tuff sequence is overlain, apparently conformably, by thin-bedded, soft, limy tuffs, which form the wide flats north of the Sierra Maestra foothills.

Structure

The beds along the northern base of the Sierra Maestra are surprisingly little deformed considering their proximity to the profound Bartlett Deep, about 25 miles (40 km.) or less to the south. The regional dip appears to be northward at angles

4/ Woodring, W. P., personal communication, 1943.

generally less than 30°, though reversals of dip are rather common. There are gentle warps with axes trending about east-west, and minor drag folds along faults.

Faults are numerous but are believed to be subordinate in importance to the broad warps, and displacements of over 100 feet (30 m.) are rare. Most of the faults are of the steep normal type, although a few steep reverse faults are known. The faults may be divided according to their general trends into two sets: an east-west set parallel to the main folds, and a set, apparently younger, trending a few degrees east or west of north.

ORE DEPOSITS

Deposits in bedrock (lode ores) and surficial mantles (granzon) of manganese oxides occur in this district, and both types are mined. The lode ores contribute by far the larger share of the production.

Classification and description

The simple classification used in the 1941 report has been slightly modified and expanded for use with ores of the Sierra Maestra district. Three main types are recognized:

1. Bedded ores.
   a. Tuff ores.
      (1). Oxide ores.
      (2). Silicate and high-silica ores.
   b. Limestone ores.
   c. Mezclado ores.
2. Nonbedded or irregular ores.
   a. Adjacent to faults.
      (1). In limestone.
      (2). In volcanic rocks.
   b. In irregular fracture zones.
      (1). In limestone.
      (2). In volcanic rocks.
      (3). In plutonic rocks.
3. Surficial ores.
   a. Cave ores.
   b. Granzon or shot ore.

The greatest volume of ore is in tuff, although the best grade of crude mineral has come from the smaller nonbedded ore bodies, particularly from stringers and pods in limestone.

Tuff ores.--The tuff ores consist of grains, nodules, pockets, and stringers of manganese oxides irregularly distributed through altered tuff beds. The degree and character of alteration of the tuff vary considerably, and in a few deposits, such as those in the Taratana district, where the tuffaceous character is locally destroyed, entire beds are replaced by manganese oxides. Grains and nodules of manganese oxides are commonly embedded in a soft, soapy, pinkish material, described by Larsen as kaolinite with much zeolite and some calcite.5/ Although some beds of tuff are essentially unaltered

5/ Larsen, E. S., in Burchard, E. F., Manganese-ore deposits in Cuba: Am. Inst. Min. Eng. Trans., vol. 63, p. 60, 1920.

and consist of semifresh fragments, most beds contain considerable calcite, chlorite, and kaolin. Many of the manganese-oxide nodules are isolated in altered tuff and in general they are arranged in layers parallel to the bedding. Part of the tuff is replaced in such a way that the original textures and structures are preserved. The principal alteration of the volcanics at Sigua and Gran Piedra is silicification, the silica being generally in red siliceous tuff (pl. 53). Tuff ores, with few exceptions, contain less than 35 percent of manganese, and they constitute the largest reserves of milling ore in Cuba. These ores are in the volcanic rocks and in intercalated tuff beds in the lower part of the limestones.

Limestone ores.--An unusual type of bedded ore consists of manganese oxides in a matrix of limestone and tuff. These ores commonly occur on the borders of tuff beds in limestone and are gradational between manganese tuff ores and mineralized limestone. Such ores, as at the Segunda Gloria mine, are commonly a mixture of manganese oxides and small unaltered and unreplaced foraminifera.

Mezclado ore.--Mezclado or intraformational conglomerate deposits are found in the limestones at Charco Redondo and Guisa. The beds contain angular and rounded fragments of manganese oxides, fragments and boulders of limestone and tuff, foraminifera, algal heads, and other fossils in a matrix of cream-colored dense limestone. The manganese fragments are obviously derived from immediately underlying beds of manganese ore and are concentrated near the base of the conglomerates. In the Taratana area, three ore beds are separated and overlain by this type of intraformational conglomerate, which grades laterally into limestone conglomerate. The beds are of little economic value, since the percentage of manganese oxide fragments is generally small.

Ore adjacent to faults.--Manganese oxide deposits occur in fault zones that cut both limestones and volcanics, and at fault contacts between these two kinds of rock. The ore is generally massive, and in some deposits it contains iron oxides and calcite. In places the ores are near lenses and stringers of jasper, which either follow the faults or extend laterally from them. At Gran Piedra, a tabular ore body in the fault zone bears masses of silicates, jasper, and pyrolusite.

Irregular fracture ores.--Thin stringers and pods of psilomelane and pyrolusite are found in fractures that cut limestones, tuffs, agglomerates, and, in one locality, a dacite (?) porphyry. The stringers are generally thin, but in places, such as the Cádiz mine, they may open into a large pocket that contains several thousand tons of ore.

Surficial ores.--Cave deposits and blankets of granzon result from normal weathering processes and are found in many places. One cave on the Antonio property contained alternating layers of manganese oxide and red clay, cut by dripstone pillars. The pellet or granzon ores occur along the outcrops of lodes, but they also form deposits at a distance from any known bedrock source.

Some granzon consists of clean pyrolusite pellets and is high-grade ore. For this reason and because it may be cheaply recovered, it is eagerly sought and is the first ore mined in a district. As this attractive material may overlie other types of ore, the working of granzon commonly leads to the discovery of lode ore. In the granzon areas distant from outcrops of lode ore, the pellets are generally small and in places it

does not pay to recover them. The manganese pellets are generally scattered through a sticky red clay, but some of the pellets at Pozo Prieto are concentrated in limestone pits that are lined with manganese oxides. Granzon is found on both limestone and tuff.

Mineralogy

The mineralogy of the ores and gangue has been very inadequately studied. Most mineral determinations have been made from hand specimens in the field, though a little detailed work has been done in the laboratory.

Ore minerals.--Psilomelane, mostly of the variety cryptomelane—manganese oxide containing potash 6/—and pyrolusite (MnO_2) are the most abundant minerals in the ores. Manganite ($Mn_2O_3.H_2O$), ranciéite, a calcium-bearing manganese oxide, braunite ($3Mn_2O_3.MnSiO_3$), orientite ($4CaO.2Mn_2O_3.5SiO_2.4H_2O$), neotocite (amorphous manganese silicate), and piedmontite (manganese epidote) have also been identified but are uncommon in most of the ores though fairly abundant in a few deposits. Ranciéite has been identified by X-ray methods by W. E. Richmond and analyzed by Michael Fleischer. As this mineral is difficult or impossible to recognize in the field, it may be much more common than has been suspected. Its presence may explain part of the several percent of calcium found in some ores that apparently contain no calcite.

Gangue minerals.--The gangue generally consists of white or black calcite, cryptocrystalline silica, and remnants of tuff, which are altered in many places to a soft soapy red or pink material identified by E. S. Larsen as a mixture of kaolinite, zeolites, and calcite. The commonest alteration products are green chlorite and clay minerals which decompose rapidly at the surface. Iron is low in most ores but is concentrated along the borders of some pockets. Veinlets of coarse-grained white calcite, black manganese-oxide-bearing calcite, and calcite colored red by finely divided hematite are locally abundant in the ores. Cryptocrystalline silica (jasper or bayate), mostly brownish red or yellow but partly black, is also a common constituent of the ore bodies, particularly near the borders of the shoots.

Origin and localization

In the progress report of 1941, the origin of the ores was discussed in considerable detail in the hope that an understanding of this subject would facilitate exploration. The conclusions there stated have in general been considerably strengthened by additional evidence accumulated during 1942. The manganese is thought to have been carried in warm waters emitted during the dying stages of the Sierra Maestra volcanism, probably after the accumulation of most of the thick beds of tuff and agglomerate. The volcanic activity continued during the deposition of part of the limestone beds, as is demonstrated by the presence of limestone fragments in the

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6/ Richmond, W. E., and Fleischer, Michael, Cryptomelane, a new name for the commonest of the "psilomelane" minerals: Am. Mineralogist, vol. 27, pp. 607-610, 1942.

agglomerates at Bueycito, and by the numerous dikes and sills that cut the beds.

Manganese-bearing solutions rose in channels through the porous volcanic rocks and deposited their mineral loads where structural and chemical conditions were favorable. The solutions also carried silica, which was deposited in the form of veinlets and of layers bordering masses of manganese ore, though this latter type of deposit is rare in the Sierra Maestra. Manganese minerals were also deposited along permeable conduits, such as fault zones and fissures in the limestone, where they form cross-cutting bodies.

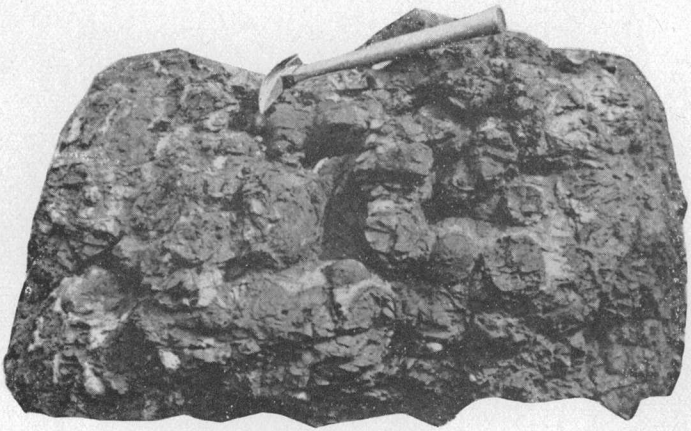
Faults and fractures have played a less conspicuous part in the processes of localization of manganese ore in the Sierra Maestra than they have elsewhere in Cuba. The gently dipping beds are not much faulted, and it is thought that the manganese-oxide-bearing solutions have commonly migrated through the permeable volcanic beds. A few faults and fractures are filled with manganese minerals and show no sign of postmineral movement; others contain manganese oxides which are broken and sheeted; in still others the manganese oxides are reduced to breccia, or locally to black gouge. The evidence is interpreted to mean that some of the fractures have been reopened and that movement was more or less continuous throughout the period of ore deposition. Many faults in the region (see pl. 52) are not mineralized and cut across manganese-bearing beds. The mineralized faults are of the type that would be expected to form in unconsolidated or poorly consolidated sediments during a period of volcanism. They are generally of small displacement; some die out at the contact between tuff and overlying limestones, others persist for short distances into the limestones, and a few cut sharply across both formations.

The permeable zone along the contact between the tuff and the overlying limestone appears to have been an especially favorable place for deposition of ore. Here the rising waters were impeded by the less permeable overlying limy beds, and the change of environment from tuff to limestone probably exerted a strong influence on ore deposition. In places the solutions worked upward along fractures in the limestones and also spread into the immediately underlying tuffaceous beds. Although many of the ore deposits are thought to have been formed by replacement of tuffs and limestones, part of those in the Taratana, Charco Redondo, and probably other areas are believed to have been formed by submarine springs, that deposited manganese oxides in the unconsolidated tuff and limestone on the sea floor. Many deposits of ore supposedly formed in this latter manner consist of elongated lenses near the basal conglomerates in the limestone. Some of the ore beds were broken by sea currents, and fragments of manganese oxides were incorporated into the overlying limy muds, to form, on solidifying, the "mezclado" or intraformational conglomerate beds of Taratana and Charco Redondo.

The nearly universal presence of limestone near the ore deposits suggests that calcium carbonate may have played a significant part in the precipitation of the ores. Manganese carbonate apparently was unstable under the conditions of deposition, for it has not been found in the deposits. It is likely, also, that enough oxygen, and locally enough silica, were present to form oxides or silicates of manganese. Oxygen might well be abundant or at least readily available under near-shore or near-surface conditions of deposition, such as are postulated for the formation of the ores. Limestone and sea water reacting with constituents of the warm waters may have changed

AERIAL VIEW OF POZO PRIETO SINKHOLE TOPOGRAPHY.

Courtesy U. S. Army.



NODULAR ORE, NON PLUS ULTRA MINE, SIGUA, ORIENTE.

Nodules of high-silica manganese ore in red tuff. Hammer handle is 14 inches long.

the physical and chemical conditions sufficiently to cause precipitation of the manganese.

It is concluded that manganese oxides and silicates were deposited directly from warm waters, in part as sedimentary beds and in part as replacement bodies, especially along and near limestone-tuff contacts. The contacts and the beds immediately above and below them are the best places to prospect. Irregularities in the beds, such as faults, sags, and rolls that may have acted as traps, should be particularly examined.

Surficial enrichment

The amount of oxidation and enrichment that has affected the manganese deposits offers a perplexing problem and one that has not yet been thoroughly studied. Most deposits show little or no recognizable surficial enrichment other than residual concentration on the outcrop. Many miners say, on the other hand, that the best ore is near running water, and in many places this is clearly true. Two outstanding examples in the Sierra Maestra district are found in the Taratana and Casualidad areas, in which the thickest and richest ore beds are below valleys, where underground circulation is rapid. In such places the ores are soft and are easily mined. It is believed that the enrichment in the limy beds may be effected by solution of the calcite and infiltration of manganese particles carried mechanically by the circulating water.

Pyrolusite is abundant in cracks and pods along outcrops of deposits that consist principally of psilomelane in depth. This relation is especially well shown in the inclined workings of the Lucia mine, where pyrolusite is the main ore mineral to a depth of 40 feet (12 m.) but gives way to psilomelane within the next 20 feet (6 m.). Pyrolusite is apparently the most stable manganese oxide at the surface, and it is thought to be largely of near-surface origin. Similarly in siliceous deposits, such as Sigua and Gran Piedra, high-grade pyrolusite ores on the outcrops result from decomposition of the original high-silica ores.

Granzon deposits have apparently been formed by actual solution and transportation of manganese oxides for short distances in ground waters. Some granzon fields are flat areas where water either stands or runs off slowly, and some are at considerable distances from any known lodes. In general, the farther the manganese has been transported the smaller the pellets and the better developed are the concentric structures. Though the pellets appear to be deposited from ground waters, there are many unsolved problems concerning their origin.

MINE DESCRIPTIONS

Interest in the Sierra Maestra manganese deposits began as early as 1887, and by 1900 most of the better known manganese denouncements were taken up. The sudden rise in prices in 1917-20 made mining active, and in the present emergency the activity has been feverish. Nearly 200 denouncements were recently taken up in the Sierra Maestra, but most of the manganese has come from relatively few mines. Many small mines have contributed a share of the total, however, and it is generally impossible to predict where and when a large pocket will be found. Most of the mines that have produced manganese ore have

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been visited, and efforts have been made to study in detail as many of the larger producers as time permitted. The properties are described in order of location, beginning at the Bueycito area at the west and ending with the Sigua area at the east.

Bueycito area

History and production.--The Bueycito mines are owned or controlled by the Sun Development Co., a subsidiary of the Sun Oil Co., of Chester, Pa. The property includes the Helen, Manuel, Costa, Carbayon, Oviedo, Vicente, Barabeitg, Emelia, and Daniel denouncements, which cover a total area of about 7,000 hectares. The Bueycito mines have been fairly productive, and a little ore has been produced from a few individually owned denouncements nearby, such as the Datil Tercera, Josefina, and El Americano.

The mines are reached by a graded, all-weather truck road from the Manzanillo-Bayamo highway, which is at a distance of about 12 miles (19 km.). A narrow-gauge railroad formerly connected the mill with the railroad at Julia, about 13 miles (21 km.) away, but it is now in a bad state of disrepair, the ties and trestles having rotted away and many of the rails having been removed.

The properties are in the rolling foothills at the northern base of the Sierra Maestra and are drained by the Buey and Yao Rivers. When the area was visited in April 1942, the Buey River was flowing about 10 cubic feet a minute over a deep gravel bed, though that was near the end of the dry winter months; sufficient water for all purposes is therefore probably available the year round. Ample timber can be obtained on the property.

Considerable high-grade ore was produced from the properties during the first World War, and the Sun Development Co. first became interested in the area about 1918. In 1922 a concentration plant containing jaw crushers, jigs, rolls, a cone classifier, and tables was installed. A small diesel plant was added and narrow-gauge tracks were laid from the mill to most of the small ore pits and workings. The mill was operated from January 1923 until July 1926, when the mine was shut down. Since then the mine has been idle, but a watchman has been kept at the plant and much of the equipment is still in usable condition.

About 150,000 tons of ore averaging 25 to 30 percent manganese was put through the mill, and about 50,000 tons of concentrates and crude ore containing about 45 percent manganese was shipped. The old tailings dump is estimated to contain about 40,000 tons with a reported average manganese content of nearly 20 percent.

No systematic mining was possible in the widely scattered small ore bodies. The ore was gouged out in every possible way, through glory holes, from open cuts, shallow adits, and shafts.

Stratigraphy.--Three kinds of rock are found in the region—agglomerate, tuff, and red to gray limestone (pl. 54). The tuffs underlie both the agglomerate and the limestone, as shown in many places on the surface and in drill holes. The agglomerate has not been seen in contact with the limestone, but fragments of both red and gray limestone in the agglomerate are

physically identical with the nearby limestones, and they contain fossils resembling those in the limestone of El Aura hill. The agglomerate is therefore probably younger than the limestone, and the observed relations indicate either (1) that the agglomerate is a surface accumulation which unconformably overlies both the tuff and limestone or (2) that the agglomerate is intrusive into and through the tuff and limestone. The presence of rounded fragments and the apparent gradation of the agglomerate into conglomerate lend support to the first idea, while the complete lack of bedding and the large size and angular character of many fragments suggest a nearby source, possibly a near-vent mud flow, which locally has spread over the surface and may elsewhere be of intrusive character.

Many of the fragments in the agglomerate are of enormous size; several that were more than 50 feet on a side have been measured. The fragments consist predominantly of tuffs and other volcanic rocks, but they include pieces of both gray and red limestone. In general they are mostly subangular, but rounded fragments predominate in places, and there the rock resembles a coarse conglomerate. The thickness of the agglomerate in the northern and western parts of the mapped area, as shown in many drill holes and old workings, is generally less than 100 feet (30 m.).

The tuff beds are generally bright green, but locally they are reddish and brownish with a tinge of purple. Material so fine-grained that its individual grains are distinguished with difficulty grades into agglomeratic beds consisting mainly of fragments an inch or more in diameter. The tuffs are in part water-sorted and are similar to the water-sorted fragmental rocks that are abundant elsewhere in the Sierra Maestra.

The limestones have a thickness of more than 100 feet (30 m.) where they are exposed on El Aura hill, in the northwestern part of the area. They are mostly gray; the red color, which is apparently due to finely divided particles of hematite, is seen only in places, especially along the contact with the underlying tuff and close to the agglomerate. Several other nearby hills have conspicuous cappings of red limestone, but as these cappings have not been examined in detail it is not known whether they represent the basal part of the formation. The limestone contains poorly preserved fossils, a few of which resemble Lepidocyclina, supposedly of upper Eocene age.

A few dikes and remnants of flows of basaltic and latitic composition 7/ are found in the agglomerate, but they appear to have no direct relationship to the ores.

Structure.--The tuff and limestone beds are generally almost horizontal, and their dips in few places exceed 25°. No faults large enough to map have been recognized in these formations, though they may be present. The fragments in the agglomerate are oriented haphazardly, as would be expected, and are broken by many small slips. A fault zone of easterly trend, which may cut both the agglomerate and the tuff, is shown in the underground workings southeast of the road at a locality about 1,000 feet (305 m.) east of the staff house (see pl. 54).

Ores.--The ores of the Bueycito mines are in tuff and are similar to the tuff ores throughout the region. The unique feature of the Bueycito district is that the ore beds have been

7/ Hewett, D. F., personal communication, 1941.

broken and now form widely dispersed and disconnected fragments in the agglomerate, a fact which explains the erratic distribution and the small size of the ore bodies—the largest known contained about 5,000 tons. Practically all exploration and mining have been directed toward the finding and recovery of these small bodies. Small quantities of manganese oxide are found in the matrix of the agglomerate and in veinlets that cut across the rock fragments. This material is thought to have been dissolved from the tuff ores and redeposited in its present location at the time the agglomerate was formed. One small ore body at the contact between tuff and limestone was mined on the Daniel denouncement.

The mineral composition of the Bueycito ores is similar to that of much of the ore in tuff. The most abundant ore mineral is psilomelane; there are smaller quantities of pyrolusite and scattered patches of manganese silicates, notably orientite (a complex manganese silicate). Pink and white zeolites are abundant and have been seen in veinlets cutting ore. Jasper was first noticed in the form of boulders scattered over the surface, but it is widely distributed in the bedrock, both as layers next to ore pockets and as isolated fragments in the agglomerate.

The total ore reserve in sight is not great; a total of 18,000 tons is regarded as blocked out. This estimate was made from examination of all the known drill records and measured from all the accessible mineral occurrences, which are widely scattered over the properties. Owing to the fragmental and discontinuous nature of the deposits, projection of ore bodies in order to figure reserves is poor practice. It is believed, however, that, in addition to the measured reserve, 32,000 tons can be obtained from the known ore pockets; the total reserves would thus amount to about 50,000 tons of ore, which would average 25 to 30 percent or better in manganese.

The property is handicapped by the high costs inherent in any mining of widely scattered small ore bodies. Diamond and churn drilling were done in the central part of the area in 1925 and 1926, and several ore bodies were found and partly mined out. The chances of finding new ore in this thoroughly explored ground are slight, but they might be better in the southern, eastern, and northern borders of the agglomerate, where ore-bearing tuff beds appear to be more continuous than in the central area. The limestone-tuff contact on the Daniel and Oviedo denouncements likewise merits more exploration.

Biaya

The Biaya prospect is southwest of the Bueycito (Helen) mine and is in an area of latite(?) tuff or lava. Several pits have been dug on seams of manganese oxide, which trend from north to northwest and dip about 70° W. The manganese oxide seen in the rather scanty showings is hard and appears to be high in silica.

Guisa area

Buenavista group

The mines known as the Buenavista group are at the headwaters of the Cautillo River on the divide known as the "Estribo del Ganado," between the Guisa, Cautillo, and Brazo Seco Rivers. There are ten or more denouncements in the district, but only a few were visited. The district produced about 1,000 tons of high-grade manganese ore in 1940 and 1941 but has been idle since then. It is most accessible from Guisa by an 11-mile (18 km.) trail; it can also be reached by shorter trails from La Unica mine and the village of La Table, but these trails are over rough country and are difficult to travel.

The area in which the mines lie is drained mainly through underground channels in the porous limestones, but some valleys floored with tuff have small streams. The area is rugged and sparsely settled and hence has been but little prospected for outcrops of manganese oxide. The limestone-tuff contact, which is widely mineralized in the Sierra Maestra, is exposed for several miles in the area and is a good place to prospect. Pockets of ore occur in the limestones, the best of them near a major east-west fault.

The principal output has been from the Maria Teresa mine, which in 1941 produced about 800 tons of ore, associated with jasper, from pockets in limestone. The ore was packed by mule to Guisa. The known pockets have been mined out and the little exploration work that has been done has failed to reveal additional ore. A small amount of ore was also mined from the Lola prospect, which is about 1½ miles (3 km.) north of the Maria Teresa. The area between the Lola and the Maria Teresa is taken up, but no ore has been produced and very little prospecting has been done.

The ore shipped was nearly all pyrolusite cut by stringers of calcite. Manganese oxide, intimately associated with hematite, is found on the Fortuna and Lolita denouncements, but part of this material runs higher in iron than in manganese and is not salable at present. Known ore reserves are small, but the chances of finding other ore pockets are believed to be good.

Cádiz mine

The Cádiz mine is about 4 miles (6 km.) south of the town of Guisa, the terminus of the paved highway from Bayamo. The property, which covers 200 hectares, lies a mile (1.6 km.) south of the Guisa River, about 8 miles (13 km.) above the confluence of the Guisa with the Bayamo River. The mine is operated by Succession de Emilio Bonich y Cia. of Habana under a lease. Other nearby denouncements include the Cádiz Segunda, Madrid, Argélia, Norah, and Casualidad, but none of these has produced much manganese ore.

The mine is reached by 7 miles (11 km.) of mule trail from Guisa or by a dirt truck road from the Bayamo River. Ore has been packed by mules to Guisa and then hauled 11 miles (18 km.) by truck to Bayamo. The dirt truck road from the Bayamo River is not used because the haul to Bayamo is over 22 miles (35 km.) long and the road is passable less than a third of the time.

The Cádiz property was taken up in 1902 but no manganese ore was produced until 1918-19 when a few tons was shipped from shallow pits and shafts. The mine was reopened in 1940 and a large pocket of ore was discovered early in 1941. Production to March 1942 totaled about 7,500 tons of ore containing more than 45 percent manganese.

The mine workings are on the summit and north slopes of a flat-topped, heavily wooded hill, at an altitude of about 1,300 feet (400 m.). The steep north slopes lead down to the Guisa River, 600 to 700 feet below. Prospecting away from the mine workings has been superficial, owing principally to the dense forest cover. The shallow mine workings are dry, and water for mining and camp use is carried up from the river. The area surrounding the principal workings is shown in plate 55.

The Cádiz hill is capped by 100 to 300 feet (30 to 90 m.) of massive gray-white limestone, which overlies a large thickness of volcanic rocks. These are the same stratigraphic units in which most of the manganese ores in the region occur, and they have been mapped continuously between the Cádiz and Taratana mines.

Coarse, green andesitic tuffs, a few beds of which are limy, make up the larger part of the volcanic section, but boulder agglomerates interbedded with red ashlike tuffs predominate near the limestone contact.

In the lower 50 to 75 feet (15 to 23 m.) of the limestone, lenticular conglomerate zones alternate with beds of platy limestone. Sections at points separated by as little as 500 feet (150 m.) differ greatly in detail, but in general the conglomerates are composed of boulders of limestone and tuff. Many of the boulders are outlined by stains of manganese oxide, which also follow some bedding planes. Above this basal conglomeratic member the limestone is thin-bedded, dense, and usually light-colored. Much of it is crystalline near fractures, and in some places original structures are destroyed by crystallization.

The hill at the Cádiz mine, in which the beds dip gently to the south, is part of a fault block between regional faults that strike northwestward. South of the Cádiz mine, near the Guama River, the limestone-tuff contact is offset to the east on the south side of a fault zone, and near the Guisa River, north of the mine, the limestone is downthrown 500 to 800 feet by two faults of northwesterly trend. A manganese-bearing zone on the north slopes of the Cádiz hill parallels the fault trend and may extend along one of these faults.

The limestones at Cádiz are cracked and brecciated in fracture zones which trend roughly north-south and east-west and generally have steep dips.

The present mine workings are shallow pits and glory holes, and the deepest shafts that were sunk in the past were only 80 feet deep. One 40-foot (12 m.) shaft encountered 10 feet (3 m.) of ore, and early in 1941 drifts in two directions had each developed 15 feet (4½ m.) of ore. By March 1942 the ore body was outlined, and it proved to be 80 by 60 feet (24 by 18 m.) in horizontal dimensions and from 10 to 40 feet (3 to 12 m.) thick. Over 6,500 tons of ore had been extracted from this one ore body. The ore was mined by hand and hoisted to the surface with a hand winch.

Most of the ore is in the lower part of the limestone; some, however, is at the limestone-tuff contact, and one ore zone on the north slope of the hill is in limy tuff. The ore in limestone is in stringers, pockets, and veinlets, but that in the tuff forms a well-defined bed. The ore is hard and massive, and gives a minimum of fines when handled. It consists predominantly of pyrolusite, but contains a subordinate quantity of psilomelane. The chief gangue of the ore is calcite—black calcite in flecks and white calcite in veinlets. The walls contain pockets of iron oxide, but the ore is nearly free from iron. In the tuff ore bed the gangue is chiefly red tuff.

The stringers of manganese oxides, which are generally from 1 to 2 inches wide, are persistent along certain fracture zones. The principal ore body was in one such zone, along which many small pits had been sunk and from which a little ore had previously been mined. In this and other nearby zones the stringers dip 50° to 80°, much more steeply than the bedding. Some stringers do not follow fracture zones and a few are parallel to bedding planes.

The ore bed in the tuff strikes N. 40° W. and dips 50° NE. The bed is rich enough to have been opened by pits for about 80 feet (24 m.), but it grades along the strike in both directions into black manganiferous tuff. The ore is massive, high in calcite, and similar in general to the limestone ore but perhaps of lower grade.

In March 1942 less than 2,000 tons remained in the main ore body and about 300 tons in the tuff ore bed. Early in 1942 the company started an exploration program and sank several shafts on favorable outcrops. One shaft uncovered a 40-ton ore body, but all others were blank. Unless new ore bodies are discovered, the life of the mine will probably be less than six months of working time. The best place to look for ore is probably the east-west zone which contained the principal ore body.

Taratana mines

The Taratana mines are about 10 miles (16 km.) south of the Central Highway and 4⅓ miles (7 km.) east of the town of Guisa. They lie in the low foothills north of the Sierra Maestra on the divide between the Guisa and Cautillo Rivers. The mines are easily accessible from Guisa over an all-weather truck road, which was recently put into good condition by the mine operators.

The properties, which cover 415 hectares, consist of the Lego and Cañada denouncements, operated by Felipe Puente of Palma Soriano, and the Segunda Gloria, Guisa, Confianza, and Chela denouncements, controlled by Dr. Escalona of Bayamo. Part of the denouncements were taken up in the early 1900's, and some manganese was produced during the first World War. The mines have been most active, however, in recent years, and the production, which has totaled over 20,000 tons, has largely been made in the past 3 years. At least two-thirds of this came from the Cañada mine and the remainder from the Segunda Gloria and Lego mines.

The mines are on the top of a low hill overlooking a broad cultivated valley to the south. The north slope of the hill, which descends smoothly to the Cautillo River, is heavily

wooded and would yield an ample supply of mine timber. Water for the mines is pumped from the valley to the southwest.

The two rock units near these mines, as elsewhere in the manganese belt of the Sierra Maestra, are a volcanic formation and an overlying limestone. The volcanic rocks are mainly green, well-bedded, water-laid tuffs, but they also include many layers of agglomerate and a few flows. Manganese oxides do not occur in the volcanics except for local stains.

The limestone is at least 300 feet (90 m.) thick and persists throughout much of the area mapped (pl. 56). At its base is a conglomerate bed 20 feet (6 m.) thick, composed of limestone boulders, tuff fragments, and fossil algal heads. This is overlain by 30 feet (9 m.) of dense limestone, in the upper part of which manganese oxides generally occur at three or, in places, four horizons, separated and overlain by intraformational conglomerates. Each conglomerate contains fragments of manganese oxide, limestone, and tuff, cemented with pink or red limestone. The greatest concentration of manganese-oxide fragments directly overlies the ore beds and decreases upward, so that the conglomerates grade into impure limestone containing a little manganese oxide. The conglomerate beds are locally known as mezclado. The uppermost conglomerate grades upward into dense white platy limestone, which makes up the rest of the section. The stratigraphic position of the manganese oxide beds was checked by mapping one thin but persistent conglomerate bed about 50 feet (15 m.) above the ore horizons.

The ore beds grade laterally into two distinctive types of rock; in places, as at the Cañada mine, the ore grades into red tuff; in other places, as at the Lego mine, it grades into an impure limestone composed of foraminifera and small limestone fragments in a matrix of pyrolusite and black calcite. This manganiferous limestone grades in turn into a foraminiferal limestone that contains no manganese. Similarly the manganese pebbles in the mezclado disappear laterally and the rock becomes a limestone conglomerate. The equivalents of the manganese-bearing beds have been traced more than a mile northwest of the mineralized zone, by means of the interbedded conglomerates and foraminiferal limestones.

A north-south fault through the Cañada mine workings brings tuff against the ore horizons, and also locally changes the strike of the beds from N. 70° W. to N. 10° W. A similar northwestward-trending fault south of the Segunda Gloria mine brings tuff in contact with the ores, and is marked by a breccia zone 100 feet (30 m.) wide, the matrix of which contains a small amount of manganese oxide. South of this fault a small area of limestone is found, but apparently the ore beds are not repeated. Both faults are later than the ore.

Three types of ore are found at Taratana. The most abundant consists of fibrous radiating psilomelane forming nodules and layers in the tuff. The second consists of dense powdery pyrolusite forming layers in the tuff. The third is the impure limestone and mezclado, which in few places contain sufficient manganese oxides to be ore. Pyrolusite and psilomelane are the only manganese minerals recognized.

The ore beds consist of characteristic tuff ore, but near the Cañada fault and beneath the Cañada Valley the ore is nearly solid manganese oxide, without conspicuous nodular and banded structures. It is believed that these solid ore beds have been enriched by percolating waters, for they lie below a valley near a fault zone and are in permeable tuff beds which

dip down the valley. In some deposits, for example at the Guisa mine, the manganese oxide beds contain flecks of black and white calcite and a few thin stringers of pyrolusite and psilomelane. Although parts of the beds are solid ore, most of the mineral must be hand-cobbed to bring its manganese content up to 40 percent.

About 45,000 tons of ore was blocked out in the mines in July 1942, and, assuming a continuation of 100 feet (30 m.) beyond the working faces at that time, another 25,000 tons is probable. Should the Lego and Cañada ore bodies connect and the entire hill near the Gloria be underlain by ore, there may in addition be 80,000 tons of possible ore. Inexpensive development drifts at the Cañada mine could prove or disprove the existence of this tonnage. A drift into the area east of the abandoned west block workings and another extending south toward the Lego mine would be adequate for the purpose (see pl. 57).

Lego and Cañada mines.--The Lego and Cañada mines are operated by the Cia. Minas en Taratana. The Lego workings are a series of short inclines on thin beds of ore which crop out on the face of a cliff. The ore is scraped by hand from the sides of the galleries, put into sacks, and hauled in bullock carts to the road near the mine office. Production amounts to only a few tons a day. In the spring of 1942 the company prospected along the fault south of the Lego workings, but in March it had not discovered any ore.

Most of the production comes from the Cañada mine, which in July 1942 was said to be producing about 35 tons a day. The mine is developed in two blocks, east and west of the Cañada fault. The west block, north of the Arroyo Cañada, produced ore in 1940 and 1941 but is now abandoned. The ore beds were developed by four drifts, which were connected by short inclines, and to the west each drift passed from ore into tuff that was of too low grade to mine. The block was mined eastward to the Cañada fault, and good ore was found along the fault, though no effort was made to explore the down-faulted ore beds to the east. Slickensided and angular ore fragments in the fault zone indicate that the ore probably continues in the downthrown block to the east.

The east block (see pl. 57) was first explored by drifts on two ore beds which cropped out. Later a third and lower bed was developed by a shaft and drifts. Within 50 feet (15 m.) of the outcrop the middle bed pinched out, but it was later found again below the main haulage level. Mining was done for a time through a gallery 10 feet (3 m.) high, which included the top and bottom beds, but this system was changed when the beds became too far apart to permit economical extraction. The ore is now mined through inclines and cross drifts between large pillars, from which the ore is scraped, wheeled or shoveled to a lower haulage level, and taken to the surface in mine cars. Development work has kept well ahead of mining. Drifting and mining are done with lightweight jackhammers, and no timber is necessary in the hard limestone country rock. The company plans to install heavier drilling equipment and could profitably use small draglines to handle the ore and waste in the inclines. The ore is stored in bins and is trucked to Bayamo by way of Guisa.

The ore beds vary in grade throughout the mine, the best ore being in the eastern and northern parts of the east block. The lower bed usually has 2 feet (0.6 m.) of massive ore in the center and 1 to 2 feet (0.3 to 0.6 m.) of nodular tuff ore on

the borders. The other beds are generally of higher grade, and the middle ore bed below the haulage level showed 5 feet (1.6 m.) of solid pyrolusite ore in July 1942. This was the best ore seen in the mine. In March the working faces towards the Lego mine to the south also showed ore, and it is very possible that this and the Lego ore bodies connect.

Segunda Gloria and Guisa mines.--The Segunda Gloria and Guisa mines are shallow workings on the outcrops of thin ore beds. The Segunda Gloria is on the western side of a small hill, and its workings consist of two short drifts with several connecting inclines. In March 1942 three feet (1 m.) of tuff ore was exposed in all working faces. Exploration in the hill to the east has failed to disclose commercial mineralization. A few pits north of the Segunda Gloria workings, some pits at the Guisa mine, and others on the eastern side of Gloria hill all contain impure limestone bearing a few percent of manganese oxides. Within 300 feet (90 m.) of the Segunda Gloria workings the ore beds pinch out in both directions along the strike.

All mining is done by hand, and the ore is hand-cobbed, sacked, and hauled by mule to the company storehouse about a mile to the west. From there it is trucked to Bayamo.

Effie

The Effie prospect, 60 hectares in area, is about 9 miles (14 km.) airline southeast of Guisa. Several small cuts, none over 6 feet (2 m.) deep, are opened in an outcrop of tuff which trends S. 75° W. and dips 35° NW. From these cuts a small amount of granzon and cobbles of manganese oxides have been recovered. The exposures were too poor to permit any estimate of reserves.

About a quarter of a mile (0.4 km.) west of the principal workings is an old cut showing manganese oxide veinlets in limestone at a tuff-limestone contact.

Yiyi

The Yiyi prospect is about 3 miles (5 km.) airline south of Guisa. Three small pits, one about 15 feet deep, have been sunk in a zone of limestone breccia which trends S. 85° E. and dips about 35° S. The zone contains, in places, as much as 3 or 4 feet (1 m.) of stringers and pockets of manganese oxide, and in a part of the deepest pit there are manganese oxide fragments in what appears to be cave rubble or breccia. About 40 tons of high-grade ore is said to have been shipped from here in 1941.

Luz

The Luz prospect, which contains 144 hectares, is about 4 miles (6 km.) airline southwest of Guisa. Two small cuts and a short adit have been driven on a bed of manganese oxides 2 inches to 2 feet (5 cm. to 0.6 m.) thick. The country rock is limestone and no volcanic rocks were seen near the workings.

Aurora

The Aurora prospect is about 7 miles (11 km.) due south of Guisa. The property is developed by a small cut, a pit 10 feet (3 m.) deep, and two short adits. About 100 tons of ore, which averaged about 45 percent in manganese, was produced from a zone of stringers and small pockets in limestone. The zone trends N. 80° W. and dips steeply to the north.

Mercedes

The Mercedes prospect adjoins the Aurora prospect, and when visited it was being worked in a small way in one pit and an open cut. The ore is in irregular veinlets in a limestone breccia along a contact between limestone and tuff. The contact strikes N. 10° E. and dips 75° W., with the tuff lying to the west.

Morita

The Morita prospect, which also adjoins the Aurora prospect, is developed by one cut and several open pits in brecciated limestone. The pits are badly slumped but a little jasper and manganese may be seen.

Margot

The Margot (Maria Lola) lies in the hills southwest of Guisa, between the Bayamo and Macamacu Rivers. The prospect is reached from El Corojo by a trail that crosses four rivers and that is difficult to travel during rainy weather.

Manganese oxides form stringers in conglomerate at the base of a thick stratum of limy tuff, and also in the underlying coarse agglomerate. The workings consist of six pits and three short adits, but mineral of possible economic value was seen in only one of the pits. The adits are in a dense, hard, black siliceous tuff about 50 feet (15 m.) stratigraphically below the ore horizon.

Antonia

The Antonia and Antonia Segunda denouncements are about 11 miles (17 km.) east of Guisa and cover a limestone-capped hill called Alto de Cobrero, which lies just north of the Guisa River. In dry weather it is possible to drive from Guisa to within 5 miles (8 km.) of the property.

Pockets of ore in a basal limestone conglomerate or breccia, which overlies volcanic tuff, have been developed by about 700 feet (210 m.) of underground drifts and several shallow pits. One small area of granzon has been found and has been superficially explored. A few tons of ore has been shipped from the property, and it is estimated that about 500 tons remains in sight. The ore must be hand-cobbed, but it yields a good grade of concentrate, with 47 percent of manganese.

Josefina

The Josefina denouncement, adjoining the Antonia, shows thin but high-grade stringers of manganese oxide in limestone. No work has been done on the property, but the showings are good enough to merit some exploration.

Desperto

The Desperto denouncement is another of the Antonia group that seems worth prospecting. Stringers of high-grade manganese oxide are exposed in several old and overgrown cuts in limestone and along a limestone-tuff contact.

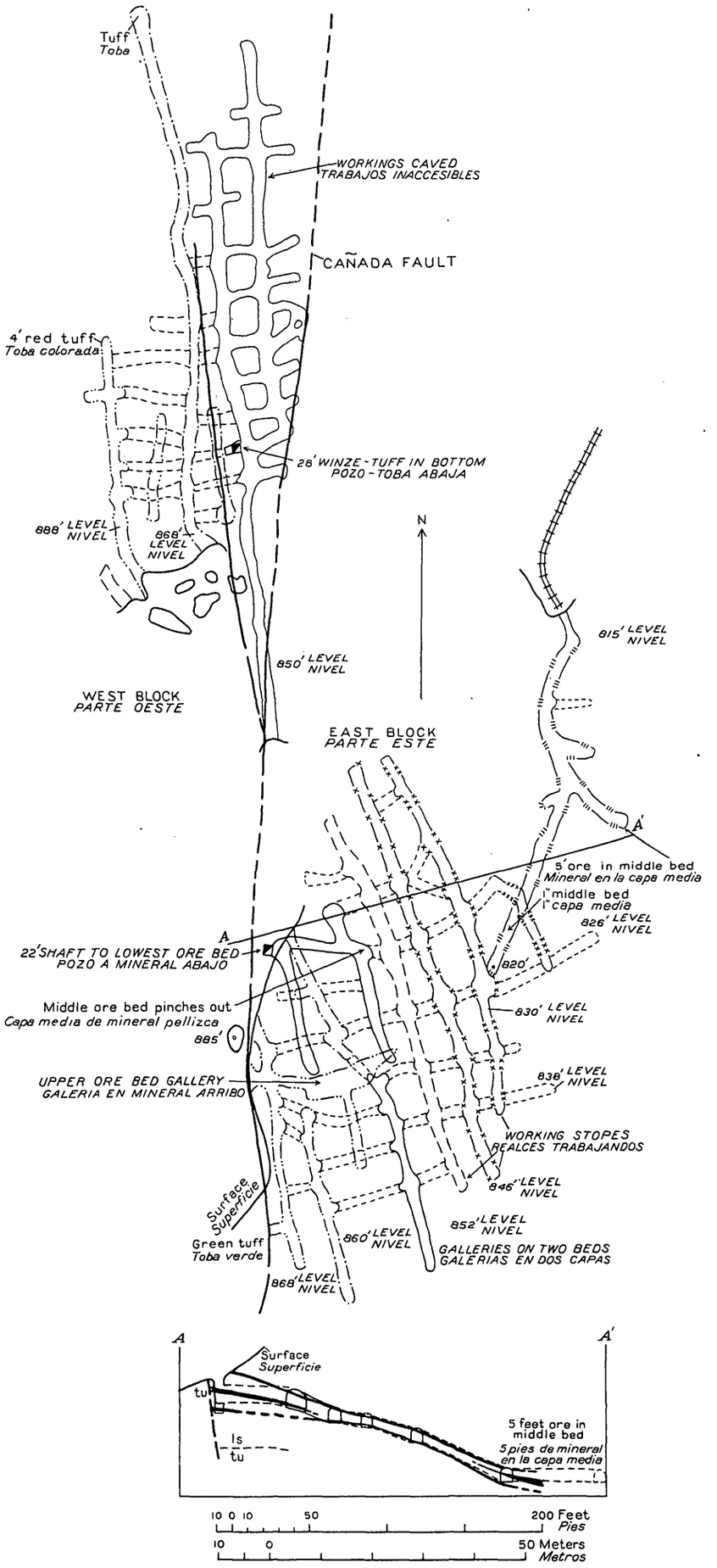
Charco Redondo area

The Charco Redondo area is 7 miles (12 km.) southeast of Santa Rita, a town on the Cuba Railroad, and lies in low rolling country north of the Sierra Maestra foothills. The district is on the western edge of a large sinkhole area and is drained by the Cautillo River, which has cut a gorge into the hard limestone country rock and has opened wide basins in the softer volcanic rocks below. Charco Redondo itself is one such basin. A truck road 7 miles (12 km.) long from Santa Rita to the mines is well-graveled and passable in all weathers except for the last kilometer, which is passable only in dry weather. Trails from the Charco Redondo area lead southward to several less accessible mines.

The principal producing mines are the Charco Redondo, Casualidad, and Lucia, which are on a group of about twenty denouncements that lie between the Taratana mines on the west and the Montenegro mine on the east. Several other mines in the district, notably the Manuel and Labor, have produced manganese but are now idle. A few of the denouncements were taken up as early as 1900, but the first attempts at mining were made between 1917 and 1920, under the stimulus of the high prices of World War I. Renewed activity in the present emergency has resulted in reopening the mines and the taking up of most of the remaining ground. Total production from the area has been about 75,000 tons, of which over two-thirds has come from the Charco Redondo and Casualidad mines.

The area was visited in 1941 and was mapped in 1942. Two of the most productive areas were then mapped in detail; the larger, shown in plate 58, covers part of the Charco Redondo, Casualidad, and Manuel denouncements, and the other, shown in plate 59, covers the Lucia. Many of the other denouncements have been visited, and much of the area has been mapped on aerial photographs.

The manganese ores are in two rock units similar to those found throughout the Sierra Maestra manganese belt—volcanic rocks overlain by limestone. These rocks have been mapped in the area between the Taratana, Charco Redondo, and Antonio mines, and they are found to be lithologically similar throughout the mapped area, which is some 19 miles (30 km.) across. At Charco Redondo the volcanics are light-green, well-bedded andesitic tuffs containing a few beds of agglomerate and limy tuff. The upper tuff beds are commonly mineralized, and a large part of the ore of this district is in the top 10 to 15



PLAN AND SECTION OF THE CAÑADA MINE WORKINGS,
ORIENTE PROVINCE, CUBA

PLANO Y SECCION DE LOS TRABAJOS, MINA CAÑADA,
PROVINCIA DE ORIENTE, CUBA

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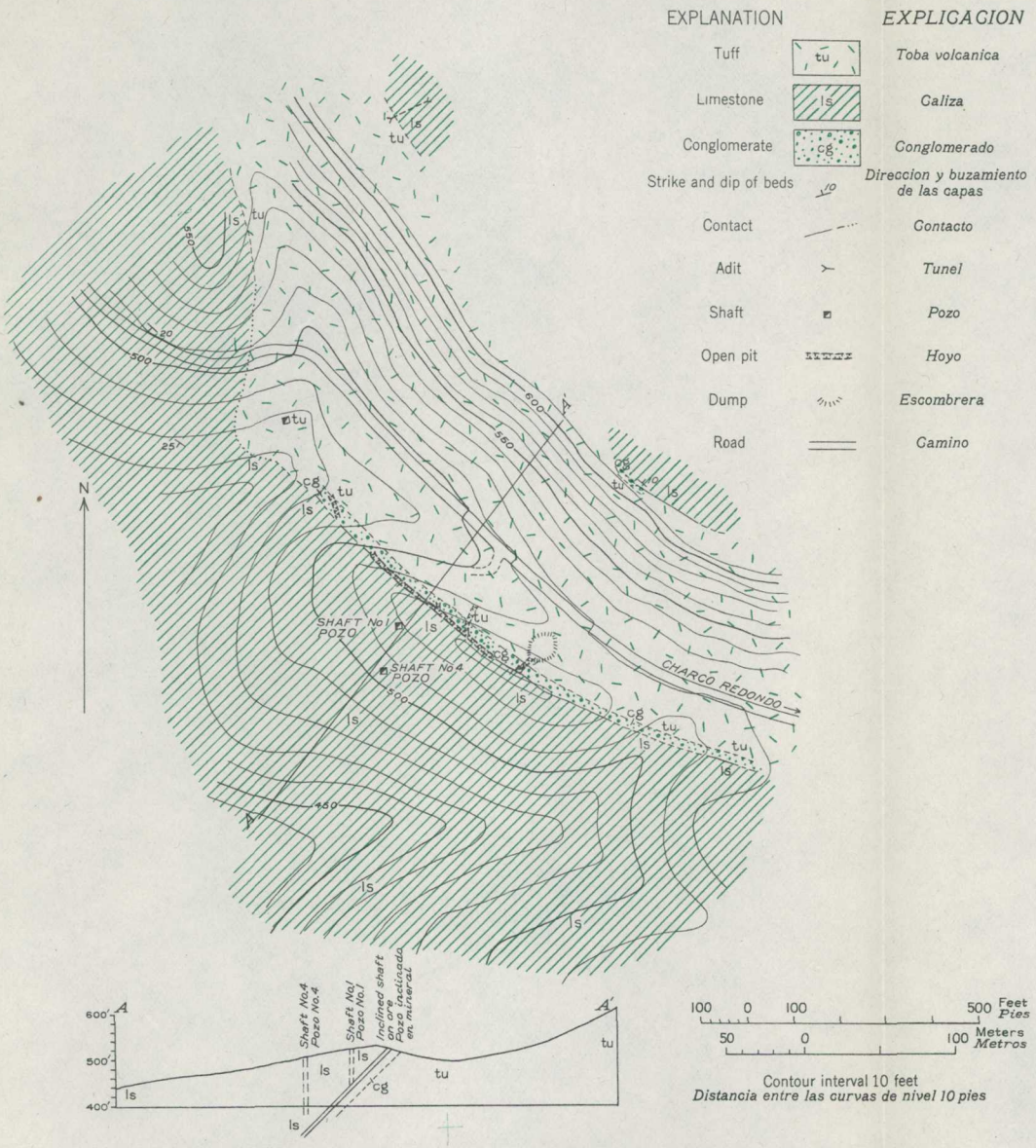

GEOLOGIC MAP AND SECTION OF THE LUCIA MINE, ORIENTE PROVINCE, CUBA

MAPA GEOLOGICO Y SECCION DE LA MINA LUCIA, PROVINCIA DE ORIENTE, CUBA

feet (3 to 5 m.) of the volcanic rocks. North of the Lucia mine the tuffs are cut by several andesitic dikes.

The tuff is overlain by thin-bedded limestone. In places there is a transitional intermediate zone of limy tuffs, but near the more strongly mineralized areas the contact is generally sharp and is marked by basal conglomerates in the limestone. These conglomerates are local; at one exposure in the Cautillo Canyon, a conglomerate grades into a limy tuff within a distance of 400 feet (120 m.) along the outcrop. Above this basal member the limestone is generally thin-bedded, dense, and full of algal heads, which locally give the rock the appearance of a limestone conglomerate. The limestone is at least 350 feet (110 m.) thick as measured in the Cautillo Canyon and is fossiliferous throughout.

Two northerly trending fault zones pass through the principal mine area. The western zone consists of a series of roughly parallel breaks, which drop the limestone down on the west from 50 to 200 feet (15 to 60 m.). Near the Cautillo River this fault zone splits into several branches, which trend southwest and southeast. Those that remain in limestone are marked by wide breccias and steep drag dips, but those in tuff are traceable only with difficulty. The eastern fault zone, which lies at the eastern edge of the map (pl. 58), drops the limestone down on the east about 100 feet (30 m.). Small faults which apparently merge into the main zone cut the limestone into several slices near the Charco Redondo office. This slicing effect is shown by displacement of ore horizons in the limestone. Some of the small faults bear manganese oxides, but others are clean breaks, with their wall rocks neither altered nor mineralized.

The regional dips in the limestone indicate that the area is a broad syncline. Near the Cautillo River, at the K6 workings, the beds strike N. 70°-80° E., and dip gently north except along the western fault zone, where the strike parallels the fault and the dip is as steep as 60° W. Farther north the beds strike N. 20° W. and the dip changes from horizontal east of the fault to 10°-15° W. west of the fault. Between the eastern and western fault zones the beds are essentially horizontal, and east of the eastern fault zone they dip to the east.

Along the limestone-tuff contact, the tuff is composed of nodules, stringers, and layers of manganese oxide in a matrix of altered tuff. The mineralization is spotty, and the ore bodies that occur on the Casualidad, Lucia, and Charco Redondo denouncements are apparently separated by poorly mineralized areas. The ore beds range in thickness from a few inches to 12 feet (a few centimeters to 4 m.), and the manganese content varies between 15 and 35 percent. The principal mineralized area is adjacent to the western fault zone, and the fault itself is sparsely mineralized at the Cautillo River. There is at least one outcrop of low-grade ore in the river gorge 1.2 miles (2 km.) west of the fault.

Bedded manganese oxides occur at several horizons in the lower 50 feet (15 m.) of the limestone. One mineral-bearing bed crops out on all sides of a hill east of the Charco Redondo office and can be traced for over 2 miles (3 km.), though it is nowhere more than 1½ feet (0.5 m.) thick. This bed contains a large proportion of manganese oxide but is too thin to be minable. In the Charco Redondo and Casualidad mines there are generally two such thin manganiferous beds, about 30 and 45 feet (9 and 14 m.) respectively above the base of the limestone. The ore beds pinch out laterally and are not recognized on

adjoining denouncements, but there is ore in what appear to be equivalent beds at the Taratana mines, farther west. On the east bank of the Arroyo Caridad, an ore bed is overlain by 6 to 8 feet (2 to 3 m.) of manganese-bearing intraformational conglomerate or mezclado, which, like similar material at the Taratana mines, contains fragments of limestone, tuff, shale, and scattered pebbles and fragments of manganese oxide, in a limestone matrix. On the west bank of the Arroyo Caridad the conglomerate is not present and the entire lower part of the limestone section is tuffaceous, grading into the tuff beneath. Foraminifera, sharks' teeth, and algal heads are common fossils in the ore beds and conglomerates.

The strongest mineralization in the limestone is roughly parallel to the western fault zone, and the ores persist to the north and south but pinch out to the east and west. The K6 drift north of the Cautillo River follows 2 to 4 feet (0.5 to 1 m.) of ore for over 800 feet (240 m.) to the north, but the same bed pinches out 200 feet (60 m.) west of the portal.

The manganese minerals recognized in the ores are psilomelane, pyrolusite, manganite, and black calcite. Psilomelane, here as in many other mines in Oriente, is the most abundant mineral; pyrolusite is common in pods and veinlets cutting the other minerals; manganite is so rare as to be a curiosity. The principal gangue is altered tuff, but pods of calcite and stringers and veinlets of jasper also occur, especially along the lower part of the beds. The tuff gangue may be a soft, decomposed material, such as that on the Casualidad denouncement, or a hard and massive tuff, such as that found in parts of the Charco Redondo mine.

Percolating ground-water alters and softens the gangue minerals and thus makes them easier to crush and wash. Locally it has improved the grade of the ore by removing gangue and depositing particles of manganese. Elsewhere, as in some of the river workings of the Charco Redondo mine and in the Lucia ore body, psilomelane appears to have been dissolved and redeposited in veinlets of pyrolusite.

The proved reserves of ore in the district amount to about 50,000 tons, averaging 25 to 35 percent manganese, of which the greater part is on the Casualidad and Charco Redondo properties. This ore has been blocked out incidentally in mining and has not been systematically explored. It is estimated that there is, in addition, 125,000 tons of probable and possible ore. The reserves might be increased by exploration, drilling, and test-pitting on properties adjacent to the Charco Redondo and Casualidad mines; ore bodies might thus be found on the Segundo Charco Redondo or Charco Azul denouncements, for example.

Charco Redondo mine

The Charco Redondo property, operated by the National Manganese Mining Corporation, of Habana, includes two denouncements, the Charco Redondo and Segundo Charco Redondo, which cover 830 hectares. The Charco Redondo denouncement covers the principal mineralized area around the older Casualidad denouncement. Most of the workings are on this denouncement, which was taken up during the first World War. Very little ore was extracted at that time, and the several attempts that were made to operate the mine in the succeeding twenty years were unsuccessful. The advent of the present war, however, has brought new life to the mine. Its production has been as high as 1,800

tons a month during the past year, and probably about 40,000 tons has been produced in the past three years.

Most of the ore has come from workings in the two ore beds in limestone, principally from the river workings, along the north bank of the Cautillo gorge, near the K6 and the U workings. Both the upper and lower beds are mined west of the western fault zone, but near the fault the beds are too thin to be worth mining. The U1, U3, U4, U5, and K6 inclines follow the beds northward, down a dip of about 8°, for distances of as much as 800 feet (240 m.). Throughout these workings the beds are between 2 and 4 feet (0.5 and 1 m.) thick, but just west of the K6 drift both beds pinch out. The same beds are exposed south of the Cautillo River and in Arroyo Caridad, where one outcrop shows 5 feet (1.5 m.) of low-grade tuff ore in the lower manganiferous horizon. In the C5 adit this ore has been developed for several hundred feet to the southeast and consists mainly of stringers in slightly altered tuff. Reserves of blocked-out ore in these workings are small, but there may be 60,000 to 75,000 tons of possible ore containing 30 percent of manganese.

The contact ore bed along the western fault at the Cautillo River is sparsely mineralized. Where it is developed in the S1, S2, S3, S4, and S5 drifts it is 2 to 4 feet (0.5 to 1 m.) thick and contains 20 to 30 percent of manganese. The same horizon is mineralized northeast of the company office (pl. 58), where outcrops and shallow pits expose as much as 6 feet (2 m.) of material that contains about 15 to 20 percent of manganese; and shallow pits west of the office show similar low-grade manganese oxide. Only a small fraction of the ore produced in the Charco Redondo mine has come from the contact ore bed, but this bed may contain 20,000 to 25,000 tons of ore that would be amenable to concentration.

The ore reserves of the mine appear to be sufficiently large to sustain a production of 1,000 to 1,500 tons a month for several years.

Larger reserves of concentrating ore may be developed near the S1 workings and south of the Casualidad property on the same hill (south of area shown in pl. 58), where shallow pits expose ore at the limestone-tuff contact in the tuff and in the overlying limestone. The contact is exposed at several places in the Cautillo River gorge and for 1.5 to 2 miles (2 to 3 km.) west of the mapped area. Manganese oxide along the contact has been found in the gorge in two places west of the map, and systematic prospecting might well reveal more, for this part of the contact lies between two strongly mineralized deposits (Taratana and Charco Redondo).

Mining methods could be greatly improved. In the K6 workings, for example, which are the most extensive in the property, and in which air hammers are used for mining, the ore is pushed in wheelbarrows up an 8° incline for 800 feet (240 m.), dumped on the ground for hand-sorting, and then reloaded into wheelbarrows and dumped into a small loading bin. Lack of adequate storage facilities forces the mine to close when the roads are wet. In all the workings, mining and hauling are done by subcontractors who cannot afford mechanical equipment, and as a result the operations have been inefficient and expensive.

Most of the ore carries from 20 to 35 percent of manganese, and it must be hand-cobbed or crushed and screened to remove the tuff and calcite; for every man employed in the mine, another is employed to clean the ore. Ore from the C5 tunnel on the south bank of the Cautillo River is carried across the

river by cableway and run through a log washer. The manganese in this body forms irregular stringers rather than nodules, and the concentrates are estimated to contain from 40 to 42 percent of manganese. Installation of a jigging and washing plant similar to those at the Yeya or the Manacas mines might increase both recovery and production, although the Charco Redondo ore is said not to be very suitable for jigging.

Casualidad mine

The Casualidad denouncement, which was taken up in 1903, covers 54 hectares within the larger Charco Redondo denouncement. The Casualidad mine was worked during World War I, but the several attempts made since then to exploit the property were unsuccessful until demand was increased by the present war. It is now being operated by Dr. Enrique de Hechavarria, of Santiago, under lease from the owners. The present monthly production averages about 500 tons, but a new plant now being installed is expected to increase this to 1,500 tons or more. Although no definite figures are available, the total production from the mine has probably been about 20,000 tons.

The principal ore bed at the Casualidad property is the one at the contact, which crops out on a hill in the block between the eastern and western fault zones (pl. 58). The best ore body lies in a small swale on the western slope of the hill. The ore, which contains 20 to 35 percent of manganese, averages 5 feet (1.5 m.) in thickness, and in some faces it is as much as 12 feet (4 m.) thick. It consists mainly of nodules of manganese oxide in a soft matrix of tuff, largely altered to chlorites, zeolites, and clay minerals, which is readily separated from the ore by washing. About 20,000 tons of ore is developed, and there is probably another 20,000 tons in reserve. The ore body continues westward to the western fault zone, and new ore might possibly be found in the downthrown block west of the fault, where no exploration has yet been done.

The contact is mineralized elsewhere on the Casualidad hill, but when the district was visited in March 1942 no ore was developed outside the mine. The chances of finding concentrating ore here are fair, however; such newly found ore is counted on, indeed, to supply a concentrator which was being installed in July 1942.

South of the Cautillo River and west of the western fault zone the contact is mineralized but the ore bed is thin and of low grade. The tuff matrix, moreover, is hard, but it is hoped that the manganese oxide can be liberated by crushing and washing. One incline follows tuff ore that carries pyrolusite stringers, which can be mined separately. Over a thousand tons of high-grade ore has been taken from this incline, and it is possible that a considerable tonnage of concentrating ore may also be developed.

The partly blocked-out reserves at the tuff contact are 25,000 tons, and an equal amount in addition is considered possible. Although the ore beds in limestone crop out on the Casualidad hill and are opened by many pits, they are not considered as reserve ore because of their thinness. The best hopes for new ore on the Casualidad denouncement probably lie in the development of the hard tuff ores on the Casualidad hill.

Mining is done almost entirely by hand methods. In the large ore body, where the ground is soft, this is no drawback, but where the ore is hard the work is slow and expensive. Installation of chutes, loading bins, power drills, and other simple devices would tend to increase production and to lower mining costs.

Until August 1942 the ores were either hand-cobbed or cleaned in a log washer located about 1.2 miles (2 km.) from the mine. Milling practice was to wash the ore and screen it, making two products. The coarse-grained product ran 47 to 48 percent manganese, and the fines, which contained a large quantity of tuff, ran only 38 to 40 percent. The new plant which was being installed in July 1942 consisted of a crusher, two log washers, and a classifier screen set to make two or three products, which also will probably differ in grade.

Lucia mine

The Lucia (Generosa) mine is about 1.2 miles (2 km.) northwest of the Charco Redondo office, on the Charco Redondo-Santa Rita road. It is operated by Srs. Gutierrez and Gomez of Santa Rita and has recently had a monthly production of about 250 tons. Mining operations did not begin until 1941, and the total production has probably been only 2,500 to 3,000 tons. The denouncement adjoins the Casilda, Vencedora, and Charco Azul properties, the last of which contains the continuation of the Lucia ore zone.

The ore body of the Lucia mine extends along a conglomeratic zone at the limestone-tuff contact (see pl. 59). It crops out for about 400 feet (120 m.) and trends N. 40° W. with a dip of 40° to 50° SW. The mineralization extends from the limestone-tuff contact downward into the tuffs from 1 to 8 feet (0.3 to 2.5 m.). Most of the ore consists of nodules in a matrix of soft, altered tuff, but stringers and veinlets of manganese oxide have been mined separately. The ore contains about 38 to 40 percent manganese as mined, but is improved to 43 or 44 percent by hand-sorting.

Two dikes, each less than 1½ feet (0.5 m.) wide, are exposed in the mine workings, but they are not mineralized and appear to be postmineral.

The ore is broken in open stopes and hoisted through a shaft, which crosses the contact at a depth of 50 feet (15 m.). In March 1942 the ore body was developed to a depth of 100 feet (30 m.) and was mined out to about 25 feet (7.5 m.). Ore reserves were calculated at 5,000 tons of 40-percent ore. Twice as much in all may be available if mineralization continues downward for another 100 feet (30 m.) beyond the lowest workings.

Outcrops east of the Charco Redondo road show sparse mineralization along the tuff-limestone contact. Openings said to be on the Vencedora denouncement failed to develop any ore, and the chances of finding new ore bodies on the Lucia denouncement were considered poor. On adjacent denouncements of the Charco Azul group, however, some exploration for a possible continuation of the Lucia ore body would seem to be worth while.

Manuel mine

The Manuel denouncement lies north of Charco Redondo, on the north edge of the Casualidad hill. The denouncement was worked for a time in 1917 to 1920, and again in 1940 and 1941, but the total production has probably been less than 3,000 tons of 40-percent manganese ore.

The workings are at the lower ore horizon of the limestone, in the same bed that extends around the Casualidad hill (pl. 58). The bed is less than 2 feet (0.6 m.) thick where it is best, and for this reason attempts to mine it have not met with much success. The denouncement occupies the northernmost end of the mineralized zone of the Casualidad hill, and prospects for finding new ore bodies in the horizon being worked do not appear to be good. The tuff-limestone contact, however, has been very little explored, and it may contain undeveloped ore bodies.

Baire-Los Negros area

Antonio mine

The Antonio mine is 7.5 miles (12 km.) southwest of Baire, a town on the Cuba Railroad, and lies in the low foothills of the Sierra Maestra. The area mapped includes parts of the Antonio, Esperanza, and Milan denouncements. Other nearby denouncements are the Solozolt, Gaceta, Sandu, and Consequencia, which are near the western edge of a group of over 60 denouncements in the area between the villages of Purial, Los Negros, and Matias.

The Antonio denouncement has been worked almost continuously since 1938, and most of the production of this area has come from it. The denouncement was taken up in 1901 and was worked for a time in 1917 and 1918, but most of the development has been done since 1938 by the Cia. Minera de Pozo Prieto. Its total production has been about 10,000 tons of ore that carried between 40 and 45 percent manganese.

The district is reached from Baire by a truck road to Purial, where branches lead to several other properties and east to the Los Negros-Baire road. The road to the Antonio mine is passable much of the time, but it needs draining and ballasting in places to become an all-weather road.

The Antonio mine is on the northern edge of a rugged area of sinkhole topography, but most of the denouncement is in a region of low relief, some of which contains shallow sinkholes. On the eastern part of the denouncement a few valleys are floored with tuff and have surface drainage, and because of their high fertility these valleys are used for growing coffee. The water table in the valleys is close to the surface, but despite this fact there is not sufficient water for washing ores except in the valleys that have surface drainage. Timber for the mines is hauled from the hills to the south.

A thick unit of limestone and an underlying tuff are the only rock units near the mine, and they are probably the same two stratigraphic units that contain many of the manganese deposits of the Sierra Maestra. The tuffs are well-bedded, water-laid, green andesitic rocks, which, though not deeply weathered, are soft and form areas of low relief and moderately thick soil cover. Near the Antonio mine they do not contain

manganese oxides, but mineralized tuff beds are found in some of the adjacent denouncements.

In contrast to the soft tuffs, the limestone is a dense, hard, white rock, which weathers with a rough "dogtooth" surface and forms deep sinkholes and shallow undrained depressions with little soil cover. The contact between limestone and tuff is in many places obscured, because areas that are underlain by tuff are bestrewn with numerous blocks of the resistant limestone. At the base of the limestone lies a conglomerate composed of algal heads, which is overlain by 20 to 30 feet (6 to 9 m.) of dense platy limestone, generally full of microfossils. In a part of the area mapped the platy limestone is overlain by a bed, 3 to 4 feet (1 m.) thick, of manganese oxide in a matrix of tuff or tuffaceous limestone. Upon this rests an impure cross-bedded intraformational limestone conglomerate as much as 5 feet (1.5 m.) thick, composed of small white limestone fragments in a gray fine-grained limy matrix. This rock accompanies the ore bed throughout the property and was used to correlate its scattered outcrops. At least 200 feet (60 m.) of limestone overlies the ore horizon, most of it platy white limestone interbedded with thin layers of algal conglomerate. About 50 feet (15 m.) above the ore horizon is a coarse sandy limestone that contains many foraminifera and megafossils.

The regional structure near the Antonio mine is believed to consist of a series of gentle folds of northwesterly trend, cut by many small faults, comprising a set that strikes about east and a set that strikes northwest. Many of the faults that strike northwestward are reflected in the topography by valleys or lines of sinkholes, which are conspicuous features of the landscape south of the Antonio mine (see pl. 52). The limestone-tuff contact at the mine forms a zigzag pattern, because of small offsets on the faults. The relative age of faults that strike northwestward and those that strike eastward is not known.

The Antonio mine lies on the crest and the southern flank of a northwest-trending anticline, which on its plunging west end is cut by a zone of northwest-trending faults (pl. 60). Near Purial, in the center of the area mapped, the faults of northwesterly trend have broken the ore bed into several blocks. West and south of Purial Valley, tuff is brought into contact with the limestone and the limestone and ore are dropped down to the southwest. Some of the faults are marked by red limestone breccia, and solution along faults has produced many small caves.

Manganese oxide occurs in and adjacent to the northwesterly trending faults, in caves formed by solution along the faults, in granzon patches on the surface, and in an ore bed.

The bedded ores are mostly characteristic tuff ore—manganese-oxide nodules and stringers in altered tuff—but at some places in the western part of the mine the ore consists of solid oxide above a thin jasper footwall. The ore bed is from 1 to 5 feet (0.3 to 1.5 m.) thick and is of considerable areal extent, but gradually pinches out to the southeast.

Stringers and pods of manganese oxide occur in or near many of the northwesterly trending faults. Most of these bodies are small, but a few of the pods contain several tons each. The oxide most abundant in them is pyrolusite. In one outcrop a mixture of pyrolusite and black fine-grained silica was seen; in another outcrop manganese oxides are mixed with copper carbonates.

A cave in limestone along a fracture that strikes northeast contained about 100 tons of manganese oxides in layers separated by clay seams. Dripstones which extended through the deposit from top to bottom indicate that the oxides were probably deposited in open spaces.

Several patches of granzon are found on the limestone, as a surficial blanket and in solution pits. Northeast of the mapped area a trench 30 feet (9 m.) wide, 100 feet (30 m.) long, and 2 feet (0.6 m.) deep has been opened in fine-grained granzon, 1/8 to 1/4 inch in size, on the Milan denouncement. This granzon is about 500 feet (150 m.) distant from the nearest known manganese-oxide outcrop, but most other nearby granzon deposits overlie outcrops of lode ores.

A few scattered shallow pits have been dug on outcrops of limestone breccia on the Esperanza (west of the mapped area) and Milan denouncements, but most of the workings in the region are on the Antonio claim. East of Purial the ore bed is explored by a large open pit, from which two drifts followed the ore bed eastward for 100 feet (30 m.). The ore bed is broken by several normal faults near the open pit and is thrown down on the west side, having been found there in the bottom of a 16-foot (5 m.) shaft. Galleries extending east and south from the bottom of the shaft show 2 to 3 feet (0.6 to 1 m.) of ore.

South of Purial, along the south side of the valley, the main ore bed in tuff crops out intermittently for several hundred feet and is broken into small blocks by faults trending northeast. Open pits expose 2 to 3 feet (0.6 to 1 m.) of ore, containing about 30 percent of manganese, along most of the outcrop, and an inclined drift which follows the bed about 150 feet (45 m.) down the dip exposes about 4 feet (1.2 m.) of ore. Near the faults (see pl. 60) ore has been mined from open pits, but the faults cut the beds near the faces of the pits and the ore is not continuous.

Ore in a limy tuff bed continues for about three-quarters of a mile southeast of the area mapped. Ore has also been mined from shallow pits and galleries on all sides of a hill called Las Auras (outside of the area mapped), but these workings are in a thin low-grade bed and mining was stopped because of the high cost of extraction.

Most mining has been done by hand methods, although an air drill was used in several of the longer galleries and a compressor and several small hoists were used in the Purial workings. Most of the ore was hand-cobbed, though the granzon and a little tuff ore were concentrated in a log washer. The cleaned ore was trucked to Baire.

Ore reserves have never been large, and in July 1942, when the Cia. Pozo Prieto sold the property, the ore in sight totaled about 1,000 tons and the mine probably contained at least 5,000 tons more. If the bedded ore continues down the dip beyond the present headings, several thousand additional tons may be developed. It should be emphasized that most of this ore is in thin beds that are costly to mine, that some is in fine-grained granzon, and that some is in pockets and caves, the discovery of which is largely a matter of chance.

The reserves of tuff ore may possibly be increased by development work from the main shaft at Purial. Drilling in the area south of this shaft indicates that there is ore down the dip but gives no idea of its grade or thickness. Additional

drilling is needed, and adjacent outcrops should also be explored down the dip.

Caribbean group

The three properties forming the Caribbean group are about 5 miles (8 km.) southwest of Baire and are served by a fair truck road.

The Adriana prospect is explored through a shaft 87 feet (26 m.) deep, from the bottom of which a drift has been driven for 250 feet (75 m.) through limestone to a contact with tuff. When the prospect was visited in March 1941 this contact had just been cut. The tuff, which was much decomposed, showed some stringers and lumps of manganese oxide but nothing of commercial value. The shaft has since been abandoned. The prospect was worked during the first World War, but the old pits and shafts are completely caved. Burchard 8/ described the deposit as an ore shoot that averaged 4 feet (1.2 m.) wide and was 50 feet (15 m.) long, and that had been mined to a depth of 90 feet (27 m.) with good ore still in the bottom.

The Montenegro property adjoins the Adriana to the south and is developed by an inclined shaft pitching 30° S., sunk to a depth of 70 feet (21 m.) on the ore bed. From the bottom of the shaft, drifts have been driven 80 feet (24 m.) S. 65° E. and 30 feet (9 m.) N. 65° W. The ore bed, which is 2 to 6 feet (0.6 to 2 m.) thick, is in altered tuff, within a few feet of a contact between tuff and limestone. The ore in the N. 65° W. drift has been badly sheared, being crushed in places to a black mud. The ore is similar to that in other tuff deposits throughout Oriente. It contains stringers and patches of high-grade ore but must be concentrated to furnish a salable product.

The Caribbean property adjoins the Adriana on the west. The property was idle in March 1941 and was not visited. It is reported to have a shaft 122 feet (35 m.) deep, from which 460 feet (140 m.) of drifting was done, all in unmineralized limestone.

La Unica

The mine called La Unica lies about 24 miles (38 km.) south of Baire. The property, which includes 21 hectares, is operated by the Cia. Manganeso de Sierra Maestra, and the ore is sold to the Cia. Minera y Commercial, S. A. Late in 1941 a dirt road running from Los Negros to the mine by way of the village of Matias was completed. This road, though impassable when wet, has considerably lowered transportation costs and has made many nearby prospects more accessible. These prospects, none of which are producing ore, include the Dulce Maria, Santiago, San Pantaleon, Tonia, Angelina, and the south end of the Pozo Prieto group (Sierpe denouncement).

The property lies in the rolling foothills against the northern base of the Sierra Maestra, in a region that is rough though not of high relief. The district is drained by the Brazo Seco, a branch of the Mogote River, which has cut a

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8/ Burchard, E. F., Manganese-ore deposits in Cuba: Am. Inst. Min. Eng. Trans., vol. 63, pp. 89-91. 1920.

steep-walled canyon 200 to 400 feet (60 to 120 m.) deep. Ample timber for mine and construction purposes can be obtained from the heavily wooded and brushy slopes near the mine.

The mine has produced a total of about 10,000 tons of ore averaging about 43 percent manganese. At present the output is between 500 and 1,000 tons a month during the dry season. The ore was packed out on mules until recently, when the road was completed, but it is now hauled by truck to Baire.

Two formations are recognized in the region: the upper is a white or light-gray crystalline limestone and the lower is a sequence of tuffs and agglomerates (pl. 61). The limestone has an apparent thickness of at least 500 feet (150 m.), and its upper part has been eroded away. The limestone weathers into the extremely rough, pitted surface that causes it to be called "dogtooth limestone." It contains no fossils but is tentatively correlated with the limestone of the Charco Redondo-Los Negros districts. The volcanic rocks, like those throughout the region, consist of alternating beds of green and reddish-brown tuffs and agglomerates.

As strikes and dips are obliterated in the crystalline limestone, the geologic structure of the area is largely unknown and is difficult to decipher. La Unica fault, a strong fault that trends about N. 20° W. and dips about 80° NE., crosses the mapped area. The block east of the fault has been dropped relative to that on the west. The amount and direction of displacement is not definitely known, but its vertical component is about 75 feet (23 m.). A few fractures parallel to the fault have been found, but they are small and cannot be traced more than a few hundred feet.

The ore body now being mined is on the east side of the Brazo Seco, about 50 feet (15 m.) above the stream level. The ore is brought to the surface through adits driven into the cliff. The adits are connected by winzes, and the ore is mined by underhand benches, which are broken to the winzes. A new adit below the old workings has recently been completed and should facilitate the mining. The ore body is enclosed in hard massive limestone, which stands well without timber. The ore is hauled by a mechanical winch about 200 feet (60 m.) up an incline to the edge of the canyon, where it is dumped on the ground, broken by hand, and cobbed, and the higher-grade ore shoveled into trucks. The ore is harder and more massive than tuff ore and probably cannot easily be beneficiated by washing and jigging.

La Unica ore body is a pipe that plunges about 25° to the east and that is about 20 feet (6 m.) wide and 15 feet (5 m.) high in a plane normal to the long axis of the pipe. It crops out in the limestone cliff east of the river and along the east side of La Unica fault. About 10,000 tons of ore has been mined in the shallow, near-surface workings, about 10,000 tons more is partly blocked out, and the end of the ore shoot has not been reached. The ore body at the outcrop is about 75 feet (23 m.) above the tuff-limestone contact. The dip of this contact is not known, and the plunge of the ore shoot may be steeper than the dip of the contact. The relation between the two should be determined if possible, since many Cuban manganese deposits are biggest and best at limestone-tuff contacts.

Other showings of manganese oxides are found at many places along La Unica fault. One flat lens, now being opened, crops out in the cliff above the principal ore body. About 700 feet (210 m.) to the north of the outcrop, on the Angelina denounce-

ment, considerable prospecting has been done on a good showing of manganese oxide, but without developing much ore; no ore has been developed in the stringers of manganese oxide which are found at many places along the tuff-limestone contact.

The mineralogy of the ores is simple. The principal manganese mineral is psilomelane, though pyrolusite occurs in minor quantity. A little brown jasper and red powdery hematite have been found near the borders of the ore shoot, but silica and iron are commonly low. The ore contains considerable black calcite, and locally it is cut by irregular stringers of white calcite. Owing to the presence of the calcite, the run-of-mine ore probably averages no better than 40 to 43 percent manganese. Hand cobbing, an expensive and wasteful process though still the most practicable, is required to raise the manganese content of the ore to 45 percent.

Pozo Prieto

The Pozo Prieto mine lies 9 miles (14 km.) south of Baire, in the rugged foothills of the Sierra Maestra. The Pozo Prieto is one of many deep sinkholes, amid craggy forested uplands, in a rugged area that extends south from the Antonio mine to the Brazo Seco River, covering most of the country between Los Negros and the Charco Redondo mine. The Pozo Prieto mine is now accessible by truck road from Baire by way of either the Antonio mine or Los Negros. The road is passable only in dry weather, but it opens up an extensive region that until a few months ago was reached only by trails.

There are about 15 denouncements in the Pozo Prieto group, and showings of manganese oxides have been found on most of them. The denouncements were taken up between 1900 and 1903 and were worked during the first World War. Since 1938 they have been operated by Cia. Minera de Pozo Prieto, in charge of Sr. Francisco Cajigas. Although most of the property is still inaccessible and the main development has been confined to the New York (Pozo Prieto) denouncement, the area gives promise of becoming more productive. Outlying denouncements have probably yielded, in all, several thousand tons of ore, though no one denouncement seems to have produced much over a thousand tons.

All mining to date has been done by primitive hand methods from shallow workings. A major handicap to mining development here is lack of water; except locally there is no surface drainage. Underground rivers fed through caves—such as Pozo Prieto cave—from the bottoms of the sinkholes are, however, a potential source of considerable water.

The area mapped in 1942 covers part of the New York and Magela denouncements at the northern end of the group (pl. 62) and shows the route of the new Pozo Prieto road.

The sinkholes are in a thick massive limestone, which overlies volcanic rocks, principally tuffs and agglomerates. These units have not been traced in detail outside of the area studied, but they are similar to the other ones that contain the manganese oxides throughout the northern Sierra Maestra. The volcanic rocks at the eastern end of the mapped area are green, thin-bedded, andesitic tuffs, but in much of the region they are agglomerates that contain many boulders. Near Hoyo Zinzonte, a nearly vertical andesitic dike trends northwestward, cutting limestone. The limestones, which are at least 300 feet (90 m.) thick, are partly in thin platy beds, which grade into massive strata of dense white limestone as much as

25 feet (8 m.) thick. The limestone includes many lenses of algal conglomerate. East of Hoyo Zinzonte the lowest bed of conglomerate—a fairly thick one—is underlain by about 30 feet (9 m.) of platy limestone, but at Pozo Prieto a conglomerate containing andesitic fragments immediately overlies the tuff and is itself overlain by at least 100 feet (30 m.) of thick-bedded white limestone. This limestone is coarse-grained and crystalline near many of the faults, and near the tuff contact it is commonly stained red with iron oxide.

There are two fault systems in the region, one trending nearly north-south and the other northwest. The faults and fissures of the first system, which strike between N. 40° W. and N. 40° E., control the topography inasmuch as the sinkholes follow them. The northwest faults, on the other hand, while not expressed in the topography, are marked by breccia zones in limestone and sheared zones in tuff, and they contain most of the manganese deposits in the area. Possibly some of these faults resulted from settling of the limestone after solution along the limestone contact, but the general relations of the two sets of faults indicate that they are due to deeper-seated forces.

The Pozo Prieto cave, through which flows the drainage from the entire valley (fig. 17), trends southeastward for about 600 feet (180 m.), then northeastward for an equal distance. The most distant accessible point in the cave is about 400 feet (120 m.) nearly due east of the entrance. The cave is at the base of the limestone and follows a system of northeast and northwest fractures. For much of the distance the back of the cave is low and the floor has no appreciable fall, but along two fault zones the floor drops rapidly, so that the face is 90 feet (27 m.) lower than the mouth. A deposit of manganese-bearing gravel occurs near the mouth of the cave, and a small amount of ore has been removed from an ore body near the face. The cave has permitted easy and cheap exploration of a large block of ground, and the other caves in the region should not be overlooked.

The ore occurs in stringer lodes, in breccias, and in pockets in the limestone, none being found in the volcanic rocks. Besides occurring in the Pozo Prieto cave, granzon lies on the limestone in several places.

The lode ores consist of compact black oxide, which is chiefly psilomelane but includes some pyrolusite. The chief gangue materials are brown iron oxides, calcite, jasper, and inclusions of limestone. The iron minerals are mainly in pockets on the edges of the ore bodies and offer no problems in mining. Black and white calcite fills veinlets and cavities in the ore, and for this reason some of the ore is not so rich as it appears.

Breccia zones near Hoyo Zinzonte have a cement of manganese oxide, and they contain pods and veinlets of manganese oxide up to several feet in diameter. These breccia deposits are typical of the manganese ores in much of the sinkhole area, and several outcrops along the south side of Pozo Prieto sinkhole contain similar material. Some deposits also contain mixtures of brown iron oxide and manganese oxide, and in one outcrop, locally known as the Riñon, the mineral is all iron oxide.

A pocket of ore that was about 50 percent manganese oxide, and that was 60 feet (18 m.) long, 40 to 50 feet (12 to 15 m.) wide, and about 5 feet (1.5 m.) thick, was found along a fissure zone north of Pozo Prieto. The pocketlike deposit in Pozo

Prieto cave was exposed in 1942 over a length of 30 feet (9 m.), a width of 15 feet (5 m.), and a height of 10 feet (3 m.), and its limits were not yet known. Similar ore pockets have been found in other areas by following veinlets of manganese oxide, and favorable outcrops south of Pozo Prieto sinkhole

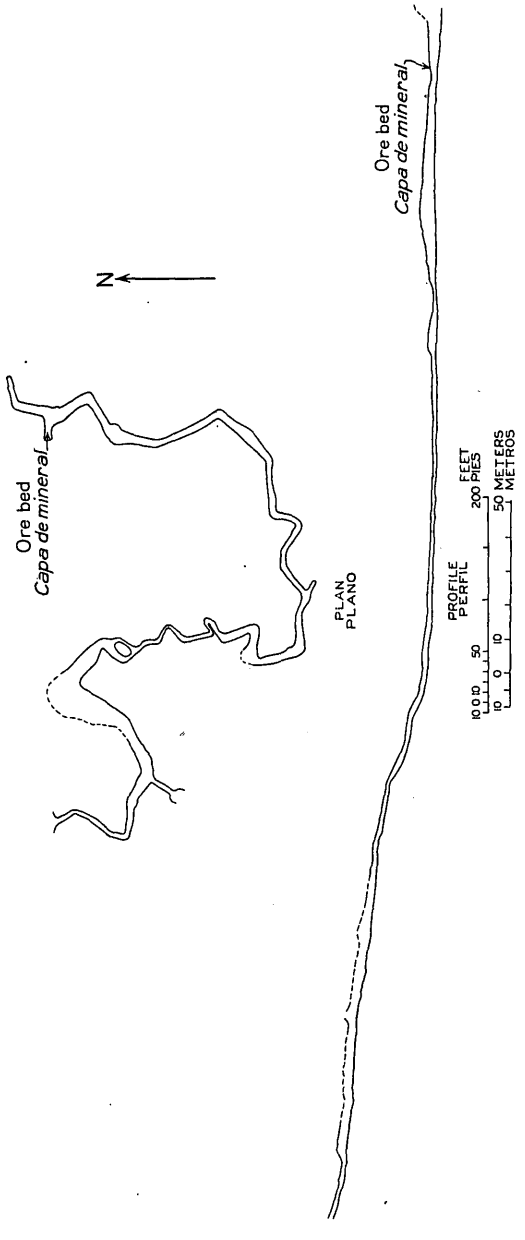


Figure 17.--Plan and profile of Pozo Prieto Cave.

indicate that pockets of manganese ore may still remain to be discovered.

The granzon of Pozo Prieto lies to the north of the sinkhole leading to the cave, and consists of manganese-oxide nodules in red clay soil and in solution pits. Much of the ore in

the pits has been cemented into boulders by secondary calcite, and some pits are lined with pyrolusite. A red lateritic soil developed on the tuffs adjoining the granzon area contains pellets of iron oxide that might readily be confused with manganese granzon. The granzon-bearing soil ranges in thickness from a few inches to several feet, and it contains about one part manganese oxide to six or seven parts of soil. The pellets are usually small—1/8 to 1/4 inch in diameter. Enough of it to yield about 2,000 tons of cleaned granzon ore is estimated to be in sight in the area. Pebbles of manganese oxide a fraction of an inch to several inches in diameter have accumulated near the mouth of Pozo Prieto cave in sufficient quantity to be mined. The pebbles have a high polish, evidently from being rolled in surface wash.

Reserves are not large, for the ore is extracted as rapidly as it is discovered. In March 1942 about 1,000 tons of lode ore was in sight, mainly in the cave and along the north side of the Pozo Prieto sinkhole. Systematic examination of the numerous manganese-bearing outcrops, with trenching of the most favorable showings, may well open up other ore bodies. As most of the ores are near or adjacent to fault zones, the most favorable areas to be examined can be roughly delimited in advance.

San Alberto

The San Alberto denouncement is at the north end of the Pozo Prieto group. The property is worked by local contractors, who scratch the surface in a most irregular way in looking for pockets of high-grade ore. The ore is all hand-picked, put in sacks, and packed on mules to the Antonio mine, where it is sold to the Cia. Minera de Pozo Prieto. Most of the ore is obtained from small cuts in a limestone breccia, at least 30 feet (9 m.) thick, which contains irregular stringers and small pockets of manganese oxide. In one place a small pocket about 20 feet (6 m.) above the base in the side of a cliff was being worked from a crude scaffold; in another place ore was being recovered from a small cave at the contact between altered volcanic tuff below and limestone breccia above. The uppermost 3 feet (1 m.) of the tuff is mineralized, and boulders and fragments of manganese oxide are recovered from the cave debris.

Adelaida

The Adelaida denouncement lies entirely within the larger San Alberto denouncement. When the property was visited, in the winter of 1940-41, residual ore was being mined from a deposit in a cave along a limestone-tuff contact. The exposures were too poor to permit any estimate of the amount of ore available.

Mascota

The Mascota prospect is on the Rio Mogote, about a mile (1.6 km.) south of the Arcadia mine and 2 miles (3 km.) east of Los Negros. A thin flat-lying ore bed, 6 inches to 1 foot (20 to 40 cm.) thick, in limestone breccia is exposed in a circular cut about 40 feet (12 m.) in diameter. Several other smaller

cuts, and a shaft reported to be about 50 feet (15 m.) deep, show stringers of manganese oxide in limestone breccia. A small amount of ore has been shipped.

Bessie

The Bessie prospect, near the top of the ridge northwest of the Mascota, is opened by one small cut in weakly mineralized limestone breccia. Several exposures of similar breccia were noticed on the hillside between the Bessie and the Mascota, and some ore is said to have been mined here in the summer of 1942.

Arcadio

The Arcadio mine lies along the Rio Mogote, 3 miles (5 km.) by airline north of east from Los Negros. A cut about 100 feet (30 m.) long by 20 feet (6 m.) wide, trending S. 80° W., has been opened in mineralized limestone breccia just above a contact with the underlying tuff. The mineralization is irregular, but in general the mineralized zone strikes S. 80° W. and dips 30° N. Several small pockets of high-grade ore are being worked, and it is reported that 10 to 50 tons of ore is being shipped each month. An adit and a shaft start from the cut 200 feet (60 m.) downhill to the southeast. The adit trends N. 18° E. for 200 feet (60 m.), but is all in unmineralized limestone breccia. The shaft, near the portal of the adit, was being sunk on a steeply dipping layer, less than 6 inches (20 cm.) thick, of high-grade manganese oxide.

Although considerable work has been done on this property without compensating results, the showings on the surface are good enough to justify carefully directed exploration, especially along the tuff-limestone contact.

Dichosa

At the Dichosa prospect, which contains 48 hectares and is about 1½ miles (2 km.) southeast of Los Negros, streaks and small pockets of ore occur in a limestone breccia directly overlying tuff. The breccia has been exposed in pits for more than half a mile (0.8 km.) along the strike. In one cut the miners were working on a layer of high-grade pyrolusite about 1 foot (40 cm.) thick, which trended S. 70° E. and dipped 65° N. A prospect adit, 40 feet (12 m.) long, which was driven into a hill about 25 feet (8 m.) below the ore horizon was entirely in agglomerate that showed no obvious mineralization. Dikes of hard hornblende latite (?) were exposed in two cuts.

Eduardo

The Eduardo prospect, about 1 3/4 miles (3 km.) due south of Los Negros, is developed by at least five cuts, all in mineralized limestone breccia. The ore zone, which is very irregular but which probably averages 4 to 5 feet (1 to 1.5 m.) in width, consists of stringers and small pockets of manganese oxide. One pit, 50 feet (15 m.) long, 10 feet (3 m.) wide, and 20 feet (6 m.) deep, illustrates very well the exceedingly

erratic and spotty nature of the deposit. A little jasper and iron oxide are associated with the manganese.

Amy

The Amy prospect, about 2 miles (3 km.) southeast of Los Negros, is on top of a hill east of the Mogote River. A cut about 100 feet (30 m.) in diameter is opened in granzon that lies on a pitted limestone surface. From the bottom of the cut a shaft has been started in limestone, and a short distance down the hill an adit, designed to undercut the granzon and to be connected with the shaft, has been driven 120 feet (35 m.) in tuff and volcanic breccia. No ore has been found in the underground workings.

Progreso

The Progreso prospect, about 7 miles (11 km.) east of south of Baire, has been superficially explored along a contact zone between limestone and underlying tuff. The contact zone, which has a strike of N. 20° E. and a dip of 55° W., contains irregular stringers of manganese oxides. A few tons of ore has been extracted, and it is said to have been of exceptionally high grade.

Santa Lena

The Santa Lena denouncement lies south of the Progreso denouncement, on the other side of a small valley. A few small pits have been dug on mineralized stringers in limestone, but no ore has been shipped.

Candas

The Candas prospect lies about half a mile (1.6 km.) east of the Antonio mine. Six small cuts in limestone breccia were seen, and several other cuts are said to have been opened in similar breccia. A little ore was being recovered from small pockets and stringers. No bedded tuff was exposed in the workings, though a few irregular patches of tuff were seen on the surface.

Fortuna

The Fortuna mine is about 3 miles (5 km.) by airline northeast of Los Negros and is connected by road to the Central Highway at Contramaestre. Workings on the property consist of an irregular glory hole, from which about 75 feet (23 m.) of drifting has been done, a new shaft which was 25 feet (8 m.) deep when seen, two abandoned shafts, an old cut, and an inclined adit 30 feet (9 m.) long. These workings are in limestone, in fracture zones which trend nearly northward, normal to the bedding. In the glory hole the ore trends nearly east-west and appears to be breccia and cave filling, consisting of fragments of limestone cemented with travertine and cut by seams of manganese oxide, which in places open out into pockets

as much as 5 feet (1.5 m.) wide. About 100 tons of ore was said to have been sold recently, and another 100 tons lay on the dump when the property was visited in the spring of 1941.

Tony

At the Tony prospect, about 2½ miles (4 km.) northeast of Los Negros, four cuts and a shaft 25 feet (8 m.) deep have been dug on small pockets and seams of manganese oxide in limestone breccia. One pocket is said to have yielded 25 tons of ore, but when this ore had been mined out no more was found and work was discontinued.

Emilito

The Emilito prospect lies north and east of the Tony, to which it is similar. Four small cuts expose limestone breccia that is sparsely mineralized, and a few lumps of ore have been found in the soil.

Yeya

The Yeya mine is on the south bank of the Mogote River, near the town of Los Negros. It is reached from Baire by an all-weather truck road 12 miles (19 km.) long. Ample water and timber are available on the property for all mining and construction purposes. The mine is on a group of denouncements, comprising the Ana Maria, Estela, San Joaquin, and Dichosa, that is controlled and operated by the Cia. Minera Cubana Illas.

Between 1940 and June 1942 the Yeya yielded approximately 9,000 tons of manganese ore averaging 45 percent or more in manganese, and the other properties in the group have produced 3,000 tons.

The ore occurs along a limestone-tuff contact, which trends nearly north and dips about 75° E. The contact is very irregular, and large blocks of limestone lie isolated in the tuff. The ore body from which most of the production was derived was mostly in the limestone and had the form of a wedge with the apex downward. A second ore body has been found further to the northwest, in tuff below limestone. It is of lower grade than the first, but because of its tuff matrix it could readily be concentrated. It crops out for a distance of only 50 feet (15 m.), through which distance its average thickness is about 3 to 4 feet (1 to 1.2 m.), but the bed is explored by an adit (the Cafetal adit) that is 200 feet (60 m.) long and still in ore. The ore body in the tuff seems to be localized at a sharp sag or small fault that cuts the limestone contact.

The ore body in limestone has been well explored and the best ore has been mined out. The outcrop was worked from a small cut and the ore body was outlined by a series of short adits (pl. 63). Later a long low-level crosscut, now used as a haulageway, was driven in the underlying tuff and connected by a raise with the upper workings. The ore was hand-cobbed or, if of high grade, was shipped directly as mined. Low-grade ore on the borders of the ore body was not mined, as it would have had to be concentrated and that could not be done until recently.

The ore is hard, compact pyrolusite with some psilomelane. It is cut by calcite veinlets and grades into a mixture of calcite and manganese oxide. Jasper is found near the ores but is not abundant.

In June 1942 the company installed a small concentrating plant of the type used so successfully at other small mines in the district. The mill, which consists of a crusher, washer, trommel, and jigs, is expected to handle tuff and limestone ores equally well.

It is estimated that 2,000 to 3,000 tons of ore was in sight in the mine in July 1942, and that enough additional ore can be found to maintain a daily production of 25 to 30 tons for at least a year. Diamond drilling of the property west of the present workings is said to have penetrated another near-surface ore bed about 2 feet (0.6 m.) thick, but no details regarding the grade or extent of the ore are known.

Defensa

The Defensa denouncement lies about 5 miles southwest of Los Negros and east of the Pozo Prieto group. The property has been explored by several pits in limestone breccia at the contact with underlying altered tuff. In one cut about 3 feet (1 m.) long a layer of ore about 2 feet (0.6 m.) thick was exposed, and a small quantity of granzon was scattered over the nearby surface.

Gaceta

The Gaceta property, which contains 52 hectares, lies to the northeast of the Antonio mine. The property has been operating for about two years, principally on high-grade granzon from a small knoll. Most of the workings are on limestone, though altered tuff is exposed in a few cuts and crops out in a few places. The workings are purposely scattered over a large area, because the operators consider this a good way to prospect for lode ore. In a few places the limestone breccia contains irregular veinlets of manganese oxides, and boulders of brown jasper are scattered over much of the surface.

Estrella

The Estrella mine, about 1.5 miles (3 km.) south of Contramaestre, is readily accessible from the railroad and the Central Highway. The surface of the ground is gently sloping and is covered with flags of platy limestone. An ore bed was found in a shaft 20 feet (6 m.) deep, put down through the limestone. It consists of about 6 feet (2 m.) of altered and mineralized tuff, which is not known to crop out near the shaft. The ore body, now largely worked out, was a large pocket, which yielded several thousand tons of good ore. It was underlain by an irregular eroded surface of massive white limestone, large blocks and pinnacles of which extended up into the ore.

The property around the mine has been explored with the diamond drill, but without finding much ore. So far as is known, however, no effort has been made to explore other tuff

beds or the base of the limestone underneath the ore that was mined.

Sorpresa

The Sorpresa denouncement lies west of the Estrella mine and about 2.5 miles (4 km.) south of Contramaestre. The property was prospected by men working for the sugar mill, called Central America, which controls the Amarito and other properties. Considerable work was done in open cuts in platy limestone, and one pit exposed two manganese-bearing tuff (?) layers about 1 foot to 3 feet (0.3 to 1 m.) thick; but as all the ore was of low grade and apparently not extensive, this exploratory work was abandoned.

Manacas area

The Manacas group of denouncements lies about 12 miles (20 km.) south of Aguacate, a small town on the Central Highway between Palma Soriano and Contramaestre. It is reached by a dirt road, which is badly in need of repair but is passable in dry weather. The mines are held under three ownerships. The Central and Orion denouncements are leased to José Fernandez, the Pasaje is controlled by Adolfo Silva, and most of the others, including the Guadalupe, Firmeza, Neptuno, Amarito, Luis Segundo, and Gladys, are owned and operated by Federico Fernandez, the owner of the sugar mill, Central America, with headquarters at Contramaestre.

The mines are in the rolling foothills at the northern base of the Sierra Maestra, in a region drained by the Caney River and by one of its principal tributaries, the Arroyo San Andreas. Ample water is available for all mining and milling purposes, and there is enough timber in the region to supply all the needs of mining and construction.

Production from the district during 1941 probably averaged about 1,000 tons of concentrates a month, but the output has recently fallen off owing to a shortage of tires and gasoline. During 1942 a log washer was used at the Central mine, and ore from the Guadalupe and Amarito mines was hauled to a small washing and jigging plant at Contramaestre. Recently a small plant consisting of a screen, log washers, and jigs has been completed at the Central mine, and a similar plant is under construction on the Amarito denouncement. The combined capacity of the two mills should be at least 150 tons of crude ore a day, and it is expected that ore shipments will be considerably increased as soon as the plants begin to operate. Costs for transportation and milling should likewise be appreciably lowered.

Two kinds of rock predominate in the district, a brownish-gray lava and a greenish or brownish tuff. The former is a fine-grained, massive, hard rock that contains numerous phenocrysts of feldspar and corroded quartz, generally less than a quarter of an inch long. A few small grains of a dark amphibole or pyroxene can be seen in hand specimens, and the cores of many of the feldspar grains enclose a little epidote. The feldspar seems to be dominantly sodic, though part of it may be potassic. The rock is tentatively called a dacite porphyry.

The tuffs are the same friable, altered, water-sorted pyroclastic rocks that occur throughout the Sierra Maestra region. Locally they grade into agglomerates. Many layers are limy, and a few limestone beds that contain a little tuff lie 100 to 200 feet (30 to 60 m.) stratigraphically above the ores. One kind of tuff grades into another, so that no detailed correlation of beds throughout the district can be made without additional study.

Dikes are numerous in the district, particularly in the porphyry. Some of them, which are light-colored, are conspicuously jointed in hexagonal columns and appear to be rhyolites or dacites; others are black and appear to be either basalts or lamprophyres.

The structure of part of the district is shown in the accompanying map (pl. 64). The rock in the central area is dacite porphyry, which is bordered by tuff dipping to the north, west, and south, parallel to the contact. The contact, exposed in many places both underground and on the surface, is generally tight and clean. Nowhere has the porphyry been seen to cross-cut the tuff, and few contact-metamorphic features have been observed. The porphyry is thought, nevertheless, to form a laccolith which has domed the overlying rocks, but it may be a flow, involved in the regional folding.

Faults are common along the porphyry-tuff contact, and in several places the faults cut both these rocks. A nearly vertical fault striking about N. 40° W., transverse to the contact, is well exposed in the western part of the Central workings. This fault cuts the ore horizon and shifts the eastern side about 150 feet (45 m.) to the south.

Mining is done through a large number of adits, pits, and shallow shafts. There has been much development work extending to a depth of about 100 feet (30 m.), but no deeper exploration has been attempted. The ore is mined by breaking it to a shaft or a winze, then dropped to a lower level and hoisted to the surface in buckets by hand winches. Mining methods are crude, and costs could be greatly reduced and production increased by installing chutes, mine cars, hoists, compressed air, and other simple conveniences.

The ore occurs in tuff beds and is similar to the tuff ores elsewhere in the region. Almost all of it either extends along the tuff-porphyry contact or lies within a few feet of it. An ore bed 1 to 1½ feet (0.3 to 0.5 m.) thick was recently found in a limy tuff about 500 feet (150 m.) north of the contact. Ore is also associated with tuff islands faulted and folded in the porphyry. In several places irregular stringers of manganese oxides and small pods of jasper are scattered in the porphyry. The ore beds vary somewhat widely in thickness. Their average thickness is about 3 feet (1 m.) and their greatest known thickness about 8 feet (2.5 m.). The ore is soft and friable and is easily mined with a minimum of dynamite. The manganese oxide is readily separated from the enclosing soft gangue and is concentrated by washing and jigging to a product containing 45 percent of manganese.

The predominant ore mineral is pyrolusite, though psilomelane is present in considerable quantity. Jasper is locally abundant, particularly in the northern part of the area, where a layer of jasper about 10 feet (3 m.) wide forms a ridge that stands above the enclosing softer tuffs. The principal gangue minerals are chlorites, zeolites, and chalcedony.

Ore probably containing 30 to 35 percent of manganese has been developed for at least 5,000 feet (1,520 m.) along the strike and to a depth of about 100 feet (30 m.). Assuming that the average width of the ore is 3 feet (1 m.) and that a third of the ore has been taken out, the reserve is estimated to be about 100,000 tons. A considerably greater tonnage may well be present, however, for the ore shows no sign of becoming leaner with depth.

Botija area

The Ford prospect, which is southeast of Palma Soriano and 2 miles (3 km.) east of the Central Highway, is the only noteworthy prospect in an area known locally as Botija, Santa Filomena, or San Juan de Wilson. The property was taken up in 1941 and was prospected by the Independent Mining Co. until September 1942, when work was discontinued.

Six tons of ore averaging about 46 percent in manganese was mined and sold. This ore came from stringers associated with jasper pods, in a zone that lies approximately parallel to the bedding of the enclosing tuff. The stringers are numerous, but they are all less than 2 inches (5 cm.) thick, and they generally die out within 10 feet (3 m.) of the jasper.

Cobre area

San Idelfonso mine

The San Idelfonso property comprises three denouncements—the San Idelfonso Primero, Segundo, and Tercero—near the town of El Cobre, about 10 miles (16 km.) northwest of Santiago. The denouncements are in a broad valley between the Cobre foothills and the main Sierra Maestra divide north of the Santiago basin. The area is drained by the Arroyo Melgarejo, a branch of the Paradas River, which flows into Santiago Bay. The mine is only 500 feet (150 m.) from the junction of the Cobre road with the Central Highway, over which the ore can be hauled to Santiago at any time of the year.

The denouncements were taken up in 1887 and 1889, but they were not worked until 1917-18, when a few tons of ore was skimmed from the outcrops. The mine was reopened in January 1941, and was still being operated in July 1942. Its total production has probably been less than 1,000 tons.

All of the area between Cobre and the Sierra Maestra divide is underlain by volcanic rocks, which have not been subdivided into stratigraphic units, and in parts of the area these are overlain by calcareous rocks. The stratigraphic sequence as a whole comprises several thousand feet of beds, including limestones, limy tuffs, and coarse- and fine-grained green tuffs; and these bedded rocks are cut by basaltic dikes and sills. Foraminiferal limestones of upper Eocene age cap the volcanics at the top of the Sierra Maestra divide. Near the mine a limy tuff bed was used as a horizon marker. The ore occurs in a coarse-grained green tuff similar to much of that occurring elsewhere in the section.

The beds near the mine strike roughly east-west and dip 10°-50° N., but the regional structure has not been worked out

and is probably complicated by faulting. East-west zones of alteration up to 3 feet (1 m.) wide are thought to mark the traces of faults, along which drag has locally increased the dips to 60°. Minor faults of northeasterly and northwesterly trend cross the ore beds, but along these there is no alteration.

Lenses and irregularly bedded deposits of manganese oxide occur in the tuffs, principally along one zone of steepened dips. Four bodies of ore have been found at this horizon. Trenches between them show that they are separate, either because they are lenticular or because they have been faulted apart. The ore in three of these bodies is in stringers less than 1 foot (40 cm.) wide and under 10 feet (3 m.) long. In the fourth ore body, which is near the junction of the highway with the Cobre road (pl. 65), and which is over 200 feet (60 m.) long and at least 20 feet (6 m.) in depth, the ore forms two beds, each about 2 feet (0.6 m.) thick, separated by 3 feet (1 m.) of white, bleached tuff. The altered country rock enclosing this ore is generally bleached and contains masses of soapy red material several feet in diameter. The same type of alteration was noticed along the east-west fault zones.

Most of the ore is hard, dull-black oxide, mainly psilomelane, though some of the finer-grained and harder material may be braunite. The ore contains much black and white calcite, and the thicker stringers are cut by veinlets of jasper. The ore is hand-sorted, because it is mingled with a large quantity of tuff and calcite.

The mine workings are shallow, being for the most part open pits, though several shafts have been sunk in tuff to depths of 20 or 30 feet (6 or 9 m.). Mining is done by hand and the total production is only a few tons a week.

The reserves of the prospect are small; possibly 500 tons may be recovered from the body near the road junction, but the other lenses appear to contain less that 10 tons each. Most of the ore averages less than 30 percent in manganese and must be carefully sorted to reach a 40-percent grade.

Segunda Veinte de Mayo

The Segunda Veinte de Mayo prospect, which contains 157 hectares, is about 1½ miles (2.5 km.) from the Central Highway and about 5 miles (8 km.) northwest of El Cobre. It was taken up May 9, 1931. The property when visited had two small cuts and a shaft 10 feet (3 m.) deep, all in tuff which contained small quantities of manganese. One cut exposes a veinlike body of manganese oxide, with a maximum thickness of 1 foot (0.3 m.), which trends N. 30° E. and dips 70° NW., and some manganese oxide boulders and granzon are scattered over the surface; not enough work has been done, however, to indicate the value of the property.

Gran Piedra area

Manganese deposits are found near the headwaters of the Indios River, a branch of the Bacanao, just north of Gran Piedra and about 20 miles (32 km.) east of the Santiago Basin. The deposits are in the high Sierra Maestra, in wooded rugged country, which is accessible by numerous horse trails, and by a

truck road, 26 miles (48 km.) long, from El Caney, originally built by French settlers in the latter part of the eighteenth century. It has now been put in condition for all-weather truck haulage to a point within 7 miles (12 km.) of the principal mine, from which point there is a truck road passable only in good weather. The haul from El Caney to Santiago is 6 miles (9 km.) on paved road.

The principal denouncements are the Chévere, Javier, and Javiercito, part of a group covering 1886 hectares that is controlled by Dr. Augustin de Varona of Habana. One denouncement in the district was staked in 1900, but no work was done until 1940, when the other denouncements were staked and development was begun on the Chévere. The total production to July 1942 has been about 1,000 tons of ore, carrying about 43 percent manganese and about 10 to 15 percent silica.

Little is known of the general geology except that the area is underlain by volcanic rocks, which are mostly thin-bedded limy tuffs near the mines, though agglomerates were seen in other localities nearby. The bedding strikes northwest and dips 40°-60° NE. The rocks are cut by numerous faults, which have about the same strike as the bedding.

Manganese silicates and oxides are found in the fault zones, the mineralized parts of which are marked by prominent outcrops of jasper, about 400 feet (120 m.) in maximum length and 20 to 30 feet (6 to 9 m.) in average width. They occur also in association with isolated masses of jasper in the tuff. The ore minerals that have been recognized are neotocite, braunite(?), pyrolusite, and psilomelane, which occur both alone and intimately mixed with jasper.

Small blocks of silicified, bleached, and contorted tuff occur within 2 to 3 feet (0.6 to 1 m.) of the ore zone, but farther away the silicification dies out and the tuff is undisturbed. The mineralized zones are as much as 20 to 30 feet (6 to 9 m.) wide, though the ore shoots within them average only 3 to 4 feet (1 to 1.2 m.) in width.

The only ore body developed is the one at the Chévere mine, which has been explored by open cuts for 400 feet (120 m.) along the outcrop. East of the workings the ore either pinches out or is cut off by a fault of low dip; west of the workings it has not been explored beyond the small hill on which it crops out (pl. 66). Several parallel manganese-bearing outcrops have been found but have not been explored. The ore is pyrolusite to the depth of 40 feet (12 m.), where a little manganese silicate appears. Early in 1942 a crosscut 30 feet (9 m.) below the open cuts was started for the purpose of intersecting the ore at depth, but it is reported not to have reached the mineral zone, although it was caved at the time the mine was visited.

The ore body probably represents the oxidized upper part of a body containing much silica, and if this is so the ore will become leaner with depth. The ore contains 44 to 46 percent of manganese and 12 to 20 percent of silica, and for each ton of such ore produced another ton containing 35 to 44 percent of manganese and 20 to 30 percent of silica is mined but is not salable.

Ore is blocked out for a length of 300 feet (90 m.), an average width of 4 feet (1.2 m.) and a probable depth of 10 feet (3 m.)—a body that would contain 1,200 tons of ore. Probably 2,400 tons more is available. At the present time

there is piled up at the mine approximately 600 tons of salable ore and 600 tons of low-manganese high-silica rock.

Other manganese outcrops were seen in the area but were not studied. Detailed examination by means of test pits on the more likely croppings would be a cheap efficient means of exploration and might develop new reserves.

Sigua area

Location and history

The Sigua district is on the crest of the Sierra Maestra, about 35 miles (56 km.) by airline east of Santiago de Cuba. The denouncements are about 10 miles (16 km.) from the mouth of the Bacanao River and are in the Division of Ramon de las Yaguas, Municipality of Caney.

The denouncements were taken up in the late 1880's, but no work was done on them until 1917-18. The district includes the Hercules, Graham, Non Plus Ultra, Fantasia, and Capricho denouncements, which have a total area of about 790 hectares. The denouncements are owned by Señor Luis Batlle-Vias of Holguin. A bed on the Graham and Non Plus Ultra denouncements was worked for a short period in 1918, when about 100 tons of ore was extracted, but from that time until recently it has lain idle.

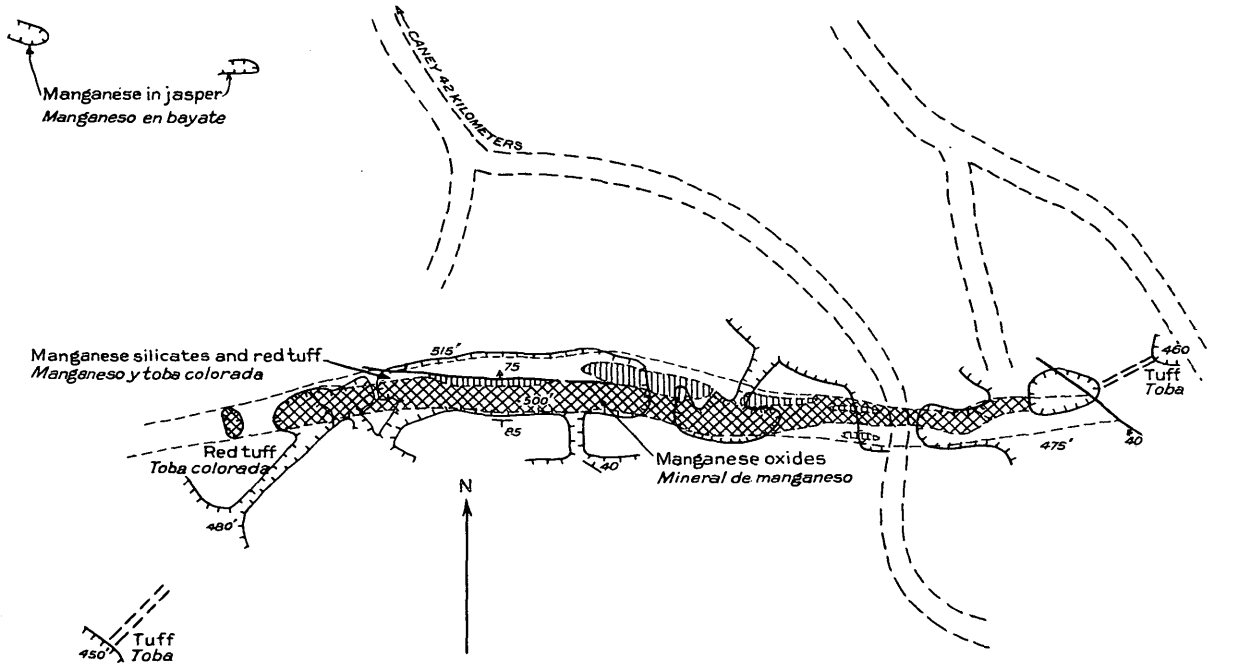
The district is reached from Santiago by way of the town of Vinent. A truck road extends from Vinent 7 miles (12 km.) eastward to Chalia, from which a 5-mile (8 km.) mule trail leads to the mines. An alternative route follows a dirt road, 16 miles (25 km.) long, from Vinent to Sigua Playa on the coast, from which a truck road 9 miles (15 km.) long extends to the denouncements. Ore could be hauled over this road to Sigua Playa for reshipment by schooner to Santiago.

The area contains a series of steep-sided ridges trending northwestward, which attain an altitude of 2,600 feet (840 m.) and are separated by canyons whose bottoms are less than 600 feet (180 m.) above sea level. The forests afford ample timber for mining and construction; water, however, is scarce in the uplands, and if large quantities were needed they would probably have to be pumped from the river 1.2 miles (2 km.) to the east.

The principal manganese zone is known to extend for 4 miles (6 km.) northwestward from the Bacanao River, and is said to extend for 4 miles (6 km.) further. The zone was studied in detail in two areas. The larger, shown in plate 67, covers part of the Hercules, Graham, and Non Plus Ultra denouncements; the smaller, shown in figure 18, covers part of the Fantasia and Capricho denouncements and lies about 2 miles (3 km.) southeast of the Non Plus Ultra denouncement.

Geology

Five rock units are recognized in the area. Three of them, which together constitute a thick sequence that is mainly volcanic, consist respectively—in ascending order—of (1) green tuff, (2) limy tuff, and (3) agglomerate. A body of dioritic



EXPLANATION — *EXPLICACION*

Manganese oxides	*Mineral de manganeso*
Jasper	*Bayate (jaspé)*
Limits of shear zone	*Limite de la faja de fracturas*
Fault, showing dip	*Falla con buzamiento*
Strike and dip of beds	*Direccion y buzamiento de las capas*
Pit boundary	*Limite del hoyo*
Road	*Camino*

SKETCH MAP OF THE CHEVERE MINE, GRAN PIEDRA AREA. ORIENTE PROVINCE, CUBA

MAPA DISENO DE LA MINA CHEVERE, COTO GRAN PIEDRA, PROVINCIA DE ORIENTE, CUBA

10 0 10 50 100 150 200 Feet *Pies*

10 0 10 20 30 40 50 Meters *Metros*

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rock is intruded into the volcanics, and on Portrero hill a coarse agglomerate appears to be intrusive into the green tuffs, although the relations are not clear.

The lower unit consists of green tuff, generally massive and coarse, resembling the tuffs that occur throughout the Sierra Maestra. It is at least 1,500 feet (450 m.) thick and forms prominent cliffs.

The base of the middle member, which is about 500 feet (150 m.) thick and limy throughout, is placed at the lowest consistently limy beds. The principal manganese zone, the Non Plus Ultra ore bed, lies near the base of the unit. The rocks that make up this unit include brown limy tuffs, dense, gray, fossiliferous limestones, and a few agglomerate members, one of which was used as a horizon marker in mapping. Details of lithology vary considerably and somewhat irregularly, but in general the beds become coarser and more agglomeratic to the southeast.

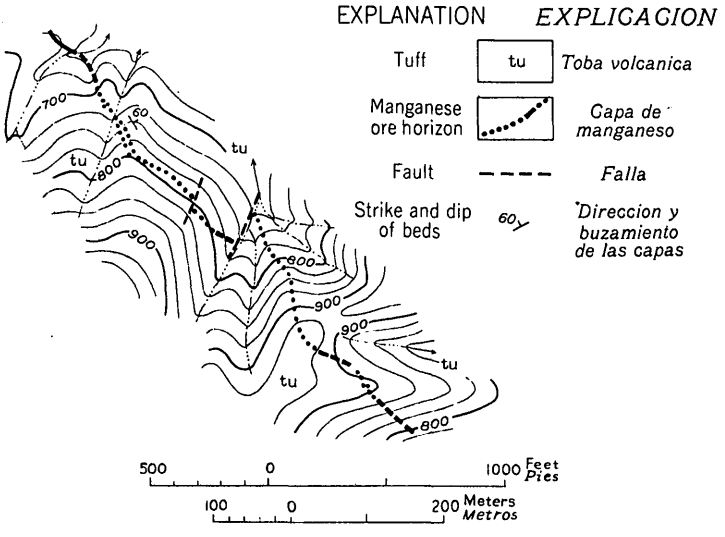


Figure 18.--Geologic map of the Fantasia and Capricho denouncements, Sigua area, Oriente Province, Cuba.

The agglomerate which forms most of the upper unit is a coarse fragmental rock that consists mainly of blocks of andesite porphyry up to several feet in diameter. It is interbedded to a slight extent with tuff and limestone and, in the upper part, with andesitic(?) lavas. The unit is so distinctive in lithologic character as to make a good horizon marker. Its total thickness is probably over 600 feet (180 m.).

The dioritic intrusive, which cuts off the bedded rocks in the southern part of the area, is a dark-green massive rock with a coarse diabasic texture. Clear plagioclase feldspar, biotite, and blebs of chloritic minerals, apparently derived from hornblende, can be recognized in hand specimens. Near the contact, the tuff has largely assumed a dense texture and a flinty appearance and some of it has been altered to hornfels; the limy beds close to the contact are banded. No distinctive

border facies of the intrusive rock was observed. The manganese horizon is not known to crop out within 400 feet (120 m.) of the contact. On Portrero hill there are outcrops of an agglomerate, composed of scoriaceous andesitic fragments, which may have been formed in or near a vent. The upper part of the agglomerate shows a bedding parallel to that of the enclosing green tuffs, but the lower part is massive and crosscuts the bedding of the tuffs. The manganese bed on the Hercules claim is in this rock.

In the northeastern part of the area the green tuffs and limy tuffs trend N. 40°-50° W. and dip 45°-60° NE., except where the strike changes on minor cross-folds. On Cemetery hill, the middle limy tuff is horizontal and is assumed to be faulted against steeply dipping green tuffs, an assumption supported by the presence on this hill of float from the Non Plus Ultra ore bed to the north. Diorite occupies most of the distance between the Sigua area and the smaller Fantasia map area to the southeast. The manganese bed has the same strike and dip in both areas, but in the Fantasia area the bed is cut by several small cross faults. The manganese horizon continues to crop out southeast of the area mapped.

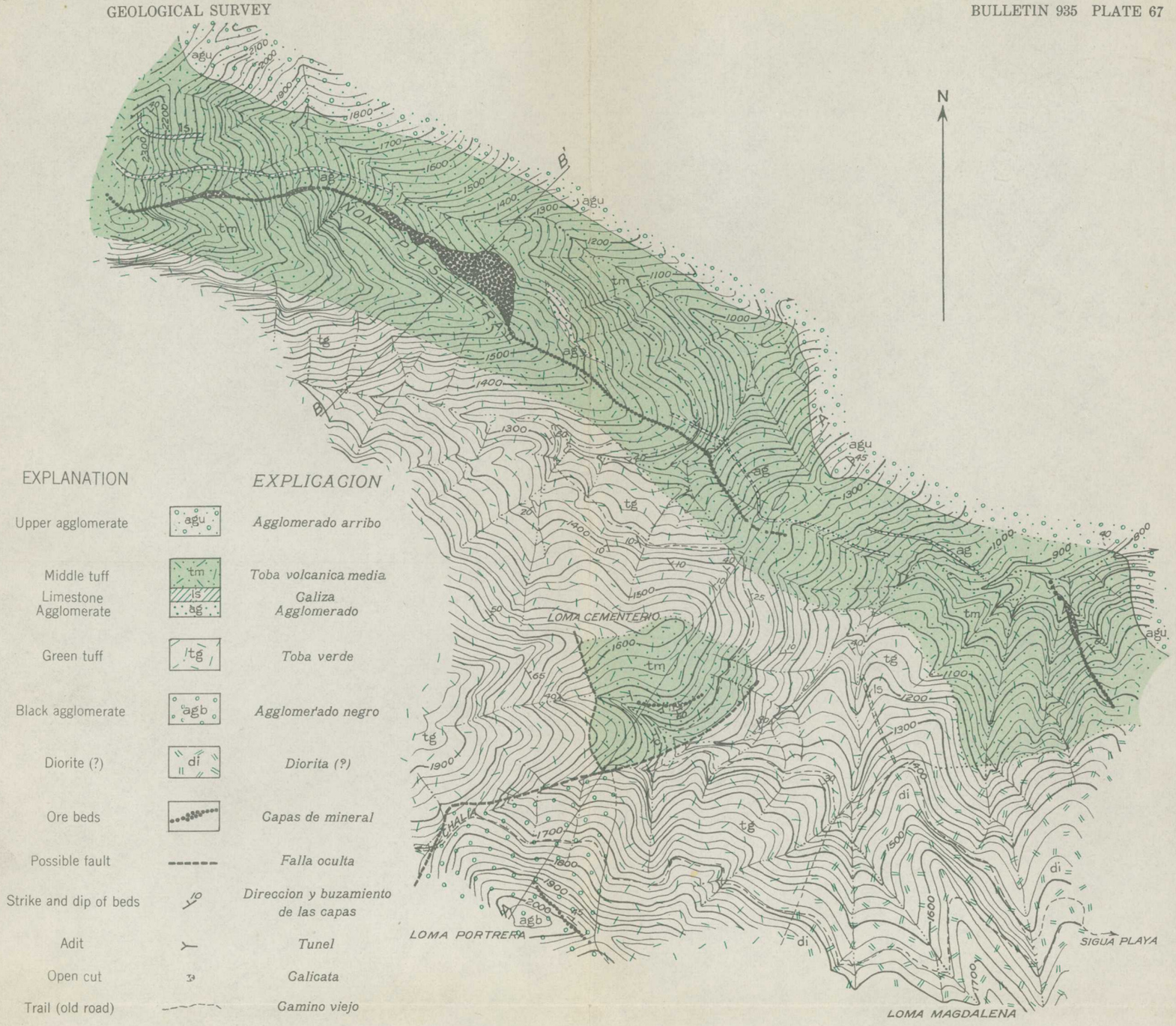
Ore deposits

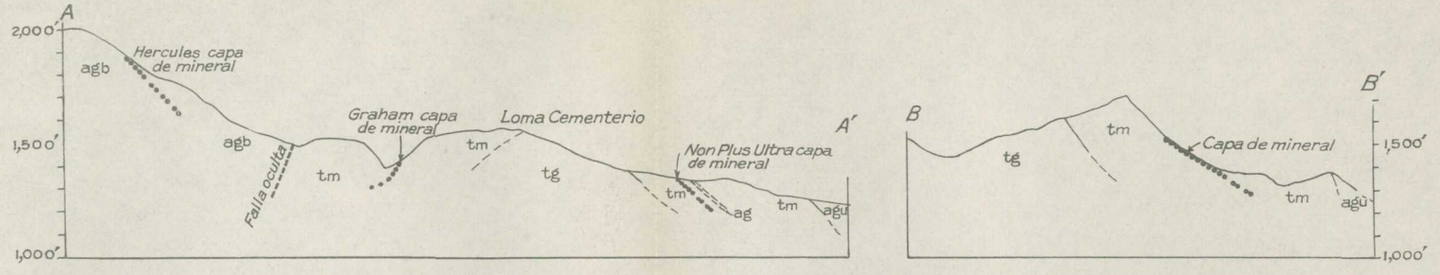
Very little development has been done on the deposits. The Non Plus Ultra is developed by a few small pits and two short crosscutting adits, in both of which the ore bed is within 20 feet (6 m.) of the portal, but the adits were continued 60 to 70 feet (18 to 21 m.) in the hope of encountering more ore at depth. The Hercules and Fantasia areas have not been explored, but the Graham outcrop is opened by four pits, from which ore was shipped in 1918.

The Non Plus Ultra contains the largest of the four occurrences of manganese-bearing rocks. On the Fantasia and Capricho there is a similarly extensive bed, but the ore at the Graham consists of small pockets in and adjacent to a mass of jasper. The Hercules ore bed on Portrero hill is thin and of small extent, but otherwise identical in character with the Non Plus Ultra bed.

Two exposures of the Non Plus Ultra bed are known in the area studied. One is exposed for over 4,500 feet (1,370 m.) along the strike; the other, to the southeast, is exposed for 750 feet (230 m.). The bed is in limy tuff about 50 feet (15 m.) stratigraphically below the agglomerate that serves as a horizon marker. Its thickness probably averages 3 feet (1 m.) but ranges from as little as 6 inches (15 cm.) to as much as 6 feet (1.8 m.). Part of the outcrop, being on a dip slope of one of the strike ridges, is as much as 150 feet (45 m.) wide and makes a considerable tonnage of mineral immediately available on the surface. Unfortunately, the great breadth of this outcrop has led to a popular belief that the deposit is fabulously thick.

The typical mineralized rock is dull black or lustrous black, massive, hard, and brittle. The minerals tentatively identified include piedmontite, braunite, neotocite, psilomelane, and pyrolusite. Probably the commonest of these is braunite, a dull steel-black, hard mineral. The ore is siliceous, and much of the silica seems to be in chemical combination with the manganese, though some of it is known to be in fine-grained mixtures of silica and manganese oxides. Piedmontite





500 0 2,000 Feet
Pies
100 0 500 Meters
Metros

Contour interval 25 feet
Distancia entre las curvas de nivel 25 pies

GEOLOGIC MAP AND SECTIONS OF THE SIGUA AREA, ORIENTE PROVINCE, CUBA

MAPA GEOLOGICO Y SECCIONES DEL COTO SIGUA, PROVINCIA DE ORIENTE, CUBA

was identified in both the Non Plus Ultra and Fantasia beds, to which it locally gives a reddish color. Considerable lustrous black, brown, or yellow neotocite is found, and psilomelane occurs in veinlets and pods. Veinlets of pyrolusite and calcite cut the other minerals, and pyrolusite forms a superficial coating, especially on the dip-slope outcrops. The typical product of weathering of the ore is pyrolusite mixed with a dull-brown powdery material.

The mineralized beds exemplify most of the structures characteristic of tuff ore. Nodular structures are common (pl. 53). In some outcrops the beds consist of black and red layers separated by lighter-red siliceous manganiferous tuff, which makes up the most common gangue and encloses the better parts of the beds. Calcite and a little jasper make up the remainder of the gangue. Much of the tuff contains some manganese, for it weathers black and on broken surfaces it shows veinlets and stains of manganese oxide.

Analyses, made by a reliable company, of samples cut on the outcrops of the ore show from 20 to 48 percent of manganese. A small part of the material from the Non Plus Ultra bed can probably be hand-picked to contain 40 percent manganese and 15 percent silica, but before the deposit could be fully utilized it would probably be necessary to devise a method for handling the lower-grade material economically.

The Graham deposit, which contains manganese oxides associated with jasper, apparently cuts the limy tuffs at steep angles. Most of the ore came from a residual blanket of pyrolusite and psilomelane with some braunite.

The reserves are mainly in the Non Plus Ultra mineral bed, on the dip-slope exposure of which there is at least 50,000 tons of ore in sight. If the bed continues from the top of the hill at the northwest corner of the map to the creek level just west of section A-A' (pl. 67), it would contain in all 900,000 tons of ore—if material containing 20 percent manganese and 20 percent silica on the average is regarded as ore. The probable tonnage of the same grade in the Fantasia bed is 100,000 tons. The Hercules denouncement may contain 100 tons of 20-percent ore, and the Graham 50 to 100 tons of 40-percent ore. Taken together, these deposits can produce a large tonnage of mineralized rock, which however would either have to be concentrated or used for special purposes that require high-silica ore.