# Geology of the Manganese Deposits of Cuba



*By* FRANK S. SIMONS *and* JOHN A. STRACZEK



GEOLOGICAL SURVEY BULLETIN 1057

*A summary report prepared in cooperation with the Dirección de Montes, Minas, y Aguas, Ministerio de Agricultura under the auspices of the Interdepartmental Conference on Scientific and Cultural Cooperation with the American Republics, Department of State*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1958

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

---

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.

# CONTENTS

# ILLUSTRATIONS

[All plates are in pocket]

## TABLES

# GEOLOGY OF THE MANGANESE DEPOSITS OF CUBA

By Frank S. Simons and John A. Straczek


## ABSTRACT

Deposits of manganese ore have been found in five of the six provinces of Cuba and have been reported from the sixth. Only Oriente and Pinar del Río provinces have more than a few known deposits and only the deposits of Oriente have yielded any appreciable amount of ore.

Deposits of Provincia de Pinar del Río are in four districts, near Bahía Honda, Gramales, Mendoza, and San Vicente and La Palma; they are bedded deposits in sedimentary rocks of Jurassic or Cretaceous age along the flanks of the Sierra de los Órganos and Sierra del Rosario on the north coast of the province.

The only deposits reported from Provincia de La Habana are on the Isla de Pinos, a large island just south of the main part of the province. These deposits are probably veins cutting metamorphic rocks of Paleozoic(?) or Jurassic(?) age.

Deposits in Provincia de Las Villas are at Amaro, Quemado de Güines, and Sierra Morena on the north coast and near Trinidad on the south coast. The northern deposits are sedimentary or residual deposits in rocks of Cretaceous age; the Trinidad deposits are veins in metamorphic rocks of Paleozoic(?) or Jurassic(?) age.

The deposits of Provincia de Camagüey are in the Sierra de las Cubitas, 45 kilometers north of the city of Camagüey, and at Finca Santa Clara, 25 kilometers southeast of the city. The deposits at Finca Santa Clara are pockets in basalt of probable Cretaceous age; those of the Sierra de las Cubitas are residual, derived from limestone of Eocene age.

Manganese deposits have been found at a great many places in Oriente, but the most productive area is in the southwestern part of the province in a belt along the north flank of the Sierra Maestra extending from Yara at the west end to Ramón de las Yaguas at the east end and covering an area of almost 8,000 square kilometers. A few unproductive deposits are along the south coast between Pilón and La Plata, in the Sigua district 40 kilometers east of Santiago de Cuba, and near Holguín.

The oldest rocks in the manganiferous area of southwestern Oriente are Upper Cretaceous(?) volcanic rocks and subordinate marine sedimentary rocks of the Vinent formation, which is exposed in the Sierra Maestra and is at least 1,500 meters thick, and shale, sandstone, and conglomerate of the upper Cretaceous Habana(?) formation which is exposed in the Sierra de Nipe and Sierra del Cristal and is at least 500 meters thick. Bedded manganese deposits occur in the Vinent formation along the south coast between Pilón and La Plata.

The Cobre formation, of late Cretaceous(?) to middle Eocene age, overlies the Vinent formation but their stratigraphic relations are unknown. The Cobre overlies unconformably the Habana(?) formation. The Cobre formation consists of at least 4,000 meters of andesitic, basaltic, and dacitic tuff, agglomerate, and lavas with minor amounts of marine clastic and limestone deposits, and a prominent limestone bed, the Charco Redondo limestone member, at the top of

the formation. All productive manganese deposits of Oriente are in the Cobre formation, usually within a few tens of meters above or below the base of the Charco Redondo limestone member.

Overlying conformably the Cobre formation are limy tuffaceous shale and sandstone strata of the middle to upper Eocene San Luis formation. This formation may be as much as 1,500 meters thick. No manganese deposits have been found in it or in any of the younger rocks. It is overlain conformably in the Río Cauto valley by 100 meters or more of unnamed Oligocene marl and shale.

Argillaceous limestone of early Miocene age crops out at the west end of the Sierra Maestra and is termed the Manzanillo formation; a similar unit of middle Miocene age unconformably overlies the Cobre and Vinent formations in the Santiago de Cuba region and is called the La Cruz marl.

Coral limestone, marl, and conglomerate of Pleistocene and Recent age fringe parts of the south coast. Pleistocene and Recent alluvial deposits as much as 30 meters thick floor many stream valleys.

Intrusive rocks of two general age groups crop out throughout southwestern Oriente. Pre-Tertiary intrusive rocks include the extensive ultramafic complex of the Sierra de Nipe and Sierra del Cristal and small dacite or quartz diorite stocks that intrude the Habana(?) formation. Tertiary intrusive rocks comprise small stocks and dikes of dacite, andesite, and basalt that cut pre-Oligocene strata in many places in the manganese districts. The diorite batholith of the Sierra Maestra is probably of Eocene age but may be as old as Late Cretaceous.

Regional structures of southwestern Oriente trend east. The principal structures, from south to north, are the Sierra Maestra, essentially a homocline of Tertiary rocks dipping northward; the synclinal basin of the Cauto and Guaninicún valleys; and a broad anticline composed of two domical uplifts, the Sierra de Nipe and the Sierra del Cristal, separated by the synclinal trough of the northward-trending Mayarí valley. Ten small circular or elliptical domes have been found on the north flank of the Sierra Maestra.

The Tertiary rocks are cut by many small faults that appear to be concentrated in three general areas: the Güisa-Los Negros area, where there are steep normal fractures with displacements as much as 200 meters; the foothills of the Sierra de Nipe, where there are steep-dipping normal and reverse faults with displacements of as much as 200 meters; and the Santiago basin-Dos Bocas valley area, where several oblique-slip reverse faults with dip-slip displacements as large as 1,500 meters have been recognized.

The ore deposits may be divided broadly into two types: bedrock or surficial. Those in bedrock may be subdivided into bedded and nonbedded deposits and further subdivisions are based on mineralogy, country rock, and association or nonassociation with jasper. Bedrock deposits have been much more productive than surficial deposits and bedded deposits have yielded all but a very small percentage of Cuba's manganese ore.

The principal ore minerals of the deposits are various manganese oxides. Psilomelane-type oxides are the most abundant primary minerals and are found in almost all bedrock deposits. Pyrolusite occurs in all deposits; it appears to be derived largely by supergene oxidation from psilomelane-type oxides and various manganese silicates and is the principal mineral in the residual ores. Hausmannite, manganite, ranciéite, and wad have been found in small amounts. Various manganese silicates are found in many deposits and are the principal primary mineral in a few. The hydrous silicates bementite and neotocite are the most abundant silicates; braunite is fairly common, and inesite, orientite, and piedmontite are known at a very few localities. Gangue minerals are largely

alteration products of andesitic and basaltic tuff. The most abundant are montmorillonite clay minerals, chlorite, and zeolite; hematite is fairly common, and black calcite is the only abundant gangue in the nonbedded deposits in limestone as well as being rather common in the bedded limestone deposits.

The bedded deposits are tabular bodies lying along certain beds of a pyroclastic sequence or along pyroclastic beds in limestone. They range from a few centimeters to 15 meters in thickness and are as much as 1,000 meters long. Most of them appear to be roughly elliptical in outline and consist of manganese oxide in a matrix of tuff or agglomerate, but a few, including one very large deposit (Sigua), are made up of varying proportions of manganese silicates in a tuff matrix. The ore ranges in grade from essentially solid manganese oxide containing 45–50 percent manganese to sparsely mineralized tuff that may contain only a few percent manganese.

The deposits in limestone ordinarily are accompanied by very little jasper, whereas those in a pyroclastic sequence often have very extensive lenses or sheets of brown, red, or black jasper. The jasper usually underlies the ore and almost invariably the ore of highest grade is nearest the jasper.

Bedded ores, particularly those in limestone, are overlain in some places by intraformational conglomerate containing fragments of manganese oxides derived from the underlying ore bed. Clastic dikes of tuff or limestone, many containing fragments of manganese oxide, have been observed at a number of deposits. Both of these features indicate that the ore bed which they overlie or cut was deposited and partly consolidated before the overlying material was deposited.

The nonbedded deposits are generally replacement bodies in Charco Redondo limestone, though a few are found in tuff, agglomerate, or other rocks. Most of them appear to be controlled by premineralization faults. The only manganese minerals in these deposits are various oxides. Only a few notably productive nonbedded deposits have been found.

Surficial deposits include granzón—pellets of manganese oxide formed under supergene conditions in clay soils, usually near outcrops of bedded ore, and fragments of manganese oxide derived directly from bedrock ore by weathering and disintegration of the parent rock—also chert rubble deposits, which have been found only in Las Villas and consist of supergene manganese oxides cementing chert fragments, and cave deposits of granzón and manganiferous clay on floors of certain limestone caves. Much surficial ore is very high grade, but deposits are usually small.

The deposits of Oriente are strikingly concentrated in the upper few hundred meters of the Cobre formation, and almost all the deposits lie within a few tens of meters above or below the base of the Charco Redondo limestone member. Although in nine areas in this province manganese ore is found on structural domes, no regional structural control can be demonstrated for the great majority of the deposits.

No single mode of origin can be given for all the types of manganese deposits nor even for all the deposits ofany given type. The bedrock deposits of Oriente are belived to be hypogene, as trey show none of the characteristics attributable to concentration by supergene processes and on the other hand, show local country rock alteration typical of hypogene mineralization. Most of the deposits consist of various manganese oxides tht have replaced tuff, agglomerate, or limestone; some of the manganese oxides may have been deposited directly as a chemical precipitate. The bedded deposits are considered in general to be syngenetic; a number of deposits offer conclusive evidence (intraformational conglomerate, clastic dikes, and conformable relationships with enclosing rocks) of suchan origin. The nonbedded deposits are clearly epigenetic but probably

formed at about the same time as the latest of the syngenetic deposits. The source of the manganese is thought to be warm springs that became especially active during the waning stages of Cobre volcanism.

The age of manganese mineralization varied from place to place. Deposits in Pinar del Río are considered to be syngenetic in origin and therefore are of Jurassic or Cretaceous age. Bedded deposits in the Vinent formation of Oriente may be Cretaceous or very early Eocene in age. Deposits in the Cobre formation are for the most part of middle Eocene age, but those several thousand meters below the top of the formation may be as old as early Eocene. The residual ores of Pinar del Río, Las Villas, and Oriente provinces have formed during the present cycle of weathering and erosion.

The most important guides to prospecting are the association of ore deposits with calcareous rocks, particularly the Charco Redondo limestone in Oriente, and the very common association of manganese ore with the prominent and easily recognized brown or black jasper. Faults in limestone are much less useful guides.

Cuba has exported large amounts of manganese ore to the United States particularly during the periods 1916 to 1919, 1937 to 1946, and 1950 to the present. Total production from the inception of mining about 1888 until 1953 is estimated at nearly 3.5 million tons. The largest producers have been the Charco Redondo, Ponupo, and Quinto mines in Oriente.

Reserves in Oriente were believed to be more than 1 million tons of concentrates from high-grade and milling-grade ore and about 4.5 million tons of low-grade crude ore in 1946. Deposits in other provinces have been too little developed to permit any sound estimate of reserves, but almost certainly only Pinar del Río and Las Villas have appreciable reserves.

One hundred seventy-two mines, mine groups, or prospects are described.

## INTRODUCTION

Cuba, the largest and westernmost island of the West Indies, lies between parallels 19°49′ and 23°15′ north latitude, and meridians 74°08′ and 84°57′ west longitude. Together with Jamaica, Hispaniola, Puerto Rico, and a number of smaller islands, it is part of the Greater Antilles, an island group at the northwest end of the West Indian island arc.

The island measures about 1,200 kilometers in length along its arcuate axis from Cabo San Antonio at the west to Punta Maisí at the east. Its width ranges from 37 kilometers in eastern Provincia de Pinar del Río to nearly 200 kilometers in western Provincia de Oriente. According to the Oficina del Censo of Cuba (Marrero, 1946, p. 3) the main island, with Isla de Pinos (the Isle of Pines) and the coastal islets, embraces an area of 114,524 square kilometers.

### COMMUNICATIONS

Most of the principal cities of Cuba are connected by railroads and by a system of highways and surfaced roads. Domestic airlines utilize air fields throughout the island and provide transportation to towns and localities not connected by rail or by surfaced roads. The great airports of La Habana and Camagüey are used by international airlines.

The main rail line extends along the axis of the island, from the city of Pinar del Río to Santiago de Cuba, in Oriente. The eastern half of Cuba is served by the Ferrocarriles Consolidados de Cuba (Consolidated Railroads of Cuba); western Cuba, by the Ferrocarriles Unidos de La Habana (United Railroads of La Habana). Branch railroads, like the Guantánamo y Occidente (Guantánamo and Western) between San Luis and Guantánamo in Oriente, connect the main line with the flanking areas.

The most important road is the Carretera Central (Central Highway), which extends from Pinar del Río to Santiago de Cuba and roughly parallels the main railroad line. Many towns and villages in the hinterland are reached by improved and unimproved roads, but many settlements, particularly in the eastern provinces, are accessible only by trail or sea or air routes.

Regularly scheduled air service to most of the large cities is offered by the Compañía Cubana de Aviación; in addition, air service to four towns on the north coast of Oriente, not accessible by either road or railroad, is available.

There are more than twenty international seaports in Cuba; the largest and most important are La Habana, in Provincia de La Habana, and Santiago de Cuba in Oriente, both of which can accommodate ships of large displacement.

## LOCATION OF THE MANGANESE DISTRICTS

Manganese deposits occur in Pinar del Río, La Habana, Las Villas, Camagüey and Oriente provinces, and have been reported from Provincia de Matanzas, but nearly the entire production of manganese ore has come from Oriente. Plate 1 is an index map showing the location of the various manganese districts.

The manganese deposits of Pinar del Río are in widely separated areas in the northern and western parts of the province. Deposits are found south of Mendoza; in the vicinity of Gramales, 30 kilometers west-northwest of the city of Pinar del Río; near San Vicente and La Palma, north of Pinar del Río; and southwest of Bahía Honda on the north coast.

On the Isla de Pinos, a part of La Habana province, manganese has been found in two localities, one west and the other northeast of Santa Fe.

In Las Villas (Las Villas is now the official name for the province formerly known as Santa Clara, the name found on most available maps), the only known manganese deposits are on the south coast, about 10 kilometers west of the town of Trinidad, and near the north coast at Amaro, Quemado de Güines, and Sierra Morena.

The manganese deposits of Camagüey are on the north slopes of the Sierra de las Cubitas, about 45 kilometers north of the city of Camagüey, and at Finca Santa Clara, about 25 kilometers southeast of the city of Camagüey.

All productive manganese deposits of Oriente have been found in the southwestern part of the province along an eastward-trending belt extending from Yara and Pilón at the west to Ramón de las Yaguas at the east and embracing an area of about 7,800 square kilometers. The principal towns, from west to east, are Manzanillo, Yara, Bayamo, Güisa, Santa Rita, Jiguaní, Baire, Contramaestre, Palma Soriano, El Cobre, San Luis, El Cristo, Alto Songo, and La Maya; the shipping point is the seaport of Santiago de Cuba. The area is served by the main rail line of the Ferrocarriles Consolidados de Cuba and by branch lines between San Luis, Bayamo, and Manzanillo and between El Cristo and La Maya. In addition, the eastern districts are served by the rail line of the Guantánamo and Western Railroad connecting San Luis and Guantánamo. A portion of the Carretera Central extends from Santiago de Cuba to Bayamo, Holguín, and northward, and paved roads lead to Manzanillo, Güisa, Dos Caminos, El Cristo, and Alto Songo. Most of the mines are reached by dirt or graveled roads, but mines in the Palmarito and Sabanilla districts ordinarily are reached only by rail. Many small mines and prospects are accessible only by trail.

Minor deposits are scattered along the south coast of Oriente between Pilón and La Plata, and a few deposits are in the Sigua district, west and southwest of Ramón de las Yaguas and about 40 kilometers east of Santiago de Cuba. Other deposits are reported in the vicinity of Guantánamo. In the northern part of the province, small deposits are known east and northeast of Holguín, and others have been reported near Baracoa.

## PREVIOUS WORK

The earliest published discussion of the geology of Cuban manganese deposits is given by Hayes, Vaughan, and Spencer (1901, p. 62–69) who examined the Boston, Ponupo, and Isabelita (Quinto) mines near Santiago de Cuba, deposits near San Nicolás, a deposit northwest of Portillo, the Manuel and Costa mines at Bueycito, and the Antonio mine near Los Negros, all in Oriente. The Bueycito deposits are described as replacements of limestone and impregnations of breccia, the Antonio deposit as a replacement of limestone, and the San Nicolás deposits as replacements by manganese carried in circulating waters.

In a later report, Spencer (1903, p. 251–255) gave a more detailed description of the mines near Santiago de Cuba. He recognized the essential contemporaneity of manganese mineralization and the deposition of jasper, the association of jasper and high-grade ore, and the bedded nature of the jasper masses. Origin of the deposits is ascribed by him to replacement of sandstone or calcareous strata by manganiferous material carried in ascending hot waters.

In 1918 Burchard and Burch made a reconnaissance of the manganese and chromium deposits of Cuba, during which a number of manganese mines in the Santiago de Cuba, Bayamo-Baire, and Camaroncito districts of Oriente were examined. In a separate report Burchard (1920) also mentioned deposits in Las Villas and Pinar del Río provinces. He postulated deposition of manganese minerals from hot solutions but believed that some of the deposits may have been formed by surface waters.

Hewett (Hewett and Shannon, 1921) examined the Oriente deposits in 1920 and described the Bueycito deposits in the course of a detailed discussion of a new mineral found at Bueycito and Banes. He believed that the manganese minerals were deposited from warm hypogene waters by replacement of latite tuff, an origin similar to that ascribed to deposits in the Santiago de Cuba district by Spencer.

## PRESENT INVESTIGATION

During the early stages of the last war, it became evident that imports of manganese ore from distant sources might be curtailed seriously or even cut off as a result of military action and attention was turned, therefore, to the manganese deposits of Cuba as a known source of great potential value to the steel industry of the United States. The potentialities of this source were apparent when the Cuban Mining Company, during the period 1932 to 1940, first succeeded in concentrating low-grade ores of southwestern Oriente. The present investigation began in November 1940, with the consent and cooperation of the Cuban Dirección de Montes, Minas, y Aguas, Ministerio de Agricultura, as a part of a program of geologic investigations in the American Republics sponsored and financed by the U. S. Department of State. Its purpose was to determine the productive potentialities of the manganese-bearing regions by geological studies that would permit a valid estimation of reserves and delineation of ore deposits and manganese-bearing areas most favorable for prospecting, exploration, and development. Another purpose was to aid in the realization of this production potential by detailed mine mapping to furnish mine operators a basis for exploration and development.

Work of the Geological Survey began in the winter of 1940–41 with a reconnaissance of deposits throughout the island by Charles F. Park, Jr., and a brief report was published in 1942 (Park, 1942a). Intensive study of the deposits of southwestern Oriente was begun in December 1941, when M. W. Cox joined the project, and a progress report on mines and districts in part of the Sierra Maestra based on field work done through September 1942 was published in 1944 (Park and Cox, 1944). In order to tie together isolated geologic mine maps and to give a comprehensive view of the occurrences of the various deposits, regional mapping of the Güisa-Los Negros manganese area was carried out from December 1942 to April 1943 by W. P. Woodring and S. N. Daviess, and their report was published in 1944.

Succeeding work included revision and amplification of early mine maps, detailed mapping of many additional mines and mine districts, and areal geologic mapping of that part of the mining area east of the Güisa-Los Negros area. Field work was begun by Straczek in October 1942 and continued almost without interruption until October 1945. A total of 25 months was spent in the study and mapping of the manganese deposits, the remainder of the time being devoted to areal mapping. Cox continued with the project until May 1943 at which time Simons joined. Simons spent 20 months in the field, 17 devoted to the study of manganese deposits and 3 to areal mapping. G. E. Lewis was assigned to the project in January 1945. The final phase of the project was devoted to the areal geologic mapping which began in December 1944 and ended in September 1945. The stratigraphy and structure of the new area covered by regional mapping are discussed in a separate report by Lewis and Straczek (1955). Señor Guido Calvache assisted in the work from October 1942 to August 1944.

The writers together studied and mapped the deposits of southwestern Oriente. Straczek examined deposits in Las Villas, some that had earlier been examined by Park and Cox. Deposits in other districts described in this report were not seen by us: those of Pinar del Río were examined in reconnaissance by Park in part of 1940 and 1941; those of Camagüey by T. P. Thayer; and those of northwestern Oriente by Thayer and P. W. Guild, both assigned to the chromite project of the U. S. Geological Survey.

This report presents an account of certain aspects of the geology of the manganese deposits of Cuba but necessarily emphasizes the results of intensive mapping and examination of the deposits of southwestern Oriente where by far the great bulk of Survey work has been concentrated. It is a compilation and expansion of the results of investigations of Cuban manganese deposits by all Survey workers assigned to the project during the period 1940–45. Part of the results has already been published but much information included in this report has not been released heretofore. Where it has been practical to do so, credit is acknowledged within the report for specific data not collected by us but placed at our disposal by various colleagues.

Certain phases of this study have not been completed, in particular the laboratory investigations of mineralogy and paragenesis, rock alteration, oxidation, and some theoretical problems bearing on origin and localization. However, we feel that a more useful purpose may be served by making available the large amount of material already at our disposal than by delaying indefinitely the publication of our completed results. The uncompleted portions of this study mentioned above will be prepared for publication at a later date.

Because of space limitations we have not attempted to include a complete description of the Quinto deposit at El Cristo in Oriente. This great deposit, which furnished approximately one-third of Cuban production during 1940–46 will be the subject of a separate publication to be prepared later.

**ACKNOWLEDGMENTS**

Direct supervision of the manganese project was successively by J. V. N. Dorr, II, and W. D. Johnston, Jr. D. F. Hewett, long familiar with the manganese deposits of Cuba, and C. F. Park, Jr., aided in planning the work from the time of its inception in 1940.

Officials of the American Embassy in La Habana, particularly C. A. Botsford, minerals attaché, and of the American Consulate at Santiago de Cuba at all times rendered their sympathetic and helpful assistance. To the officials of the United States Metals Reserve Company Agency and the United States Commercial Company Agency, we owe thanks for production statistics and analyses made available to us during 1942–45.

Officials of the Cuban Government, in particular Antonio Calvache, mining engineer consultant and now director of the Dirección de Montes, Minas, y Aguas, Ministerio de Agricultura, cooperated fully in the project. Without the real cooperation of the many mine owners, operators, and mine foremen who expressed wholehearted interest in the work and who offered accommodations at their properties, usually refusing payment, our work could not have been accomplished. We were encouraged and stimulated by requests for technical assistance on the part of many mine operators and hope that the advice offered together with the mine maps made available to them repaid in part their many courtesies. Our many friends among officials of the Cuban Mining Company at El Cristo facilitated the work by permitting the use of drafting and printing machines and equipment otherwise not readily available to us. The Cuban Mining Company, through Mr. F. S. Norcross, Jr., made available to us the many geologic maps and exploration records it had accumulated, and its parent organization, the Freeport Sulphur Company, has given permission for publication of such material in this report.

Officials of many sugar companies were instrumental in furthering the work by offering accommodations and placing transportation facilities at our disposal, for which we are everlastingly grateful.

We acknowledge with pleasure the help given us by the late Dorothy K. Palmer and D. W. Gravell, both of the Atlantic Oil and Refining Company, La Habana, and by J. F. de Albear, our Cuban colleague and former chief of the Comisión Geológica of Cuba, in the identification of fossils.

Through the generous cooperation of the United States Navy and United States Army Air Force, aerial photographs of the southwestern Oriente manganese field were taken and made available. These furnished a much needed base on which the many mines and prospects could be located, the areas most favorable for prospecting could be delineated, and the regional geology could be mapped.

## GEOGRAPHY

Cuba in general is an island of low relief. About half of the island's surface lies at an altitude of less than 100 meters and about 95 percent at less than 300 meters. Oriente includes the largest area of land above 300 meters in altitude.

The coastline, except in southern and eastern Oriente and in a small section in southern Las Villas, is low-lying and in many places swampy. Numerous islets dot the shallow water along most of the coast. Palmer (1945, p. 1) has shown that an emergence of 15 meters would unite nearly all the islands, including the Isla de Pinos, with the main island.

### TOPOGRAPHY

Cuba may be divided roughly into six topographic divisions. They are, from west to east: Pinar del Río; La Habana, Matanzas, and western Las Villas; the Isla de Pinos; central and eastern part of Las Villas; Camagüey and the northwest part of Oriente; and southern and eastern Oriente. These divisions correspond closely to those proposed by Hayes, Vaughan, and Spencer (1901, p. 10) and by Massip (1942, plate opposite p. 44) but are more generalized than those proposed by Palmer (1945, p. 1–5).

Pinar del Río is dominated by a northeastward-trending chain of two mountain ranges, the Sierra de los Órganos to the southwest and the Sierra del Rosario to the northeast. The ranges are essentially continuous but are separated by a low area drained by the headwaters of the Río San Diego.

The Sierra de los Órganos is the site of the picturesque, steep-sided, round-topped mogotes, or knobs, of limestone; these have been likened to the tubes of a gigantic organ, a resemblance that has given rise to the name "Organ Mountains". The highest points in the Sierra de los Órganos reach altitudes of somewhat more than 400 meters. The Sierra del Rosario, however, is characterized by gentle slopes and craggy summits that reach an altitude of 728 meters in the Pan de Guajaibón, the highest point in Pinar del Río.

Along both flanks of the Sierra de los Órganos are low hills that give way to low-lying flat land as the coasts are approached.

The terrain of La Habana, Matanzas, and the western part of Las Villas is, in general, of low relief, although in northern and central La Habana and in northwestern Matanzas, altitudes of 200 meters are not uncommon. A belt of low hills extends from La Habana to the city of Matanzas, and a second belt of hills, most prominent in La Habana between San Antonio de las Vegas and San José de las Lajas, extends from Bejucal eastward to Limonar. Southwestern Las Villas includes the Península de Zapata (shoe) and the great Ciénaga (swamp) de Zapata that separates the peninsula from the mainland. The belt of low relief, exclusive of coastal swamps, extending along the south coast of Cuba from western Pinar del Río to central Matanzas, has been named the "peneplain of western Cuba" by Massip (1942, p. 73–79).

The Isla de Pinos lies about 100 kilometers south-southwest of Batabanó, the port of embarkation for the island on the south coast of La Habana. It embraces an area of 2,126 square kilometers, and is divided into two parts by the Ciénaga Lanier extending across the southern part of the island from the deep reentrant of Ensenada de la Siguanea on the west coast to Boca de la Ciénaga on the east coast. The northern part of the island rises from a low coastal plain to a somewhat higher central plain dotted by hills as much as 300 meters high.

Central and eastern Las Villas forms a well-defined topographic region whose mountainous terrain contrasts strongly with the essentially featureless plains of Matanzas to the west and Camagüey to the east. Low, northwestward-trending ridges rise to altitudes of 300 meters or less in the northern part of the province, and extend into northwestern Camagüey. These ridges are locally called the "cordillera". In the south, the Sierra de San Juan, Sierra de Trinidad, and Sierra de Sancti Spíritus, here collectively referred to as the Sierra de Trinidad, occupy the position of the coastal plain from near Cienfuegos southeastward to Trinidad. At Trinidad, the coastal plain reappears and the Sierra de Trinidad trends eastward to Sancti

Spíritus, where it dies out. The Sierra de Trinidad consists of a mountain chain divided into two areas by the deep, rugged canyon of the Río Agabama. Several of the peaks of the Sierra de Trinidad are more than 900 meters high; the highest is Loma San Juan, 1,157 meters in altitude.

Nearly the entire topographic region of Camagüey and northwest Oriente is an area of low altitude and relief. Departures from this strikingly level terrain are few, concentrated mainly in the Sierra de las Cubitas and the Sierra Camaján, north of the city of Camagüey, and in a belt extending from Victoria de las Tunas through Holguín to Bahía de Nipe in Oriente. The maximum relief is about 300 meters. The southeast part of this region is occupied by the western end of the Cauto valley and the swampy delta of the Río Cauto. This river, the longest in Cuba, empties into the Golfo de Guacanayabo, a large reentrant in southwest Oriente.

The topographic region of southern and eastern Oriente presents the most striking and varied landscape of Cuba. Most prominent of the several mountain ranges is the Sierra Maestra, extending along the south coast and bordering the Oriente Deep of the Caymán Trough. The use of the name "Sierra Maestra" by various writers has not been consistent. Hayes, Vaughan, and Spencer (1901, p. 11) apply the name to the range of mountains stretching from Cabo Cruz to Guantanamo Bay; this usage has been widely accepted. Taber (1931, p. 533) originally used "Sierra Maestra" for the entire system of south coast ranges, and also for the single range between Cabo Cruz and Santiago de Cuba. In addition, he mentions the local use of "Sierra de Cobre" for that portion of the Sierra Maestra south of El Cobre. In a later paper (1934, p. 569–570) he proposes the name "Turquino Range" for the section of the Sierra Maestra between Cabo Cruz and Bahía de Santiago, and "Gran Piedra Range" for the Sierra Maestra between Bahía de Santiago and Guantanamo Bay; these names in their Spanish form have been accepted in the latest authoritative work on the geography of Cuba (Marrero, 1951) and are adopted in this report.

The Cordillera del Turquino ("Turquino Range") and Cordillera de Gran Piedra ("Gran Piedra Range") are structurally similar and appear to be structurally continuous; they may be considered, therefore, logically as components of a single mountain unit. However, the mountains east of Guantanamo Bay are topographically and geologically quite distinct from the western mountains, and their inclusion as parts of the Sierra Maestra seems questionable. In this report we follow the usage of Hayes, Vaughan, and Spencer (p. 11), Taber's later report (1934, p. 569–570), and Marrero and restrict the use of the name "Sierra Maestra" to the south coast mountain chain between Cabo Cruz and Guantanamo Bay.

East of Guantanamo Bay are two low, parallel, northward-trending irregular ranges of hills, the Sierra de Maguey (or Maquey) and the Sierra La Vela, separated by the southward-flowing Río Yateras. Farther east, beyond the Río Sabanalamar, the highlands of the south coast merge with the north coast mountains in the Sierra de Purial.

The mountain chain of northern Oriente begins south of Bahía de Nipe and extends east-southeastward to Punta Maisí. The westernmost mountains are the Sierra de Nipe, bounded on the west by the lowlands of the Cauto valley and on the east by the valley of the Río Mayarí. The Sierra del Cristal, east of the Mayarí valley, is separated from the Cuchillas de Toa ("Toar" on some maps) by the broad topographic basin of Sagua de Tánamo. The deep and sinuous valley of the Río Toa separates the Cuchillas de Toa from the Sierra de Purial at the east end of the island. The highest peak, in the Sierra de Purial, is somewhat more than 1,200 meters high.

Between the north and south highland areas is the drainage basin of the Cauto, Guaninicún, and Guantánamo rivers, a lowland area that extends from the Guantánamo basin north and west to the broad Cauto valley of western Oriente.

## CLIMATE

Cuba lies just south of the Tropic of Cancer in the trade wind belt between the equatorial rain belt (the doldrums) and the subtropical high pressure belt (the horse latitudes). The island has a marine climate much like that of southern Florida and temperatures vary only slightly from month to month. Seasonal variations in rainfall are very pronounced because of the northward migration of the pressure belts in the summer and as a result summers are rainy and winters are dry.

The mean annual temperature ranges from 73° in parts of Camagüey to 79° in parts of Oriente and averages 77° for the entire island. The coldest months are January and February, which average 67° to 75°; during the hottest months, July and August, temperatures average 78° to 83°. Freezing temperatures occur only rarely. The highest recorded temperature is 107.6° at Sagua de Tánamo in Oriente. Mean, highest, and lowest temperatures for seven stations are given in the following table.

*Temperatures (° F) for 7 stations in Cuba*

[Data from Bennett and Allison, 1928, p. 312]

| | Pinar del Río | La Habana | Isla de Pinos | Camajuaní, Las Villas | Camagüey | Preston, Oriente | Santiago de Cuba |
|---|---|---|---|---|---|---|---|
| Number of years | 20 | 21 | 9 | 16 | 13 | 10 | 16 |
| January: | | | | | | | |
| Mean | 71.4 | 69.8 | 73.4 | 67.6 | 71.6 | 73.6 | 75.4 |
| High | 89 | 89 | 90 | 89 | 91 | 90 | 90 |
| Low | 46 | 50 | 52 | 44 | 46 | 50 | 57 |
| February: | | | | | | | |
| Mean | 72.2 | 69.9 | 71.8 | 68.2 | 73.3 | 73.8 | 75.1 |
| High | 92 | 88 | 93 | 88 | 94 | 98 | 90 |
| Low | 48 | 51 | 50 | 41 | 49 | 53 | 59 |
| March: | | | | | | | |
| Mean | 74.6 | 72.0 | 75.4 | 70.6 | 75.8 | 74.8 | 76.6 |
| High | 94 | 90 | 93 | 90 | 98 | 98 | 92 |
| Low | 49 | 55 | 52 | 46 | 52 | 58 | 58 |
| April: | | | | | | | |
| Mean | 77.3 | 74.3 | 78.0 | 72.5 | 78.0 | 76.1 | 78.2 |
| High | 99 | 92 | 97 | 95 | 97 | 93 | 93 |
| Low | 51 | 57 | 57 | 49 | 51 | 62 | 57 |
| May: | | | | | | | |
| Mean | 80.6 | 77.2 | 80.2 | 75.8 | 79.0 | 78.4 | 79.7 |
| High | 104 | 93 | 102 | 98 | 102 | 98 | 94 |
| Low | 57 | 59 | 63 | 53 | 56 | 62 | 65 |
| June: | | | | | | | |
| Mean | 81.6 | 78.6 | 81.0 | 77.2 | 80.3 | 80.0 | 80.7 |
| High | 101 | 94 | 99 | 98 | 101 | 98 | 95 |
| Low | 66 | 65 | 68 | 59 | 62 | 64 | 62 |
| July: | | | | | | | |
| Mean | 82.8 | 79.2 | 81.9 | 78.0 | 81.6 | 80.8 | 81.9 |
| High | 104 | 93 | 99 | 97 | 100 | 98 | 97 |
| Low | 66 | 65 | 66 | 61 | 67 | 62 | 67 |
| August: | | | | | | | |
| Mean | 82.6 | 79.5 | 81.7 | 78.4 | 81.6 | 81.2 | 82.2 |
| High | 100 | 93 | 97 | 99 | 100 | 98 | 96 |
| Low | 69 | 67 | 68 | 62 | 66 | 68 | 68 |
| September: | | | | | | | |
| Mean | 81.5 | 79.0 | 80.7 | 77.2 | 80.4 | 81.0 | 81.0 |
| High | 98 | 95 | 95 | 95 | 98 | 102 | 97 |
| Low | 64 | 68 | 68 | 61 | 64 | 66 | 67 |
| October: | | | | | | | |
| Mean | 79.4 | 77.2 | 79.2 | 75.6 | 78.6 | 80.2 | 80.0 |
| High | 96 | 93 | 97 | 91 | 97 | 98 | 95 |
| Low | 62 | 61 | 63 | 57 | 62 | 66 | 67 |
| November: | | | | | | | |
| Mean | 75.0 | 73.2 | 76.2 | 71.5 | 75.6 | 77.4 | 77.7 |
| High | 91 | 91 | 91 | 90 | 93 | 96 | 93 |
| Low | 52 | 56 | 53 | 50 | 52 | 62 | 61 |
| December: | | | | | | | |
| Mean | 72.5 | 70.4 | 74.0 | 69.2 | 73.1 | 75.0 | 76.2 |
| High | 89 | 91 | 91 | 88 | 93 | 95 | 93 |
| Low | 47 | 56 | 52 | 40 | 45 | 56 | 55 |

Variations in rainfall result in a "wet season," from May to November, and a "dry season", from December to April. During the wet season rainfall is commonly in the form of late afternoon thundershowers. Data on monthly and annual rainfall at 27 stations are given in the following table.

In eastern Cuba the rainiest months are June and September, and there is a relatively dry period during July and August. In the southern part of Oriente, the rainiest months are May and October; along the north coast the rainy season reaches its peak in November. The extremes of rainfall are worth noting because many dirt roads in the country are usually impassable during the wet season. Rainfall data for the entire island, for the western provinces, and for the Isla de

*Monthly and annual rainfall (inches) at 27 selected stations*

[Data from National Observatory of Cuba, summarized in Rept. No. 2 of Agricultural Attaché, U. S. Embassy, Habana, Jan. 2, 1947. Data for Isla de Pinos only from Bennett and Allison (1928, p. 310)]

| Province and station | Years covered | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinar del Río: | | | | | | | | | | | | | | |
| Guane | 1929–46 | 1. 74 | 1. 58 | 2. 25 | 2. 25 | 5. 16 | 7. 61 | 4. 57 | 6. 42 | 7. 17 | 5. 83 | 1. 14 | 1. 22 | 46. 94 |
| San Cristóbal | 1931–46 | 1. 34 | 1. 58 | 2. 17 | 3. 24 | 5. 47 | 10. 0 | 5. 83 | 6. 22 | 5. 55 | 5. 39 | 1. 30 | 1. 34 | 49. 63 |
| La Habana: | | | | | | | | | | | | | | |
| National Observatory | 1909–46 | 2. 25 | 1. 62 | 1. 89 | 2. 01 | 3. 78 | 6. 06 | 4. 14 | 4. 02 | 5. 47 | 7. 21 | 3. 70 | 1. 89 | 44. 04 |
| Experiment Station | 1922–46 | 2. 44 | 2. 09 | 2. 48 | 4. 18 | 8. 32 | 9. 69 | 8. 07 | 9. 41 | 7. 80 | 8. 51 | 2. 64 | 1. 54 | 67. 17 |
| Hershey | 1923–46 | 3. 74 | 2. 21 | 1. 74 | 2. 64 | 5. 31 | 5. 39 | 4. 84 | 4. 53 | 6. 79 | 8. 15 | 3. 78 | 1. 77 | 49. 89 |
| San Antonio | 1927–46 | 1. 46 | 1. 38 | 2. 44 | 3. 54 | 7. 49 | 9. 81 | 7. 80 | 6. 77 | 6. 42 | 6. 38 | 2. 05 | 1. 58 | 57. 12 |
| Isla de Pinos | 13 | 1. 47 | 2. 16 | 2. 40 | 3. 93 | 8. 63 | 11. 96 | 7. 58 | 7. 67 | 11. 06 | 9. 93 | 2. 30 | 1. 59 | 70. 68 |
| Matanzas: | | | | | | | | | | | | | | |
| Conchita | 1925–46 | 1. 22 | 1. 46 | 2. 17 | 3. 78 | 8. 51 | 9. 10 | 7. 91 | 9. 14 | 7. 88 | 5. 47 | 1. 62 | 1. 50 | 59. 76 |
| Guipúzcoa | 1928–46 | 2. 13 | 1. 38 | 2. 68 | 4. 06 | 7. 36 | 10. 90 | 6. 54 | 7. 01 | 10. 02 | 6. 89 | 2. 28 | 1. 58 | 62. 83 |
| Las Villas: | | | | | | | | | | | | | | |
| Perseverancia | 1929–46 | . 83 | . 83 | 2. 40 | 3. 82 | 7. 91 | 7. 69 | 7. 36 | 8. 58 | 9. 81 | 7. 52 | 9. 06 | 1. 07 | 58. 73 |
| Santa Lutgarda | 1930–46 | 1. 73 | 1. 07 | 2. 24 | 3. 94 | 7. 45 | 8. 91 | 7. 73 | 6. 74 | 7. 84 | 7. 56 | 4. 29 | 1. 62 | 58. 12 |
| Adela | 1933–46 | 1. 81 | . 98 | 2. 68 | 3. 58 | 7. 80 | 9. 30 | 6. 30 | 7. 64 | 9. 22 | 10. 02 | 3. 70 | 1. 97 | 65. 00 |
| Camagüey: | | | | | | | | | | | | | | |
| Jatibonico | 1926–46 | 1. 18 | . 67 | 2. 17 | 2. 96 | 7. 29 | 9. 06 | 6. 50 | 7. 29 | 6. 96 | 7. 13 | 1. 81 | . 91 | 53. 93 |
| Vertientes | 1924–46 | 1. 38 | . 83 | 1. 77 | 4. 06 | 9. 46 | 8. 66 | 7. 76 | 8. 35 | 8. 47 | 7. 53 | 2. 36 | 1. 34 | 61. 97 |
| Jaronú | 1922–46 | 2. 13 | 1. 22 | 1. 85 | 3. 27 | 8. 15 | 7. 21 | 4. 72 | 5. 44 | 8. 08 | 9. 61 | 5. 12 | 2. 17 | 58. 97 |
| Najasa | 1930–46 | . 99 | . 75 | 2. 13 | 4. 09 | 8. 24 | 6. 54 | 5. 20 | 6. 11 | 6. 18 | 5. 36 | 3. 04 | 1. 10 | 49. 73 |
| Lugareño | 1925–46 | 2. 56 | 1. 03 | 2. 44 | 3. 78 | 7. 29 | 7. 05 | 4. 06 | 3. 70 | 4. 88 | 6. 94 | 5. 12 | 2. 05 | 50. 90 |
| Oriente: | | | | | | | | | | | | | | |
| Manatí | 1924–46 | 1. 26 | . 79 | 1. 30 | 3. 19 | 6. 62 | 6. 50 | 3. 74 | 4. 33 | 4. 88 | 5. 95 | 4. 14 | 1. 50 | 44. 20 |
| Gibara | 1922–46 | 2. 60 | 1. 30 | 1. 54 | 2. 36 | 5. 56 | 3. 31 | 1. 54 | 2. 56 | 3. 39 | 6. 62 | 7. 60 | 3. 27 | 41. 65 |
| Boston | 1905–46 | 2. 76 | 1. 85 | 1. 77 | 3. 04 | 5. 71 | 3. 27 | 1. 81 | 3. 00 | 4. 26 | 6. 86 | 6. 97 | 3. 47 | 44. 77 |
| Tánamo | 1914–43 | 4. 49 | 3. 66 | 3. 35 | 4. 33 | 6. 11 | 3. 47 | 2. 72 | 2. 36 | 3. 19 | 7. 33 | 10. 00 | 5. 44 | 56. 45 |
| Río Cauto | 1922–46 | . 83 | . 75 | 1. 18 | 3. 08 | 8. 95 | 7. 56 | 5. 48 | 6. 81 | 6. 70 | 5. 24 | 2. 17 | . 75 | 49. 50 |
| Borjita | 1934–46 | 1. 30 | 1. 85 | 1. 50 | 3. 43 | 7. 16 | 5. 91 | 5. 55 | 5. 95 | 7. 33 | 8. 28 | 2. 80 | 1. 42 | 52. 48 |
| Almeida | 1933–46 | 1. 10 | 2. 32 | 2. 44 | 5. 04 | 7. 88 | 7. 36 | 4. 06 | 6. 74 | 5. 04 | 11. 40 | 3. 98 | 1. 30 | 58. 66 |
| Santiago de Cuba | 21 | 1. 47 | . 87 | 1. 72 | 3. 32 | 6. 45 | 5. 39 | 2. 26 | 3. 58 | 6. 66 | 7. 40 | 3. 61 | 1. 06 | 43. 79 |
| Isabel | 1922–46 | . 91 | . 98 | 1. 62 | 2. 80 | 6. 18 | 6. 38 | 5. 14 | 6. 81 | 6. 38 | 7. 60 | 3. 82 | . 87 | 49. 47 |
| Los Caños | 1922–46 | . 39 | 1. 81 | 1. 26 | 2. 13 | 3. 86 | 2. 92 | 2. 09 | 3. 90 | 4. 45 | 8. 00 | 2. 44 | 1. 18 | 34. 43 |

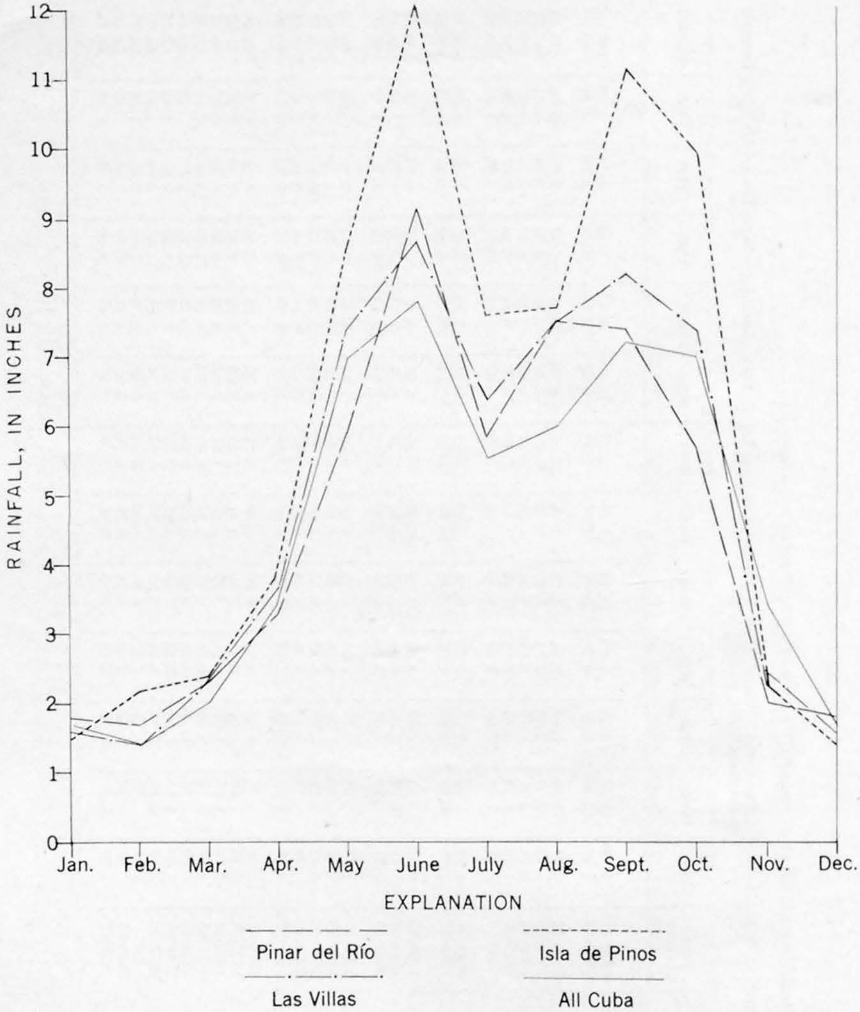



FIGURE 1.—Graph showing seasonal variation in rainfall for Cuba.

Pinos are shown in the graph of figure 1. In figure 2 two areas of Oriente are compared with all of Cuba.

The island lies in the path of the northeast trade winds. From May to October the trades are northeasterly; during the rest of the year the winds are southeasterly. The western provinces lie on the eastern margin of the Caribbean hurricane belt, and occasionally are subjected to severe hurricanes, most of which come during the last half of the wet season, from August to October. Eastern Cuba is rarely in the path of hurricanes.

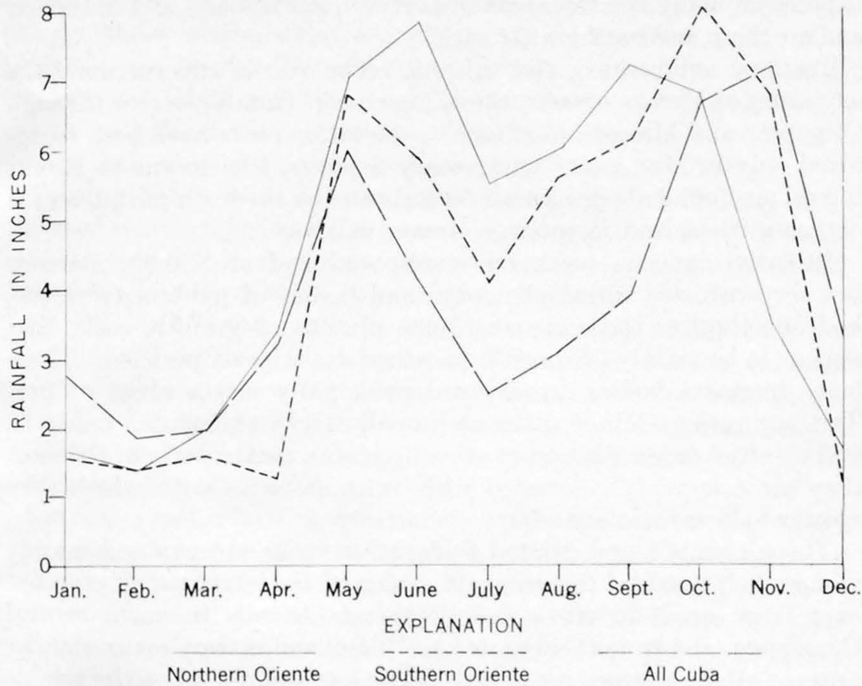



FIGURE 2.—Graph showing seasonal variation in rainfall in Oriente, Cuba.

# REGIONAL GEOLOGY

## GENERAL FEATURES OF THE GEOLOGY OF CUBA

Cuba is underlain by rocks ranging in age from Paleozoic(?) to Quaternary. Pre-Tertiary rocks are exposed over about one-third of the island. The oldest rocks, regarded by some geologists to be Paleozoic(?) in age and by others to be Jurassic(?), are metamorphosed sedimentary, volcanic, and intrusive rocks, principally mica and chlorite schists and crystalline limestones, that crop out in four rather widely separated areas: on the Isla de Pinos (Hayes, Vaughan, and Spencer, 1901, p. 113–116; Page and McAllister, 1944, p. 181–187) where they are the dominant rock; in the Sierra de Trinidad in southern Las Villas (Thiadens, 1937, p. 7–11); in extreme northeastern Camagüey (Thayer, 1942, p. 9–11); and in the Sierra de Purial in eastern Oriente (Meinzer, 1933, p. 252–253). No fossils have been found in these highly metamorphosed rocks, and they can be dated no more closely than probably pre-Upper Jurassic.

The next oldest stratified rocks appear to be sedimentary and volcanic rocks known from fossil evidence to range in age from Late Jurassic to late Cretaceous. These rocks crop out over most of the area of Pinar del Río, Las Villas, and Camagüey provinces and are exposed in many smaller areas in northern La Habana and Matanzas and northern and southern Oriente.

Tertiary sedimentary and volcanic rocks overlie and surround the exposures of Mesozoic rocks; they range in age from Paleocene through Oligocene and Miocene to Pliocene; the latter rocks have been recognized only in Matanzas. Quaternary deposits, Pleistocene to Recent in age, are found along narrow coastal belts on the main island, on the outlying islets, and in interior stream valleys.

Intrusive igneous rocks are widespread and are chiefly more or less serpentinized ultramafic rocks and bodies of gabbro, troctolite, and anorthosite; there are also some plutons of granitic rocks that appear to be mainly of dioritic to quartz dioritic composition. These large intrusive bodies are exposed principally in the areas of pre-Tertiary rocks. Minor dikes and small stocks of dacitic, andesitic, and basaltic composition occur at many places, particularly in Oriente; they are commonly associated with volcanic rocks with which they appear to be genetically related.

The ultramafic and related feldspathic rocks are exposed mainly along a belt north of the geographic axis of the island; they crop out over large areas in north and northeast Oriente, in north central Camagüey, and in northeastern Las Villas, and occupy many smaller areas in all the western provinces. None has been found on the Isla de Pinos. The largest single area of ultramafic rocks is in northern Oriente where about 2,000 square kilometers of these rocks are exposed.

The granitic intrusive rocks for the most part lie south of the belt of ultramafic rocks. Batholiths of granitic rocks are found in south-central Las Villas, in southwest Camagüey, in western Oriente, and along the southern flank of the Sierra Maestra in southern Oriente.

Opinions on the age of the ultramafic group of rocks range from pre-Early Cretaceous to post-Late Oligocene. The Dutch geologists believe that the ultramafic rocks were emplaced in early Late Cretaceous time (Rutten, 1936, p. 17; Vermunt, 1937, p. 6, 18; Mac Gillavry, 1937, p. 17; Keijzer, 1945, p. 13, 65); all of these workers agree on one period of intrusion over the whole island. Flint, Albear, and Guild (1948, p. 42–44) believe that the Lower(?) to Upper Cretaceous volcanic and sedimentary rocks of the Camagüey and Holguín districts are younger than the ultramafic rocks, contrary to the conclusions of the Dutch. All agree that uppermost Cretaceous (Maestrichtian) sedimentary and volcanic rocks are younger than the ultramafic rocks.

Opinions on the age of the quartz dioritic group of intrusive rocks range from Late Cretaceous to Eocene. All workers agree that these intrusive rocks are younger than the ultramafic rocks and the volcanic and sedimentary rocks of Early(?) to Middle Cretaceous age but there is less agreement as to the upper limit of age and to the number of cycles of intrusion. Most of the Dutch workers believe that all the quartz dioritic rocks are approximately the same age, Late Cretaceous but pre-Maestrichtian (Rutten, 1936, p. 18–19; Vermunt, p. 22; MacGillavry, p. 18–20; Wessem, 1943, p. 13; Keijzer, p. 106, 113). Thayer and Guild (p. 920) and Flint, Albear, and Guild (p. 52) concur with MacGillavry and Van Wessem on the age of the quartz diorite batholiths of central Camagüey.

Taber (1934, p. 583–584) concluded that the Sierra Maestra batholiths of southern Oriente are Eocene in age and Lewis and Straczek (1955) support this conclusion. Keijzer (p. 106–107) concluded that these same intrusives were Late Cretaceous in age.

De Vletter (Vletter, 1946, p. 34–39), apparently recognizing that other intrusives than the uppermost Cretaceous dioritic intrusive rocks may have been the source of the dioritic pebbles in the Maestrichtian beds, and citing evidence of contact metamorphism of "Old Eocene" beds near a batholith in western Oriente, believes the intrusive to be post-Cretaceous in age.

Extrusive and related intrusive rocks include extensive formations that range in age from Paleozoic(?) to Eocene, and some extrusive rocks of Pleistocene to Recent age are reported. The Paleozoic(?) chlorite schists of the Sierra de Purial in Oriente may be metamorphosed volcanic rocks according to Guild (oral communication), and metavolcanic rocks older than the serpentine were noted by Thayer (1942, p. 9) in the area south of Bahía Navas in northeast Oriente; similar rocks of the Sierra de Trinidad in Las Villas may also be of volcanic origin (Thiadens, p. 7–11). The most widespread volcanic and associated intrusive rocks are of Early(?) to Late Cretaceous age and have been found in every province. Cretaceous to middle Eocene extrusive rocks, with which the principal manganese deposits of Cuba are associated, appear only in southern, central, and western Oriente; the Eocene rocks in other provinces are sedimentary rocks. Late Pleistocene or Recent extrusive rocks are reported to cover areas of as much as 200 square kilometers in central Las Villas, western Camagüey, and on the border of Oriente and Camagüey (Palmer, 1945, p. 20).

The major structures trend approximately parallel to the arcuate axis of the island except in Oriente where the principal structural trend is east-northeastward in the northern part of the province and eastward in the southern part. The Paleozoic(?) or Jurassic(?) basement rocks in the Sierra de Purial, Oriente, trend eastward according to Meinzer (p. 252) and Guild (oral communication); in the Sierra de Trinidad, Las Villas, they trend northeastward to eastward (Thiadens, p. 58–60); and on the Isla de Pinos the metamorphic basement rocks trend northward across the structural trend of the main island (Hayes, Vaughan, and Spencer, p. 115). Upper Jurassic to lower Tertiary rocks are generally strongly folded and faulted but the later Tertiary (Oligocene and Miocene) rocks are only mildly disturbed.

Major thrust faults and overturned folds involving beds as young as middle and late Eocene have been observed in many places. Thrust faults in Camagüey strike west-northwestward and dip north; in northwestern Oriente there are similar thrusts (Thayer and Guild, p. 920–927; Keijzer, p. 28; Vletter, p. 44–45). Middle Eocene orogenic movements appear to have resulted in the folding and thrust faulting of rocks in central Camagüey and western Oriente (Thayer and Guild, p. 926). In the Bahía de Santiago area of southern Oriente overturned beds and steep reverse and tear faults involve beds as young as late Eocene.

The Sierra de Trinidad in southern Las Villas is thought by Palmer (1945, p. 23) to be an overthrust block riding on younger rocks, but Thiadens (1937, p. 48–49) could find no convincing evidence of such a thrust. Palmer (1945, p. 23) also describes great thrust zones in northern Las Villas, which he believes to be middle or early late Eocene in age. Thrust faults in Pinar del Río have been described by Palmer (1945, p. 21) and Vermunt (1937, p. 32–34).

## PINAR DEL RIO

### STRATIFIED ROCKS

The accurately dated rocks of Pinar del Río range in age from Late Jurassic to Recent. Pre-Jurassic rocks may be present but conclusive evidence for them is lacking thus far.

The oldest rocks, with which most of the bedrock deposits of manganese are associated, are exposed in the Sierra de los Órganos and Sierra del Rosario and consist of shale and limestone with subordinate amounts of sandstone. These rocks were first divided into two principal units, the Viñales and Cayetano (or San Cayetano) formations, by De Golyer (1918, p. 139), but the age of these formations, their relative stratigraphic position, and their structural relationships are still matters of considerable contention among various workers (de la Torre, 1910; Brown and O'Connell, 1922; Lewis, 1932; Metcalf, 1932; Dickerson and Butt, 1935; Vermunt, 1937; Palmer 1945). Imlay (1942) has summarized the various viewpoints and believes that the fossils of the San Cayetano formation (p. 1439) are of late Oxfordian and perhaps early Kimmeridgian age (early Late Jurassic); that the fauna of the Viñales limestone (p. 1433) is to be correlated with the upper part of the Portlandian stage (very Late Jurassic); and that the two formations are separated by an important unconformity involving part of the Kimmeridgian and Portlandian stages (p. 1422–23, 1440).

The massive Viñales limestone, presumably named after the town of Viñales, forms the main mass of the Sierra de los Órganos, where it weathers to the steep-sided mogotes. According to Lewis (1932, p 536), the limestone is about 2,000 feet thick and in places is interbedded with shale.

The Cayetano formation is widespread in both the Sierra de los Órganos and the Sierra del Rosario but has not been recognized outside of Pinar del Río. It consists predominantly of indurated dark-colored shale with subordinate interbedded sandstone and limestone.

The Cayetano shale is interbedded with red or reddish-brown impure foraminiferal limestone beds with which many of the manganese deposits are associated. In hand specimen these rocks are dense and fine grained, in places somewhat recrystallized and foliated. All contain numerous Foraminifera, averaging perhaps 0.2 millimeters in diameter, set in a very fine grained carbonate matrix containing much finely disseminated cryptocrystalline red iron oxide, probably hematite. The only other recognizable constituents of the rocks are sparse irregular grains of quartz or feldspar, too small to be identified with certainty, and cryptocrystalline chert.

Origin of the "red rocks" is uncertain, but they may be related to the origin of the associated manganese deposits. Similar rocks are associated with volcanic rocks in southwestern Oriente and manganese deposits are found with these beds also. Park (1946) describes similar beds associated with manganese deposits intercalated in volcanic rocks on the Olympic Peninsula in Washington. Rocks of volcanic origin are apparently not present in the Cayetano although according to Palmer (1945, p. 5), this formation may be equivalent to and grade into volcanic rocks of the Cretaceous "Tuff Series" (see p. 24).

The age of the Viñales and Cayetano sequence is uncertain, but it seems likely that rocks of both Jurassic and Cretaceous age are present.

The Sierra del Rosario is flanked on the north by a series of volcanic and sedimentary rocks correlated by Vermunt (p. 15–17) with the "Tuff Series" of Las Villas (Rutten, 1936, p. 7–10). The "Tuff Series" consists of porphyritic and diabasic volcanic rocks, breccia, and tuff with intercalated beds of limestone, chert, and shale, which conformably overlie the youngest strata of Vermunt's "San Andrés" formation (Viñales plus Cayetano). Sedimentary rocks, chiefly limestone, become more abundant toward the base of the series. Vermunt considers the "Tuff Series" to be Late Cretaceous in age; Palmer (1945, p. 5, 11) considers that it ranges in age from Early Cretaceous to latest Cretaceous, and overlaps in age the Viñales and Cayetano beds.

The youngest Mesozoic rocks in the manganese districts are those of the uppermost Cretaceous (Maestrichtian) Habana formation, first named by Palmer (1934, p. 123–145) from exposures at La Habana. Vermunt (1937, p. 22–27) found rocks of the Habana formation throughout the two mountain ranges of Pinar del Río. The formation consists of limestone, calcareous sandstone, and conglomerate.

The Sierra de los Órganos and Sierra del Rosario are flanked on the south and partly flanked on the north by Tertiary and Quaternary sedimentary rocks. These rocks are all outside the manganiferous zones, except for a reported occurrence of manganese about 10 kilometers north of the city of Pinar del Río, apparently in an area underlain by Eocene sedimentary rocks.

### INTRUSIVE ROCKS

Serpentinized ultramafic and associated gabbroid rocks were found by Vermunt (1937, p. 17–18) in many places scattered throughout the region underlain by Mesozoic rocks. He described altered dioritic intrusive rocks of doubtful late Cretaceous age from two small areas—one between Guane and La Sierra, about 40 kilometers southwest of Pinar del Río, and the other on the west side of Bahía Honda. No direct evidence concerning the age of these rocks was found.

### STRUCTURE

Although no detailed studies of the structure of the region have been attempted most workers agree that the major structure of the Pinar del Río mountains is anticlinal (Hayes, Vaughan, and Spencer, 1901, p. 25; DeGolyer, 1918, p. 145; Vermunt, 1937, p. 32–33; Palmer, 1945, p. 21–23), and most have recognized complications due to folds and faults. Palmer believes that the broadly anticlinal Sierra de los Órganos is cut by major thrust faults parallel to the range and extending along its full length; overthrusting was from the northwest. Vermunt (1937, p. 32–34) apparently thought that only relatively minor thrusts were involved and did not record their attitude or direction of displacement.

### ORE DEPOSITS

Deposits of copper, lead, chromite, iron, barite, kaolinite, and asphalt as well as manganese are known in Pinar del Río. The most important copper deposit is Matahambre, which was discovered in 1913 and is still producing copper concentrate. Descriptions of the Matahambre deposit have been given by Allende (1927, p. 40–52, 62–70; 1935, p. 429–31), and Ross (1935, p. 436–437). According to Calvache (1944, p. 92, 102) a total of approximately 1,151,000 tons of concentrate was produced at Matahambre between 1919 and 1944.

## ISLA DE PINOS, LA HABANA

The manganese districts of the Isla de Pinos are in the southern part in an area underlain by highly metamorphosed rocks including quartz-mica schist, quartzite, and marble. The rocks in general strike north to northwest and dip steeply to the northeast. Hayes, Vaughan, and Spencer (1901, p. 114–115) named the rocks the Gerona marble and Santa Fe schist and considered them to be interbedded "to some extent" and of probable Palezoic age. Rutten (1934) described those metamorphic rocks in some detail and estimated a minimum thickness of 15,000 meters for the sequence. He believes that at least the upper part of the Isla de Pinos section is Jurassic in age and suggests a correlation with the Jurassic rocks of Pinar del Río, a correlation previously proposed by Brown and O'Connell (1922, p. 642–643) and by Lewis (1932, p. 535–536), who, however, believed that the entire sequence was younger than Middle Jurassic age. The considerably greater degree of metamorphism of the Isla de Pinos rocks is thought by Palmer (1945, p. 6) to militate against such a correlation, but he recognizes a similarity between the two sections.

Igneous rocks evidently are not abundant; they include diorite schist (Hayes, Vaughan, and Spencer, p. 115) or amphibolite (Rutten, 1934, p. 403), intruded before the regional metamorphism, and younger postmetamorphic pegmatites, dikes and irregular bodies of feldspar-quartz porphyry, and rhyolite dikes (Page and McAllister, 1944, p. 184–187).

A number of thus far uneconomic mineral deposits, including manganese, have been discovered on the island. Allende (1923) mentions deposits of lead, antimony, copper, and iron, and a tungsten deposit near Ensenada de la Siguanea has been described in detail by Page and McAllister.

## NORTHWESTERN LAS VILLAS

The manganese districts of northwestern Las Villas are included in the "Alturas del Noroeste" or northwest highlands of Massip (1942, p. 97), which form part of the "cordillera" of northern Las Villas, a range of low ridges trending parallel to the north coast of the province.

The oldest rocks are cherty limestone, with locally interbedded marl, sandstone and tuff, extending along a narrow belt from Corralillo southeastward almost to Chambas in Camagüey. The limestone that contains ammonite opercula has been called the "Aptychi" formation and assigned an Early Cretaceous age by Rutten (1936, p. 10, 53) who studied the geology of the area. He (Rutten, 1936, p. 5, 11) believes that the "Aptychi" formation grades southeastward into the lower part of the Cretaceous volcanic and sedimentary rocks of the

"Tuff Series." Palmer (1945, p. 5) also regards the lower "Tuff Series" as equivalent to the "Aptychi" beds.

The association of manganese with the "Aptychi" formation is interesting inasmuch as Vermunt (1937, p. 5, 12) correlates the aptychi-bearing strata of the "San Andrés" formation of Pinar del Río with the "Aptychi" beds of Las Villas, and Palmer (1945, p. 5, 7) correlates the Viñales formation (part of the "San Andrés") with the "Aptychi" formation. As already mentioned, manganese deposits are also associated with the Viñales and Cayetano ("San Andrés") beds in Pinar del Río.

The "Aptychi" formation is overlain unconformably by dense limestone, limestone breccia, and conglomeratic limestone which Rutten (1936, p. 24, 53) has referred to the northern facies of the Upper Cretaceous (Maestrichtian) Habana formation. The next oldest rocks are marly or sandy limestone of late Eocene age that unconformably overlie the older rocks. Some of these rocks according to Rutten (1936, p. 25) are more or less tuffaceous and may well be correlative with the Eocene volcanic and sedimentary rocks of southwestern Oriente. Oligocene and Miocene limestone flank the older rocks north and south of Quemado de Güines where they conformably overlie the upper Eocene rocks (Rutten, p. 26–27). The Oligocene and Miocene rocks have been named the Güines limestone by Palmer (1934, p. 134–136).

Serpentine and related rocks and several small stocks of dioritic intrusive rocks were mapped by Rutten between the manganiferous belts of northwestern Las Villas. He concluded that the serpentine and associated gabbroic rocks intrude the "Tuff Series," citing as evidence inclusions of uralitized diabase which he believes to have come from the "Tuff Series." This evidence is not conclusive because the so-called inclusions of diabase may be dikes, as Rutten himself admits, and moreover Flint, Albear, and Guild (1948, p. 48) say that fine-grained dikes commonly are found in the serpentine of the Camagüey district as small sheared blocks resembling inclusions. The dioritic rocks intrude and metamorphose the "Tuff Series" and are believed by Rutten (1936, p. 18, 19) to be unconformably overlain by Habana formation.

The structure of northwestern Las Villas has not been studied in detail. Rutten's paper includes no cross section of the area and the many anomalies of his map decrease its usefulness. Palmer (1945, p. 15) considers the northern "cordillera" to mark a zone of overturning and overthrusting, and figures a structure section across eastern Las Villas showing Lower Cretaceous rocks of the northern "cordillera" thrust northward over Upper Cretaceous strata. This direction of thrusting is in direct opposition to that along thrust faults mapped by Flint, Albear, and Guild (p. 49–52, pl. 18), which appear along the strike projection of the Las Villas thrusts. This apparent anomaly needs explanation. In the manganese district of northwestern Las Villas, cherty limestone of the "Aptychi" formation strikes N. 50–80° W. and dips 25°–60° S.; faults may be present but were not observed in the brief time spent in the area.

Rutten (1936, p. 28) distinguishes three orogenic periods in northern Las Villas. The first, a relatively mild phase, occurred during the Late Cretaceous before deposition of the Habana formation in Maestrichtian time; the second was a stronger orogeny, possibly accompanied by overthrusting, in lower to middle Eocene time; the third and last was a strong phase that followed deposition of the Oligocene strata but preceded deposition of the Oligocene and Miocene Güines limestone.

## SOUTH-CENTRAL LAS VILLAS

The Sierra de Trinidad, in which the manganese deposits of south-central Las Villas are found, is composed of a thick sequence of metamorphic rocks. The rocks have received very little study, the most detailed general work being that of Thiadens (1937, p. 7–11) who describes the rocks as mica schist, calcareous mica schist, and marble with smaller amounts of chlorite, serpentine, and amphibole schist. This "Schist Formation" according to him ranges from 7,100 to 11,700 meters in thickness.

No fossils have been found in the Sierra de Trinidad metamorphic rocks. Thiadens (1937, p. 8) correlates the rocks with the Isla de Pinos sequence and with the lower part of the "San Andrés" formation in Pinar del Río, and assigns them a Late Jurassic age. Previous workers who have made similar correlations of these rocks have assigned the metamorphic rocks a possible Paleozoic age (Spencer, 1895, p. 71–72; Hayes, Vaughan, and Spencer, 1901, p. 20–21; Lewis, 1932, p. 534–536).

The structure of the central and western Sierra de Trinidad, and also possibly of the eastern portion of the range, is anticlinal (Thiadens, p. 23–25). Palmer (1945, p. 48–49) considers the Sierra de Trinidad to be a block overthrust from the south, but Thiadens (p. 48–49) failed to find decisive evidence for thrust faulting.

No mineral deposits of economic importance have been discovered in the Sierra de Trinidad. Fernández de Castro (1865, p. 7–8) mentions the finding of gold near Trinidad, and Allende (1928) has described a pyrite deposit on the north flank of the range near Cumanagua. Several copper deposits have been reported north and east of the Sierra de Trinidad (Hayes, Vaughan, and Spencer, p. 55–61).

## CENTRAL CAMAGÜEY

Manganese deposits occur on the north slope of the Sierra de las Cubitas and on the Finca Santa Clara about 25 kilometers southeast of the city of Camagüey. The geology of the area has been described by MacGillavry (1937), and a small part was investigated in greater detail by Thayer and Guild (1947) and Flint, Albear, and Guild (1948).

The oldest rocks are metamorphic, including phyllite, schist, hornfels, tactite, and gneiss that underlie a small area about 6 kilometers southeast of the city of Camagüey and occur as inclusions in the serpentinized ultramafic rocks of the region. Upper Jurassic (Portlandian) and Cretaceous(?) limestones and subordinate interbedded chert, tuff, and shale are the oldest fossiliferous rocks; they are known to be exposed only in the Sierra de Camaján near the southeast end of the Sierra de las Cubitas. Volcanic rocks, mainly water-laid andesitic tuff and subordinate flow and dike rocks, and interbedded limestone and radiolarian chert of the Cretaceous "Tuff Series" unconformably overlie the ultramafic and associated igneous rocks (Flint, Albear, and Guild, p. 44). The manganese deposits southeast of the city of Camagüey appear to be localized in volcanic rocks of the "Tuff Series."

The greater part of the Sierra de las Cubitas is formed of Upper Cretaceous limestone, which Palmer (1945, p. 13) calls the Jaronú limestone and which Flint, Albear, and Guild (p. 44) believe to be equivalent to the "Tuff Series." Narrow belts of Eocene limestone are found on the south flank and the far north slope. The Eocene rocks consist of limestone, marl, and chalk; they unconformably overlie the older rocks. Manganese deposits apparently occur in the Eocene rocks.

## NORTH-CENTRAL ORIENTE

The principal manganese districts of Oriente are in the Sierra Maestra and its foothills, the upper Guaninicún and Guantánamo valleys, and the southern foothills of the Sierra de Nipe and Sierra del Cristal. The only other manganese district studied lies east of Holguín in north-central Oriente and was visited by Thayer and Guild. Known occurrences of manganese near Guantánamo and near Baracoa were not seen by the authors.

The oldest rocks of the Holguín district are a complex of serpentinized ultramafic rocks that contain inclusions of altered diorite and tactite apparently derived from unexposed basement rocks. These rocks are unconformably overlain (Thayer and Guild, 1947, p. 926) by tuff and intercalated lenticular limestone of the "Tuff Series" (Vletter, 1946, p. 11–15), and by limestone, limestone conglomerate, conglomerate, marl, tuff and lava of the Habana formation.

Limestone and interbedded fine-grained, reddish-brown, noncalcareous tuff and shale unconformably overlie the serpentine complex

30 kilometers east of Holguín; the manganese deposits are associated with these rocks (Guild, written communication). In or near this same area Keijzer (1945, p. 26–27) has found conglomerate, sandstone, marl, and limestone containing middle or late Eocene fossils, but the age of the manganese-bearing rocks is not known.

In the manganese district 10 to 15 kilometers east-northeast of Holguín the associated rocks include limestone that overlies volcanic rocks which in turn rest unconformably on serpentine or are faulted against it (Thayer, unpublished report). The age of the limestone and volcanic rocks has not been established but possibly they are Eocene and may be correlated with the volcanic and sedimentary rocks of the Cobre formation in the southwestern Oriente manganese field.

Major structures of the Holguín manganese districts trend easterly. Eocene and older rocks are strongly folded into narrow synclines and anticlines and are cut by many faults, most of which appear to be thrust faults of small displacement (Keijzer, p. 24).

## GEOLOGY OF SOUTHWESTERN ORIENTE

Southwestern Oriente has been only partly mapped geologically. Mapping by Woodring and Daviess (1944) and by Lewis and Straczek (1955) has covered the chief productive zone of the manganese belt and the stratigraphy, structure, and lithology of the rocks have been studied. Woodring and Daviess mapped some 1,000 square kilometers. About 3,900 square kilometers were mapped by Lewis, Straczek, and Simons; the three workers together mapped the geology of the Santiago basin northward to and including El Cristo and Ponupo districts; Straczek and Lewis continued regional mapping to cover the area from the Sierra Maestra to the south end of the Sierra de Nipe, between Ramón de las Yaguas and Palma Soriano; and Straczek mapped the remaining gap between Palma Soriano and the east edge of the Güisa-Los Negros area of Woodring and Daviess.

Geological work elsewhere has been confined to the areas in the immediate vicinity of mines and indicates that in general the same rock units extend throughout the manganese-bearing belt. The geology of the mines and mining districts of southwestern Oriente was mapped by Park, Cox, Straczek, and Simons; many small mines and prospects were mapped by us in conjunction with the areal mapping of the south-central Oriente manganese field.

### ACCESSIBILITY AND CULTURE

The network of railroads and highways in southwestern Oriente is supplemented by many unimproved roads and trails leading into manganese districts, small towns, settlements, and farms not directly accessible by railroad or highway. The various access roads and most of the principal trails are shown on the maps (fig. 3, pl. 2).

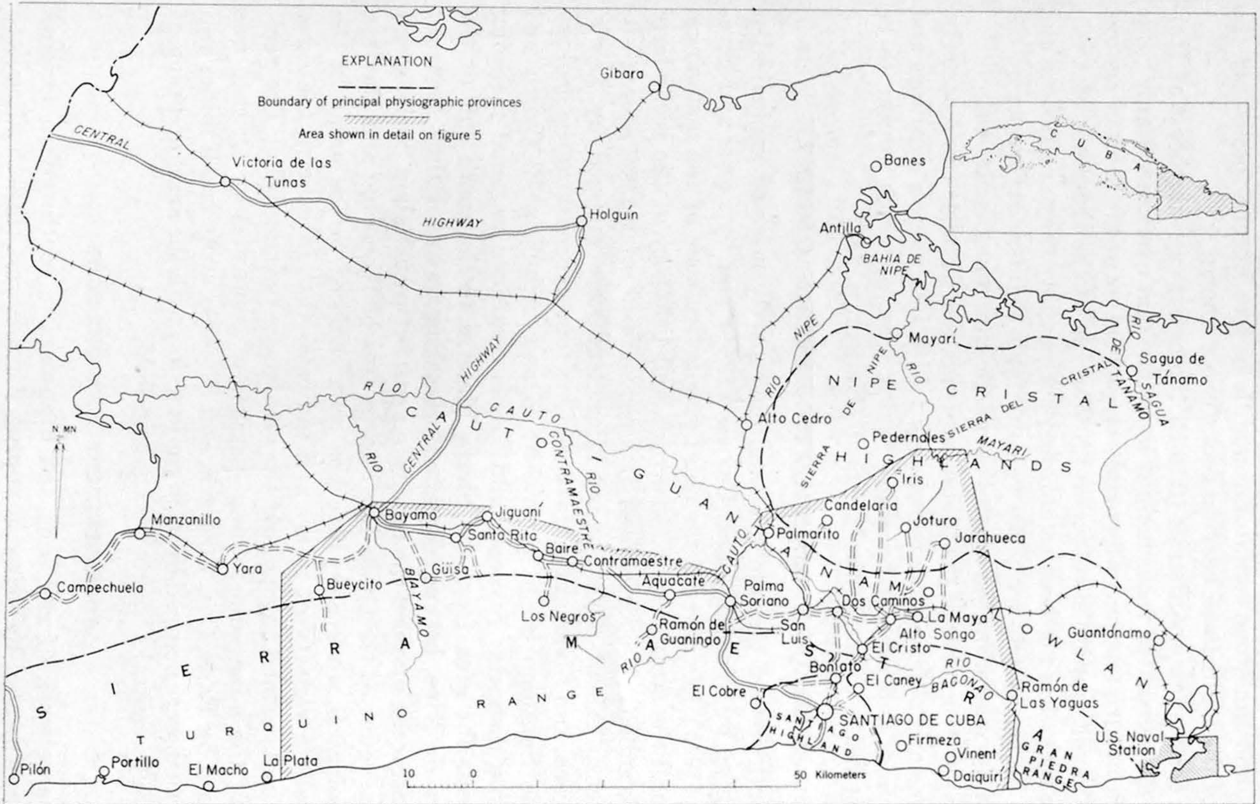



FIGURE 3.—Index map of Oriente, Cuba.

The thickly populated lowland areas of the region are largely under cultivation or in pasture; they are the sites of immense sugar plantations and dairy and cattle farms. Valleys and lowland areas within the foothills of the mountain tracts contain many small farms on which the occupants eke out a living raising corn, tobacco, plantains, and root crops, such as the sweet potato, malanga, and yuca. More prosperous farms are located near the principal transportation routes, especially near the cities and towns. Coffee is grown throughout the foothills and hilly parts of the lowland areas, but most of the coffee groves (cafetales) are in the thinly populated higher foothills and mountains, generally above 300 meters in altitude.

Streams are numerous. The larger ones and some of the smaller ones are perennial but many small streams are ephemeral and disappear during the dry season from November to April. The occasional failure of a rainy season causes severe damage to crops and livestock, especially in areas such as that between Bayamo and Manzanillo, and milling operations at some mines must be curtailed or shutdown for lack of water during some dry seasons.

Hardwood and pine forests are limited to foothills and mountainous areas, the largest tracts now being in the higher and most inaccessible regions. The forests support a small lumber industry and supply timber for mining and charcoal for domestic use. Much charcoal comes from brushlands that have been cut over several times.

## PHYSICAL FEATURES

The physical features of southwestern Oriente are dominated by the Sierra Maestra, a mountain system about 250 kilometers long that forms an imposing topographic barrier along the south coast from Cabo Cruz to Guantanamo Bay. North of the Sierra Maestra is a broad lowland area, herein referred to as the Cauto and Guantánamo lowlands, that extends from the Golfo de Guacanayabo to Guantanamo Bay. Flanking the eastern part of this lowland are the broad Sierra de Nipe and Sierra del Cristal.

These principal physical features have been mentioned and briefly described by Hayes, Vaughan, and Spencer (1901, p. 10–12, 14). Later Taber (1931, 1934) gave a more detailed description of the physiography and physiographic history of the Sierra Maestra and adjacent regions. Keijzer (1945) presented a general description of the physical features of the region including part of the Sierra Maestra and Sierra de Nipe and the intervening Cauto and Guantánamo valley. Woodring and Daviess (1944, p. 360–363) briefly described the essential physical features of the Güisa-Los Negros area and subsequently Lewis and Straczek (1955) described the adjoining south-central Oriente area. Reference is made here to only a few of the broad physical features which will assist in the location and description of the geologic features of the region. The physiographic features mentioned are described in detail by Lewis and Straczek, and the most prominent features are shown on figure 3.

The rugged Sierra Maestra has a narrow uneven crest line flanked by steep-sided ridges. The Santiago basin and the narrow Dos Bocas valley that extends northeastward from Boniato, near the north edge of the basin, to El Cristo form a low gap separating the Turquino range on the west from the Gran Piedra range on the east. The south flank of the Sierra Maestra is drained by many small streams of steep gradients. Streams on the north flank have flatter gradients and most of them flow northward into the Cauto and Guantánamo lowlands; the north side of Gran Piedra range is drained by the Río Baconao which flows eastward in its upper course and then swings southeastward across the range to the south coast.

The Turquino range culminates near its middle in Pico Turquino, the highest point in Cuba. Published estimates of the altitude of Pico Turquino range from 1,950 meters (Massip, 1942, p. 129) to 2,620 meters (Bennet and Allison, 1910, p. 210), but most writers have accepted the altitude of 2,005 meters given on U. S. Navy Hydrographic Chart 2612. West of Pico Turquino the crest line of the range slopes to sea level at Cabo Cruz and to the east it slopes unevenly to a pass about 600 meters in altitude at the head of the Ríos Cauto and Contramaestre; east of this low point the crest line again rises to culminate in Loma El Gato at an altitude of about 1,100 meters. Sierra de Boniato forms the east end of the Turquino range; it is a nearly straight ridge 24 kilometers long and averaging about 300 meters in height that extends from the head of Dos Bocas valley westward to Puerto de Moya where the Carretera Central crosses the range. The shorter and lower Sierra de Puerto Pelado, 2 kilometers south of Sierra de Boniato and parallel to it, is a conspicuous hogback.

Gran Piedra range, which extends from the Santiago basin to Guantanamo Bay, culminates in Gran Piedra ("great stone") at an altitude of 1,200 meters. From this high point the crest line lowers markedly toward the basin and toward the deep valley of the Río Baconao. Beyond this valley the highest point barely exceeds 300 meters.

The Sierra Maestra rises abruptly from the coast along much of its length, especially along the Turquino range whose steep south flank is a continuation of the north side of the Oriente Deep. However, small discontinuous lowlands intervene along parts of the coast. The Santiago lowland surrounds Bahía de Santiago at the east end of the Turquino range and extends eastward to the Río Baconao as a belt in places less than one kilometer in width. Altitudes in the Santiago lowland are as much as about 150 meters above sea level. The Pilón lowland at the west end of the Turquino range extends from Pilón, where it is 6 to 7 kilometers in width, westward around the end of the Turquino range at Cabo Cruz.

The north flank of the Sierra Maestra is characterized in its upper part by steep-sided ridges and narrow valleys. At lower altitudes, the ridges become a belt of foothills marginal to the Cauto and Guantánamo lowlands. The foothill belt is only a few kilometers wide along the western Turquino range but widens to about 15 kilometers just east of the Río Bayamo valley and continues as a belt several kilometers wide to the east end of Gran Piedra range. Altitudes of the foothills rarely exceed 500 meters. Some of the higher foothill areas are the region between the Ríos Bayamo and Contramaestre, a terrain of limestone hills that includes the Pozo Prieto karstland and the narrow belt of hills and dissected tableland, the Boniato piedmont, lying north of Sierra de Boniato.

The Cauto and Guantánamo lowland is an extensive belt of broad plains and low hills that extends from the Golfo de Guacanayabo east-southeastward to Guantanamo Bay. The westward-flowing Río Cauto, which drains most of this area, is the largest river in Cuba. Most of the lowland is less than 150 meters in altitude, and the extensive Cauto plain occupying the western part of the area has an altitude of less than 60 meters. The highest area in the lowland is at Alto Songo on the divide between the headwaters of the Río Guaninicún, the principal eastern tributary of the Cauto, and the eastward-flowing Río Guantánamo.

The Sierra de Nipe and Sierra del Cristal together with flanking uplands are described by Lewis and Straczek (1955). Only the southern margins of these highlands are considered as part of the southwestern Oriente manganese field.

The westward-trending upper Mayarí valley separates the Sierra del Cristal from an extensive hilly and mountainous upland to the south. This upland includes El Infierno basin 7 kilometers northwest of Jarahueca, a broad shallow topographic depression surrounded on three sides by low hills. The valley of the Río Piloto, a tributary of the Río Mayarí, and the valley of the Río Jagua, tributary to the Río Cauto, separate the Sierra de Nipe from the extensive upland to the south. The two uplands are separated by the northward-trending valley of Río Jarahueca, the southern prolongation of the lower Mayarí valley.

The broad upland south of the Sierra de Nipe is drained by the Ríos Jagua and Guaninicún tributary to the Cauto, the Río Joturo tributary to Río Jarahueca, and the Ríos Caoba and Piloto of the Mayarí river system. The area includes nearly flat, irregularly shaped plateaus, about 550 meters in altitude, and several headwater basins, whose floors lie 180 to 250 meters below the surrounding table lands. The Pedernal plateau, northernmost of these tablelands, rises between the Río Piloto and Río Caoba valleys; the dissected Florida Blanca plateau lies to the south; and La Prueba plateau, southernmost of the tablelands, extends south and southeast of La Prueba to San Benito. Basins lie on three sides of Florida Blanca plateau. La Burra basin, named after the locality of Sabana la Burra at the headwaters of the Río Jagua, is the largest of these essentially closed depressions; its east side marks the west edge of the Florida Blanca plateau. The smaller completely closed Sumidero basin is on the east and southeast side of the Florida Blanca plateau at the head of the Río Sumidero, a tributary of the Jarahueca; it is separated from the still smaller Villafaña basin to the southwest by a steep narrow ridge.

Manganese districts are in the Sierra Maestra, the Sierra de Nipe, and Sierra del Cristal, and the Cauto and Guantánamo lowlands, at altitudes ranging from 100 to about 1,000 meters above sea level. Most of them are on the lower north flank of the Turquino range and in the southern Sierra de Nipe foothills, mainly below 500 meters in altitude. The only deposits on the south flank of the Sierra Maestra are near the west end of Turquino range, on the north side of the Santiago lowlands north of Bahía de Santiago, and in the Río Cobre and Dos Bocas valleys which drain into the Santiago lowlands.

## STRATIFIED ROCKS

Southwestern Oriente is underlain by volcanic and sedimentary rocks ranging in age from Late Cretaceous or older (?) to Quaternary. Six formations and three unnamed sequences of strata, aggregating 7,000 meters or more in thickness, are recognized. The oldest rocks are exposed in the Sierra Maestra, the Sierra de Nipe, the Sierra del Cristal, and locally in hills and lowlands bordering these mountains. The Late Cretaceous (?) (or older?) Vinent formation in the Sierra Maestra comprises principally volcanic rocks with intercalated minor marine sedimentary rocks and is at least 1,500 meters thick; the base of the Vinent formation was not found. The Habana (?) formation in the foothills of the Sierra de Nipe and Sierra del Cristal consists of sedimentary and minor volcanic rocks about 300 meters thick, which rest unconformably on ultramafic rocks.

The Cobre formation, of Late Cretaceous (?) to middle Eocene age, overlies the Vinent formation in the Sierra Maestra but the stratigraphic relations are not known. It rests unconformably on Habana (?) formation in the southern uplands of the Sierra de Nipe and Sierra del Cristal. The Cobre consists of at least 4,000 meters of volcanic rocks with smaller beds of marine limestone and clastic rocks. The next youngest unit is the San Luis formation of middle to upper Eocene age. This formation, consisting largely of calcareous shale and sandstone, underlies much of the Cauto and Guantánamo lowlands and the outer foothills of the mountain areas. The San Luis formation rests conformably on the Cobre formation but is overlain by several formations at various places. Along the edge of the Cauto plain and in one small area in the southern Sierra de Nipe foothills it is overlain conformably by unnamed sediments of Oligocene age. In the Santiago lowlands it is overlain by the La Cruz formation and at the western end of the Sierra Maestra by the Manzanillo formation, both of Miocene age. These formations also overlap the San Luis formation, and rest unconformably on rocks of the Cobre and Vinent(?) formation. Pliocene rocks are not known definitely to occur in southwestern Oriente. Quaternary strata include marine sedimentary rocks along parts of the south coast and fluviatile deposits in most of the river valleys.

The calcareous sedimentary rocks are invariably fossiliferous. The most abundant fossils are Foraminifera, but corals are common and gastropods and pelecypods are locally abundant, especially in the Late Cretaceous, Oligocene, and Miocene strata. Discussions of the paleontology may be found in Woodring and Daviess (1944), Bermúdez (1950), and Lewis and Straczek (1955). In this report, brief mention is made of only a few hitherto unpublished fossil determinations.

Correlation of the stratified rocks of southwestern Oriente with those elsewhere in Cuba is attempted in only a general way; at the present stage of geologic study in Cuba correlations such as those of Keijzer (1945, p. 12–165) can be accepted only with reservation.

The manganese deposits of southwestern Oriente are found largely in Tertiary volcanic and sedimentary rocks; a few deposits are found in sedimentary and volcanic rocks tentatively assigned a Cretaceous age.

## CRETACEOUS(?) SYSTEM

### VINENT FORMATION

The Vinent formation was named by Taber (1934, p. 575) after the town of Vinent, 30 kilometers east of Santiago de Cuba. The type area is on the southeast edge of the manganese belt of southwest Oriente; certain rocks near the west end of the belt also have been assigned tentatively to this formation. Only a few minor manganese deposits are known in the Vinent.

#### DISTRIBUTION

The Vinent formation forms a narrow discontinuous belt along the base and south flank of the Gran Piedra range, from the town of Sevilla east to the Río Baconao, and similar rocks crop out along the south flank of the Turquino range. Taber (1934, p. 575–576) briefly described an incomplete section exposed a short distance northeast of

Vinent, but the formation has never been studied in detail. Rocks which Taber considered as part of the Vinent formation have been mentioned and briefly described by Spencer (Hayes, Vaughan, and Spencer, p. 78–80), Kemp (1915, p. 11, 36), Lindgren and Ross (1916, p. 44), Singewald and Miller (1916, p. 73–74), and Roesler (1917, p. 82–84), in connection with their studies of the iron deposits of the Gran Piedra range.

Vinent formation has been reported in the Turquino range along the coast between Santiago de Cuba and Pilón, 150 kilometers west. Taber (1934, p. 576) includes certain rocks just west of Bahía de Santiago in the Vinent formation, and Burchard (1920, p. 94) noted rocks on the Río Camaroncito, 22 kilometers east of Pilón, which Taber suggests (1934, p. 576) belong to the Vinent. We have tentatively assigned to the Vinent the rocks between the Río Palma Mocha and Río El Macho west of Pico Turquino.

### THICKNESS AND STRATIGRAPHIC RELATIONS

Taber (1934, p. 576) estimated the thickness of the Vinent formation to be more than 1,500 meters, but more accurate estimates of the thickness of the formation must await detailed geologic study. Neither the top nor the bottom of the formation has been recognized, nor has its relation to the overlying Cobre formation been determined with certainty. Our study has shown that at least 1,500 meters of volcanic rocks, tentatively assigned to the Cobre formation, lie between known Vinent and unequivocal Cobre; no stratigraphic break within this sequence has been observed. These intermediate rocks are massive and apparently unfossiliferous.

### STRATIGRAPHY AND PETROGRAPHY

The Vinent formation consists largely of andesitic and basaltic lava flows, flow breccia, agglomerate, breccia and tuff, with interbedded limestone and marble, slate, argillite, quartzite, and conglomerate. Kemp (1915, p. 11–12) noted a dense blue limestone in the Daiquiri iron district northwest of Vinent, a quartzite east of Vinent, and fine-grained dark-green slate and volcanic breccia at the iron pits of Sigua, east of Vinent. Earlier, Spencer (Hayes, Vaughan, and Spencer 1901, p. 79–91) mentioned hornblende and epidote schists associated with the iron deposits at Firmeza but Kemp (p. 12) suggests that the "schists" are probably the result of local contact metamorphism. Roesler (p. 83–87) described porphyritic diabase with intercalated limestone and marble in the Firmeza district and believed that the diabase was in part extrusive. Similar rocks in the Firmeza district may have been fine-grained tuff.

Porphyritic andesite, cellular basalt, volcanic breccia, conglomerate, quartzite, and metamorphosed limestone were listed in Taber's (1934, p. 576) description of the Vinent.

A bed of black fossiliferous argillite at least 50 meters thick is interbedded with massive andesitic flows, flow breccia, and agglomerate along the Río Palma Mocha, about 3 kilometers from the coast. Between the Río Palma Mocha and Río El Macho fine-grained gray impure limestone, calcareous siltstone, and siliceous shale crop out along parts of the coast. The base of this sequence was not observed, but at least 100 meters of beds are exposed. These rocks have not been observed elsewhere in the Sierra Maestra; they appear to be stratigraphically below the volcanic rocks found farther inland.

From Río El Macho eastward to Río La Plata beds of impure fossiliferous red limestone and calcareous red argillite as much as 3 meters thick are interbedded in andesitic and basaltic pyroclastic rocks; several small manganese deposits are associated with these hematitic beds. The red rocks are megascopically and microscopically similar to those associated with the manganese deposits in Pinar del Río and the Olympic Peninsula in Washington; the latter deposits have been described by Park (1942b, 1946). Hematitic limestone and argillite occur at the Igualada prospect, 2 kilometers east of Río El Macho; at El Palito prospect, 750 meters north of the Igualada; at the Estrella del Norte prospect, north of the Igualada prospect; and at the Magdalena mine in the Río Magdalena valley. These red beds may be stratigraphically equivalent but much more detailed mapping would be required to decipher the stratigraphy of this highly folded sequence of beds.

The microscope shows the red calcareous rocks to be somewhat tuffaceous and to consist of many Foraminifera, mainly Globigerina dusted with hematite, with smaller amounts of feldspar and quartz (?) set in a fine-grained matrix containing much finely divided hematite. Commonly the rocks are veined with calcite. The enclosing pyroclastic rocks at the Brazo de Felipe denouncement are basaltic tuff containing grains of albite, augite, rare epidote, and olivine (?), fragments of lava, and Foraminifera in a matrix of microcrystalline calcite. On the Magdalena denouncement the red beds occur in porphyritic andesitic or basaltic lavas that contain phenocrysts of albite and grains of pyroxene partly altered to epidote, chlorite, and magnetite; a little secondary quartz is also present.

The rocks north of the red-bed and volcanic-rock sequence were not examined, but the stream gravels indicate that they are mainly volcanic rocks intruded by diorite. To the south, impure brown-weathering limestone, argillite, and siliceous rocks crop out discontinuously along the coast; their stratigraphic position and greater induration suggest that they underlie the volcanic-rocks and red bed series.

Burchard (1920, p. 94) noted a "light-colored quartzite" overlying reddish shale at the San Juan prospect on the west side of the Río Camaroncito, but Park, and later the writers, found only brown recrystallized jasper, much of it resembling quartzite, overlying red fine-grained calcareous tuff. These rocks, which appear to be stratigraphically higher than the red-bed and volcanic-rock series to the east, may belong either to the Vinent or to the overlying Cobre formation.

### ORIGIN AND CONDITIONS OF DEPOSITION

The sedimentary rocks of the Vinent formation probably were derived from a land area not far from the site of the Gran Piedra range; the presence of conglomerate and sandstone and the shallow-water fauna in lenticular masses of limestone near Daiquirí suggest deposition under near-shore shallow marine conditions. Taber (1934, p. 591) suggested that the source area was probably south of the present coast, but there is equal reason to believe that it could have been to the east or north.

The alternation of marine sedimentary rocks and volcanic rocks suggests that many of the volcanic rocks were laid down under submarine conditions. This conclusion is supported by the calcareous nature of the pyroclastic rocks. Some of the volcanic rocks may be subaerial deposits. Pillow structures, often considered typical of lavas extruded under submarine conditions or in contact with wet sediments (Buddington, 1926), are notably rare in the lava of the Vinent formation even in places where the flows are interbedded with marine sediments. Either the lavas were not submarine or the physicochemical conditions were unsuitable for the formation of pillows.

Origin of the red hematitic limestone and calcareous argillite is conjectural. Park (1946, p. 309–321) suggested that the "red rocks" associated with the spilitic pillow lavas on the Olympic Peninsula are chemical precipitates, finely divided calcium carbonate having been released from sea water through agitation and heating by submarine volcanic activity. This idea was previously advanced by Kania (1929). Park believes that part of the necessary calcium was released through albitization of calcic feldspars by reaction of hot lavas with sea water, and that at the same time iron and manganese were released by alteration of mafic minerals. Some such process may have been involved in the formation of the red rocks in the Turquino-Portillo area. Although these beds are not associated with altered pillow lavas, they are enclosed in albitic tuffs and massive flows whose alteration by reaction with sea water might have released iron and manganese. The abundance of Foraminifera in the red rocks would then be regarded as fortuitous. Similar rocks of the Cayetano formation in Pinar del Río, which are interbedded with rocks of presumably nonvolcanic origin, may have a different origin.

The source of the Vinent volcanic rocks is not known but the great thickness and wide distribution of these rocks suggest many near-shore submarine vents. The lack of reworked volcanic debris indicates that there were few, if any, high volcanic islands.

#### AGE AND CORRELATION

The age of the Vinent formation has not been satisfactorily established, but meager fossil collections indicate a Cretaceous age. T. W. Vaughan, who examined corals and sponges collected by Singewald and Miller (1916, p. 74) from limestone near Daiquirí, concluded that the age is definitely Mesozoic, probably Cretaceous. Fossils collected by the writers from the black argillite on the Río Palma Mocha were identified by Ralph Imlay of the Geological Survey as *Actaeonella*-like gastropods "most probably of Upper Cretaceous, or late Lower Cretaceous age, judging by known occurrences of similar forms" (written communication).

Correlation of the Vinent with other formations of Cuba is still speculative. Keijzer (1945, p. 106) correlated the Vinent tentatively with the lithologically similar Cretaceous "Tuff Series" and this correlation seems reasonable. The rocks west of Pico Turquino cannot yet be correlated definitely with the type Vinent in the Gran Piedra range. The present tentative correlation is based on lithologic similarity and indefinite fossil evidence.

### HABANA(?) FORMATION

#### DISTRIBUTION

Rocks tentatively assigned to the Habana(?) formation are exposed in La Burra basin and Sumidero basin, flanking the Florida Blanca plateau, and in El Infierno basin 14 kilometers east of the Sumidero basin.

The Habana(?) formation occupies topographic depressions with surfaces of low relief. Areas underlain by the formation are easily distinguished on areal photographs by the fine dendritic drainage pattern developed on them.

#### THICKNESS AND STRATIGRAPHIC RELATIONS

The thickness of the Habana(?) formation is not known. In the Sumidero basin it is about 200 meters thick and in La Burra basin, at least 500 meters thick, but the base of the formation is not exposed in either basin. The Picote conglomerate member of the Habana(?) formation has a maximum thickness of about 275 meters at Monte

Picote. The Habana(?) formation rests unconformably on the serpentine complex of the Sierra de Nipe and is overlain with angular unconformity by the Cobre formation in all known areas.

##### STRATIGRAPHY AND PETROGRAPHY

The Habana(?) formation has been studied and mapped only in La Burra and Sumidero basins. It comprises chiefly interbedded tuffaceous shale, sandstone, conglomerate, and pyroclastic rocks, which are intruded and metamorphosed by many small stocks of highly altered igneous rocks. Rudistid-bearing reef limestone, chert, and pyritic lignite occur locally. Detailed descriptions of the formation are given in Lewis and Straczek (1955) and need not be repeated here.

##### AGE AND CORRELATION

The Habana(?) formation of the Sumidero and La Burra basins is evidently Late Cretaceous in age (Lewis and Straczek) but the age of the similar rocks in El Infierno basin is not known. Correlation of the Habana(?) formation with rocks in the Sierra Maestra cannot yet be made with certainty; it may be equivalent to part of the Vinent formation or to the lower part of the Cobre formation.

### UPPER CRETACEOUS(?), PALEOCENE(?), AND EOCENE SERIES

#### COBRE FORMATION

The Cobre formation is the thickest and most widespread rock unit of southwestern Oriente and within it occur the great bulk of the manganese deposits. A knowledge of the distribution, lithology, and stratigraphic relations of the Cobre rocks and a consideration of their origin and conditions of deposition is therefore of practical importance, particularly as a genetic relation between the Cobre rocks and the manganese deposits seems probable.

##### DISTRIBUTION AND TOPOGRAPHIC EXPRESSION

The Cobre formation is widely distributed throughout the Sierra Maestra, particularly on the north slopes, and is also found in the hills south of the Sierra de Nipe and Sierra del Cristal and in small areas in the broad Cauto and Guantánamo lowland. The formation was named by Taber (1931, p. 537–538), presumably from the town of El Cobre, 13 kilometers west of Santiago de Cuba.

The best and most continuous exposures of the Cobre formation are on the north slope of the Sierra Maestra where these rocks occupy a belt 10 to 30 kilometers wide extending from northwest of Pilón on the west to the Río Baconao on the east, a distance of more than 200 kilometers. Cobre rocks are also exposed on the south slopes of the Sierra Maestra at Sierra de Boniato and El Cobre in the northern part of the Santiago basin and at the eastern end of the Turquino range opposite Portillo and Pilón.

The Cobre formation is exposed in the hills bordering the Sierra de Nipe along the structural uplift between the Río Jagua and Río Guaninicún from Palmarito eastward to the Río Jarahueca. Cobre rocks also occur in the hills south of the Sierra del Cristal and east of the Río Jarahueca.

Rocks younger than the Cobre occupy most of the broad Cauto and Guantánamo valley, but the formation is exposed in several small domical structures in this area.

Areas underlain by Cobre rocks have in general the greatest relief of the region, with deep valleys and steep-sided ridges. The principal streams have coarse dendritic drainage patterns. A karst topography is developed on the thicker limestones of the formation.

#### THICKNESS AND STRATIGRAPHIC RELATIONS

The Cobre formation is at least 4,000 meters thick in the Gran Piedra range and the eastern part of the Turquino range. It thins northward and is only a few hundred meters thick on the flanks of the Sierra de Nipe and Sierra del Cristal. Taber (1934, p. 577) estimated its thickness to be more than 4,500 meters and perhaps as much as 6,000 meters.

The base of the Cobre formation has not been recognized in the Sierra Maestra and its relation to the Vinent formation is uncertain. To the north, in the foothills of the Sierra de Nipe, the Cobre formation lies unconformably on the Habana(?) formation and the serpentine complex of the Sierra de Nipe. Presumably the same relations exist on the flank of the Sierra del Cristal (Guild, written communication).

The Cobre formation is overlain conformably by the San Luis formation.

#### LITHOLOGIC CHARACTER

The Cobre formation consists principally of volcanic rocks with subordinate interbedded sedimentary rocks. Waterlaid pyroclastic rocks, broadly classified as agglomerate and tuff, form the chief type of volcanic rock, but the formation contains also a few intercalated lava flows and flow breccias. The sedimentary rocks include limestone (much of it markedly tuffaceous), tuffaceous siltstone and fine-grained siliceous tuff, and small amounts of tuffaceous sandstone and shale. The coarse pyroclastic rocks grade into finer pyroclastic and sedimentary rocks, and lava flows interfinger all these rocks. Because of the extremely abrupt lateral gradation and vertical variation in character of the rocks accurate correlation over distances of more than a few kilometers is not possible, although some limestone beds can be traced for many tens of kilometers. Even general correlations are difficult because of the paucity of fossils, particularly in the lower part of the formation.

The various rock types have widespread lateral and vertical distribution within the formation, but lava flows are most abundant in the lower part and limestone in the upper part. Coarse-textured pyroclastic rocks also appear to be most abundant in the lower and middle parts.

The coarse pyroclastic rocks are grouped together under the name "agglomerate" and include some rocks that would ordinarily be called volcanic breccia and some that may well be mud flows. A detailed classification following that proposed by Wentworth and Williams (1932) is not possible because no intensive study of the pyroclastic rocks has been attempted. As used herein, an agglomerate is a pyroclastic rock consisting of rounded, subangular and angular ejecta greater than 32 millimeters in diameter, commonly lying in a matrix of tuff; the fragments include accessory and accidental as well as cognate ejecta.

Agglomerates are irregularly distributed in the Cobre and occur throughout the formation, but they are most abundant and thickest in the middle and lower parts. Commonly these rocks occur as beds, a few meters to 300 meters or so in thickness, intercalated with or grading into tuff, limestone, or lava flows; a few agglomerates appear to be intrusive. The unweathered rocks are light green, gray, reddish gray or purple. The thicker beds are generally massive but many thin beds have a distinct layering. Ordinarily the individual agglomerate beds are conformable with enclosing beds, but a few disconformable contacts have been observed. A detailed discussion of distribution and petrography of the agglomerates is given in Lewis and Straczek (1955).

The agglomerate consists of rounded to angular fragments of lava, tuff, and limestone in a matrix of tuff that may be calcareous and even fossiliferous. The tuff matrix is invariably more highly altered and is usually lighter in color than the coarse constituents. The proportion of large fragments to small is variable but in general fragments less than 32 millimeters in diameter make up 50 to 75 percent of the rock. Exceptionally, individual blocks are as much as 15 meters in length but most are less than 30 centimeters in diameter. Most of the fragments, whether lava or tuff, are subrounded or subangular rather than angular, but they do not have the shape or structure of bombs and apparently were ejected as cognate and accessory material. The rounding of the fragments is related to the origin and conditions of deposition of the agglomerate (p. 45–46).

The bulk of the coarse constituents is porphyritic lava, in part vesicular or amygdaloidal, and the balance is made up of tuff or limestone. Some beds contain almost no tuff fragments whereas others consist almost entirely of tuff blocks set in a matrix of tuff; these latter rocks will be referred to as tuff agglomerates. Irregular blocks of white or gray limestone ranging from a few centimeters to as much as three meters in longest dimension occur in minor amounts in many agglomerates; the limestone is fossiliferous in many places.

Tuff-agglomerate is especially abundant in the Güisa-Los Negros area where it is exposed at many manganese mines including Charco Redondo, Lucía, Taratana (fig. 4) and Yeya. Small amounts of tuff-agglomerate that grade into "normal" agglomerate are found at most of the manganese mines in other parts of the Sierra Maestra. The thickest and most extensive tuff-agglomerate is in the Bueycito district where a bed at least 50 meters thick apparently covers an area of more than 25 square kilometers. Tuff-agglomerate occurs also in the southern foothills of the Sierra de Nipe at the Esperancita and Valle de Manganeso mines.

Tuff-agglomerate forms lenticular beds or pods enclosed in bedded tuff or limestone and grades laterally into "normal" agglomerate, tuff, or limestone; contacts are sharply gradational and conformable although somewhat irregular. The agglomerate is characteristically massive and completely unsorted; it consists of a heterogeneous mixture of rounded to subangular, somewhat elongate blocks of variably altered fine- to coarse-grained, massive or bedded tuff set in a matrix

FIGURE 4.—Coarse agglomerate at base of limestone, north end of Lego workings, Taratana mine. Most of the blocks are of fresh hard andesite or basalt; a large block of tuff can be seen in the upper left-hand corner. Matrix is calcareous tuff.

of tuff. In general less than 10 percent of the blocks are lava or limestone but at the Lucía and Charco Redondo mines there are local concentrations of angular to subrounded blocks of limestone as much as 3 meters in diameter (fig. 5). The tuff blocks are usually not more than 2 meters wide but some blocks in the agglomerate of the Bueycito district exceed 15 meters in length. In the mine areas manganese oxides are disseminated in the matrix of the agglomerate and less commonly the tuff blocks are partly replaced by manganese oxides; some of the agglomerate contains no manganese.

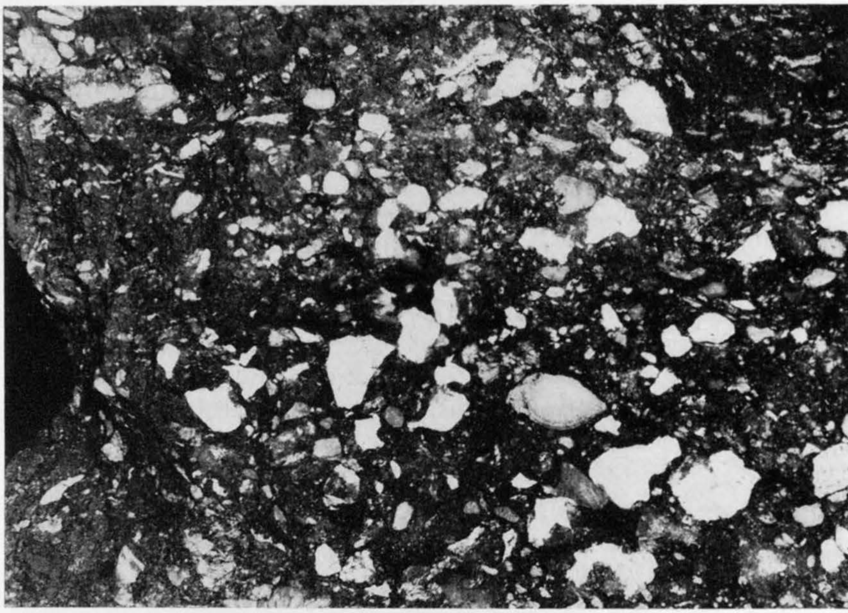


FIGURE 5.—Tuff-limestone conglomerate, 6th level of Lucía mine. White fragments are limestone, other blocks are tuff. Matrix is tuff impregnated with manganese oxides. Height of the exposure is about 1 meter.

Origin of the tuff-agglomerate is conjectural; it may be conglomerate, as Park and Cox (1944, p. 333) suggest for the bed in the Lucía mine and as Woodring and Daviess (1944, p. 367) suggest for this and certain other beds at or near the base of the Charco Redondo limestone in the central part of the Güisa-Los Negros district, or it may be of direct volcanic origin, either as mud flows or agglomerate. Features supporting the interpretation as conglomerate are: the predominance of tuff and limestone among the coarse constituents; the common occurrence at or near the base of a limestone; and the conspicuous rounding of the coarse components. However, certain facts seem to militate against such an interpretation. The massive, completely unsorted nature of the rocks and the haphazard distribution of large blocks argue against normal water transport. Moreover, there is little evidence of erosion of the soft underlying tuffs that might be expected of any current strong enough to move such coarse debris. The suggestion that these rocks are basal conglomerate is unconvincing because most of them are enclosed in tuff. Even at the Lucía and Charco Redondo mines, several centimeters to several meters of tuff intervenes between agglomerate and overlying limestone; the same conditions are found at the Valle de Manganeso, Esperancita, and Jesús Segundo mines.

It is difficult to explain the podlike form of some tuff-agglomerate lenses if these rocks are conglomerate. At the Yeya mine a tuff agglomerate occurs as a lenticular mass about 12 meters in thickness, at least 60 meters in length, and 25 meters in width. It occupies the stratigraphic position of a limestone bed into which it grades abruptly. The base of this agglomerate coincides with the base of the limestone, which is thickest at the site of the agglomerate pod, and its top is approximately the top of the limestone. Thick-bedded tuff underlies and overlies the limestone and agglomerate. This tuff-agglomerate is very similar to the more extensive, flatter lenses noted at the other mines mentioned.

The source of the debris making up the tuff-agglomerate must be local; the agglomerate blocks could not have been transported far because they are composed of tuff so soft that a pick readily may be driven into them.

The tuff-agglomerate may be of volcanic origin and either mud flow or agglomerate, or both. Possibly during periods of mild explosive activity in which little or no cognate material except tuff was formed, blocks derived from previously deposited, semiconsolidated tuff were piled up around vents from which they moved as submarine mud flows. Evidently sufficient movement occurred for the rounding of tuff blocks by attrition, although in part the rounding may be due to spalling.

The Cobre agglomerate appears to be mainly basaltic or andesitic in composition, but some is dacitic; the tuff matrix seems to have the same composition as the coarse constituents. Ejecta of lava in individual beds of agglomerate appears in general to differ little in mineralogic composition but in some agglomerate the ejecta range from basaltic to dacitic, suggesting that some of the fragments are accidental. Petrographic descriptions are given in Lewis and Straczek (1955).

Tuff is the most abundant pyroclastic rock and is probably the most common rock type of the Cobre formation. The tuff is usually well-bedded but some deposits are thick-bedded or even massive, especially where they are associated with agglomerate. Finer grained tuff usually shows more perfect bedding than the coarse-grained varieties. The unweathered tuff is gray, light brown, or green, less commonly pink, red, or whitish gray; it weathers to brown or dark gray. Many of the Cobre tuff deposits are limy and fossiliferous, particularly those in the middle and upper part of the formation, and in these rocks cross-bedding is not uncommon. Most limy tuff deposits are well bedded, even flaggy rocks, but a few are massive.

The tuffs are andesitic, basaltic or less commonly, dacitic in composition and are predominantly crystal tuff, though a few lithic tuff deposits are also known. Petrographic descriptions of the various types of tuff are given in Lewis and Straczek (1955).

Lava flows form only a small part of the Cobre formation. Like the associated pyroclastic rocks, the lavas range in composition from basaltic to dacitic; some have been reported to be rhyolitic (Taber, 1934, p. 578–579). They are scattered throughout the upper and middle Cobre but are relatively abundant in the lower Cobre of the Sierra Maestra where they are locally the dominant rock type.

The lavas of the Cobre formation are more or less altered, dark-gray, greenish or reddish-gray rocks that are usually porphyritic and fine grained to glassy in texture. Flow layering is commonly not visible. Amygdaloidal structures are sometimes present but rarely are conspicuous. A few flows have well-formed columnar jointing; fewer still show pillow structures.

Flow breccias are not uncommon and are of two types. The "normal" flow breccia consists of angular fragments of cognate lava and subordinate amounts of accessory and accidental fragments in a matrix of lava. This type appears to have formed in the usual manner by the disruption of solidified crusts and the incorporation of this material in the flowing lava. The second type of flow breccia is very different and perhaps should not be called a flow breccia as there is some question regarding its origin. The fragments are rounded to subrounded rather than angular in outline and range in color from a distinct brick red to greenish gray in contrast to the gray or greenish gray of the matrix. Most of the fragments appear to be cognate or accessory; they are fine grained, nonporphyritic, and nonvesicular like the matrix lava and appear to have the same andesitic or basaltic composition. The boulders range in size from several centimeters to as much as 30 centimeters and make up about 50 percent of the rock. This second type of flow breccia is most abundant in lower Cobre rocks.

The origin of the second type of flow breccia is conjectural. Any mechanism for the formation of this unusual rock must explain the following features: the rounding of the fragments; the reddish color of many of the fragments, indicating an oxidizing environment as contrasted with the unoxidized condition of other boulders and matrix lava; the scarcity of vesicles in boulders and matrix lava; the lack of a fine-grained or glassy selvage around the boulders; the textural and compositional similarity of fragments and matrix lava; and the scarcity of fragments less than 5 centimeters in diameter.

The structural features commonly described for volcanic rocks do not appear to explain adequately all of these features. The rounded boulders do not appear to be detached and engulfed pillows for they do not have a fine-grained or glassy selvage, are for the most part nonvesicular, and do not have the elongate shape common to pillows. The fragments also lack the characteristics of ordinary bombs, which generally have a glassy skin or a "bread-crust" surface and are vesicular. The boulders differ also from the lava balls described by Stearns (1926, pp. 337–339) which have a core of cognate or accessory lava surrounded by a skin or envelope of lava. The textural and apparent compositional similarity of fragments and matrix lava strongly suggests a common source. The fragments appear therefore to be cognate, although they may possibly be accessory. However, if the boulders are accessory then differences in texture and composition should be expected, considering the variety of lavas known to occur in the Cobre.

The reddish color of many of the boulders is probably due to oxidation before their introduction into the molten lava. Such a phenomenon is well known. Oxidation of ferrous iron to ferric and consequent alteration of basaltic lavas to a red color has been described by Jagger (1931) from the lava pits of the Hawaiian volcanoes, and Washington (1909, p. 148) recognized oxidation of ferrous iron in rocks on heating in air.

The scarcity of vesicles is more difficult to understand. Evidently there was almost complete dissipation of gases prior to the solidification of these lavas.

It is much more difficult to explain the anomalous rounding of the boulders. Rounding by attrition in molten lava seems unlikely, and rounding of the boulders before their introduction into lava is equally difficult to explain. Their textural similarity rules out as a possible source the fragments in the surrounding agglomerate; moreover, some of these "breccias" are interbedded with lava flows, tuff deposits, or sedimentary rocks. The rounding perhaps might be attributed to partial melting of originally angular fragments of cognate lava that were introduced into superheated, gas-fluxed lava in a vent before solidification or extrusion as flows. Such melting probably could not take place under ordinary temperature conditions for in normal flow breccia there is little evidence of assimilation by melting of the fragments. The fragments could have been derived from the sides of a vent (Jagger, 1931, p. 2) or could have come from solidified crusts floating on molten lava. At Kilauea in 1924, broken rock collapsed into the vent and new lava frothed its way through crevices of the oxidized breccia; according to Jagger (p. 67) "the half-melted breccia is lifted or lowered as a paste by the gas-charged melt in its interstices." It should not be difficult to imagine such a superheated charge solidifying, after dissipation of the charged gases, either in the vent or after extrusion as a flow. This would mean localization of such "flow breccias" in or near vents, and certain field facts support this inference.

Petrographic descriptions of the various lavas are given in Lewis and Straczek (1955).

Clastic sedimentary rocks of the Cobre include tuffaceous sandstone, siltstone, shale, and rare volcanic conglomerate that occur in minor amounts throughout the formation. The tuffaceous sandstone and shale appear to have been derived from previously deposited volcanic debris. Although most of the Cobre pyroclastic rocks appear to be water laid, the clastic rocks are distinguished by more conspicuous bedding and better rounding of the component grains. In general the individual clastic beds are no more than a few tens of meters thick but in places as on the upper Río Mogote they are interbedded with pyroclastic rocks in sections as much as 150 meters thick. The clastic rocks also include limestone breccia and conglomerate (p. 49).

Limestone is relatively common in the middle and upper part of the Cobre formation but scarce in lower Cobre rocks. It occurs as lenses which attain lengths of many kilometers and reach a maximum thickness of a few hundred meters. Because of their close association with many manganese deposits the limestone beds of the Cobre have a practical economic importance and may have a genetic significance as well.

Most of the limestone beds are very tuffaceous and contain pyroclastic debris ranging in size from fine sand to blocks more than 30 centimeters across. Massive to thick-bedded, white or gray coarse-grained fossiliferous limestone is most common; thin-bedded, flaggy limestone is less abundant. The less tuffaceous massive or thick-bedded limestone usually weathers to a rough, jagged or pinnacled surface known as "diente de perro" (dog-tooth) limestone. Very impure or thin-bedded limestone commonly weathers to smooth outcrops.

The thinner lenses of limestone form single beds but the thicker lenses are commonly interbedded with pyroclastic rocks. Many manganese deposits are localized in the intercalated pyroclastic rocks or in pyroclastic rocks near a limestone contact. Contacts with tuff or agglomerate are usually sharp and abrupt but in many places limestone grades laterally or vertically into calcareous tuff. Many limestone beds are conglomeratic or brecciose; some are marked by basal conglomerate or breccia of poorly rounded volcanic debris and limestone pebbles cemented by limestone. The conglomerate appears to be derived from local sources and is intraformational. Some of the thick limestone, in particular the Charco Redondo member, contains beds of intraformational conglomerate ranging in thickness from a few centimeters to about 5 meters and extending for hundreds of meters along the outcrop.

All the Cobre limestone beds appear to be fossiliferous but in some identifiable fossils are scarce. Over 40 species of large and small Foraminifera have been identified, and algae and corals are widespread and in places abundant. Gastropods, pelecypods, and brachiopods are much less common and most are poorly preserved. Numerous shark teeth occur in beds of tuff and manganese oxide intercalated in limestone (Burchard, 1920, p. 57). See figure 6.

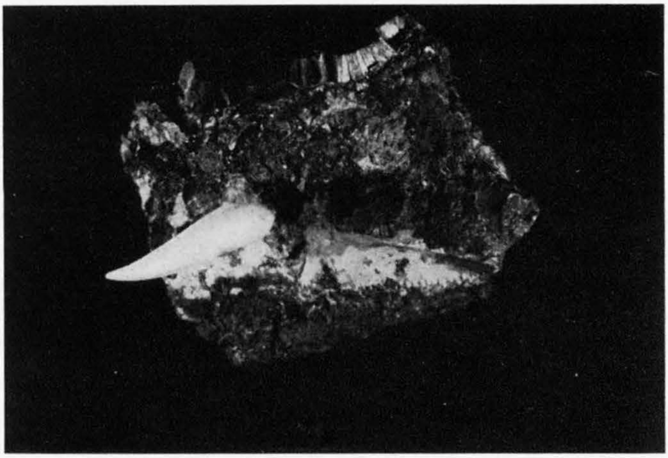


FIGURE 6.—Shark tooth embedded in manganese oxide from lower ore bed of K–6 workings, Charco Redondo mine. At lower right is the mold of another tooth. Natural size.

In this report mention will be made only of certain limestones associated with manganese deposits. A detailed discussion of the stratigraphy and paleontology of the Charco Redondo limestone member and various other limestones is presented by Lewis and Straczek (1955).

Limestone is scarce in the Cobre formation of the Gran Piedra range. Thin lenses of limestone, estimated to lie 200 to 350 meters below the top of the Cobre, occur at the Boston and Mirón mines, the Caridad and Mary prospects, and near the San Luis, Tordera, and Augusto Luis mines.

In the general vicinity of Santiago de Cuba, thin limestone lenses are found 900 to 1,500 meters below the top of the Cobre at the Piedra Pisada prospect on Sierra de Boniato 4.5 kilometers north of El Cobre and at the María and El Tesoro prospects 5 kilometers northwest of El Cobre.

Limestone lenses 3 to 10 meters thick are interbedded with pyroclastic rocks at the María Lola mine northwest of El Plátano on the Río Bayamo and at the Dátil mine, 9 kilometers west of El Plátano; these lenses are probably about 1,000 meters below the top of the Cobre.

In the Bueycito district a lentil of gray to red limestone, about 30 meters thick, crops out several hundred meters or more below the top of the Cobre.

Few details are known of the geology of the region west of Bueycito. At the Covadonga manganese prospect on the Río Jibacoa, 23 kilometers south-southwest of Yara, a bed of foraminiferal limestone 4 to 5 meters thick is interbedded in tuff. This limestone is probably at or near the top of the formation. At the Ponupo de Manacal mine, at the western end of the manganese belt, a bed of very tuffaceous foraminiferal limestone is intercalated in tuff and agglomerate.

The most widespread and economically important limestone of the manganese belt lies at the top of the Cobre formation. It was named the Charco Redondo limestone by Woodring and Daviess (1944, p. 367–368) after the Charco Redondo mine in the Güisa-Los Negros area. These writers considered the limestone to be a formation separate from the Cobre, but Lewis and Straczek (1955) prefer to designate it as a member of the Cobre formation because of its lenticular character, its discontinuous nature, and its tendency to interfinger and grade into Cobre volcanic rocks. The latter nomenclature is adopted in this report.

The Charco Redondo limestone member reaches its greatest thickness in the central part of the Güisa-Los Negros area where it is about 150 meters thick. It is commonly massive or thick bedded in its lower part and thin bedded and platy in its upper part or where it is rather thin. The upper thin-bedded part is relatively continuous and widespread, in contrast to the lower more massive beds, which commonly lens out abruptly into volcanic rocks.

The lower contact is everywhere conformable; the limestone may rest directly on agglomerate or tuff or may grade into these rocks through a zone of calcareous tuff and tuffaceous limestone beds ranging in thickness from a few to many meters. The upper contact is conformable with the San Luis formation and is gradational into San Luis shale through a zone ranging from a fraction of a meter to a few tens of meters in thickness.

The limestone is white to cream-colored and typically weathers gray. Less commonly it is colored greenish gray by disseminated nontronite or celadonite, particularly near contacts with altered pyroclastic rocks and manganese deposits. Most of the limestone is relatively pure but near contacts with volcanic rocks the amount of tuffaceous debris increases, sometimes markedly. Small nodules and lenses of chert have been observed only southeast of the Taratana mines (Woodring and Daviess, 1944, p. 369) and along the Río Juan Mulato south of the Sierra de Nipe.

The massive limestone is cavernous and weathers to the typical "diente de perro" surface. In places an extremely rugged karst topography, with huge sinks and subterranean drainage, has developed. The sinks and valleys of the largest karstland, in the central Güisa-Los Negros area, have formed along faults and joints and show a strikingly rectilinear pattern on aerial photographs. Smaller karstlands include the Nuevo Mundo karst area southeast of Sabana la Burra basin, the Pedernal karst area north of the same basin, and a small area on the north side of Florida Blanca plateau. The floors of most of the sinks and valleys in the karst areas appear to be at or near the base of the limestone and coffee is grown on them.

Lenticular beds of tuff and manganese oxides, ranging in thickness from a knife edge to nearly 2 meters, occur in the lower part of the Charco Redondo limestone in the north-central part of the Güisa-Los Negros area and in the southern foothills of the Sierra de Nipe. In places, for example the Taratana and Charco Redondo mines, as many as four beds of tuff and manganese oxides, separated by a few centimeters to a few meters of massive limestone, are superimposed. Beds of manganiferous tuff and tuff-agglomerate also are distributed sporadically near the base of the limestone.

Intraformational conglomerate beds are common in the Charco Redondo limestone member. Two principal types are known: one consists of rounded to subangular pebbles of limestone, tuff, and lava, and angular fragments of manganese oxides in a limestone matrix; the other is made up largely of subrounded pebbles and cobbles of limestone and minor volcanic debris. The clastic constituents of these conglomerates have a maximum diameter of 30 centimeters. The first type, which contains approximately equal amounts of limestone pebbles and manganese oxide fragments with little volcanic material, attains a maximum thickness of about 4 meters; this conglomerate overlies beds of manganese oxides and tuff at several mines (figs. 27, 29). Tuff beds associated with the conglomerate indicates that volcanic activity preceded or followed deposition of the conglomerate, and bomblike blocks of lava within the conglomerate suggests contemporaneous volcanism. The constituents of the conglomerates appear to have been derived in part from the underlying beds, in part from nearby beds, and in part from volcanic activity.

### PELUDA VOLCANIC MEMBER

Certain volcanic and minor sedimentary rocks in small areas on the southwest side of Sabana La Burra basin have been mapped separately from the Cobre formation and named the Peluda volcanic member, after the locality of La Peluda. These rocks contain no manganese deposits. For a description of them, the reader is referred to Lewis and Straczek (1955).

### STRATIGRAPHIC DISTRIBUTION OF VOLCANIC ROCKS

The various rock types of the Cobre formation seem to show a crudely systematic distribution that is apparently related to the different centers of volcanism. Although very little work has been done on this subject, a few generalized findings may be summarized.

Everywhere dacitic rock types appear to alternate with basaltic types, but the apparent local dominance of one type over the other suggests a lateral rather than a vertical variation within the formation. In the southern foothills of the Sierra de Nipe, most of the rocks appear to be andesitic or dacitic. Those of La Peluda area to the east appear to be andesitic or basaltic, as do the volcanic rocks of the Florida Blanca-Guanabá area. The lower Cobre lava flows in and south of the Lomas de Uraguá appear to be mainly dacitic, but they interfinger with basaltic flows toward the Santiago basin; conversely, the lower Cobre lavas of the upper Río Bayamo-Río Los Diablos area appear to be chiefly basaltic. Middle to upper Cobre rocks north of El Cobre, in the drainage basins of the Ríos Yarayabo and Domingo, range from basaltic to dacitic and we cannot say which phase is dominant. Upper Cobre volcanic rocks of the Güisa-Los Negros area seem to be mainly andesitic and basaltic. Each of the above areas is believed to have been a major center of volcanism.

Vertical variation of composition in the different inferred volcanic centers is less apparent. The latest pyroclastic rocks in some areas, as in the Quinto, Ponupo, and Sabanilla region, are some of the most silicic observed, but elsewhere in the same apparent stratigraphic zone they are basaltic.

### ORIGIN AND CONDITIONS OF DEPOSITION

The bulk of the Cobre volcanic rocks appear to be water laid, and many limestone beds and a great volume of limy tuff containing a marine fauna indicate a marine environment. The distribution of lava flows and coarse pyroclastic rocks shows that many of the source vents were within the area now underlain by Cobre rocks. Within this area there were no widespread land areas or islands, although small ephemeral islands may have existed from time to time. We agree with Park (1942a, p. 78) that "the source of much of the volcanic debris is apparently near the core of the Sierra Maestra." In addition to vents in the Sierra Maestra area there is strong evidence of volcanic sources outside and north of the Sierra Maestra. These sources can be inferred from the distribution of great thicknesses of massive agglomerate and tuff together with associated silicic lava flows. Geologists in general seem to agree that massive agglomerates accumulate near their source.

Centers of volcanism apparently are sporadically distributed. A thick accumulation of massive agglomerate and pyroclastic rocks in Arroyo Bruñi north of the Florida Blanca plateau suggests a center of volcanism, and massive pyroclastic rocks and associated dacitic lava flows in the Mogote San Nicolás hills east and southeast of Palmarito indicate another center. The pyroclastic rocks grade into finer debris away from these apparent centers and between them the Cobre formation is demonstrably thinner. The suggestion has already been made (Lewis and Straczek, 1955) that the older Peluda volcanic rocks between these centers have a local source. Thick massive agglomerate and associated lava flows and flow breccias on Sierra de Boniato north and northwest of El Cobre and massive agglomerate on the north flank of the Gran Piedra range apparently mark two or more major centers. Thick accumulations of lava flows in the eastern and central Turquino range each indicate a nearby vent. Other centers probably existed in the domical structures of the Jutinicú, Sabanilla, and Ponupo districts, each having cores of massive agglomerate and tuff. Massive agglomerate and tuff in the Güisa lowlands may mark another center of volcanism.

A minimum of 11 volcanic centers are indicated or inferred in an area of about 4,000 square kilometers; the distance between these centers ranges from 10 to 30 kilometers. Precise location of the volcanic centers is difficult because they may have been partly or wholly obscured by later deposits and because detailed knowledge of the distribution of the volcanic rocks is lacking in some areas, particularly in the higher parts of the Sierra Maestra. It is especially difficult to evaluate the relative importance of the various inferred centers. Lower Cobre volcanic rocks in the Gran Piedra and Turquino ranges could have come from centers thought to be exposed on the north flank of the mountains; the lavas and bordering interfingering pyroclastic rocks would then represent the upturned flanks of these centers. On the other hand, these centers may be secondary or minor and the major centers may have been still farther to the south, even south of the present Sierra Maestra. It seems certain only that north of the high Sierra Maestra most of the volcanic rocks came from local submarine centers.

Conditions postulated for the deposition of the Cobre volcanic and sedimentary rocks are similar to those in many places where submarine eruptions have occurred from Tertiary to Recent times. The nonfossiliferous volcanic character of the lowermost Cobre strata suggest that the sea may have been rather deep at the onset of volcanic activity or possibly that the beds are of nonmarine origin, but reef limestones in the middle and upper parts of the formation indicate that shallow-water marine conditions prevailed during the deposition of most of the rocks. Beds of tuffaceous sandstone and shale, lenses of conglomerate, and many local unconformities furnish evidence of wave or current action or perhaps of local subaerial erosion. The deposition of over 4,500 meters of volcanic and sedimentary rocks in a predominantly shallow water environment must mean that the area was downwarped progressively during the period of volcanism and sedimentation.

Submarine eruptions of the type believed to have taken place during deposition of the Cobre formation have occurred throughout historical time. Examples include Falcon Island in the southwest Pacific (Hoffmeister, Ladd, and Alling, 1929, p. 461–471), Graham Island in the Mediterranean Sea (Washington, 1909, p. 131–150), and Anak Krakatau in the Sunda Strait. These islands consist of basaltic pyroclastic debris and have been built up, reduced to shoals by marine erosion, and rebuilt several times. Islands of andesitic pyroclastic material were formed during the submarine eruptions of Sakurajima (Koto, 1916, p. 48), and at Santorini, north of Crete, an island was built up of pyroxene dacite volcanic rocks.

According to Hoffmeister, Ladd, and Alling (p. 469) explosive eruptions have been the dominant type of volcanic activity since Eocene time in the southwest Pacific, where high islands have been built up from deep sea platforms. During deposition of the Cobre formation, however, it is improbable that any area ever stood high above sea level or was subjected to prolonged weathering and erosion. Widespread surfaces of erosion or nondeposition may be present in the lowermost Cobre rocks, which have been studied only slightly and have yielded no identifiable fossils, but it is improbable that any significant hiatus occurs in the more carefully studied and fossil-rich middle and upper parts of the formation.

The earliest, Hawaiian-type volcanic activity built up a widespread platform of lavas at what is now the site of the eastern and central Turquino range. The later and much more abundant pyroclastic debris was deposited during vulcanian eruptions.

The great bulk of this pyroclastic material apparently was thrown out as solid fragments of cognate and accessory lava. Intermittent eruptions of the pelean type, with the emission of "nuées ardentes" or glowing clouds may have taken place but this type of eruptive activity was probably not common inasmuch as high subaerial volcanoes were either rare or nonexistent. Washington (1926, p. 383) in referring to possible future eruptions of Santorini volcano, states,

> there is . . . no likelihood of the occurrence of destructive nuées ardentes, such as happened at Pelée and Sakurajima, since the altitude of the central cones is too low.

Gravity as well as explosive action is evidently a necessary agent in the initial stages of a "nuée ardente" eruption (Anderson and Flett, 1903, p. 509–510; Fenner, 1923, p. 71).

Volcanism was probably intermittent at the various centers so that limy sediments, in large part the tests of benthonic and pelagic Foraminifera, were able to accumulate in areas of diminished volcanic activity. Much limy material also was mixed with pyroclastic debris even during periods of violent eruption, as attested by the limy matrix of tuff and some agglomerate.

Accumulating volcanic ejecta and sediments probably formed cones at each active center. H. S. Ladd (written communication) reports slopes of more than 40 degrees on some of the islands in the southwest Pacific. Kuenen (1935, p. 67–73) has found that submarine slopes on volcanoes in the eastern part of Indonesia range from 4 degrees to 45 degrees for the first 200 meters of depth. Although he found average slopes as high as 34 degrees, he concluded that submarine slopes probably averaged less than 22 degrees. Thus many of the Cobre rocks may have had initial dips in excess of dips now observed.

Most of the volcanic islands of the Pacific and Indonesian areas are spaced so far apart that there is overlapping of only the fine pyroclastic debris. In southwestern Oriente the volcanic centers were evidently so closely spaced on a shallow submarine platform that coarse pyroclastic ejecta from adjoining eruptive centers overlapped and interfingered. Such overlapping would seem to require many more vents than have been indicated or inferred for the area if the pyroclastic material was contributed directly from the erupting vents, for coarse ejecta are usually thrown only a few kilometers at most. For example, during the eruption of Sakurajima in 1914, fragments of basic andesite were thrown 3 to 3.5 kilometers (Koto, p. 65); at Halemaumau, on Hawaii, blocks of accessory basalt were hurled as far as 1 mile from the crater (Jagger, 1947, p. 476). Wentworth (1926, p. 19) states that during pyroclastic eruptions on Oahu all bombs and blocks fell within 1 mile of the vents. During an eruption at Santorini, blocks as large as one meter across were thrown 1 kilometer (Washington, 1926, p. 367).

It seems reasonable to infer that during eruptive activity in Cobre time the coarse constituents of the agglomerates (over 32 millimeters in diameter) would not be thrown more than 5 kilometers from a surface vent; under submarine conditions they probably would not be thrown as far. Even with allowance for probable undiscovered vents, the eruptive centers of southwestern Oriente appear to be too far apart to permit direct deposition of all the pyroclastic material between the centers. It is probable therefore that much unconsolidated volcanic debris moved down submarine slopes as mud flows, perhaps triggered by earthquakes. If island areas existed, some material may have been carried as nuées ardentes. Thus, the presence of coarse volcanic ejecta between widely spaced centers and the rounding of coarse agglomerate constituents might be explained.

The critical slope at which pyroclastic material will slide under submarine conditions is conjectural but must be related to the type and size of the constituents and the thickness of the deposit. Kuenen (p. 70) believes that

> "the most mobile marine sediments known, can accumulate in thicknesses of upwards of one meter on angles of 15 degrees in strongly seismic regions at all depths,"

and it is likely that pyroclastic deposits would accumulate on even higher slopes. However, Lacroix (in Perret, 1935, p. 90) says that volcanic debris was carried down submarine slopes near Pelée to depths of 2,500 meters and distances of 12 miles from shore, an average slope of only 7.5 degrees. It is known that surface mudflows of volcanic origin have flowed for many kilometers down slopes of only a few degrees.

### AGE AND CORRELATION

The Cobre formation apparently ranges in age from Late Cretaceous to Eocene. Cobre strata of known Eocene age are estimated to be at least 2,500 meters thick, or a little more than half the estimated minimum thickness of the formation. The oldest definitely dated Cobre rocks appear to be Paleocene in age (Bermúdez, 1950, p. 223). No diagnostic fossils have been found in the section in the Sierra Maestra between definitely dated Cobre rocks and the underlying Vinent formation. The upper part of the Cobre, including the Charco Redondo limestone member, is evidently of middle Eocene age (Keijzer, 1945, p. 110–112; Bermúdez, 1950, p. 246; Lewis and Straczek, 1955).

A few new fossil determinations are given below; for discussion and faunal lists, the reader should consult Bermúdez (1950) and Lewis and Straczek (1955). Specimens of tuffaceous foraminiferal limestone from the Ponupo de Manacal mine in the Portillo district and from the Covadonga prospect in the Jibacoa district of the western Turquino range were studied by D. W. Gravell of the Atlantic Oil and Refining Company, La Habana, who reported as follows:

> in polished surfaces the [Ponupo de Manacal] samples are seen to consist of gray, clastic, tuffaceous limestone containing . . . abundant rather worn and

broken *Discocyclina* cf. *D. cubensis*, *D.* cf. *crassa*, *Amphistegina* sp., *Operculinoides*, miliolids, a few *Dictyoconus* cf. *D. Americanus* (Cushman), fragments of *Asterocyclina* sp., and calcareous algae up to 3 or 4 millimeters in length. . . . The fauna is a shallow, warm, marine water assemblage.

For the Covadonaga limestone bed, a

buff-colored, hard limestone with small patches and stains of manganese oxides. Polished surfaces show . . . sections of *Globigerina*, miliolids, *Amphistegina*, very small fragments of *Dictyoconus*, and small specimens of what is either *Coskinolina* or *Dictyoconus*, some *Pseudorbitolina* cf. *P. cubensis*, small fragments of *Discocyclina* and *Asterocyclina* sp., and fragments of a small *Lepidocyclina* . . .

Gravell determined the age of these limestone deposits as middle Eocene.

Rocks apparently equivalent in age to the Cobre have been found in many parts of Cuba, but no unequivocal Paleocene or Eocene volcanic rocks are reported outside of southwestern and north-central Oriente. However, Palmer (1945, p. 5) thinks volcanic and sedimentary rocks of the "Tuff Series" may be as young as Paleocene or early Eocene. With his interpretation, the uppermost part of the dominantly volcanic "Tuff Series," a series exposed in every province, would be equivalent to at least part of the Cobre formation. Work of members of U. S. Geological Survey in the Camagüey district and of De Vletter in western Oriente lends some support to the suggestions of Palmer. The Charco Redondo limestone member and Darton's (1926, p. 327) Guaso limestone in the Guantánamo basin appear to bear the same relation to the overlying San Luis formation and seem to be of the same age (Keijzer, p. 88–92).

### SAN LUIS FORMATION

The San Luis formation, named by Taber (1934, p. 584–585) presumably after the town of San Luis, crops out mainly in the Cauto and Guantánamo lowlands and in the adjoining outer foothills of the Sierra Maestra and on the flanks of the Sierra de Nipe. The formation flanks the Gran Piedra range on the north and according to Keijzer (1945, p. 84–85) extends eastward as far as the Guantánamo basin. It extends westward as far as the Río Cautillo in the Güisa-Los Negros area, where the formation occupies the structural basin of the upper Cautillo valley, and may extend farther west along the northern side of the Turquino range.

Regions underlain by the San Luis formation have in general a gently rolling terrain of low relief. The lowlands developed on San Luis rocks support much of the sugar cane grown in the area.

The thickness of the formation is not accurately known; it is estimated to be 700 to 1,000 meters thick along the Río Contramaestre and may be as much as 1,500 meters thick near Palma Soriano. The formation thins to less than 100 meters on the southern flanks of the Sierra de Nipe.

The San Luis formation overlies conformably the Cobre formation and the basal contact is nearly everywhere gradational into the Charco Redondo limestone. It is overlain conformably or disconformably by Oligocene sedimentary rocks in the northern part of the manganese field.

The San Luis rocks consist mainly of limy fossiliferous tuffaceous sandstone and shale with minor amounts of conglomerate, limestone, and marl. These rocks are gray, greenish gray, or brown on fresh surfaces and weather brown. The coarse clastic rocks are clean, fairly well sorted and usually are thick bedded or massive. The conglomerate is composed of well-rounded pebbles, cobbles, and boulders of volcanic rocks with minor amounts of granitic rocks, fine-grained siliceous and tuffaceous limestone, gray limestone, chert, and siliceous shale, in a matrix of clean sand cemented by clay or, less commonly, by limestone. The sandstone is well-sorted and in places is crossbedded. It is made up of rounded pebbles of volcanic rocks and grains of feldspar and quartz cemented by clay or limestone. The shale is gray, chocolate, or reddish-brown where unweathered; it is generally nonfissile, and usually is very sandy. All the shale contains abundant Foraminifera.

The San Luis formation is Eocene in age; the lower part of the formation has been assigned a middle Eocene age and the upper part a late Eocene age by Lewis and Straczek. Taber (1934, p. 585) suggested that the San Luis may be equivalent to Darton's Guaso limestone of the Guantánamo basin, but Keijzer (1945, p. 84) would correlate the San Luis formation with Darton's Guantánamo shale. According to Bermúdez (1950, p. 258) the formation is of early late Eocene age and is slightly older than the Guantánamo formation.

No manganese deposits have been found in the San Luis formation. For additional information on lithology, stratigraphy, and faunas the reader is referred to Lewis and Straczek.

### OLIGOCENE SERIES

Rocks to which no formation name has yet been assigned crop out along the north-central edge of the manganese field. This sequence has been traced from the southwest foothills of the Sierra de Nipe to a point 4.5 kilometers north-northwest of Contramaestre. Presumably these rocks extend northward into the Cauto plain. Oligocene rocks also crop out on the dissected plateau northwest of the confluence of the Ríos Caoba and Mayarí.

The thickness of the Oligocene strata is unknown but is at least 100 meters in the Cauto lowlands. The rocks overlie conformably the San Luis formation; the upper contact has not been observed.

Foraminiferal marl, limy mudstone, and shale, with intercalated lenses of bioherm limestone and white chalk make up the known Oligocene rocks. These relatively fine grained sediments contrast strongly with the underlying conglomerate, coarse and fine sandstone, and shale of the San Luis formation.

Abundant Foraminifera and corals indicate an Oligocene age for these strata (Lewis and Straczek, 1955).

### MIOCENE SERIES

#### LA CRUZ FORMATION

La Cruz formation occupies most of the Santiago lowlands. It was originally described by Hayes, Vaughan, and Spencer (1901, p. 23) and later was named and described in greater detail by Vaughan (1918, p. 276). The formation consists of a few tens of meters of calcareous, tuffaceous sandstone and poorly sorted shale, conglomerate, and highly fossiliferous conglomeratic limestone. The nearly flat lying La Cruz strata unconformably overlie highly folded Cobre pyroclastic rocks in the Santiago basin; farther east toward Siboney it overlies the Vinent formation and dioritic rocks. Grains, pebbles, and cobbles of tuff, lavas, fine-grained intrusive rocks, and fine-grained, dense limestone, all apparently derived from the fringing Cobre formation, are conspicuous in the coarse La Cruz clastic rocks.

La Cruz formation has been assigned a middle Miocene age by various workers (Vaughan, 1919, p. 218–219 and 1922, p. 115–116; Cooke, 1921, p. 137; Woodring, 1928, p. 61; Keijzer, 1945, p. 116–118; and Bermúdez, 1950, p. 295).

#### MANZANILLO FORMATION

The Manzanillo formation underlies a coastal belt extending from the northwest coast of Cabo Cruz to the town of Manzanillo and may extend inland as far as Bayamo. Taber (1934, p. 586–588) who named and described the formation, gives no thickness, but hills as high as 180 to 200 meters above sea level are underlain by Manzanillo rocks. According to him,

> The Manzanillo formation consists chiefly of highly calcareous, yellow to light gray, bedded marl, but in places it grades into clayey or sandy layers. Prolonged weathering results in red clay soils.

The Mazanillo formation has been assigned a early Miocene age by Taber (1934) and Bermúdez (1950, p. 295).

### PLIOCENE(?) SERIES

No rocks of Pliocene age are known definitely in southwestern Oriente, although fossils of doubtful Pliocene age have been reported from a hill 18 kilometers south of Media Luna at the west end of the Sierra Maestra by Taber (1934, p. 587–588).

## QUATERNARY SERIES

### COASTAL LIMESTONE

Cavernous, highly fossiliferous limestone, marl, and conglomerate fringe parts of the coast of southwestern Oriente (Hayes, Vaughan, and Spencer, 1901, p. 23–34), and in places form a thin blanket over older rocks. Taber (1934, p. 589–590) points out that the fossil corals in the rocks are similar to living forms, and therefore regards these rocks as in part Recent and in part Pleistocene in age.

### ALLUVIUM

Alluvium occupies many of the stream valleys of southwestern Oriente, especially in the lower Sierra Maestra foothills and in the Cauto and Guantánamo lowlands where it attains a maximum thickness of 30 meters. The richest soils of the region for raising sugar cane are developed on alluviated plains on which rivers are entrenched to depths of a few meters to several tens of meters. The alluvium is believed to range in age from Pleistocene to Recent, and some may be as old as Pliocene.

## INTRUSIVE ROCKS

Intrusive rocks are sporadically distributed throughout southwestern Oriente. They cut all formations older than Oligocene, although few are known to intrude the San Luis formation. Most of the intrusives are small stocks or dikes. The largest intrusive bodies are the great mass of ultramafic rocks in the Sierra de Nipe and Sierra del Cristal highlands and the dioritic batholiths on the south flank of the Sierra Maestra.

Two general age groups of intrusive rocks are recognized: a pre-Tertiary assemblage which includes the ultramafic complex of the Sierra de Nipe and Sierra del Cristal highlands and certain dacitic or quartz dioritic rocks that intrude the Habana(?) formation of La Burra basin, and a Tertiary group comprising small stocks and dikes of dacite, andesite, and basalt that intrude pre-Oligocene rocks in many places throughout the manganese belt. The Sierra Maestra diorite batholiths are probably early Tertiary in age but may be as old as Cretaceous.

The pre-Tertiary intrusive rocks are discussed in detail by Thayer (1942, p. 9–16), and Lewis and Straczek (1955).

Data on the field relations, petrography, and age of two dioritic batholiths in the eastern Turquino range and Gran Piedra range are summarized by Lewis and Straczek. In addition to these two batholiths, there is probably a third similar body at the west end of the Turquino range. We have seen large and small stocks of dioritic rocks believed to be outliers of this batholith between the Ríos El Macho and La Plata, on the coast west of Pico Turquino, and at the head of the

Río Los Diablos north of the divide of the Turquino range. Apparently no dioritic rock crops out on the west slope of Pico Turquino although the east side may consist of diorite (G. C. Bucher, Santiago de Cuba, written communication).

## STRUCTURE

The structural features and structural history of southwest Oriente are discussed in considerable detail by Lewis and Straczek (1955). In order to avoid needless repetition, this report will include only a brief summary of the salient features.

The essentially homoclinal character of the Sierra Maestra, the broadly anticlinal nature of the Sierra de Nipe and Sierra del Cristal highlands, and the intervening synclinal valley of the Ríos Cauto and Guantánamo were recognized early by Hayes, Vaughan, and Spencer (1901, p. 26–28), and subsequent geologic work has not changed materially their general concept of the structure of central Oriente. The regional structural trend is eastward and is clearly reflected in the San Luis and older formations; post-Eocene rocks are essentially flat lying. Within the manganese belt, the easterly structural trend in the western Turquino range deviates southeastward in the Güisa-Los Negros area, eastward again in the region around Santiago de Cuba, and southeastward in the eastern half of the Gran Piedra range. The Sierra de Nipe and Sierra del Cristal are two great domical uplifts separated by a synclinal trough whose northward-trending axis is followed by the Mayarí and Jarahueca valley (Thayer and Guild, 1947, p. 928).

In the general vicinity of Santiago de Cuba, both open and tight asymmetric folds overturned to the north have been mapped. Farther west, in the Güisa-Los Negros area, folds are broad and open. Eastward-trending major folds have been observed in the Turquino range at the west end of the manganese belt, but no detailed work has been done there. The southern foothills of the Sierra de Nipe have a broad anticlinal structure.

A number of small circular or elliptical domes are found far out on the north flank of the Sierra Maestra and in the Cauto and Guantánamo lowlands. The domes range from less than 1 to 5 kilometers across. Domes near the Sierra Maestra (Botsford, Cuatro Caminos, Gloria, Manacas, Mucaral, Uraguá) are elongate parallel to the easterly regional structure. Domes farther north are roughly circular (Jutinicú, Ponupo, and Santa Cruz) or elongate in a northerly direction (Sabanilla). Manganese deposits are found at all but one of the domes (Santa Cruz); this relationship is discussed in the section on ore deposits (p. 102).

Major faults seem to be concentrated in three areas. In the Güisa-Los Negros area most of the faults are steep-dipping fractures with normal displacements of as much as 200 meters; they cut the Charco Redondo limestone member of the Cobre formation and are commonly marked by steep cliffs and deep, narrow valleys. A southward-dipping thrust fault was mapped at the Charco Redondo mine. In the foothills south of the Sierra de Nipe many small steep-dipping faults and a few minor southward-dipping thrust faults are known; the largest fault may have a displacement of 200 meters. A major zone of deformation extends along the north rim of the Santiago basin and up Dos Bocas valley. Several large southward-dipping oblique-slip reverse faults with dip-slip displacements of as much as 1,500 meters and a few small southward-dipping thrust faults have been recognized.

## PHYSIOGRAPHY

The highland areas of southwestern and central Oriente are in the youthful stage of the present erosion cycle. A complex physiographic history is attested by the following features: the accordant levels of plateaus and mesas and locally of ridge crests; the "terraced" ridge crests in the Sierra Maestra; the different levels of river terraces and entrenched meanders found throughout the area; the elevated marine coastal terraces; the drowned or filled coastal valleys.

Accordant surfaces are found on the extensive Nipe plateau, at an altitude of about 650 meters; on the Pedernal and Florida Blanca plateaus which are nearly as high; on La Prueba plateau, about 550 meters above sea level; and on Loreto mesa, about 650 meters high. Differences in rock types and truncated structures indicate that these plateaus are remnants of an old erosion surface and their near accordance and close grouping suggest that they are parts of the same surface or of closely related surfaces. The present low relief shows that erosion subsequent to their formation has been very slight. Greater differential uplift with increasing distance from the Cauto-Guantánamo synclinal axis may explain the differences in altitude.

The Nipe plateau is developed mainly on altered and deeply lateritized ultramafic rocks but on the margin the surface extends across limestone and clastic rocks that appear to be as young as Oligocene. This surface is probably to be correlated with the deeply dissected northward-tilted Moa surface (Thayer and Guild, 1947, p. 929) on the north side of the "Cuchillas de Toar" (Spencer, 1908, p. 326). The Pedernal plateau, separated from the Nipe plateau by the deep valley of the Río Piloto, is formed on very gently dipping rocks of Eocene (Cobre and San Luis formations) and Oligocene age; Florida Blanca plateau, across the Río Caoba from Pedernal plateau, is formed on Cobre rocks which in places are covered by several meters of red soil. These two plateaus are capped by the Charco Redondo limestone member on which a karst topography has formed. La Prueba plateau is cut across gently dipping shale, sandstone, and fine conglomerate of the San Luis formation, and Loreto mesa north of the Gran Piedra range is capped by a resistant, nearly horizontal conglomerate bed of the same formation.

Old erosion surfaces in other parts of the Sierra Maestra are preserved on locally accordant ridge crests with moderate to gentle northerly slopes. Red soils and weathered zones as much as a few feet in thickness occur locally on crests of some of the higher ridges of volcanic rocks, generally above 650 meters in altitude. The dissected Boniato piedmont, lying about 450 meters above sea level along its southern margin, may be a remnant of an old erosion surface. At the west end of the Turquino range accordant crests of sharp ridges and piedmont slopes of low relief dip northward to merge with the Cauto plain or disappear into the Golfo de Guacanayabo (Taber, 1934, p. 571 and 595).

In the Santiago lowlands flat-topped hills, eroded mainly on gently-dipping strata of La Cruz formation, appear to be remnants of a much-dissected ancient marine surface (Taber, 1934, p. 595) now lying at less than 175 meters above sea level.

These old erosion surfaces seem to indicate that the whole region north of the Sierra Maestra was reduced to a plain of low relief before rejuvenation by uplift inaugurated the present period of active dissection. The laterites of the Sierra de Nipe and Sierra del Cristal highlands (Spencer, 1908, p. 326; Thayer and Guild, 1947, p. 929) and possibly the red soils on the Florida Blanca plateau were formed during intensive weathering of this plain. It is less certain that the red soils on high ridge crests in the Sierra Maestra are contemporaneous with the laterites, because we are not sure that the same erosion surfaces are represented in both areas. The notable dissection of erosion surfaces in the Sierra Maestra, as contrasted with the well-preserved accordant summits of the Sierra de Nipe and the Sierra del Cristal highlands and that part of the northern Sierra Maestra foothills including Loreto mesa, suggests that a large part of the Sierra Maestra either had not been reduced to a plain of low relief (Taber, 1934, p. 596) or was uplifted and eroded before the area to the north. Perhaps both these possibilities were realized.

The surface on the Sierra de Nipe and the Sierra del Cristal highlands has been dated as Oligocene (Weld, 1909, p. 309) and late Tertiary (Spencer, 1908, p. 326), but Taber, who correlated it with vestiges of surfaces in the Sierra Maestra and with the surface that bevels Miocene rocks in the Santiago lowlands, suggested a Pliocene age. He stated (1934, p. 595) that

> erosion of the older rocks was going on in most of Oriente during, and even prior to, Miocene time but the results found in Cuba would seem to require a continuation of the process through most of Pliocene time.

Thayer and Guild (1947, p. 928–929) accept a Pliocene age for the Moa surface.

It seems very likely that the Sierra de Nipe, Moa, Pedernal, Florida Blanca, La Prueba and Loreto surfaces and perhaps the Boniato piedmont and surface remnants in the Sierra Maestra may be correlated, but we do not believe that the surface in the Santiago lowlands ever was part of the more widespread and much higher one. Mapping by Lewis and Straczek in the Santiago area has shown that the differences in altitude between highland and lowland surfaces (several hundred meters) cannot be accounted for by faulting; they concluded that the lowland surface is a plain of marine erosion distinct from the plain in the highland areas and perhaps as young as Pleistocene.

Thus, the relative positions of the Santiago lowland and the high Sierra Maestra must have been determined before deposition of the middle Miocene La Cruz formation in the lowland area. According to such an interpretation, the present high Sierra Maestra area was fairly high land as early as the middle Miocene. It would follow then that the elevated erosion surface of the Sierra Maestra was formed before middle Miocene time (before the La Cruz formation was deposited) and inasmuch as it cuts beds of the lower Miocene Manzanillo formation, later than early Miocene in age. The Moa surface of the Sierra de Nipe and Sierra del Cristal highlands would therefore seem to be younger than that in the Sierra Maestra; the former may be as young as Pliocene, the latter may be as old as early to middle Miocene. These relative ages accord with the greater physiographic maturity of the Sierra Maestra highlands as compared with the Sierra de Nipe and Sierra del Cristal highlands.

Meandering streams are deeply entrenched throughout the Sierra Maestra. The upper Río Bayamo is entrenched as much as 150 meters and the Río Baconao, on the north side of the Gran Piedra range, has carved a series of tremendous superimposed entrenched meanders 250 to 300 meters deep across a conspicuous hogback of Charco Redondo limestone. Streams in the Santiago lowland are entrenched as much as 100 meters. Elsewhere, as in the Cauto and Guantánamo lowlands, depth of entrenchment is generally less than 30 meters.

## GEOLOGIC HISTORY

The decipherable geologic history of southwestern Oriente began before Late Cretaceous time with the emplacement of great masses of ultramafic rocks in the present area of the Sierra de Nipe and Sierra del Cristal highlands. The age of the host rocks is unknown. By Late Cretaceous time this ultramafic complex had been stripped of its cover and eroded to form part of the clastic sediments of the Habana(?) formation deposited to the south. Concomitant volcanism contributed the intercalated pyroclastic beds of the formation, and minor stocks of dacitic and dioritic rocks (possibly related to the volcanic rocks) were intruded into the Habana strata. Folding, uplift and erosion were followed by deposition of the Late Cretaceous(?) Peluda volcanic member of the Cobre formation.

During Cretaceous time, or possibly even earlier, the general area of the Sierra Maestra was a site of active volcanism and minor sedimentation. Submarine lava flows and clastic sediments were deposited to form the Vinent formation. It seems likely that at least part of the Vinent (or lowermost Cobre?) volcanism in Late Cretaceous time was contemporaneous with Habana volcanism. The scarcity of coarse volcanic ejecta in the Habana formation(?) suggests a relatively distant source that may have been in the Sierra Maestra region. The Late Cretaceous deformation recorded in rocks of the Habana formation(?) has not been recognized in the Sierra Maestra (Lewis and Straczek, 1955). More or less continuous volcanism may have taken place in this southern area concurrently with sedimentation, volcanism, and deformation in the northern area.

Volcanism and minor sedimentation continued from Late Cretaceous to middle Eocene time. The sources of the volcanic material of the Cobre formation were probably local centers, either submarine vents or possibly low-lying volcanic islands. The entire area of Cobre deposition was one of gradual subsidence, the amount of subsidence being greatest to the south; the Sierra de Nipe and Sierra del Cristal highland area appears to have received volcanic debris and sediments only in the latest stage of Cobre deposition in the middle Eocene. Concurrently with Cobre volcanism, many stocks and dikes of dacitic, andesitic and dioritic, and basaltic rocks were emplaced. Most of them were intruded probably in the middle Eocene, and the Sierra Maestra dioritic batholiths may have been emplaced at this time also. Minor basaltic dikes representing the waning stages of Cobre volcanism were intruded at least as late as the late Eocene and possibly the Oligocene.

A few manganese deposits, probably syngenetic, were formed during deposition of the Vinent formation but most of the deposits of this type were formed in lower and middle Eocene time; the largest were formed toward the end of Cobre volcanism in the middle Eocene. A few minor deposits are epigenetic and are localized along faults believed to be of Cobre age. Folding and faulting probably occurred throughout the deposition of the Cobre because of differential crustal adjustments, due to the tremendous outpourings of volcanic material, compaction of this material, and emplacement of intrusive masses.

Volcanic activity was followed by orogenesis, uplift, and formation of a land mass, probably south of the present Sierra Maestra. Erosion of this land mass, composed of Vinent and Cobre rocks intruded by dioritic plutons, began in the middle Eocene and continued with increasing intensity until the upper Eocene. Clastic debris of the San Luis formation was deposited in a shallow basin to the north. Uplift appears to have diminished or ended some time toward the end of the Eocene, when coarse clastic rocks of the San Luis formation gave way to fine sediments of the Oligocene rocks in the Cauto basin and the Sierra de Nipe.

The intense deformation of upper Eocene strata of the San Luis formation must have taken place between late Eocene and middle Miocene (before deposition of La Cruz formation) time; it probably reached its climax during the renewed uplift of the Sierra Maestra region and was evidently accompanied by depression of the area south of the Sierra Maestra, presaging formation of the Oriente Deep. During the following period of renewed erosion, the Santiago basin was carved out. Localization of strong erosion at this point may be attributed to the presence of a zone of intense deformation and a consequent local weakening of the rocks involved. After subsidence of the Santiago basin, sediments derived from the adjacent Sierra Maestra were laid down in middle Miocene time as the La Cruz formation.

In the Cauto lowlands and the Manzanillo-Bayamo area, north of the Sierra Maestra, sedimentation continued throughout Oligocene and early Miocene time. At least part of the fine clastic deposits of the Manzanillo formation and the Oligocene and Miocene beds of the Cauto lowland came from the Sierra Maestra land mass to the south; some may have been derived from the Sierra de Nipe and the Sierra del Cristal region.

In late Miocene time, all of southwestern Oriente again was uplifted. Intensive weathering and erosion apparently continued throughout the Pliocene and extensive surfaces now represented by the Nipe and other plateaus were developed. La Cruz rocks also may have been beveled during the Pliocene (Taber, 1934, p. 595–596).

Uplift was renewed in late Pliocene or post-Pliocene time with elevation and northward tilting of the Sierra Maestra region, including the La Cruz and Manzanillo formations. At the same time the Nipe surface was elevated to its present height of about 600 meters above sea level, accompanied, according to Thayer and Guild (1947, p. 928–929) by domical uplift centered in the Sierra de Nipe and Sierra del Cristal area. There is no need to postulate differential uplift of the Sierra Maestra as one or more fault blocks, independent of the area underlain by La Cruz rocks, as suggested by Taber (1934, p. 603–604). However, it is probable that movement was renewed on established faults such as those in and near the Santiago basin and the oceanic trough along the south coast; such movement may be reflected by the minor faults cutting slightly warped and tilted La Cruz beds. Intensive erosion of the late Miocene and Pliocene peneplaned surfaces initiated by this uplift has continued to the present day.

Coastal terraces, filled estuaries, and deeply entrenched streams reflect stages of uplift and subsidence in Pleistocene and Recent time. Seismic activity along the Oriente Deep indicates that crustal adjustments are still taking place.

The various karstlands of the area surely postdate the several ancient erosion surfaces and are therefore post-Pliocene features; their evolution continues at the present time. Red clay soils and residual deposits of manganese have been formed on the mature karstlands, such as those on and near the Florida Blanca plateau.

## MANGANESE DEPOSITS

Exploitation of manganese deposits in Cuba has been restricted mainly to southwestern Oriente where the largest and greatest number of economically important deposits occur. However, deposits in other parts of Cuba are of interest as future sources of manganese and they will become more important if increasing demand for manganese leads to the development of better methods of concentration. Even deposits of manganese silicates such as those of Pinar del Río are of some potential importance although they probably will not be usable for a long time. In many places in this report the terms "low-grade ore" and "siliceous ore" are applied for convenience to material that at present is simply manganiferous rock.

Emphasis is placed on the manganese deposits of southwestern Oriente in this report, inasmuch as the bulk of our geologic work has been done in that region which has been and will continue to be by far the most important source of ore. However, the deposits in southwestern Oriente include all the types found elsewhere in Cuba, therefore the deposits in this limited area of the island will serve as examples of the deposits found throughout the country.

### MINERALOGY

Only a short summary of mineralogy will be given in this report; a detailed description involving extensive laboratory investigations will be prepared at a later date.

The manganese minerals are grouped for convenience into two principal divisions, oxides and silicates. This subdivision has economic significance also, as the silicate minerals to date have had no commercial value.

#### MANGANESE OXIDES

*Hausmannite* ($Mn_3O_4$).—Hausmannite is a rare mineral in Cuba. It was identified positively only at the Magdalena mine in the south coast district of Oriente and at El Frank prospect in Pinar del Río.

Hausmannite may also be present at La Siomara mine and El Maceo prospect in Pinar del Río.

*Manganite* ($Mn_2O_3 \cdot H_2O$).—The hydrous manganese oxide manganite was recognized in the field at the Charco Redondo, San Luis, and Unica mines and was identified through X-ray studies by J. M. Axelrod of the Geological Survey in ores from the Bueycito, Lucía, Manacas, Polaris, Quinto, Sonia, and Sultana mines, all in Oriente. In the Unica deposit manganite occurs as curious matted furlike aggregates of tiny needles traversing quartz crystals in vugs.

*Psilomelane-type oxides* (*mainly manganates of* Ba *and* K).—The psilomelane-type oxides (Fleischer and Richmond, 1943, p. 271) are the most abundant ore minerals in the Cuban deposits. They are found in all provinces where manganese deposits are known but are especially prominent in Oriente. The psilomelane minerals are by far the most common primary minerals of the deposits, and their relative scarcity compared to pyrolusite in most outcrops or in the higher parts of many mine workings is due to supergene oxidation. Important deposits in which psilomelane-type oxides are predominant include Boston, Bueycito, Charco Redondo, Corinto, Jutinicú, Lucía, Manacas, Ponupo, Quinto, Sabanilla, Taratana, Unica, and Yeya. Psilomelane minerals also compose the bulk of the ore in the chert-rubble deposits of Las Villas. The potash-bearing species cryptomelane was identified by J. M. Axelrod by means of X-ray photographs in ores from the Charco Redono, Guanabá, Lucía, Manacas, Ponupo, Ponupo de Manacal, Quinto, Taratana, and Unica deposits in Oriente, and psilomelane, a hydrous species containing barium, was found by Axelrod in ore from the Fortuna and Sonia mines in Oriente.

The psilomelane minerals usually occur as radiating or columnar aggregates of narrow prisms or needles (figs. 7–12). These aggregates commonly terminate in the rounded surfaces characteristic of botryoidal psilomelane. Psilomelane may form solid layers of high grade ore (figs. 14, 16), scattered rounded nodules (figs. 17, 18, 25) or finely disseminated granules (figs. 14, 30). At least two new psilomelane-type minerals have been discovered in Cuba. One of these minerals, tentatively named "delatorreite" after Carlos de la Torre, eminent Cuban paleontologist, is the most abundant of the psilomelane-type oxides.

*Pyrolusite* ($MnO_2$).—Pyrolusite is the most widely distributed manganese oxide mineral and is second in abundance to psilomelane-type oxides. It is found at all deposits and is the principal mineral at the Augusto Luis, España, Cádiz, Briseida, Guanabá, and Progreso mines in Oriente. It was found also in large amounts at the Taratana mine. A considerable part of the pyrolusite at the Boston, España, Lucía,

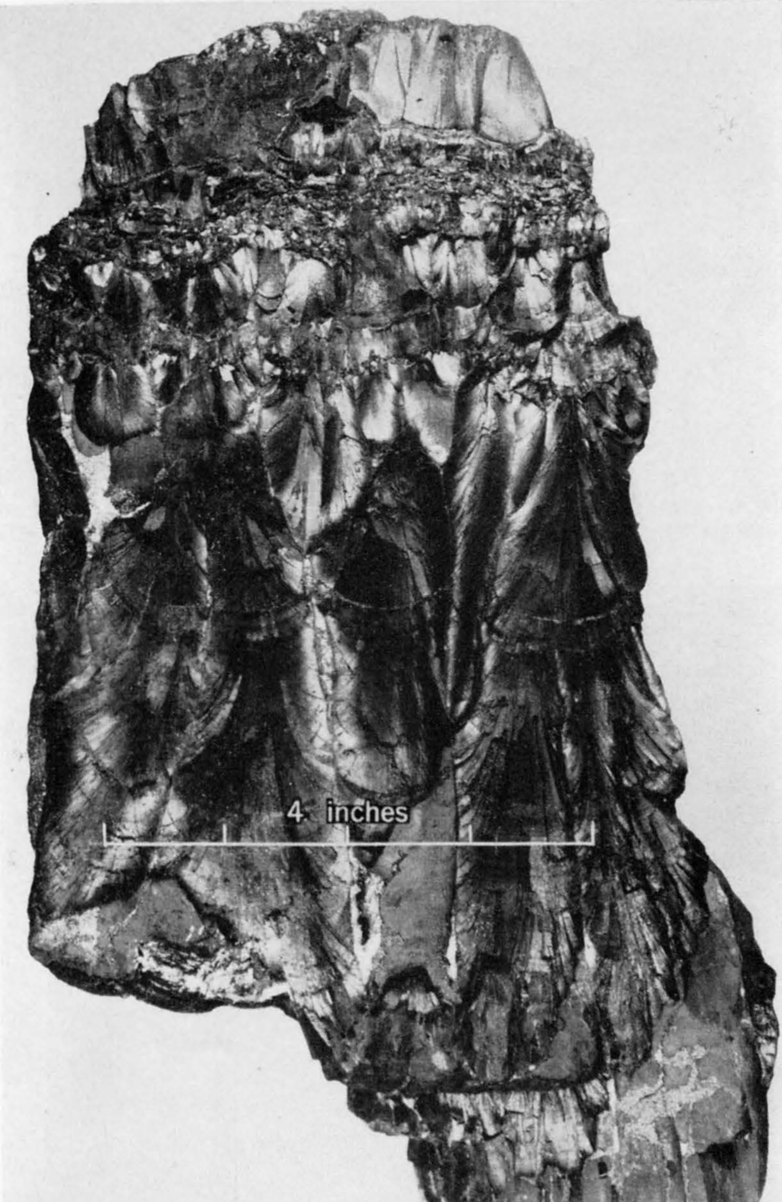



FIGURE 7.—Coarse radiating psilomelane-type manganese oxide, Taratana mine. Specimen shown in position as found; the fibers of manganese oxide invariably diverge downward. Unreplaced remnants of limy tuff are scattered through the ore.

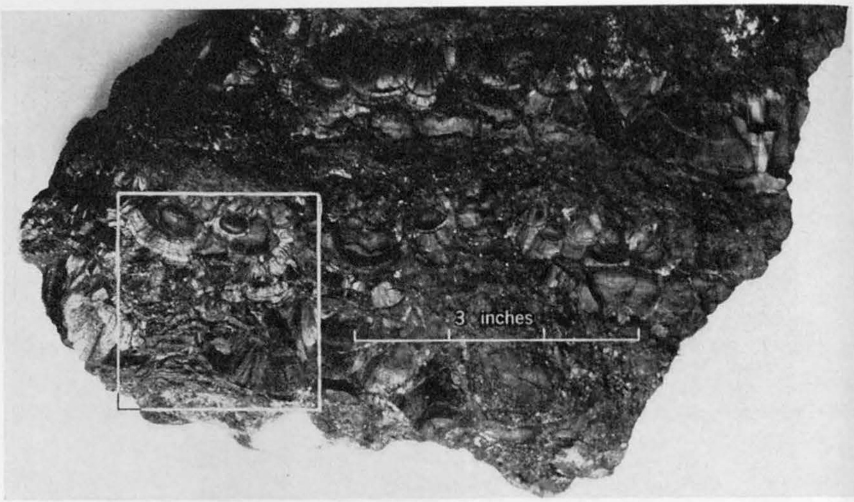



FIGURE 8.—High-grade psilomelane-type oxide from Cañada workings, Taratana mine. Layers of coarse botryoidal psilomelane alternate with thin beds of fine-grained material. Fibers all diverge downward. Inset is shown in figure 9.

FIGURE 9.—Closeup of inset shown in figure 8. Note the fine radiating fibers that make up the kidneys of ore.

Sabanilla, and many other mines has been derived by supergene oxidation from psilomelane-type oxides, and pseudomorphs of pyrolusite after psilomelane are very common (for example, fig. 13). Pyrolusite also forms by surficial oxidation from the various manganese silicates; the pyrolusite so formed often has a characteristic shiny appearance which provides a reliable clue to the nature of the primary minerals.

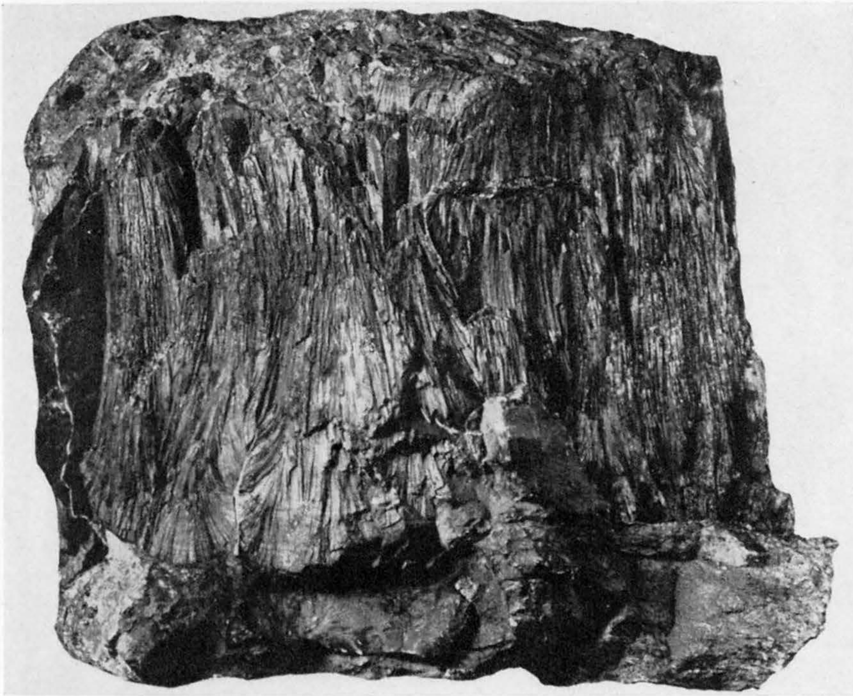


FIGURE 10.—Finely columnar psilomelane-type oxide, Boston mine. Note the feathery downward terminations of the columnar aggregates. Specimen courtesy of the Compañía Minera Boston. Natural size.

Pyrolusite is the predominant manganese mineral in the surficial deposits of Oriente. It occurs as fragments, pebbles and most commonly as pellets having a pronounced concentric structure; these pellets appear to be reconstituted manganese oxide that has been transported and redeposited under supergene conditions.

*Ranciéite* ($(Ca, Mn)O \cdot 4MnO_2 \cdot 3H_2O$).—Ranciéite has been identified in the field definitely only at the Yeya mine in Oriente and questionably at the deposits near Trinidad in Las Villas. It was found by Axelrod in ore from the Ponupo No. 3 deposit in Oriente and the Alta Gracia prospect in Pinar del Río.

428472—58——6

FIGURE 11.—Coarse columnar psilomelane-type oxide, Guanabá mine. Note the downward thickening and flaring of the individual columns. Specimen courtesy of the U. S. Commercial Company Agency, Santiago. Natural size.

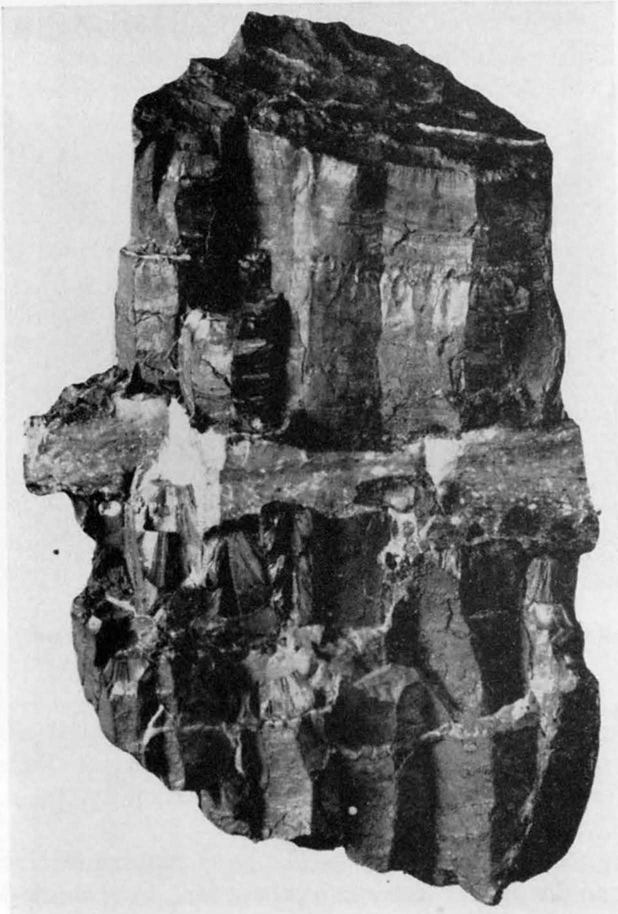


FIGURE 12.—Columnar psilomelane-type oxide, Ponupo 1 and 2 deposit. The psilomelane has replaced incompletely a white foraminiferal limestone (light-colored band across center). Natural size.

*Wad.*—The dull earthy manganese oxides collectively known as wad are relatively rare in the Cuban deposits. In the bedrock deposits they are abundant only at the Ponupo de Manacal mine and to a lesser extent at the Santa Ana mine, both in Oriente. Wad is very abundant in the residual deposits of the Quemado district in Las Villas and is the principal manganese mineral in the unimportant cave deposits of Oriente.

### MANGANESE SILICATES

*Bementite* ($H_{10}Mn_8Si_7O_{17}$).—The brown hydrous silicate bementite is fairly common in the silicate deposits. It was recognized at El Fiño and El Maceo prospects in Pinar del Río and is abundant in the Chévere and Polaris deposits in Oriente. It probably is widespread

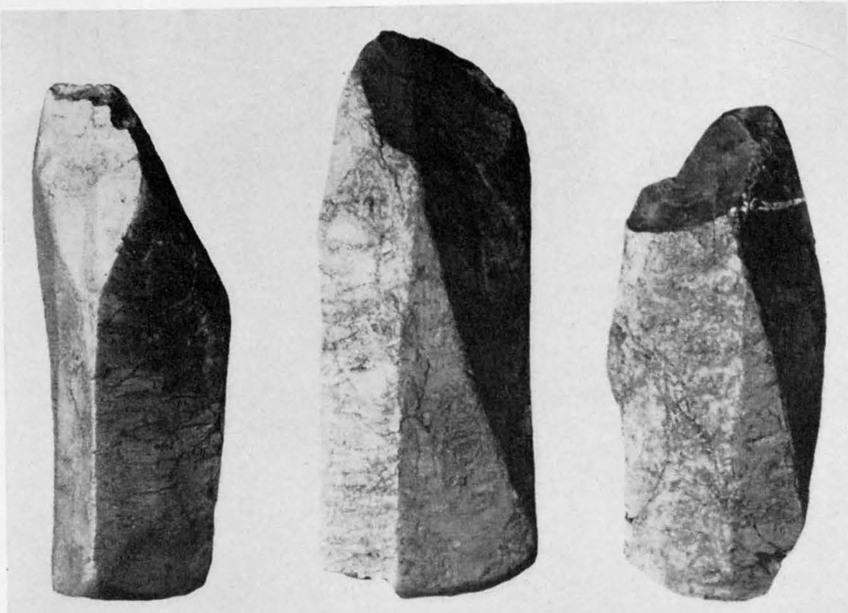


FIGURE 13.—Coarse columnar pyrolusite, Lucia mine. Note fine colloform banding in left and center specimens. Probably formed from original psilomelane-type oxide. Natural size.

in the Sigua deposits of Oriente and may be present at the Siglo Veinte deposit in the south coast district of Oriente. Outcrops of bementite are always oxidized, at least surficially, to shiny black pyrolusite.

*Braunite* ($3Mn_2O_3 \cdot MnSiO_3$).—The hard grayish-black manganese silicate braunite is a widespread constituent in the ore deposits of Oriente, but is a principal mineral only in the Sigua district and at the Venecia mine in the south coast district. It was recognized in considerable amount at the Amarito and Pasaje mines in the Manacas district and at the Cubeñas mine in the Bueycito district. Small amounts are found at the Abundancia, Ibars de Urgel, Polaris, and Unica deposits and in many of the deposits in the south coast district. Some of the pyrolusite at the Cubeñas mine is derived by oxidation from braunite.

*Inesite* ($Mn_7Ca_2Si_{10}O_{28}(OH)_2 \cdot 5H_2O$).—The pink hydrous manganese silicate inesite was seen only at the Estrella del Norte prospect in the south coast district of Oriente, where it forms small pockets of radiating prisms in impure red limestone.

*Neotocite.*—The amorphous or cryptocrystalline hydrous manganese silicate neotocite is a minor constituent at a number of mines and prospects in Pinar del Río and Oriente provinces. In Pinar del Río it was seen at El Fiño and El Maceo prospects, associated with bementite. In Oriente it is very abundant at the Polaris mine and was recognized also at the Abundancia, Antonio, Chévere, La Gloria, Ibars de Urgel, Javier, María Antonia, Siglo Veinte, and Sigua deposits. Neotocite, like its common associate bementite, is always partly oxidized to a shiny or dull black mineral.

*Orientite* ($4CaO \cdot 2Mn_2O_3 \cdot 5SiO_2 \cdot 4H_2O$).—The orange-brown hydrous manganese calcium silicate orientite is a minor mineral in certain deposits of the Bueycito district. Its occurrence has been described in detail by Hewett and Shannon (1921).

*Piedmontite* ($HCa_2(Al,Mn)_3Si_3O_{13}$).—The pink or red manganese epidote piedmontite was recognized at only three deposits: El Maceo in Pinar del Río, Finca Santa Clara in Camagüey, and Sigua in Oriente. At the Finca Santa Clara deposit, it forms small rosettes in pockets in basalt and at Sigua it is disseminated through the ore beds in many places and also occurs as tiny crystals in vugs.

*Rhodonite* ($MnSiO_3$).—Rhodonite was not recognized during the course of this study but has been reported from the Trinidad area in Las Villas by Rogers in 1917.

*Unidentified silicates*.—In addition to the silicates mentioned above, a number of nondescript brownish minerals believed to be manganese silicates were seen at the Hatuey mine in Pinar del Río and in the Holguín district and the La Justa prospect in Oriente. These minerals are quantitatively insignificant and they have not been further studied.

### GANGUE MINERALS

The principal gangue of the bedded deposits is altered andesitic, basaltic, or dacitic tuff, and the gangue minerals are largely products of the alteration of these tuffs.

*Ankerite* [$(Ca, Mg, Fe, Mn) CO_3$].—Ankerite has been reported by Rogers in 1917 from deposits near Trinidad in Las Villas.

*Barite* ($BaSO_4$).—Barite was found at Bueycito by Hewett (1921, p. 497) in druses associated with orientite.

*Calcite* ($CaCO_3$).—Black calcite is the only abundant gangue mineral in the nonbedded limestone deposits of Oriente. The black color is due to very finely disseminated manganese oxide. It is very common at the Cádiz and Unica deposits. Black calcite is a minor mineral in gangue of the Abundancia, Charco Redondo, Corinto, Ibars de Urgel, and Taratana mines and at the Camarón and Igualada prospects in the south coast district.

*Chalcedony* ($SiO_2 \cdot nH_2O$).—Small amounts of bluish-white chalcedony are disseminated in ore at the Ibars de Urgel and Manacas deposits. A description of the jasper so commonly found in the manganese deposits has been given in a previous section.

*Chlorite* (*hydrous silicates of* Al, Mg, Fe).—Bright-green or yellow-green chlorite is a common alteration product. It is especially abundant along contacts of jasper lenses, resembling the green nontronite in its mode of occurrence. Green chlorite was identified at the Manacas, Ponupo de Manacal, Sabanilla, and Santa Ana deposits, and a yellow-green chlorite was noted at the Esperancita deposit.

*Hematite* ($Fe_2O_3$).—Fine-grained earthy hematite is a minor mineral in several deposits in Pinar del Río and at the Buenavista, Eduardo, Estrella del Norte, and Unica deposits in Oriente. Specular hematite is known only from the Magdalena deposit in the south coast district of Oriente.

*Montmorillonite group.*—The most common alteration products are clays of the montmorillonite group. Nontronite is very abundant in the deposits associated with jasper. It occurs along the contacts of jasper lenses, particularly on the barren side of lenses that form one wall of an ore deposit. Inasmuch as jasper is usually found along the footwall of ore beds, nontronite is most abundant below the jasper. Such a relationship has been noted at the Augusto Luis, España, Rosita Segunda, San Luis, Tordera, and Santa Rosa mines, and probably would be found at many other deposits, such as Esperancita, Ponupo de Manacal, and Sabanilla if detailed study were made of rock alteration.

In the manganese-bearing tuff, the most abundant alteration product seems to be a pink manganiferous montmorillonite. Such a mineral has been identified in ore beds at the Augusto Luis, España, San Luis, and Santa Rosa mines and its presence is suspected at many other deposits whose gangue is largely a pinkish altered tuff.

*Pyrite* ($FeS_2$).—Pyrite has been reported from the Ponupo deposit in Oriente by Park (1942a, p. 83). It was not found during our studies.

*Quartz* ($SiO_2$).—Quartz is excessively rare in the Cuban manganese deposits. Outside of its occurrence as a primary constituent of dacitic tuff, it was found in appreciable quantities only in the Unica deposit of Oriente, where it forms small crystals in vugs.

*Zeolites* (*hydrous silicates of* Al, Ca, *and* Na).—Various pink and white zeolites are widespread but not plentiful alteration products at the Bueycito, Esperancita, Manacas, Polaris, Sabanilla, Santa Ana, and Yeya deposits. The zeolites usually are disseminated in the ore, but at Bueycito they are in tiny veinlets cutting ore beds. Analcite, heulandite(?), and laumontite(?) were identified by Larsen (in Burchard, 1920, p. 60) in ores from the Abundancia mine in Oriente, and Hewett (1921, p. 497) found analcite, chabazite, laumontite, and stilbite at Bueycito in Oriente.

## CLASSIFICATION AND DESCRIPTION OF DEPOSITS

The manganese deposits may be classified simply according to mode of occurrence, form and structural relations to wall rock, general mineralogy, and rock associations. A descriptive classification has been adopted not only because it facilitates description of the deposits but because it should prove to be the most useful in the search for new ore bodies and in the exploitation of the deposits. The great importance we attach to an understanding of the genesis of the deposits as it affects their exploration and exploitation is summarized on pages 111–112.

The present classification has evolved from the original scheme first proposed by Park (1942a, p. 84) and based mainly on rock environment, and is a modification of the basically similar system used by Park and Cox (1944, p. 313) and by Woodring and Daviess (1944, p. 383). The classification is by no means as detailed as it might be but a more complete breakdown would make the classification unnecessarily involved and would decrease its usefulness by emphasizing differences that may be more apparent than real.

### BEDROCK DEPOSITS

The bedrock deposits are enclosed in consolidated rock. They form two principal groups distinguishable by their form and by their relations to enclosing strata: the bedded deposits are lenticular bodies that in general lie parallel to bedding, whereas the nonbedded deposits are crosscutting bodies. The bedrock deposits have yielded all but a small part of the total manganese.

#### BEDDED DEPOSITS

The bedded deposits are found throughout Cuba and are the most productive type. This group contains not only the greatest number of deposits but also the largest known deposits. In many places they have crosscutting features in minor detail but in general are comformable to the enclosing strata. They are usually thin compared to their extent along the bedding and are therefore tabular bodies. Individual deposits range in thickness from a few centimeters to as much as 12 meters, have strike lengths that range from a few tens of meters to as much as 1.5 kilometers, and contain from a few hundred to 1 million tons or more of ore. The bedded deposits show the same wide range in attitude as their enclosing rocks and may be flat lying to vertical or even overturned. They occur in volcanic rocks with associated interbedded sedimentary rocks and in sedimentary rocks intercalated in volcanic rocks; a group of them form lenses in a sequence of sedimentary rocks in which volcanic rocks appear to be absent.

The bedded deposits form two more or less distinct mineralogic groups. In one group the principal manganese minerals are oxides, and manganese silicates are absent or scarce; in the other, manganese silicates are apparently the dominant minerals and manganese oxides are subordinate. Most of the bedded deposits clearly belong to one or the other of these mineralogic groups but a few are transitional. Some deposits consist of fine-grained jasper impregnated by manganese oxides and appear to contain only small amounts of manganese silicates. The transitional deposits as well as those of manganiferous jasper have all been placed tentatively in the silicate group, inasmuch as some of them, though containing a large proportion of manganese oxides at the surface, contain a relatively greater amount of manganese silicates at depth (for example, the description of the Polaris deposit, pp. 151–153). The bedded deposits fall into two groups on economic grounds also; the oxide deposits have yielded most of the ore whereas the silicate or manganiferous jasper deposits have been little exploited. Some deposits in the latter group contain fairly large reserves of low-grade high-silica manganese rock.

A number of the bedded deposits are associated with large masses and beds of jasper, but many contain little or no jasper. Distinguishing deposits containing much jasper from those containing little or none is of limited practical importance in classification, for these subclasses do not differ essentially in mineralogy, size, shape, or grade, although in general the largest deposits are associated with much jasper, and the highest grade oxide deposits contain little if any. Moreover, in the oxide deposits containing masses of jasper the highest grade ores are intimately associated with the jasper.

### OXIDE DEPOSITS

All known deposits of the bedded oxide group are found in southwestern Oriente; these deposits are the most productive in Cuba. They have been studied in greater detail than the other types and have yielded the most convincing evidence on origin.

The mode of occurrence of the various deposits is strikingly similar. All are in or are associated with water-laid pyroclastic rocks with the exception of one minor deposit in red calcareous argillite interbedded in pyroclastic rocks. Most of the deposits are in tuff or tuff-agglomerate at or near the base of a limestone bed; usually the ore bed is separated from the limestone by from several centimeters to many meters of barren pyroclastic rocks. A number of deposits lie along thin tuff beds interbedded in limestone; most of these deposits are rather distinctive in that they are higher in grade than the other bedded oxide deposits and yield shipping ore with only a small amount of hand sorting, whereas most of the other ores require milling. A few deposits are at or near the top of limestone beds, and many are distant from any known limestone.

Contacts of ore and limestone are commonly sharp; those between ore and pyroclastic rocks are usually gradational through a narrow zone. The lower contact is gradational in some deposits whereas the upper contact is generally very sharp. The ore beds taken as units are parallel to bedding of the enclosing stratified rocks but local minor crosscutting features are abundant. Lenses of limestone may be enclosed within ore beds, which in turn are enclosed in limestone; in the Taratana mine one such lens several meters long and about 30 centimeters thick is transected at several places and irregularly replaced by manganese oxides (fig. 16).

The beds of manganese oxide may either lens out abruptly or thin out gradually. Some ore zones finger out into barren pyroclastic beds; such interfingering seems to be most pronounced along the lower contact of the ore zone but usually is on too small a scale to be shown on a map. Beds in limestone generally thin out gradually; their thickness is roughly proportional to that of the tuff host rock and they extend beyond the lateral limits of the tuff only as beds a few centimeters thick in which the matrix of the manganese oxides is mainly limestone. In the Taratana district the thin marginal beds consist in places of manganese oxides containing disseminated unreplaced and unaltered Foraminifera. Some ore beds in limestone, such as those of the Corinto, Progreso, Antonio, and New York mines, pinch out conterminously with their tuff matrix, whereas elsewhere, for instance at La Gloria mine, the mineralized bed may extend beyond limits of ore as a barren layer of tuff. Some ore beds, as at the Progreso, Antonio, Yeya, and New York mines, are irregular bodies that do not thin gradually but instead end abruptly against stratigraphically equivalent limestone.

Multiple deposits of as many as four manganese-bearing layers, stratigraphically superposed one above the other and separated by pyroclastic rocks or limestone from 30 centimeters to many meters thick, occur at several mines. The phenomenon of stratigraphic superposition is all the more remarkable because commonly the thickest parts of the various beds coincide roughly, although the beds generally are not entirely coincident in lateral extent. Commonly the ore beds are elongate and the long axes of the superposed ore shoots are roughly parallel. At several mines two or more superposed beds converge and join, with attendant thinning and pinching out of the intervening limestone or pyroclastic beds (pl. 12). It is possible that this feature is observed rather infrequently only because development of many mines is not extensive enough or because convergence took place in parts of beds which have since been eroded. This vertical coincidence (in a stratigraphic sense) of ore beds, ore thicknesses, and ore shoots may prove to be more common as exploration and development proceed at many properties, although not all beds of a multiple group may be minable and therefore the extent of each bed may never be known.

Many examples of multiple-bedded oxide deposits are known. Mines of the Quinto group in El Cristo district have as many as three superposed beds. The lowest bed seems to be the least extensive, although it has not been thoroughly explored. It is separated by a few meters of tuff and agglomerate from the overlying bed, which is the thickest and most extensive of the group. This bed is overlain in turn by another bed separated by pyroclastic rocks from a featheredge to 20 meters thick. The two upper beds, both of which have been mined extensively, converge downdip and join to form one (pl. 7).

In the Tordera, San Luis, and Portugal mines and also in El Cristo district, three beds are superposed. The lowest bed is the most extensive and is separated from the next higher one by 5 to 25 meters of tuff. The second bed is separated from the highest by 3 to 6 meters of tuff and agglomerate.

Two manganiferous beds occur in the Manacas district; they are separated by 15 meters of pyroclastic rocks.

In the Taratana district four ore beds are superposed; all are along thin tuff beds in limestone. The lowest bed is the thickest and most extensive; it is separated from the uppermost bed, which is somewhat thinner and less extensive, by about 6 meters of limestone and conglomerate containing two thin and less important beds.

Three beds of manganese oxide are known in part of the Charco Redondo district. The lowest is in a discontinuous layer of tuff-agglomerate and tuff, 4 meters or less in thickness, at the base of limestone (fig. 25); the intermediate, a few centimeters to a little more than one meter thick, is along a thin tuff bed in limestone about 6 meters above the lowest bed; and the highest, also along a thin tuff bed in limestone, is about 5 meters above the intermediate bed. At one place these beds converge and join to form one bed as the intervening limestone pinches out.

The bedded oxide deposits consist mainly of psilomelane-type oxides and pyrolusite, with minor manganese silicates, that impregnate tuff, are disseminated as nodules, grains and irregular masses in tuff, and form parallel lenticular layers from a fraction of a centimeter to nearly a meter in thickness in tuff. Some ore beds of the Taratana and Charco Redondo districts consist of solid manganese oxides with only a little tuff and resemble beds of coal (figs. 14–16). Commonly the manganese oxides impregnate and replace preferentially the finer grained components of the tuff, leaving the coarser grains and fragments embedded in manganese oxide (figs. 17–19). The structure and

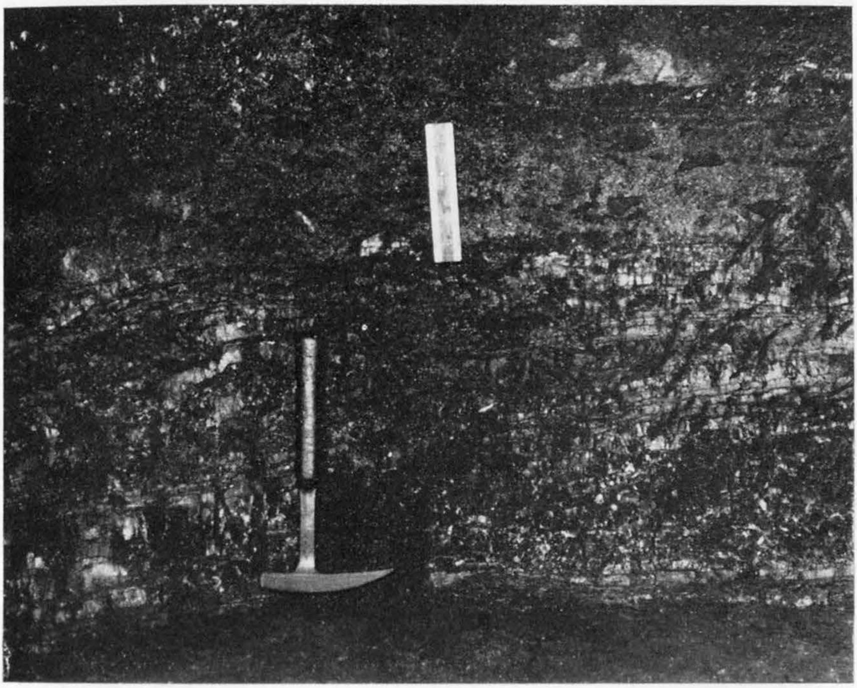


FIGURE 14.—Lower ore bed, K–6 working of Charco Redondo mine. Hammer rests on hanging-wall layer of high-grade botryoidal psilomelane-type manganese oxide about 42 centimeters thick. Scale is on 18 centimeter bed of low-grade manganiferous tuff. High-grade ore appears again at footwall.

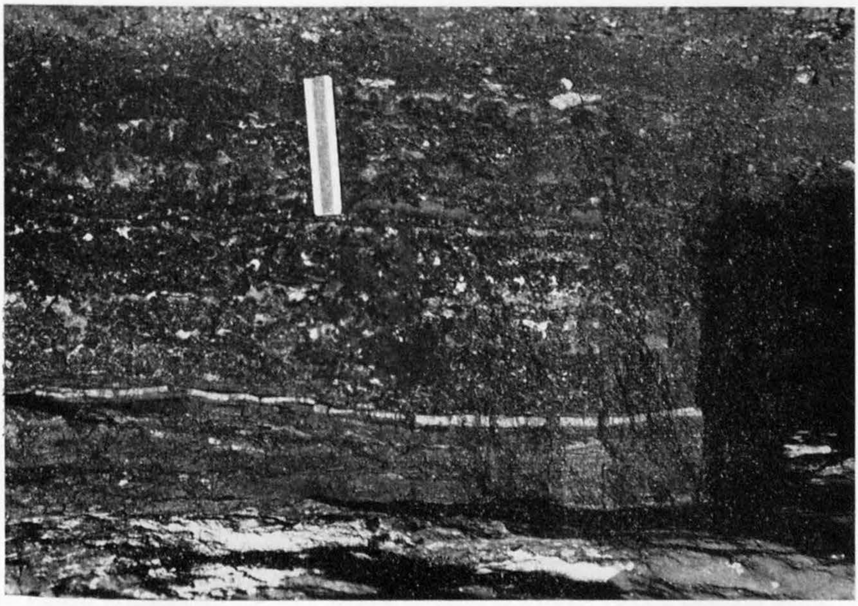


FIGURE 15.—Lower ore bed in K–6 workings of Charco Redondo mine of essentially solid medium-grade manganese oxide. Scale is 18 centimeters long. Tiny gray flecks in ore are unreplaced tuff; larger white patches are calcite.

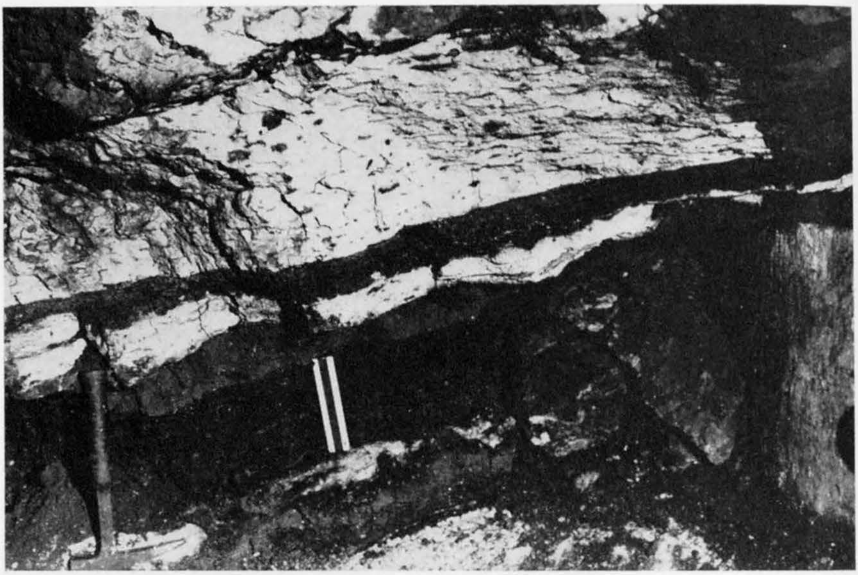


FIGURE 16.—Lower ore bed and overlying thin ore bed, Lego workings of Taratana mine. The thin ore bed averages less than 3 centimeters in thickness but is found throughout the mine, 15 to 60 centimeters above the lower ore bed. Scale rests on black psilomelane-type oxide, overlain by a few centimeters of dull gray pyrolusite.

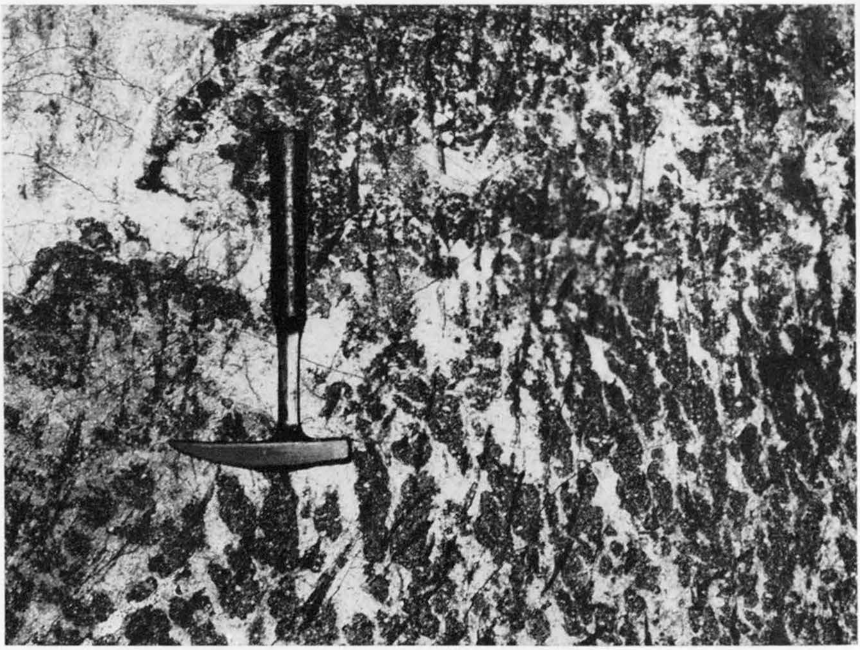


FIGURE 17.—Low-grade tuff ore in basal ore zone, central workings, Casualidad mine. Nodules and irregular patches of manganese oxide replace soft highly altered tuff. Note sharp irregular contact between ore and unreplaced tuff and abundance of unreplaced tuff grains and fragments in the nodules. The black streaks are pick marks in the soft ore.

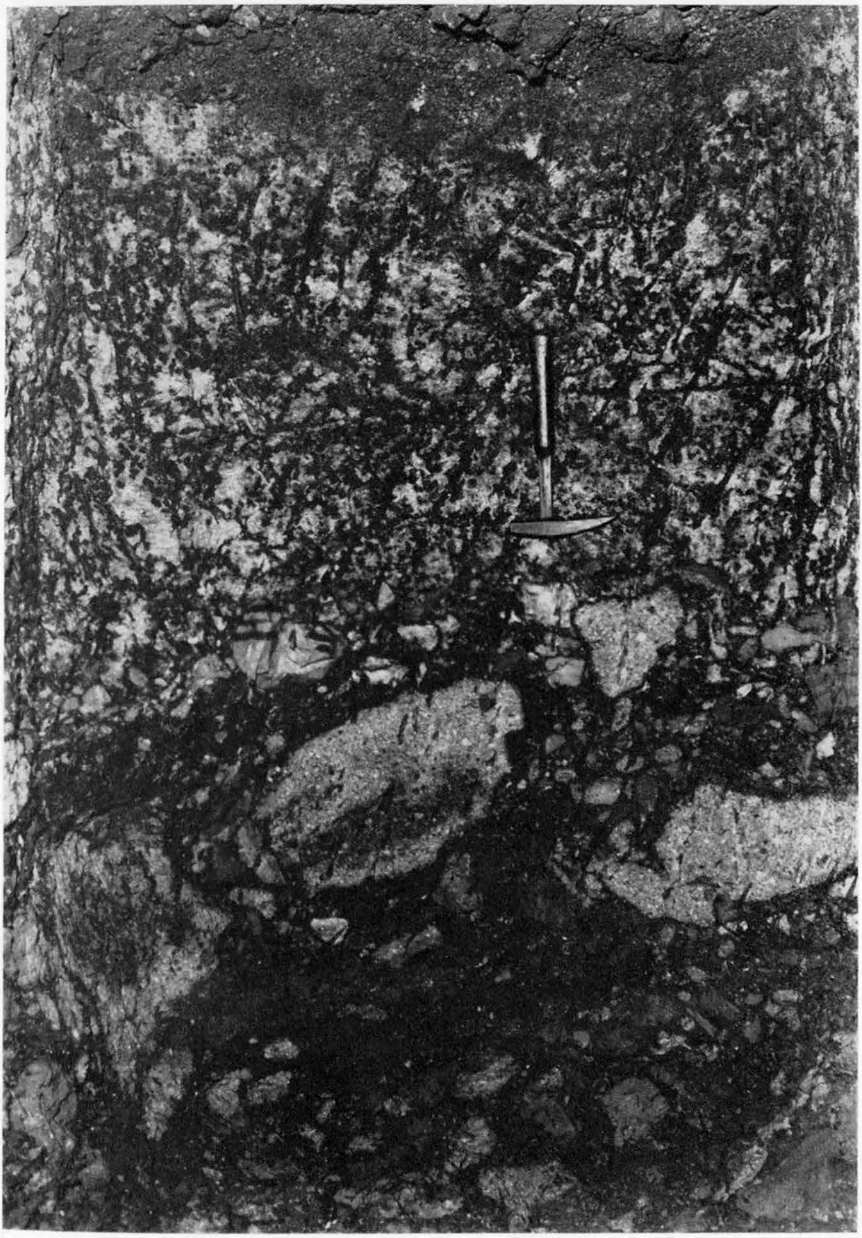


FIGURE 18.—Basal ore zone, central workings of Casualidad mine. Lower half of picture is low-grade nodular tuff ore similar to that in figure 17; upper half is coarse agglomerate whose matrix has been replaced irregularly by manganese oxide. Note large size and irregular shapes of the agglomerate fragments. Total height of exposure is about 2 meters.

FIGURE 19.—Manganese oxide replacing matrix of tuff-agglomerate in basal ore zone, Socías workings of Charco Redondo mine. Scale is 18 centimeters long. Note coarse high-grade psilomelane-type oxide at hanging wall and incipient replacement by manganese oxide of large tuff fragment below and to right of scale.

texture of the tuff agglomerates, almost invariably massive, is remarkably preserved and accentuated, for the manganese oxides commonly impregnate the tuff matrix whereas the larger boulders and blocks of coarse tuff and limestone are usually unreplaced, although tuff blocks here and there are in some places partly altered to manganese oxides (figs. 19, 20). Blocks of altered tuff and lava, usually rounded and as much as 1.5 meters long, are scattered through many ore beds and are rarely replaced by manganese oxides.

Small amounts of manganese silicates were recognized at the Abundancia mine in the Palmarito district, the Polaris and La Gloria mines in the Candelaria district, and the San José and La Justa prospects in the Güisa district. Only in part of the Polaris deposit are the manganese silicates abundant enough to have a markedly deleterious effect on the grade of the ore.

Manganese oxides in tuff commonly show a rather unusual structure that is interpreted as a replacement phenomenon and is characterized by tuberose or rounded elongate masses of manganese oxides that cut across tuffs more or less normal to the bedding planes. These elongate nodules are roughly parallel and usually are crowded close together, in places touching one another but in other places separated by

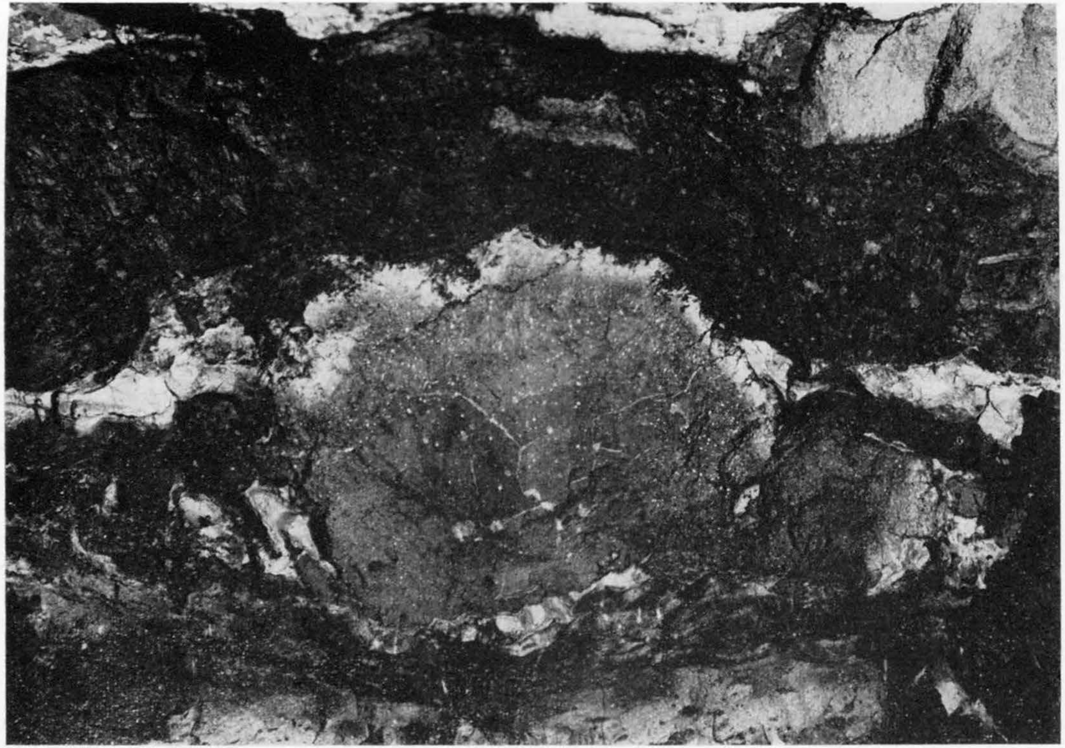


FIGURE 20.—Large boulder of amygdaloidal lava in lower ore bed, west-central part of the Cañada workings, Taratana mine. The boulder is 67 centimeters long. It is fresh at the center but is bleached and slightly replaced by manganese oxide along its upper edge. Arching of the layers of psilomelane-type oxide over the boulder may be an original structure but also may be due in part to subsequent differential compaction. The lack of alteration along the lower border of the boulder and the depression of the layers of manganiferous tuff below the boulder suggest that the boulder was dropped onto a semiconsolidated bed of tuffore.

barren altered tuff. They are concentrated in distinct layers and occupy well-defined strata. They project downward, in a stratigraphic sense, from the base of layers of solid manganese oxides, from the base of massive layers of tuff impregnated by manganese oxide, and from the base of mineralized tuff-agglomerate. They have never been observed to project upward from such layers, and are accordingly somewhat analogous to stalactites except that they were not formed by precipitation in open space but by a process of replacement. They may be called replacement "stalactites" for want of a better term. They also bear a crude resemblance to dendrites except that they are not flattened forms but are roughly circular in a plane normal to their long axes. In some deposits, for instance the Quinto mine near El Cristo, layers of these replacement "stalactites" alternate with layers of massive manganese oxides; some of the "stalactites" project from the base of massive layers to end against the layer below, whereas others do not reach the lower layer but taper downward and end abruptly in altered tuff.

The replacement "stalactites" range in length from a few centimeters to nearly a meter, and in diameter from a fraction of a centimeter to as much as 10 centimeters. The shorter "stalactites" are commonly simple and terminate downward in a rounded end; the longer forms are compound or branching and the individual branches terminate in rounded ends. Commonly the branches are short and project in an overlapping manner from the main stems so that in outcrop the "stalactites" appear to have a pseudobotryoidal structure (figs. 21, 22).

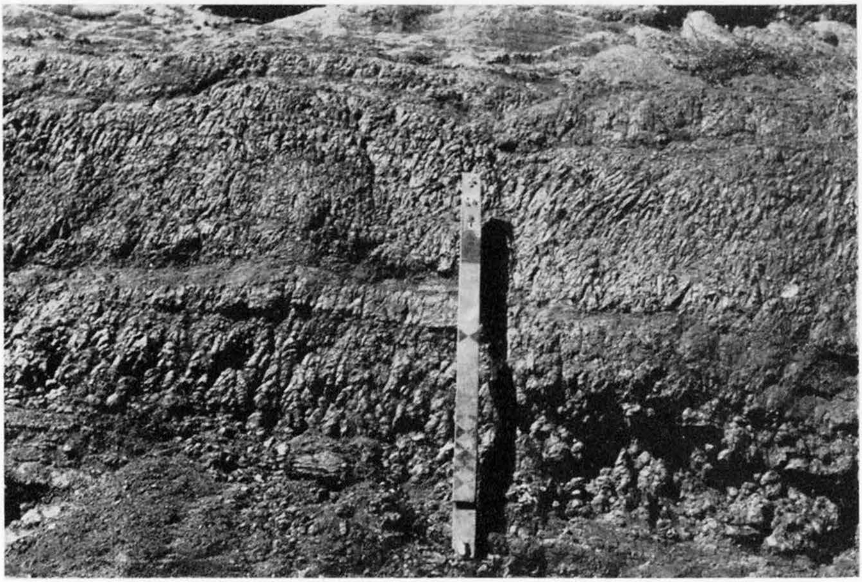


FIGURE 21.—Replacement stalactite ore, main bed of Quinto deposit. Stadia rod is about 5 feet (1.5 meters) long. The stalactites are concentrated along two tuff beds separated by a thin layer of disseminated ore.

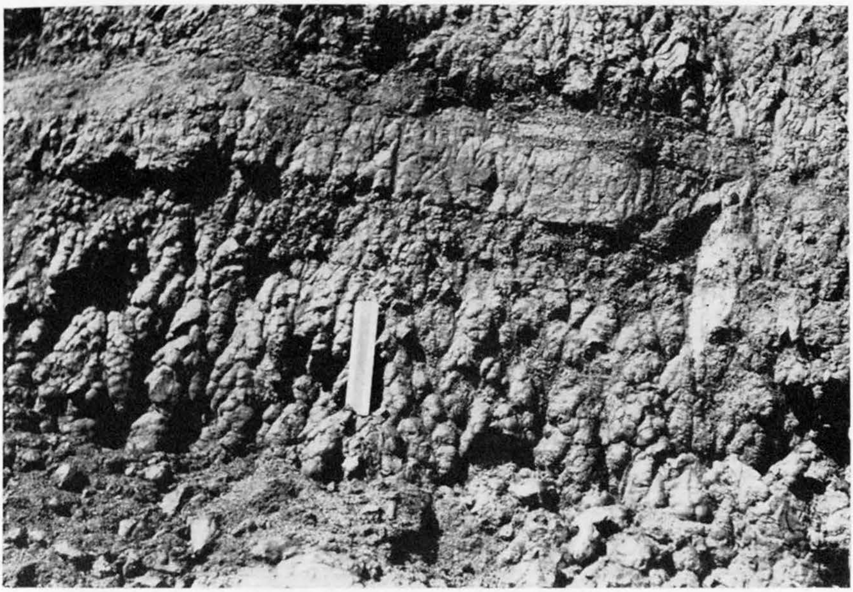


FIGURE 22.—Closeup of part of ore bed shown in figure 21, showing appearance of stalactites in detail. Scale is 18 centimeters long.

Bedding structures of the enclosing tuff extend undisturbed across the "stalactites" and are commonly emphasized by differential concentrations of manganese oxides along certain tuff layers (fig. 23). The "stalactites" part readily in parallel layers along the bedding planes.

Some "stalactites" consist of practically solid manganese oxides but more commonly they contain many unreplaced grains of tuff altered largely to clay. Many contain about as much altered tuff as manganese oxides, and are therefore very low in grade.

Replacement "stalactites" occur also in limestone beds in or adjacent to ore beds in tuff (fig. 24) and in calcareous tuff (fig. 25). They are similar to those in tuff but as a rule are more perfectly developed, have a more pronounced treelike form, and consist of nearly pure manganese oxides. They always lie at a high angle to the bedding, just as in the tuff deposits, and they always appear to have grown stratigraphically downward.

Lenticular masses of jasper, (called bayate in Cuba) are associated with many of the deposits. The lenses differ greatly in size. The largest known single lens, in the ore bed of the Ponupo mine in the Ponupo district, is about 450 meters long, 300 meters wide, and as much as 30 meters thick; the smallest masses are mere nodules (fig. 26). With a few exceptions, the jasper lenses are most extensively developed in deposits in altered tuff either completely enclosed in pyroclastic rocks, or with limestone along only one contact. A few insignificant jasper lenses and nodules not more than a few meters long

FIGURE 23.—Single nodule from replacement stalactite in main ore bed of the Quinto deposit. Natural size. Note slight concentration of manganese oxide along certain tuff layers and prominent parting parallel to bedding (top). White flecks are unreplaced tuff grains.

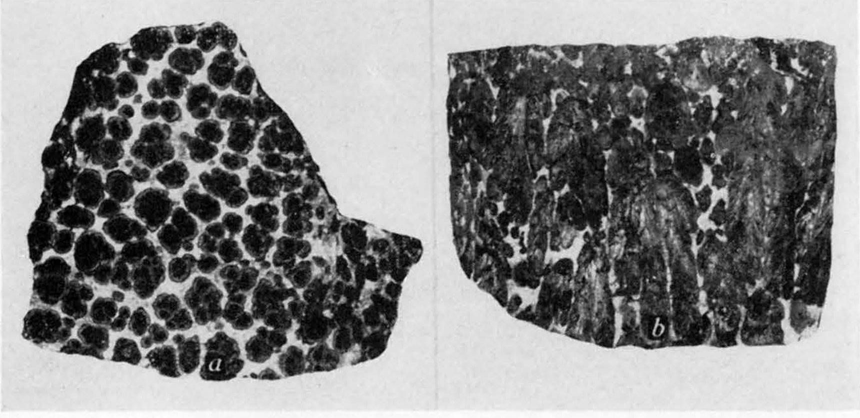



FIGURE 24.—Limestone replacement ore, Juanita mine. Irregular feathery pencils of psilomelane-type oxide replace massive limestone; pencils usually are separated by a thin septum of calcite. Natural size. A, Polished surface cut perpendicular to pencils of manganese oxide. B, Natural surface, parallel to pencils. Note feathery nature of the manganese oxide.

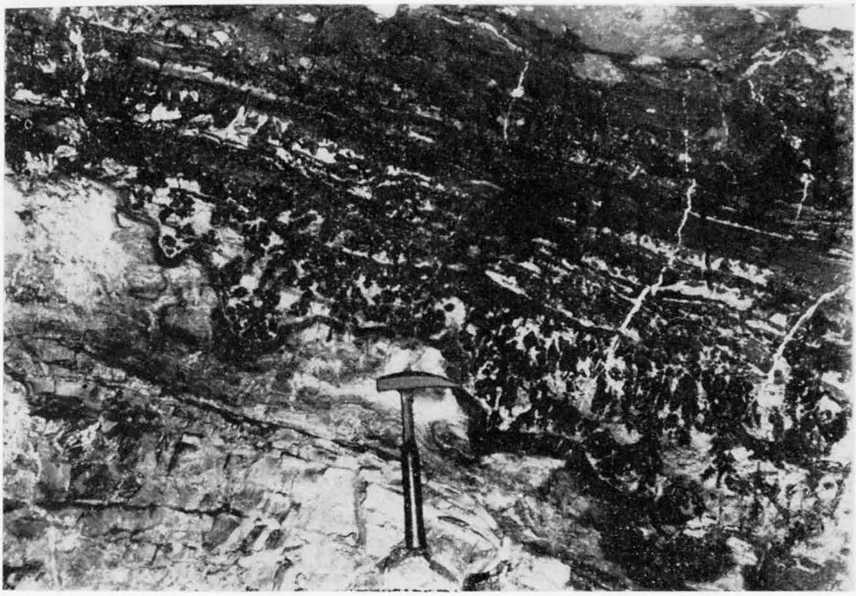


FIGURE 25.—Bedded and nodular manganese oxide replacing calcareous tuff in the basal ore zone, Caridad workings of the Charco Redondo mine. Note the highly irregular lower contact of ore and tuff, outlined by thin layer of jasper. Gangue is calcareous tuff and calcite; white veinlets are calcite. Footwall is tuffaceous limestone.

and several centimeters thick occur in some manganiferous tuff-agglomerate beds, as at the Lucía mine, and along ore beds in limestone in the Charco Redondo and Taratana districts. Within a given deposit the jasper is found for the most part in the manganese-bearing beds. At many deposits there is no jasper.

The jasper masses in general are conformable bodies which lens out abruptly and may even terminate in a vertical wall. Jasper interfingers with tuff in only a few places (fig. 41). A few crosscutting masses at the Dolores mine in Sabanilla district and the Santa Ana mine (pl. 26) in Los Negros district extend below the manganiferous zones and replace the underlying tuff, but no large jasper mass is known to cut across a manganese bed or to replace overlying pyroclastic rocks. At the Juanita deposit in the Ponupo district, a few veinlets of jasper cut ore. Beds of manganiferous tuff almost invariably overlie the jasper lenses although sometimes they extend only part way up the flanks of larger lenses so that the central part of the jasper mass may occupy the entire manganiferous zone. Ordinarily the jasper lenses rest conformably on intensely altered barren pyroclastic rocks, but in a few places a jasper lens is both overlain and underlain by a manganiferous zone. In these places a barren tuff bed a fraction of a meter thick usually separates the two zones beyond the edges of the jasper lens. Only at the Concha mine on the Río Camaroncito in the south coast district does a manganiferous zone underlie a jasper lens whose upper contact is barren of ore.

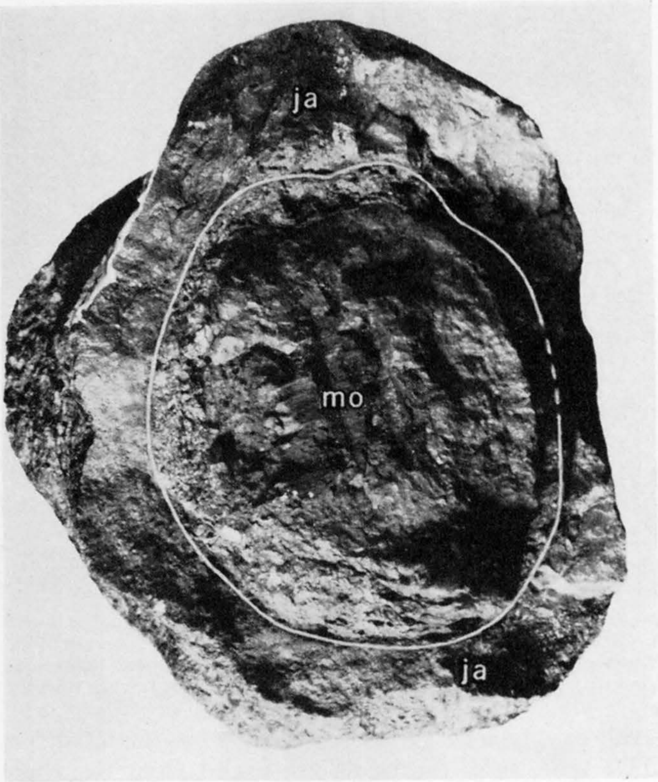



FIGURE 26.—Nodule of manganese oxide (mo) with rind of jasper (ja), Quinto deposit. The fine laminations near the center of the nodule are relict bedding of nearly completely replaced tuff. Jasper was formed later than the manganese oxide. Natural size.

In places jasper forms extensive thin beds a few centimeters thick that alternate with thin beds of intensely altered tuff. These beds are found in zones a few meters thick which underlie beds of manganiferous tuff associated with typical lenticular masses of jasper. Such beds are known only at the Sultana mine in the Ponupo district and at the Quinto group of mines in El Cristo district.

More rarely jasper forms crosscutting veins as much as one meter wide and traceable for several meters along the strike. These veins appear to occupy joints or faults of small displacement. None has been traced into conformable masses of jasper.

Pyroclastic beds over the jasper lenses are very commonly if not invariably domed, and the beds along the steep flanks of the lenses are oversteepened, thinned out, and faulted. The faults occur only along or near the edges of the jasper lenses; they usually transect bedding only on the flanks of the lenses and pass into bedding-plane faults away from the jasper. These features appear to result from differential compaction of incompetent pyroclastic beds over resistant jasper which probably occurred very shortly after the deposition of the pyroclastic bed. Such an origin is further suggested by the fact that underlying beds are not depressed and usually are not cut by the peripheral faults. The structural and stratigraphic relations of jasper masses and manganiferous tuff are evident in the Tordera, San Luis, and Portugal mines of El Cristo district, and are shown on the fence diagram (pl. 9) and structure contour map (pl. 10) of that area.

Manganese oxides are closely associated with jasper lenses and are found either within the jasper itself as irregular masses at or near the tops of the lenses or in bedded deposits extending outward along the fringes of the lenses. At many deposits the manganiferous beds a short distance from the jasper lenses are too low grade to be mined. Good examples of this intimate association of jasper and ore are the deposits of the San Luis, Tordera, and Portugal (pls. 8, 10), España (pl. 6), and Augusto Luis (pls. 4, 5) mines in El Cristo distract and the Esperancita mine (pls. 18, 19) in the Jagua district. In the San Luis, Tordera, and Portugal deposit at least 28 individual jasper lenses from 30 to 50 meters in diameter and as much as 10 meters thick are crowded into an area of 1,000 meters by 400 meters. However, the size and number of jasper lenses in a deposit bears little relation to the amount of manganese ore in it. Only one jasper lens has been found along the extensive and productive beds of the Manacas district, whereas one of the largest single lenses known, at the San Roque deposit in El Cristo district, is associated with very little manganese.

No single mode of origin can be invoked to explain all the features of the jasper masses. Some almost surely have formed by replacement (fig. 26), others perhaps owe their present characteristics to postdepositional movements, and many of the lenses are probably primary sedimentary units. At the Dolores mine in the Sabanilla district, jasper lenses along beds of manganiferous tuff terminate abruptly against stratigraphically equivalent intraformational conglomerate composed of fragments of limestone and manganese oxide. Both the upper and lower contacts of the jasper, without offset, form the corresponding contacts of the conglomerate, and the contact between jasper and conglomerate, which is nearly at right angles to the bedding, is irregular and frozen. The only reasonable explanation is that the jasper replaced the conglomerate. At another deposit (Juanita) barren jasper partly replaces a lenticular limestone. Probably very few of the jasper bodies represent lenses of completely silicified limestone; remnants of unreplaced limestone in jasper are exceedingly rare, and no limestone whatsoever is found at or near many deposits that have abundant jasper.

Intraformational conglomerate is associated with many bedded oxide deposits and consists mainly of angular fragments of manganese oxide and subangular to rounded pebbles and cobbles of limestone cemented by limestone (figs. 27, 28, 29). Minor constituents include

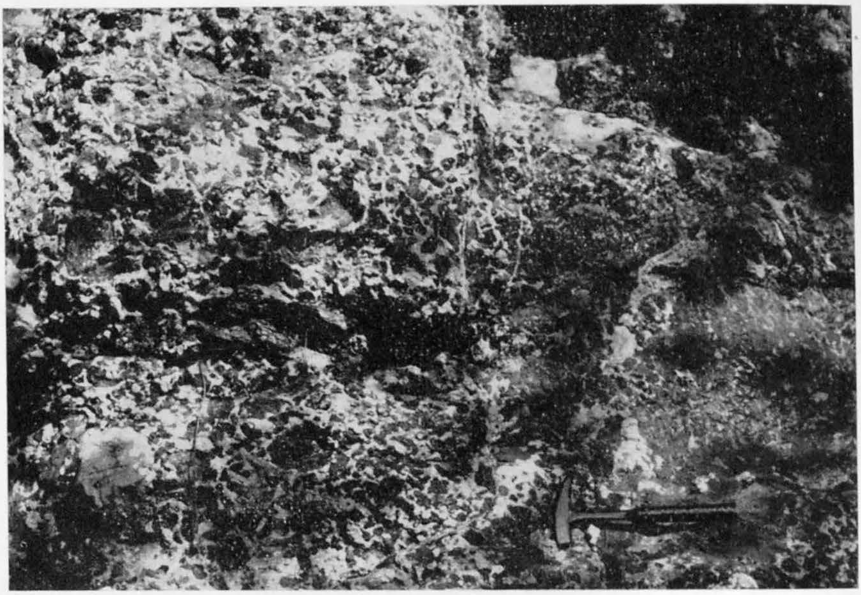


FIGURE 27.—Conglomerate composed of fragments of tuff, limestone, and manganese oxide in limestone matrix, near the portal of the Caridad workings, Charco Redondo mine. This conglomerate lies 1.5 to 2.5 meters above the Caridad ore bed. The material is known locally as mezclado (mixed) ore.

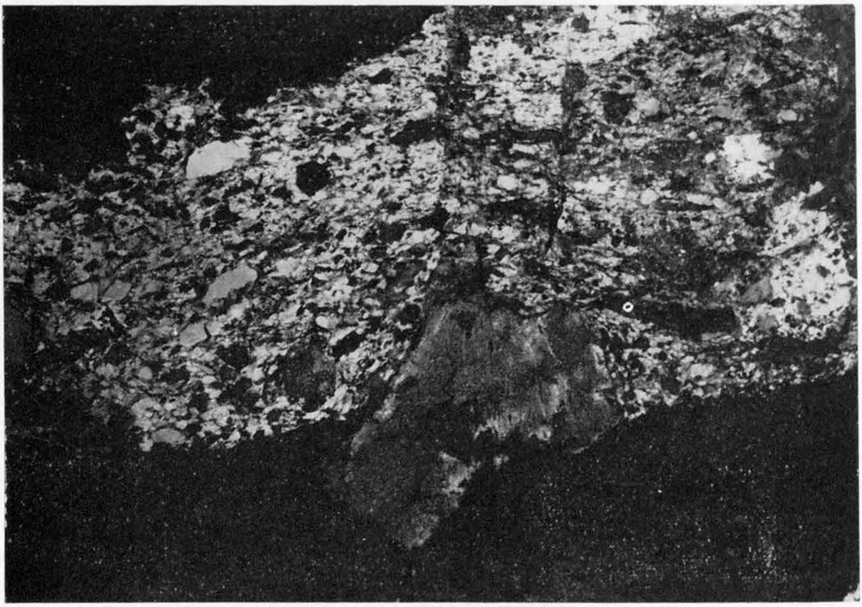


FIGURE 28.—Lens of limestone-tuff conglomerate in lower ore bed, southwest corner of Cañada workings, Taratana mine. Note large block of tuff (35 cm long) lying across contact between ore and conglomerate, and arching of conglomerate over the block. The ore is all pyrolusite. Height of exposure is about 1 meter. The layers of manganese oxide near the boulder of tuff are sharply dished, suggesting that the boulder was dropped into a semiconsolidated bed of ore.

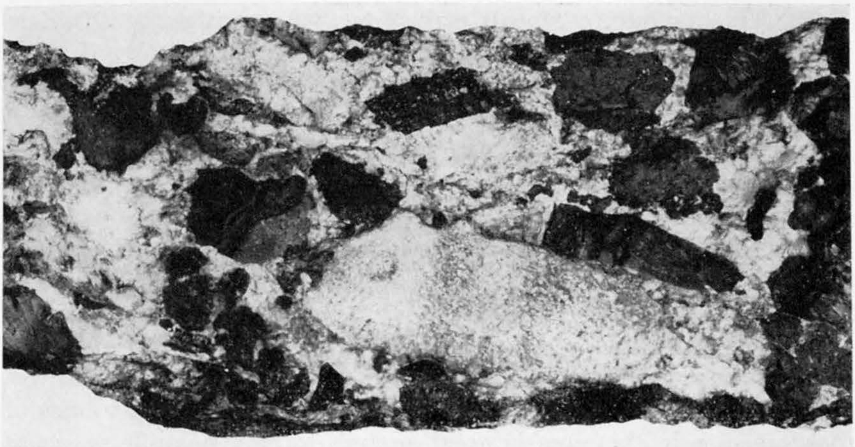


FIGURE 29.—Intraformational breccia of limestone, tuffaceous limestone, and manganese oxide in a limestone matrix, Taratana mine. Natural size. This rock is found above and below the upper ore zone throughout the mine.

fragments of tuff and lava, fragments of algal heads, and Foraminifera. This conglomerate forms extensive layers as much as 4 meters thick that overlies ore beds or forms lenses within them. It does not extend beyond the ore deposits and is found only with them. A rarer type of intraformational conglomerate consists of angular fragments of tuffaceous manganese oxides as much as 3 centimeters across, set in a matrix of altered tuff and manganese oxides. Such conglomerate is thin and of very local extent; it was noted at the base of the main ore bed of the San Luis mine in El Cristo district and in the intermediate ore bed at the Charco Redondo mine in the Güisa district.

The conglomerate beds are generally massive and poorly sorted; the proportion of fragments to matrix is extremely variable. The limestone of the pebbles and cobbles is similar to that of the matrix; it is usually foraminiferal and sometimes very tuffaceous. The fragments of manganese oxide range from a few millimeters to as much as 15 centimeters in diameter and in places make up 15 or 20 percent of the conglomerate. These fragments are similar in structure, texture, and mineralogic composition to the associated bedded ores. They are quite uniformly disseminated through the conglomerate except where it rests on locally eroded areas of the ore beds; in these places the fragments are concentrated near the base of the conglomerate. It is clear, therefore, that the fragments are derived from the immediately underlying bed and it is equally clear that these rocks are not fault breccias, for the following reasons:

1. The beds are conformable with the enclosing tuffs and limestone.

2. The angular fragments of soft manganese oxides and tuff are not crushed or deformed.
3. Some of the fragments are rounded and probably water worn.
4. The matrix limestone is uncrushed and contains undeformed disseminated Foraminifera.
5. Some conglomerate beds grade upward and laterally into normal nonconglomeratic limestone.

Apparently beds of consolidated manganese oxide and, more rarely, limestone were broken up by marine bottom currents and the fragments mixed with limy muds and ash accumulating at the same site.

The most extensive intraformational conglomerate beds are those at the Taratana mine in the Güisa district, where they form layers from 1 to 4 meters thick among the upper three ore beds. The volume of conglomerate in this area is great enough to be a possible source of ore, but the rock is estimated to contain only 3 to 10 percent manganese. Other conglomerate beds are found at the Dolores mine in the Sabanilla district where they are underlain and overlain by manganese oxides; at the Ponupo mine in the Ponupo district; at the Estrella mine in the Maffo district; at the Montenegro and Fortuna mines in Los Negros district; at the Caridad workings of the Charco Redondo mine in the Güisa district; and at La Gloria mine in the Candelaria district. At the Lucía mine in the Güisa district a lens of intraformational conglomerate only 4 meters long and 30 centimeters thick lies near the middle of a manganese-bearing tuff-agglomerate bed.

"Dikes" of tuff and limestone, analogous to clastic dikes, cut many of the bedded oxide deposits. These dikes generally cut the beds at a high angle and are observed most frequently within the ore beds themselves. They range in thickness from a few millimeters to 30 centimeters, and in length across the bedding from several centimeters to a few meters; their length parallel to the bedding appears to be at least several meters for the larger dikes. The dikes are traceable either to overlying tuff or limestone beds or, more rarely, to the underlying beds, and narrow noticeably away from the apparent source beds. They cut through layers of manganese oxide and manganiferous tuff and agglomerate (Park, 1942a, pl. 23B). Walls of the dikes can be matched in most places and the lack of offset of bedding features indicates that the dikes are not emplaced along faults.

The tuff dikes are usually fine- to medium-grained and similar in color and texture to the beds into which they can be traced. Some dikes are composed of bright-brick-red tuff, apparently colored by finely disseminated hematite and traceable to red tuffs overlying the manganiferous zones.

The limestone dikes are composed of white to cream-colored limestone containing disseminated Foraminifera, and are similar to overlying fossiliferous beds into which they can be traced.

Dikes of both limestone and tuff commonly contain angular fragments of manganese oxides megascopically indistinguishable from the minerals in the ore beds cut by the dikes. Some of the detached fragments have been moved only a short distance from their original positions and can be matched into the places from which they were dislodged. At the Quinto mine a tuff dike containing angular fragments of manganese oxide has been partly replaced by later-formed manganese oxides which have been shown by megascopic and X-ray studies to be texturally and mineralogically similar to the earlier manganese oxides.

Many tuff dikes traceable to overlying beds have been observed at the Ponupo mine and the Quinto mine; a few have been found also in the Charco Renondo and Lucía mines. At the Jutinicú mine in the district of the same name and at the Montenegro mine the few tuff dikes seen appear to be traceable to the underlying beds.

Limestone dikes are far less common than tuff dikes; they have been found in the Muñeco workings of the Charco Redondo mine (fig. 30), and in the Lucía mine (figs. 31, 32).

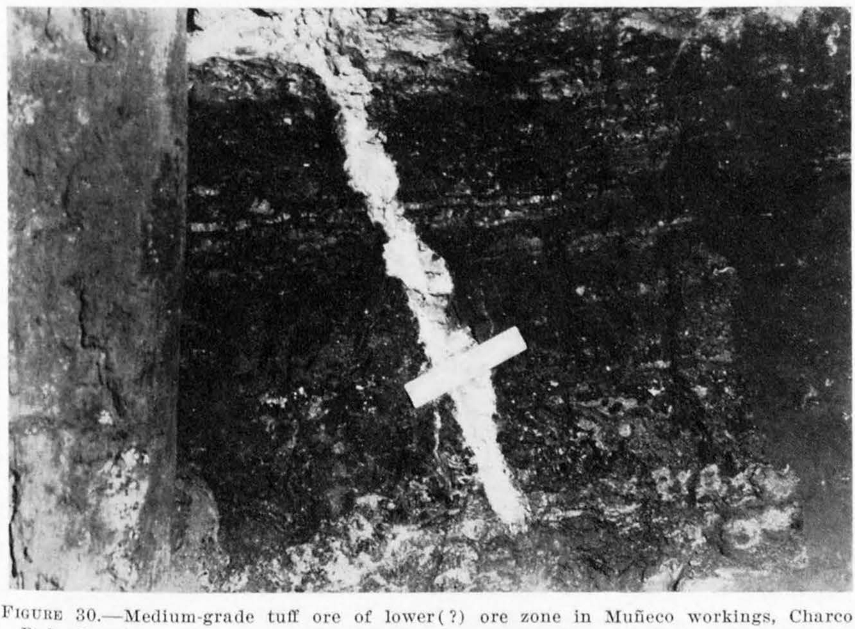


FIGURE 30.—Medium-grade tuff ore of lower(?) ore zone in Muñeco workings, Charco Redondo mine. This ore contains 30–35 percent manganese. A few patches and thin beds of high-grade ore are visible just above center and at lower right center. Ore is cut by an irregular dike of white limy tuff. Scale is 18 centimeters long.

FIGURE 31.—Dikelet of fossiliferous limestone cutting manganiferous tuff conglomerate, Lucía mine. Note alteration rinds around several tuff blocks, for example in the upper right-hand corner.

### SILICATE AND SILICEOUS OXIDE DEPOSITS

The bedded deposits of manganese silicates and siliceous manganese oxide differ mineralogically from those of the bedded oxide group and show a greater variation in mineralogy and rock associations. The silicate deposits in water-laid pyroclastic rocks are very similar to the bedded oxide deposits except in mineralogy and may be genetically related to them. Another group of deposits, apparently mineralogically distinct, occurs in red argillaceous limestone or calcareous argillite intercalated in volcanic rocks. A third general group occurs in similar "red rocks" interbedded in shale, and a fourth group of deposits consists of mineralized siliceous shale interbedded with limestone. Most of the deposits contain some free silica in the form of jasper.

The silicate deposits are more widely distributed than the oxide deposits. Those interbedded with pyroclastic rocks are found only in Oriente, mainly in southwestern Oriente; those in "red rocks" intercalated in volcanic rocks have been found only in southwestern Oriente; those in "red rocks" in shale are known only from Pinar del Río; and the shaly deposits in limestone have been found in northern Oriente and in Pinar del Río.

Most of the silicate deposits have not been exploited and many have not been intensively explored because the siliceous nature of the ore has precluded economical concentration. A few deposits have been mined selectively at the surface for their supergene manganese oxides, but, as the proportion of manganese silicates invariably increases at relatively shallow depth, recovery from these deposits has been small.

The principal manganese silicates are bementite and neotocite. Braunite is fairly widespread but nowhere very abundant. The other silicates are merely curiosities quantitatively.

The silicate deposits are lenticular or tabular bodies, most ranging from a few meters to some 100 meters in length and containing a few hundred to a few thousand tons of ore. The largest deposit, at Sigua in south-central Oriente, is traceable for nearly 1.5 kilometers, ranges from several centimeters to about 2 meters in thickness, and contains several million tons of low-grade ore.

The ore bodies in general are conformable with the enclosing rock, though locally they may transect bedding. Contacts between the ore minerals or jasper and country rock and between manganese minerals and jasper are sharply gradational. Jasper in some deposits contains finely disseminated manganese oxides and silicates. In places the manganese minerals show a crude stratification that appears to be pseudomorphic after replaced country rock but much of the material is massive. Replacement "stalactites" occur only in deposits intercalated in pyroclastic rocks in prospects of the Sigua and Gran Piedra areas of southwestern Oriente.

Lenticular masses of jasper in the deposits intercalated in pyroclastic rocks have much the same form and relation to associated manganese minerals as in the oxide deposits. Little, if any, jasper occurs in the deposits in "red rocks" interbedded in volcanic rocks. Some of the deposits in "red rocks" in shale beds contain much jasper whereas others contain only a little. Where jasper does occur in these deposits it is very intimately associated with the manganese minerals, and jasper and manganese are less distinctly segregated than in the deposits in pyroclastic rocks.

### NONBEDDED DEPOSITS

The nonbedded deposits form a group that is subordinate in number, size, and economic importance to the bedded deposits. As far as we know they consist only of manganese oxides, and many appear to be mineralogically similar to the bedded oxide deposits. Little, if any, jasper is associated with these deposits. Most of the nonbedded deposits are in sedimentary and volcanic rocks in southwestern Oriente; a few are found in metamorphic rocks of southern Las Villas.

Most of the nonbedded deposits form irregular bodies in limestone, and seem to be generally controlled by premineralization fractures. None of these deposits appears to be truly veinlike. The largest ore bodies, containing as much as 16,000 tons of ore, are distinctly pipelike in form with a circular or elliptical cross section; the ore bodies of the Cádiz (in part), Unica (fig. 45, p. 234), and Ruiseñores (fig. 44, p. 231) mines are typical. More commonly, however, the deposits consist of small irregular pockets a few centimeters to several meters across in brecciated limestone beds. Some of these breccia zones appear to be crosscutting and therefore of tectonic origin, but many seem to be sedimentary breccia a few meters thick. Pockets of tuff and blocks of tuff in the sedimentary breccia suggest that volcanism was contemporaneous with their formation. Manganese oxides in the breccia may either follow bedding planes in the limestone or form stringers transecting bedding. Some of the deposits at Hoyo Zinzonte in the Pozo Prieto area of Los Negros district are typical.

The nonbedded deposits in limestone are generally massive and contacts between ore and wall rock are usually sharp, but in places contacts are gradational through a zone several centimeters wide. Local zones of replacement "stalactites" or dendritelike branching nodules lie along some contacts, and stringers of manganese oxides very commonly extend from the ore bodies into minor fractures.

Nonbedded deposits also include irregular pockets and lenticular bodies in tuff, tuff-agglomerate, and felsite. Most of the individual ore bodies or pockets in a given deposit are found in definite stratigraphic zones several meters thick and therefore resemble the bedded deposits. This resemblance extends also to their mineralogy. Typical deposits include those of the Yeya mine in Los Negros district, where the main ore body rather closely resembles a bedded deposit except that it appears to be controlled by a number of small premineralization fractures; the Luis Antonio-Doncella mine in the Jarahueca district, where the ore bodies are associated with premineralization fractures; and the Effie mine in the Güisa district, whose irregular deposits in tuff may also be associated with a premineralization fault.

Minor nonbedded deposits occupy fault and fracture zones cutting limy schists and schistose marbles in southern Las Villas. These deposits consist of small pockets and lenses of manganese and iron oxides; they differ in mineralogy and texture from the deposits in southwestern Oriente and probably are of different origin.

### SURFICIAL DEPOSITS

The only economically important surficial deposits are the thin mantles of clay and soil containing pellets, pebbles, and fragments of manganese oxides and known in Cuba as granzón. Other surficial deposits, very subordinate in size and economic importance, consist of chert rubble cemented in part by clay and manganese oxides, and still smaller deposits that are merely accumulations of clay, granzón, and soft powdery manganese oxides on the floors of some limestone caves.

The surficial deposits are found in areas underlain extensively by limestones and rest either on limestone or on volcanic rocks near limestone outcrops. Many surface mantles of granzón in southwestern Oriente lie on or near bedrock deposits, as do all known cave deposits. However, many surficial deposits elsewhere in Cuba do not seem to be near any bedrock deposits, although those of the Quemado district of northern Las Villas are closely associated with chert rubble deposits.

Individual granzón deposits (granzoneras) are known to cover many hectares and to be as much as 2 meters thick, but most deposits are less than one hectare in area and only a few will average 1 meter in thickness. The largest granzón deposits contain more than 1 million tons of crude ore. The proportion of manganese oxide to clay and soil ranges from practically none to about 20 percent of the total volume. Pellets of manganese oxide are usually less than 2 centimeters in diameter and commonly are made up of concentric layers of oxides. In places the pellets are highly ferruginous and are sometimes referred to as perdigones (buckshot). Deposits may contain many fragments of chert in addition to manganese and iron oxides. Some deposits in southwestern Oriente contained high-grade granzón with low-iron content which was mined out rapidly because it was very easy and cheap to concentrate. In southwestern Oriente much of the granzón is concentrated in small pockets in hollows between solution pinnacles of limestone ("diente de perro").

The chert rubble deposits consist of irregular pockets of manganese oxides and red clay cementing numerous angular fragments of chert; the deposits grade into clay and chert rubble containing little or no manganese. Individual bodies are as much as several meters in width and at least 30 meters in length, and are known to be at least 5 meters thick; they contain as much as several thousand tons of low-grade ore. These deposits have been found only in Las Villas and as yet have not been exploited (p. 135–136).

Cave deposits of manganese oxides have been found only near Purial and Pozo Prieto in southwestern Oriente, and a little ore has been recovered from them. These deposits consist of clay, granzón, and soft manganese oxides that have accumulated in thin layers on cave floors. Some deposits overlie and grade into bedded tuff ores and others occur near bedded or nonbedded deposits in limestone. Park (1942a, p. 93) describes a cave deposit of the Antonio mine in Los Negros district into which stalactites of calcium carbonate project. Individual cave deposits apparently contain no more than a few tons of ore.

### RELATIVE IMPORTANCE OF VARIOUS TYPES OF DEPOSITS

The estimated production from seven types of deposits in Oriente during the period 1942–1945 inclusive is shown in the following table. It is obvious that the bedded oxide deposits yielded the overwhelming bulk of Cuban ore produced during that period.

*Estimated production of shipping grade ore from different types of manganese deposits in Oriente, 1942–45*

| Type of deposit | Approximate production (long tons) | Percentage of total production | Principal mines |
|---|---|---|---|
| Bedded oxide deposits: | | | |
| In pyroclastic rocks associated with jasper. | 761,000 | 76.0 | Augusto Luis, Boston, Bueycito, España, Portugal, San Luis, Tordera, Esperancita, Guanabá, Jutinicú, Llave, Manacas, Ponupo, Ponupo de Manacal, Quinto. |
| In pyroclastic beds in limestone | 163,500 | 16.3 | Antonio, Charco Redondo, Corinto, Progreso, Taratana. |
| In pyroclastic rocks not associated with jasper. | 26,500 | 2.5 | Briseida, Casualidad, Cubeñas, Dátil, Lucía, Montenegro, Valle de Manganeso. |
| Nonbedded oxide deposits: | | | |
| In limestone | 15,000 | 1.5 | Cádiz, Ruiseñores, Unica. |
| In pyroclastic rocks | 6,500 | .6 | Yeya. |
| Silicates and oxide deposits in pyroclastic rocks associated with jasper. | 1,500 | .1 | Chévere, Sigua.[1] |
| Surficial deposits | 30,500 | 3.0 | Briseida, La Gloria, Guanabá, Llave. |
| Total | 1,004,500 | 100.0 | |

[1] No recorded production.

## GEOGRAPHICAL DISTRIBUTION OF DEPOSITS

The geographical distribution of the various types of Cuban manganese deposits is summarized below by provinces. The deposits characteristic of three of the five provinces in which manganese has been found are rare or nonexistent elsewhere.

### PINAR DEL RÍO

The bedrock manganese deposits of Pinar del Río are found in (1) red or reddish-brown impure foraminiferal limestone intercalated in dark-colored shale, (2) in red limy shale, (3) along contacts between argillite and limestone, (4) along bedding of white, pink, or red limestone, and (5) in dark shale and argillite. Some deposits are known to be in rocks of the Cayetano and Viñales formations, of Jurassic to Cretaceous age. Manganese oxides were observed at all the prospects studied, but most of them appear to be supergene as considerable amounts of manganese silicates or manganiferous jasper were noted at many deposits. The bedrock deposits are tentatively classified as bedded silicate deposits in sedimentary rocks. Residual deposits are found also in La Jagua and Gramales districts.

### LA HABANA

The only two manganese prospects seen in La Habana were on the Isla de Pinos, but the nature of the deposit could not be determined at either prospect because of poor outcrops and lack of exploration. The country rocks are metasedimentary and the deposits are probably veins.

### LAS VILLAS

Manganese deposits are found in northwestern Las Villas near Amaro and Quemado de Güines, and in the southwestern part of the province near Trinidad. The Amaro deposits are in thin-bedded argillite and chert. They are very low grade and have not been studied in detail; they may be classified either as bedded or nonbedded oxide deposits in sedimentary rocks. A few small surficial deposits are known.

Deposits of the Quemado district are surficial deposits of the granzón and chert rubble type formed on chert, siliceous limestone, and limestone of Jurassic or Cretaceous age.

In the Trinidad district, narrow veins of manganese oxide cut a sequence of metasedimentary rocks. The oxides appear to be supergene, derived perhaps from manganiferous carbonates. The deposits are a nonbedded type peculiar to the district.

### CAMAGÜEY

Only two deposits were seen in Camagüey. One, near Jaronú, is a surficial granzón type and the other is a unique occurrence of manganese oxide, associated with piedmontite, in pockets in basalt.

### ORIENTE

Because of the great number and variety of deposits in Oriente only very brief mention can be made of the distribution of the different types within the province. The task is made somewhat easier by the fact that certain districts are characterized by certain types of deposits.

Bedded oxide deposits in pyroclastic rocks are predominant in the Bueycito, El Cobre, El Cristo, Iris-Joturo, Jagua, Jutinicú, Manacas, Palmarito, Ponupo, and Sabanilla districts and are found in a few places in the Iris-Joturo district.

Bedded oxide deposits in pyroclastic beds in limestone are typical of the Candelaria, Güisa, Maffo, and Los Negros districts and are found rarely in the Iris-Joturo district.

Bedded silicate deposits in pyroclastic rocks predominate in the Chévere and Sigua districts and are found to a lesser extent in the south coast district. Silicate deposits in sedimentary rocks are restricted to the south coast district, particularly along Río El Macho.

Nonbedded oxide deposits are found here and there in the Jarahueca district (in felsite and limestone), the Güisa district (in limestone), and Los Negros district (in agglomerate and limestone).

Surficial deposits of the granzón type have been important producers only in the Candelaria, Iris-Joturo, and Palmarito districts. The only cave deposits are in Los Negros district.

## RELATION OF DEPOSITS TO REGIONAL GEOLOGY

Certain relationships between ore deposits and regional geology have been established for the deposits of Oriente. Unfortunately, insufficient work has been done elsewhere in Cuba to draw many valid conclusions; perhaps the only significant generalization is that the deposits of Pinar del Río and Las Villas provinces are found in rocks of Upper Jurassic or Lower Cretaceous age which have been correlated with each other by both Vermunt (1937, p. 5, 12) and Palmer (1945, p. 5, 7).

### RELATIONS TO STRATIGRAPHY

The manganese deposits of Oriente are found almost entirely in the Cobre formation and the great bulk of the deposits lie within a few hundred meters of the top of the formation. This relation was first suggested by Spencer, who stated (Hayes, Vaughan, and Spencer, 1901, p. 63): ". . . there is strong evidence for believing that they [the ore deposits] lie usually at the same geological horizon . . ." Among the bedded deposits in pyroclastic rocks, the largest deposits (Quinto, Ponupo, Jutinicú, and Sabanilla districts) are in the uppermost 50 meters of the formation; a great number of important deposits (Briseida, Esperancita, Guanabá, Lucía, Montenegro, and Valle de Manganeso) are at or just below the base of the Charco Redondo limestone member, 80 to 120 meters below the top of the Cobre; and the large deposits of the Augusto Luis, Boston, España, Portugal, San Luis, and Tordera mines are 300–400 meters below the top. Deposits of the Palmarito district appear to be a short distance below the base of the Charco Redondo limestone. The most prominent exception are the deposits of the Manacas district, which lie 2,000–2,500 meters below the top of the Cobre, and the unexploited silicate deposits of the Sigua district, which also are at least 2,000 meters below the top of the formation. A few small deposits in the Santiago basin are evidently 1,500 to 2,000 meters below the top of the Cobre. The precise stratigraphic positions of deposits of the Bueycito district and the Ponupo de Manacal mine are not known, but the Bueycito deposits probably are at most only a few hundred meters below the top of the Cobre.

Deposits, both bedded and nonbedded, in pyroclastic rocks in limestone are restricted to the Charco Redondo limestone member and are usually near its base. Thus the large deposits of the Cádiz, Charco Redondo group, Taratana, and Unica mines and many smaller deposits of the Candelaria, Iris-Joturo, Güisa, and Los Negros districts are also within 100 meters of the top of the Cobre formation. The Yeya deposit, a nonbedded deposit in pyroclastic rocks, also is enclosed in the Charco Redondo limestone member.

The close relation of the manganese deposits to contacts between pyroclastic rocks and limestone was noted first by Park (1942a, p. 88–90) and later was emphasized by Park and Cox (1944, p. 316–317) and Woodring and Daviess (1944, p. 384–386).

Unquestionably, the most productive part of the Cobre formation has been the zone a few tens of meters above or below the base of the Charco Redondo limestone member. The only important deposits lying well below this zone are those of the Boston group, Bueycito district, España, Portugal, San Luis, and Tordera mines, Manacas district, Ponupo de Manacal mine and possibly the Llave mine; during the period January 1942 to August 1945 these mines yielded only about 12 percent of the total Cuban production.

Aside from the deposits that lie entirely within the Charco Redondo member, both bedded and nonbedded, a number of productive bedded deposits are in pyroclastic rocks immediately below the base of the limestone (Abundancia, Briseida, Casualidad, Charco Redondo in part, Guanabá, Montenegro, Ponupo, Valle de Manganeso), and other large deposits (Jutinicú, Lucía, Quinto) as well as a host of small deposits are in pyroclastic rocks within a few meters of the base.

Sizeable deposits lying directly above or below limestone beds other than the Charco Redondo member include the Boston group, Caridad, Dátil, and Santa Rosa mines. Finally, a number of small deposits near Río El Macho in the south coast district are in limestone or calcareous argillite interbedded with tuff. Other examples of the association of calcareous rocks and manganese have been given in the section on limestone of the Cobre formation (p. 47–49).

If a syngenetic origin for the bedded deposits is accepted (and we believe that evidence for such an origin is conclusive for many of those deposits) then it follows that many times periods of deposition of manganese minerals were followed, or less commonly preceded, by periods favorable for the accumulation of calcareous sediments.

Although the spatial association of limy rocks and ore deposits appears to be too widespread and general to be purely fortuitous, nevertheless a more general association is that between pyroclastic rocks and ore. With the exception of a few medium-sized nonbedded deposits (Cádiz—in part, Fortuna, Luis Antonio—Doncella, Ruiseñores, and Unica) and a number of minor deposits wholly enclosed in limestone, all the productive deposits are in beds of tuff or agglomerate.

428472—58——8

The great number of deposits in pyroclastic beds at or near the base of the Charco Redondo limestone and the absence of volcanic rocks above the Charco Redondo suggests that in many cases the waning or cessation of explosive volcanic activity was favorable to the deposition of manganese ores.

In a very general way the sequence of events at many deposits has been: intense explosive volcanic activity; waning volcanic activity with deposition of manganese ores and beginning of calcareous sedimentation; deposition of limestone and tuffaceous limestone with sporadic interruptions of volcanic activity followed by deposition of manganese minerals; and quiet deposition of limestone. The change from deposition of pyroclastic rocks to deposition of limestone may possibly be correlated with increasing hot spring activity during the final stages of volcanism; we believe that the manganese ores were furnished by hot springs which might also have provided part of the calcium needed for formation of the Charco Redondo limestone.

### RELATIONS TO STRUCTURE

The productive manganese deposits of Oriente are scattered over an area of almost 8,000 square kilometers underlain by rocks of the Cobre formation. No broad regional structural control of the deposits can be demonstrated. Several nonbedded deposits (Cádiz, Fortuna, Ruiseñores) are clearly localized by premineralization faults in limestone and the large Unica deposit may also be controlled in part by a premineralization fault, but most local structures in mineralized areas are postmineralization and, although they may be important from the viewpoint of exploration and exploitation, could not have played any part in localization of the ore deposits.

Perhaps the only relation of ore deposits to large structures worth mentioning is the localization of bedded deposits on elliptical or circular structural domes. Ten of these domes have been recognized, six (Botsford, Cuatro Caminos, Gloria, Manacas, Mucaral, Uraguá) in the northern foothills of the Sierra Maestra and four (Jutinicú, Ponupo, Sabanilla, Santa Cruz) still farther north. Manganese deposits are found on all but one dome (Santa Cruz) and four of these deposits are very large (Jutinicú, Manacas, Ponupo, Sabanilla). Inasmuch as the evidence for a syngenetic origin is particularly convincing for these four deposits, the association with domical structures would appear fortuitous. However, the cores of the Jutinicú, Ponupo, and Sabanilla domes consist of massive agglomerate and tuff probably representing former centers of volcanic activity. It seems probable that these same centers were the source of the hot springs believed to have deposited the manganese ores; thus the domes may be genetically related to the surrounding manganese deposits and no direct structural control need be sought.

The Manacas dome differs somewhat from the other domes in that it is composed of massive dacite porphyry upon which the ore-bearing pyroclastic rocks were deposited; the domical form is attributed in part to differential compaction of the overlying beds. The syngenetic ore beds may have been deposited by hot springs coming from a source near the same conduit through which the dacite plug was extruded.

The six domes along the Sierra Maestra foothills are elongated parallel to the regional easterly structural trend, and it is possible that their domical forms are due in part to the relatively resistant nature of their cores during tilting and folding of the surrounding rocks. However, the Jutinicú and Ponupo domes are roughly circular and their shapes are probably original, accentuated perhaps by later differential compaction over resistant cores.

## ORIGIN

### PREVIOUS THEORIES OF ORIGIN

The earliest general theory of origin for some of the Cuban manganese deposits was proposed by Spencer (Hayes, Vaughn, and Spencer, 1901, p. 63–64), who says:

> In many places, as at the Boston, Isabelita [Quinto of this report], and Ponupo mines, the evidence is complete that the manganese minerals have been brought to the position they now occupy by circulating waters and that they have replaced both the sandstone and the limestone.

In reference to the association of jasper and ore, he states:

> From the mode of occurrence it is judged that the jasper and the ore are of contemporaneous origin and were formed through the action of hot springs.

With reference to the occurrence or ore along arches in several districts, he says:

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

Burchard, who studied the Cuban deposits in 1918, says (1920, p. 56–57):

> The deposits of manganese oxides associated with masses of jasper or bayate appear to have been one of the earliest of the several types of ore to be formed. The field relations of the jasper bodies indicate that the jasper has been deposited in the limestone and glauconite beds by solutions that have enlarged openings along joints and crevices and locally replaced the enclosing rocks by silica and manganese minerals. The relations of the manganese minerals to the jasper as observed in thin sections suggest that the manganese and silica have been deposited very nearly contemporaneously. . . . The nature of the regularly bedded deposits . . . is of considerable interest. . . . The original material of the beds,

without much question, is volcanic tuff. . . . The manganese minerals appear to have been introduced later in waters that readily moved along the porous beds, the materials of which they partly replaced . . . the proximity of volcanic rocks to the manganese-bearing areas in Oriente Province, and the broader structural relations of the region suggest the possibility that the managanese was derived from volanic rocks of the Sierra Maestra, transported by artesian waters and deposited, together with silica, as masses of manganiferous jasper in joints, fissures, and cavities in the limestone and other rocks in the local anticlines of the basin, as well as along the beds of the more porous tuff.

Norcross, in his discussion of properties of the Cuban Mining Company, says (1940, p. 2):

The rocks associated with the deposits of manganese ore are Early Tertiary marine volcanic tuffs accompanied occasionally by limestone. These strata were warped and folded almost contemporaneously with deposition, and were later intruded by a granodiorite batholith, which now is exposed in the Sierra Maestra chain. Manganese mineralization in Oriente Province is of a regional character and probably had its inception in hydrothermal activity incidental to this intrusive epoch. Faulting attended and followed the mineralization.

Hewett (*in* Park, 1942a, p. 91–92) considers the bedded oxide deposits, such as Charco Redondo, to be of sedimentary origin, but he believes that all the hydrous silicates (bementite, neotocite, orientite), zeolites, and silica in the region are products of widespread hydrothermal activity and that some of the manganese oxides also were deposited by hot waters.

Park's ideas on origin are summarized in his report (1942a, p. 92–93):

The deposits have none of the characteristics of superficial accumulations of manganese oxides concentrated by weathering. Cuba is subject to alternating seasons of heavy rainfall and drought, and much of the land is deeply weathered. Under such conditions superficial concentration by ordinary weathering processes should be expected. Such deposits, however, are unusual. Granzón and soft black powdery soil derived from nearby bedrock deposits are widely distributed but accumulations of residual manganese oxides derived, like bauxite and lateritic iron ores, from the decomposition of large rock masses are unknown. . . . Pyrite is found near several ore bodies, both above and below them. The presence of unaltered pyrite in porous beds directly overlying manganese oxides indicates that ordinary processes of oxidation have not been active since the formation of the pyrite. . . . It is concluded that the manganese of the deposits of Oriente, excluding the granzón, was derived from warm springs. It is believed that the warm waters rising along conduits deposited manganese oxides at favorable places along the conduits and in adjacent porous beds, partly by direct deposition in openings and partly by replacement of tuff or limestone; it is also believed that warm water reaching the sea deposited manganese oxides as a primary sediment. Deposition is thought to have taken place during the last stages of the Sierra Maestra volcanic activity, in late Eocene and possibly early Oligocene times. The largest deposits were formed in a broad zone around the center of greatest volcanic activity . The ultimate source of the manganese is not known. Although this explanation is advanced particularly for the deposits of Oriente, a similar origin is considered to be likely for the deposits in Pinar del Río and Las Villas Provinces.

In a later publication (Park and Cox, 1944, p. 316–317), certain of Park's earlier ideas are discussed at greater length:

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

### ORIGIN OF DEPOSITS IN ORIENTE

It is obvious from the foregoing descriptions of the various types of manganese deposits that no single mode of origin can be proposed for all the types nor indeed for all the deposits of any given type. The following discussion of the origin of bedded and nonbedded deposits will be limited to the deposits of Oriente.

#### BEDDED DEPOSITS

A number of features of bedded deposits furnish evidence as to their origin.

1. The matrix of tuff ores and the tuffaceous matrix of manganese-bearing agglomerate are usually intensely altered to a montmorillonite

clay, commonly a pink manganiferous variety. This alteration is limited to the manganiferous portions of a given bed and disappears within a short distance laterally from the mineralized area.

2. If lenticular jasper masses are associated with a given deposit in pyroclastic rock, the country rock along the lower contact of the jasper is usually intensely altered to nontronite but manganese mineralization is usually weak or nonexistent. Manganese ore is found largely in the upper parts of the jasper lenses or in pyroclastic beds overlying the jasper.

3. The bedded deposits in plan are roughly circular or elliptical, whether they are in pyroclastic rocks or in limestone. Many individual deposits were mined out during the period of our work in Cuba, and this general circular or elliptical habit has been verified in many cases (Briseida, Corinto, España, Montenegro, Portugal, San Luis, Tordera, and Taratana).

4. Some bedded deposits consist of two or more beds stratigraphically superposed vertically one above the other. Although the superposed beds may not be entirely coincident in lateral extent, the thicker parts of the beds commonly are coincident.

5. In the deposits associated with jasper, the highest-grade ore is invariably in or close to the jasper, and the grade diminishes, some places abruptly and some places gradually, as the distance from the jasper mass increases.

6. Bedded ores in limestone are almost always in intercalated beds of tuff or agglomerate, and both ore and pyroclastic rock usually lens out at about the same place.

7. Some of the largest deposits are closely associated with intraformational conglomerate or breccia containing angular fragments of ore. Such conglomerate overlies ore beds at the Charco Redondo, Montenegro, Ponupo, and Taratana deposits and underlies or is interbedded with ore beds at La Gloria, Lucía, Sabanilla, and San Luis mines. The nature of this conglomerate has already been discussed (p. 49). It is composed of fragments derived in part from the immediately underlying bed; inasmuch as some of these fragments are of manganese oxide, the underlying ore bed must have been deposited and at least partly lithified before the conglomerate was formed.

8. Clastic dikes of tuff or limestone have been noted cutting ore beds in the Charco Redondo, Lucía, Ponupo, and Quinto mines; in these mines the dikes can be traced to beds overlying the ore bed (figs. 30, 31, 32*A*). Other dikes seen at the Jutinicú, Lucía, and Montenegro mines are possible traceable to the underlying beds (fig. 32*B*). It seems likely that these clastic dikes are rather common and that they have been observed rather infrequently only because they usually are destroyed during mining. The parent rock of the

dikes obviously was unconsolidated at the time of formation of the dikes, and the dikes cut ore beds and contain fragments of manganese oxide. Accordingly, the ore beds must have been deposited and at least partly consolidated before the dikes were formed, that is, they were formed during the period of sedimentation rather than afterward.

9. In the deposits in pyroclastic rocks, the contact of the ore bed with the underlying tuff or agglomerate is usually gradational through a narrow interval, whereas the upper contact of the ore bed is generally very sharp. Contacts between bedded ore and limestone are almost always sharp, although occasionally, as at the Juanita de-

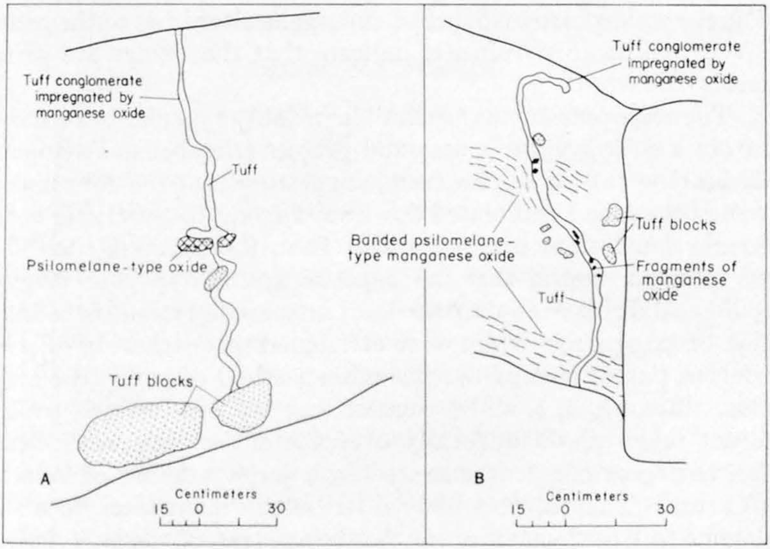



FIGURE 32.—*A*, Tuff dikelet cutting manganiferous conglomerate and ore, first level, Lucía mine. *B*, Tuff dikelet with fragment of manganese oxide, cutting manganiferous conglomerate, Lucía mine.

posit in the Ponupo district, the limestone may be altered for a short distance away from the contact.

10. Most of the deposits may be considered stratigraphic units as little or no crosscutting of sedimentary structure, except on a small scale (for example, figs. 16, 25), can be detected. The apparent large scale crosscutting—shown for instance, by the Quinto deposit, in which the stratigraphic interval between the top of the highest ore bed and the base of an overlying limestone ranges from a few centimeters along the north edge to 10 or 15 meters along the south edge, 300–400 meters away—may be due more to lenticular bedding than to actual crosscutting of bedding; the lenticular nature of the Cobre pyroclastic beds is evident in many places (for example, fig. 49, p. 247). Even the deposits associated with much jasper, which commonly takes

the shape of a thick lens or series of lenses, may be considered stratigraphic units in a broad way, although in detail much of the jasper and associated ore may transect sedimentary structures locally. A good illustration of the stratigraphic nature of a large group of small deposits associated with jasper is given by the Portugal, San Luis, and Tordera mines (see especially pl. 9).

11. Practically all of the deposits, and all the productive ones, are in beds of tuff or agglomerate. These beds may be part of a sequence of pyroclastic rocks or may be interbedded with limestone.

12. The complete absence of manganese carbonate and the scarcity of manganese minerals other than oxides in most of the deposits, as well as the widespread evidence of supergene alteration of the psilomelane-type oxides to pyrolusite, indicate that the oxides are primary minerals.

13. The replacement "stalactites" invariably taper or branch downward (in a stratigraphic sense) and project from beds of manganese-oxide-bearing tuff or agglomerate, suggesting that the solutions that deposited them had percolated downward from the overlying beds.

Certain conclusions may be drawn from the features cited above. Items 1 and 2 suggest that the deposits are of hypogene origin, as it would be difficult to explain the local intense alteration if the concentration of manganese oxides were attributed to weathering of a manganiferous parent rock or to some other method of supergene concentration. Items 3, 4, 5, and 6 suggest that the ore-forming processes have not taken place uniformly over the entire manganese-bearing region but have been concentrated in a large number of relatively small areas. That is, no widely distributed "manganese formation" analogous to iron formation can be demonstrated. Item 4 indicates that the same source of ore was active during more than one period. Items 7 and 8 are conclusive evidence that the deposits characterized by these features are syngenetic and were formed during or very shortly after deposition of the beds along which they lie. For deposits in pyroclastic rocks, 9 offers corroborative evidence of syngenetic origin. Item 10 is also suggestive of a syngenetic origin, although admittedly it could not suffice by itself without additional evidence. Items 6 and 11 suggest that the source of the manganese ore may have been volcanic vents, particularly in view of the fact that many bedded deposits, including some in limestone, are accompanied by very coarse tuff-agglomerate which could not have been deposited a great distance from its source (figs. 18, 19, 20, 28). In any event, it seems certain that volcanic vents from which pyroclastic material was being ejected were active during manganese deposition at some sites; the large block of lava in figure 20 and even more strikingly the smaller block of tuff in figure 28 appears to have been dropped into unconsolidated or semiconsolidated beds of manganese oxide during the actual formation of the ore bed.

It is impossible to prove that all the bedded deposits are syngenetic in origin, but it seems certain that a considerable number, including all the largest ones (Charco Redondo, Ponupo, Quinto, Taratana) were formed shortly after the deposition of their matrix material.

The silicate and siliceous oxide deposits are morphologically indistinguishable from the oxide deposits and are thought to have a similar origin. Some deposits in the south coast district are similar to the deposits of the Olympic Peninsula in Washington, whose origin has been discussed in detail by Park (1946, p. 312–314, 320–323).

### NONBEDDED DEPOSITS

The nonbedded deposits are irregular bodies in either limestone (Cádiz, Ruiseñores, Unica), tuff (Effie), tuff-agglomerate (Yeya), or felsite (Luis Antonio-Doncella). They all lie at or near the base of the Charco Redondo limestone member. These ore bodies have formed by replacement of their host rocks, usually along fractures or faults, and are clearly epigenetic (see fig. 45, p. 234). They are found however, in the same general environment as the bedded deposits, except that the Ruiseñores and Unica deposits are not closely associated with pyroclastic rocks, and are similar mineralogically. It seems likely that they were formed at a late stage in the period of manganese deposition, perhaps more or less contemporaneously with the uppermost of the bedded deposits in limestone; at least there is no reason to postulate a much later stage of mineralization, especially considering that no hypogene manganese deposits have been found in rocks younger than the Cobre formation.

### SURFICIAL DEPOSITS

Very little work has been done on the origin of the granzón type of surficial deposit. Park and Cox (1944, p. 317) say:

> Granzón deposits have apparently been formed by actual solution and transportation of manganese oxides for short distances in ground waters. Some granzón 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.

We have been able to add practically nothing to their summary except to emphasize the close relation, in Oriente at least, between bedrock deposits and surficial deposits; all the highly productive surficial deposits in Oriente (Briseida, Gloria, Guanabá, Llave, Pozo Prieto) are clearly derived from immediately adjacent bedrock deposits. Part of the ore is obviously detrital, but part of it seems to have been dissolved, transported short distances, and redeposited.

The origin of the chert rubble and residual deposits of Quemado de Güines in Las Villas is discussed in the description of that area (p. 132–138).

### SOURCE OF MANGANESE

According to the general ideas on origin presented above, that the Oriente manganese deposits are hypogene, syngenetic to a large degree, and intimately associated with pyroclastic volcanic rocks, we believe that the most likely source of the manganese was hot springs which became particularly active during Cobre volcanism. The association of syngenetic deposits with structural domes having cores of coarse agglomerate, discussed on page 102, and the common association in other deposits of coarse agglomerate and ore suggest that in some cases these springs may have issued through the same vents as the pyroclastic rocks. The intimate association of manganese oxide and jasper appears to be very strong evidence that the source of both was the same; jasper is usually deposited before the manganese minerals, but the two appear to be inextricably linked in every deposit in which they occur together. The prominently bedded nature of much of the ore, the localized intense alteration of country rock, the great amounts of manganese concentrated in relatively small areas, and the occurrence of beds and irregular masses of essentially solid manganese oxide do not support the theory that the manganese was derived from the volcanic rocks themselves. This theory has been discussed by Park and applied by him to the manganese deposits of the Olympic Peninsula in Washington (1946, p. 320–323) but these deposits are geologically very different from most of the Oriente deposits and furthermore they contain far smaller amounts of manganese, amounts that are insignificant compared to the tonnages present in many of the Cuban deposits.

The preceding short summary of our views on the origin of the Cuban deposits is not meant to be a final statement. Inasmuch as laboratory studies, many bearing on the problem of origin, have not yet been completed, only a resumé of the field evidence has been presented. A more extensive treatment of origin and localization, including a detailed discussion of the very common association of jasper and manganese oxide and the environment in which the psilomelane-type oxides were deposited, will be forthcoming at a later date.

## AGE OF MINERALIZATION

### DEPOSITS IN PINAR DEL RÍO

The manganese deposits of Pinar del Rio are found in rocks of the so-called Viñales, Cayetano, and "San Andrés" formations which appear to be Late Jurassic or Early Cretaceous in age. Inasmuch as the ore deposits are believed to be syngenetic in origin for the most part, they also are of Jurassic or Cretaceous age.

#### DEPOSITS IN LAS VILLAS

The chert rubble and residual deposits of northwestern Las Villas are derived from manganiferous rocks of Late Jurassic or Early Cretaceous age. The age of the primary deposits is thus similar to that of the Pinar del Río deposits. The age of the secondary deposits is not known with certainty but they almost surely are not older than Pleistocene.

The vein deposits near Trinidad are in metamorphic rocks whose age has been given as Paleozoic by some writers and as Late Jurassic by others. The age of the mineralization is unknown.

#### DEPOSITS IN ORIENTE

##### SOUTH COAST DISTRICT

The manganese deposits in the south coast district are in beds which we have correlated tentatively with the Vinent formation of Taber (1934, p. 575). The age of the Vinent formation is uncertain but is probably Cretaceous; the manganese deposits are thought to be syngenetic and the mineralization therefore would also be of Cretaceous(?) age.

##### OTHER DISTRICTS

All the manganese deposits in Oriente other than those in the south coast district are in rocks of the Cobre formation. This formation probably ranges in age from Late Cretaceous to middle Eocene, but the oldest accurately dated beds are lower Eocene and the upper part of the formation, including the Charco Redondo limestone member, is of middle Eocene age. Most of the bedded syngenetic deposits are therefore of middle Eocene age and it seems likely that the nonbedded deposits are of approximately the same age. The bedded deposits of the Manacas and Sigua districts, which lie 2,000–2,500 meters below the top of the Cobre formation, may be as old as early Eocene.

### GUIDES TO PROSPECTING

The more valuable guides to prospecting in Oriente are the concentration of ore deposits in the upper part of the Cobre formation and the association of ore and jasper. Less useful guides are the localization of deposits in limestone along faults and the association of ore with structural domes.

The most important guide is the striking spatial relation of almost all the productive deposits to the upper part of the Cobre formation, particularly to a zone at or near the base of the Charco Redondo limestone member which fortunately is a prominent lithologic unit in most of the manganese districts. Other limestone units also are known to be associated with ore deposits (p. 47–48). The most favorable zone is at the base of the Charco Redondo limestone; this zone is particularly favorable in areas near productive deposits, and even weak mineralization in these areas should be tested.

Outcrops of ore within the Charco Redondo limestone are easily seen and always merit at least a small amount of exploration as the main deposit may well be obscured by surficial accumulations of travertine. The history of the Taratana deposit, which yielded about 100,000 tons of high-grade ore, is a case in point; the main outcrop of this large deposit was neglected for many years because it was almost completely covered by secondary calcite.

Ore is commonly associated with jasper, and any outcrop or accumulation of float of this easily recognized and conspicuous rock should be investigated. The presence of large masses of jasper is not a sure clue to an ore deposit but in more examples than not it will at least indicate manganese mineralization. Upper contacts of jasper masses are more favorable than lower contacts but of course both should be explored if any manganese oxide is evident.

Indications of mineralization along known faults in limestone are favorable for exploration, as several productive deposits (Cádiz, Ruiseñores, Unica) have been found in such an environment. However, this criterion is not as useful as the preceding ones, as it could be utilized best only in areas covered by adequate geologic maps, of which only a few are available.

Structural domes are favorable sites for manganese deposits; nine of these domes are known to be mineralized. However, it is rather unlikely that many more such domes will be found in Oriente. Only one unexplored dome, that at Cuatro Caminos, offers much promise and even it is highly speculative.

## PRODUCTION

Production of manganese ore from Cuba for the years 1900–1948 is shown graphically in figure 33. Production in the United States from 1906 to 1948 and total United States imports from 1910 to 1948 are shown on the same graph for comparison. For 1943, the year of maximum production from Cuba, imports from that country formed about 20 percent of the total ore imported into the United States. The Cuban contribution to United States imports has ranged from 22 percent in 1938 to essentially none for 1908–1915 and 1920–1931, and has been a major factor in United States imports only from 1916 to 1919 and from 1937 to 1946.

Three classes of ore have been shipped from Cuba: hand-sorted or untreated ore, washed and jigged ore, and sintered flotation concentrate. Cuban manganese ore as shipped ranges in grade from 42 to more than 50 percent manganese and deleterious elements are present in negligible amount. Nonsintered ore, which ranges in grade

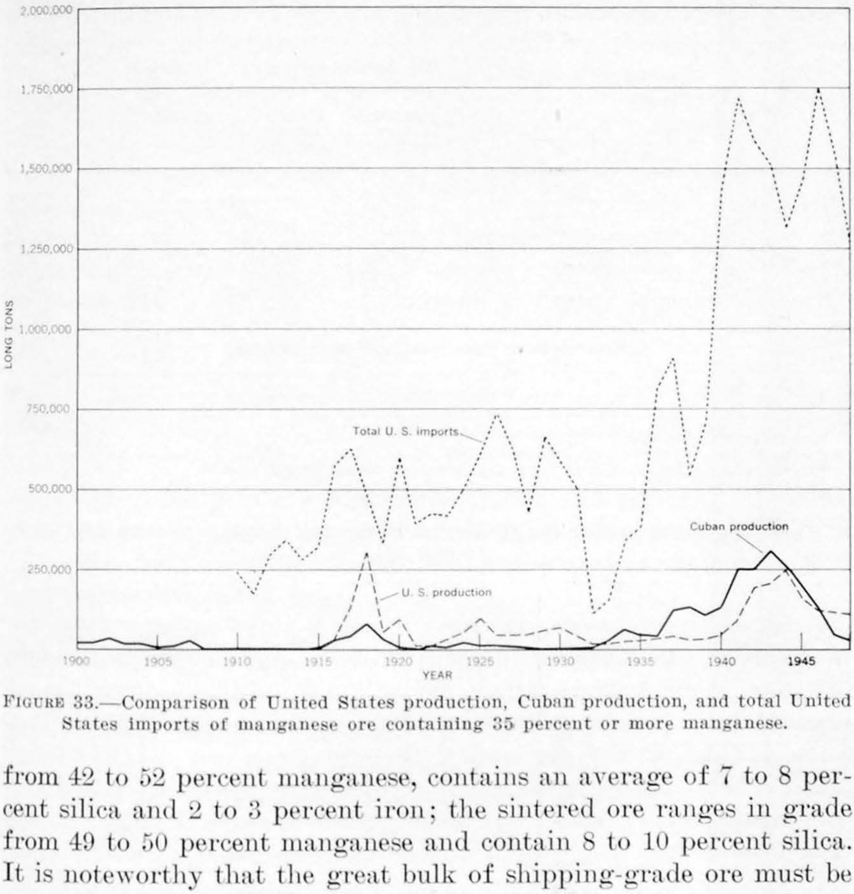



FIGURE 33.—Comparison of United States production, Cuban production, and total United States imports of manganese ore containing 35 percent or more manganese.

from 42 to 52 percent manganese, contains an average of 7 to 8 percent silica and 2 to 3 percent iron; the sintered ore ranges in grade from 49 to 50 percent manganese and contain 8 to 10 percent silica. It is noteworthy that the great bulk of shipping-grade ore must be concentrated by methods other than hand-sorting; the approximate relative amounts of ore produced in each class from 1942 to 1945 were as follows: hand-sorted ore, 18 percent; washed and jigged ore, 26 percent; sintered concentrates, 56 percent.

Annual production for the period 1940–1950 by types of ore is summarized in table 1 which emphasizes the great importance of sintered ore of the Cuban Mining Company during the period 1940–1946; during 1942–1946 more sintered ore was produced than non-sintered and it is likely that the same relative production was achieved in 1940 and 1941.

During the war years from 1942 to 1945 more than 95 percent of the ore was obtained from 17 mines or mine groups, each producing more than 6,000 tons of ore. These mines and their total production from January 1942 to August 1945, are listed in table 2. By far the largest quantity of ore was obtained from the Quinto and Ponupo mine groups of the Cuban Mining Company, which together accounted

TABLE 1.—*Annual production of manganese ore from Cuba, in long tons, 1940–50*

| Year | Metallurgical grade ore | | Chemical grade ore (82–83 percent $MnO_2$) | Total |
|---|---|---|---|---|
| | Nonsintered (45 percent Mn) | Sintered (50 percent Mn) | | |
| 1940 | [1] 130, 645 | | | 130, 645 |
| 1941 | [1] 243, 405 | | | 243, 405 |
| 1942 | 104, 573 | 140, 745 | | 245, 318 |
| 1943 | 145, 008 | 161, 290 | | 306, 298 |
| 1944 | 120, 295 | 133, 496 | | 253, 791 |
| 1945 | 64, 639 | 130, 236 | (2) | 194, 875 |
| 1946 | 35, 054 | 88, 123 | 5, 521 | 128, 698 |
| 1947 | 43, 144 | (3) | 4, 766 | 47, 910 |
| 1948 | 23, 531 | | 4, 382 | 27, 913 |
| 1949 | 50, 534 | | 10, 982 | 61, 516 |
| 1950 | [4] 88, 212 | | [4] 8, 705 | [4] 96, 917 |
| Total, 1940–49 | | | | 1, 640, 369 |

[1] Imports from Cuba; includes sintered ore.
[2] Purchases of chemical-grade ore initiated in 1946.
[3] Sintering plant of Cuban Mining Company ceased operations Dec. 21, 1946.
[4] Short tons.

TABLE 2.—*Total production of largest mines in Oriente, January 1942 to August 1945*

| Mine | Total production (Long tons) | Approximate average grade (percent Mn) | Mine | Total production (Long tons) | Approximate average grade (percent Mn) |
|---|---|---|---|---|---|
| Antonio | [1] 10, 000 | 43 | Llave | 6, 908 | 51 |
| Boston | 7, 412 | 44 | Manacas group | 9, 869 | 51 |
| Briseida | 10, 954 | 46 | Montenegro | 9, 352 | 41 |
| Bueycito | 12, 727 | 47 | Ponupo de Manacal | 6, 963 | 43 |
| Cadiz | [1] 10, 000 | 43 | Quinto-Ponupo group | [2] 37, 705 | 45 |
| Casualidad | [1] 25, 000 | 43 | Quinto-Ponupo group | [3] 565, 767 | 50 |
| Charco Redondo | 40, 519 | 44 | Taratana group | 90, 289 | 46 |
| España, Portugal, San Luis, and Tordera group | 76, 110 | 46 | Unica | [1] 20, 000 | 43 |
| | | | Yeya | [1] 15, 000 | 48 |

[1] Estimated production.
[2] Nonsintered ore from properties of Cuban Mining Co.
[3] Sintered ore from properties of Cuban Mining Co.

for about 56.5 percent of the total production in the form of sintered concentrate; approximately two-thirds of this ore came from the Quinto group. By 1945, nine of the mines listed (Boston, Bueycito, Cádiz, Casualidad, Montenegro, Ponupo de Manacal, Taratana, Unica, and Yeya) were producing either no ore or only a fraction of their former output owing to near or complete exhaustion of economically recoverable ore. These 9 mines accounted for about 19.5 percent of the total ore produced during the period 1942–1945.

## RESERVES

Generalized estimates of reserves are given in table 3. The figures are for June 1, 1954. The terms "measured," "indicated," and "inferred" are used, insofar as possible, in accordance with Geological Survey usage standards, except that the grade of mine-run ore was

TABLE 3.—*Summary of manganese ore reserves of Oriente, Cuba, as of June 1, 1954*

| | Ore, in thousands of long tons | | | Total reserves |
|---|---|---|---|---|
| | Hand-sorted | Milling grade | Low grade | |
| **Reserves** | | | | |
| Measured | 1,200 | | | 1,200 |
| Indicated | 1,000 | 400–750 | 1,500–2,000 | 2,900–3,750 |
| Inferred | 30–115 | 200–550 | 800–3,000 | 1,030–3,665 |
| Grade.........percent Mn | 35–50 | 20–35 | 10–30 | |
| Concentration ratio | 1:1 to 1.5:1 | 2:1 to 6:1 | 3:1 to 3.5:1 | |
| **Reserves in terms of concentrate (42–50 percent Mn)** | | | | |
| Measured | 1,200 | | | 1,200 |
| Indicated | 700–800 | 100–200 | 400–600 | 1,200–1,600 |
| Inferred | 20–100 | 50–150 | 200–1,000 | 270–1,250 |

estimated visually in ore bodies not drilled and sampled. Deposits more or less outlined by drilling include Abundancia, Jutinicú, Sabanilla, and the Ponupo group; the Quinto ore body is incompletely explored by drill holes.

Reserves in the table 3 are divided into three categories of ore: direct-shipping or hand-sorted ore; milling-grade ore amenable to concentration in washing and jigging plants; and low-grade ore. The concentration ratios and estimated reserves in terms of concentrates (effective reserves) are given. It is assumed that the milling-grade ores will be concentrated by the same methods employed in the past and that therefore the concentration ratios will not be materially changed; more efficient milling methods might significantly increase effective reserves of mines employing simple washing and jigging plants. The low-grade ores have been milled successfully only by flotation followed by sintering of the flotation concentrates. Concentration ratios for low-grade ores containing 16 to 18 percent manganese can be assumed to range from 3 to 1 to 3.5 to 1 if flotation is employed; the ratio will be somewhat lower for the higher-grade ores.

Reserves of the Quinto and Ponupo mines are distributed in both milling-grade and low-grade categories because part of their ore contains 20 to 30 percent of manganese and is believed to be amenable to concentration in jigging plants. Low-grade reserves of these mines include ore of milling grade which would be mined together with low-grade ores.

Reserves in terms of concentrates of 42 to 50 percent grade from hand-sorted and milling-grade ores are estimated to be 1,200,000 tons measured, 800,000–1,000,000 tons indicated, and 70,000–250,000 tons inferred. All of the measured reserves and most of the indicated reserves are in the Charco Redondo mine, and the remainder of the reserves is concentrated in relatively few deposits. Development since World War II has led to discovery of major reserves well in excess of a million tons of high-grade shipping ore in the Charco Redondo mine. For milling-grade ore, most of the indicated reserves are in the Ponupo mines. The largest inferred reserve of milling-grade ore is in the Manacas group of mines. Reserves in the low-grade category are concentrated largely in the Quinto and Ponupo mines; indicated reserves in these mines are estimated to be about 1.5 million long tons, which would yield 400,000 to 500,000 tons of concentrates of 50 percent grade if concentrated by flotation or some other equally effective process.

Reserves not listed in the summary table for Oriente include the manganese silicate ores of the Sigua district and the residual ores of the Quemado district of northern Las Villas, which heretofore have not been utilized because of concentration problems. The reserves of these areas are listed below:

| *Reserves* | *Sigua district* | *Quemado district* |
|---|---|---|
| Measured tons | 50, 000 | ---------- |
| Indicated tons | 400, 000–600, 000 | 800, 000–1, 000, 000 |
| Inferred tons | 500, 000–1, 000, 000 | 1, 000, 000–1, 500, 000 |
| Grade percent Mn | 15–25 | 5–9 |

## FUTURE POSSIBILITIES OF THE DEPOSITS

Manganese has been mined in Cuba since 1895 but the period of greatest activity in the industry was from 1937 to 1946, particularly from 1941 to 1945. During this latter period only three deposits were exploited that had not been discovered during or prior to the first World War. The Taratana mine was found in 1940 and produced about 100,000 tons of high-grade ore before it was exhausted; the Corinto mine, discovered in 1942, yielded 4,300 tons of ore; and the Ruiseñores mine, also discovered in 1942, produced only 740 tons. This very low discovery rate and the relatively small amount of ore produced from "new" mines, particularly during a period of very active prospecting and exploration, suggests that most if not all of the easily discovered manganese deposits have been found, at least in Oriente.

It is clear from the preceding section on reserves that the known deposits are by no means exhausted. Reserves of hand-sorted ore may be more than 2 million tons and reserves of concentrate from milling-grade ore may total 150 to 350 thousand tons. However, most of the reserves of hand-sorted ore are in the Charco Redondo mine and about two-thirds of the milling-grade reserves are in the Manacas and Ponupo deposits; these three deposits are the only ones capable of furnishing notable tonnages of hand-sorted and milling-grade ores during the near future, and only the Charco Redondo mine can be considered as a reasonably sure source. In contrast, 18 mines that produced some 220,000 tons of concentrates from hand-sorted or milling-grade ore during the period 1940–1945, or about 16 percent of the total production, appear to be essentially exhausted; these mines are listed below. Nine of the largest producers during that period are included in this list. In addition, the open-pit ore at the Quinto deposit, which produced approximately 35 percent of the total Cuban output during 1942–1945, is exhausted.

*Mines whose known reserves are exhausted or severely depleted*

| *Mine* | *Total production 1940–45* | *Mine* | *Total production 1940–45* |
|---|---|---|---|
| Augusto Luis | 2, 266 | Ibars de Urgel | 526 |
| Boston | 7, 412 | Lucía | 6, 000 plus? |
| Briseida group | 11, 319 | Montenegro | 9, 352 |
| Bueycito group | 12, 727 | Portugal | 6, 836 |
| Cadiz | 10, 000 | Ruiseñores | 741 |
| Casualidad | 25, 000 | Taratana | 98, 477 |
| Corinto | 4, 319 | Unica | 20, 000 |
| Esperancita | 4, 178 | Yeya | 15, 000 |
| Federico | 2, 457 | | |
| Gloria | 4, 783 | Total | 241, 393 |

It seems likely that production levels attained during 1940–45 will not be reached in the future if only hand-sorted or milling-grade ores are mined. The future of a large-scale manganese-mining industry therefore depends to a great extent on utilization of the low-grade ores of deposits such as Bueycito, Casualidad, Jutinicú, Ponupo, Quinto, and Sabanilla. This class of ore has been concentrated successfully only by flotation.

During 1940–45 the economics of mining low-grade ore and concentrating it by flotation were such that only one plant was operated. Obviously the initial investment in a flotation plant is considerably greater than in a washing and jigging plant of the same capacity, and the technical requirements for operators are also much more exacting. Apparently the prices of manganese ores prevailing during the second World War were not high enough to justify such an investment for plants, for example, at the Casualidad or Bueycito deposits. The price schedules prevailing in Cuba during 1942–1949 are shown graphically in figure 34, and corresponding domestic prices are shown for comparison.

The location of the various low-grade deposits is also a prime factor in the economics of flotation concentration. During 1940–1946, ore from the Ponupo and Quinto deposits was treated at a central plant in El Cristo. Ores from Jutinicú and Sabanilla might also have been

428472—58——9

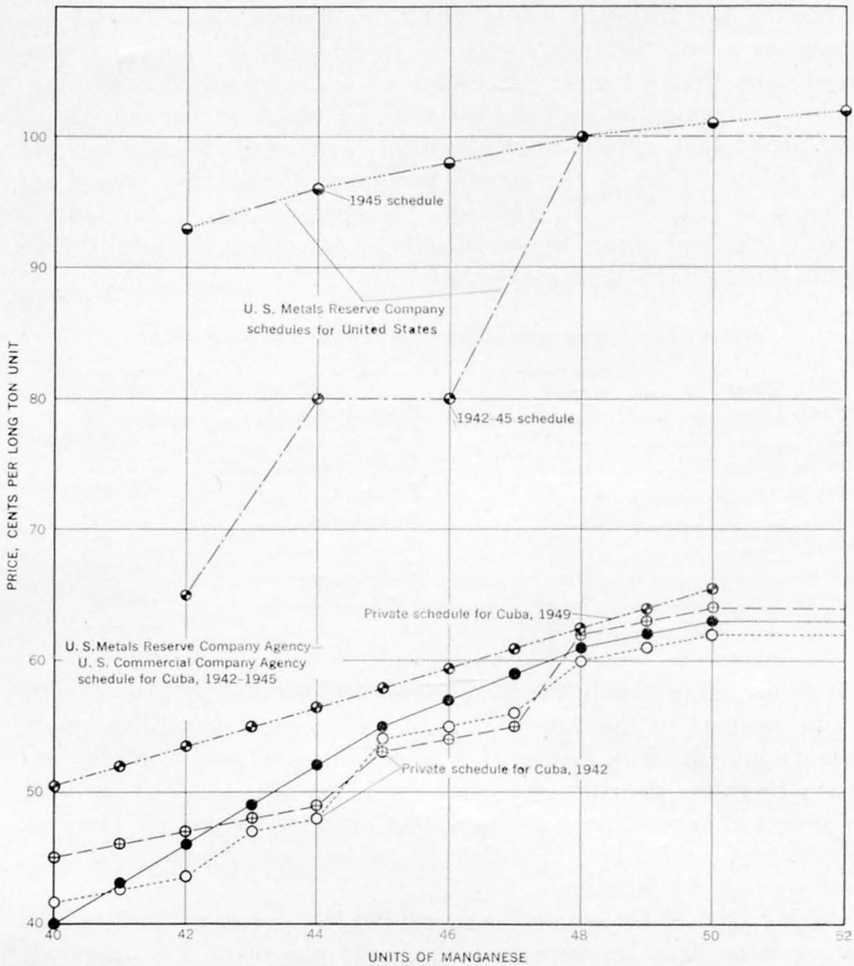



FIGURE 34.—Price schedules for manganese ore, United States and Cuba, 1942–49.

concentrated at El Cristo if prices had been high enough to cover the slightly increased cost of transportation. On the other hand, the Abundancia, Bueycito, Casualidad, and Charco Redondo deposits are so far from El Cristo that utilization of their low-grade ores was out of the question.

From the standpoint of reserves only, the Ponupo and Quinto deposits can easily supply a flotation plant of moderate size (500–1,000 tons) and the Charco Redondo and Casualidad deposits could supply a somewhat smaller plant. The Bueycito deposits are rather doubtful and would have to be studied carefully before any decision to install even a 50-ton mill could be made. The Abundancia deposit must be considered as marginal. None of the remaining low-grade deposits could possibly support a flotation plant by itself.

Another important factor is that all the deposits mentioned above would have to be mined by underground methods. Heretofore the only economical recovery of these ores has been by open-pit mining, and the increased costs of underground mining would be a major consideration in any projected operation.

A few very general guides to prospecting have been given in a preceding section. In addition to these, a number of more specific suggestions for exploration of certain particularly promising areas are summarized in the following table, in approximate order of favorability.

*Mines and mine areas favorable for prospecting and exploration*

| Mine or mine area | Nature of country rock | Grade of ore (percent Mn) | Type of work required to increase reserves or find new ore |
|---|---|---|---|
| Quinto mine | Pyroclastic rocks | 16–18 | Drilling as deep as 150–250 meters required on north side of known ore body. |
| Charco Redondo mine | Limestone | 35-45 | Drifting and driving short winzes and raises on ore zones to delimit known ore bodies and drilling in nearby areas as deep as 150 meters. |
| Manacas mines | Pyroclastic rocks | 20–35 | Sinking inclined shafts on ore beds. |
| Casualidad mine area | do | 10–25 | Drilling area to east of known deposit. |
| Valle de Manganeso mines | do | 30–35 | Sinking of shafts or drilling to depths of 20 or 50 meters to pick up faulted extension of deposit; wildcat drilling down valley. |
| Antonio mine | Limestone | 35–45 | Drifts from known ore bodies. Drilling to a depth of 50 meters in nearby areas. |
| Cuatro Caminos area | Pyroclastic rocks | Low-grade | Drilling in limestone to a depth of 50 to 100 meters. |
| Between Charco Redondo and Taratana mines. | Limestone | High-grade | Drill holes as deep as 150 meters. Thin beds of high-grade ore are known to occur in this area. |
| Ponupo-La Maya area | | Low-grade | Drill holes to depth of 200 or 250 meters required. |

The most promising deposit to be explored by drilling is the downdip (north) extension of the Quinto ore body. This ore body is known to be about 1,000 meters long and has not as yet been drilled north of a fold-fault structure along which the ore-bearing zone has been dropped 150 to 200 meters below the surface (pl. 7).

The Charco Redondo deposits could be explored conveniently by drifting to the limits of known ore bodies and by drilling in adjacent areas. Both hand-sorting and milling-grade ore have been found in this area.

At the Manacas mines, the downdip extensions of ore zones that crop out for many hundreds of meters along the strike could be explored by means of inclined shafts.

The Casualidad deposit adjoins the Charco Redondo area. The eastern limits of the ore have not been determined; a large area east of a fault and east of the known ore body is believed to be worth drilling.

A bed of low-grade ore crops out at the southwest end of the Cuatro Caminos dome, only a few kilometers from the Ponupo district. The Cobre rocks in this area have not been explored. Short drill holes (perhaps 50 meters) would be required to intersect the ore zone just below the base of the Charco Redondo limestone that underlies the dome. Exploration at Cuatro Caminos would be speculative in view of the limited extent of known mineralization.

The area between the Charco Redondo and Taratana mines is favorable for wildcat drilling. Thin ore beds cropping out in this area may widen downdip to minable thicknesses.

The ore deposits of the Ponupo area have been delimited by drilling and further exploration would not be required, but the area between the Ponupo mines and the town of La Maya, as well as the east end of the complex anticlinal structure that extends from LaMaya through Alto Songo, appear to warrant wildcat drilling, although drilling as deep as 200–250 meters might be required to penetrate the covering rocks of the San Luis formation and reach the favorable ore horizon near the top of the Cobre formation.

Indicated reserves of the Quemado district in Las Villas have been determined principally by systematic test pitting and sampling, and additional test pitting would be desirable. However the ore in this district cannot be concentrated by simple methods such as washing or jigging because of the intimate association of manganese oxide, iron oxide, and chert, and therefore poses the problem of concentration.

## HISTORY OF MINING

The presence of manganese deposits in Cuba was probably known in early colonial times, perhaps as early as the 16th century. The earliest published mention of manganese deposits seems to be that found in the monumental treatise of Sagra (1842, p. 66). His description is taken from an unpublished work written in 1802 by Ramírez, which mentioned "kidney-like peroxide of manganese in a shallow vein near the city of Santiago del Prado."

According to Calvache (1944, p. 58), manganese was discovered in 1882 in Oriente near El Cristo, Ponupo, and Bueycito. The first ore shipment, a 50-ton lot from the Boston mine near El Cristo, is said to have been sold in the United States in 1887 (Hayes, Vaughan, and Spencer, 1901, p. 62). In 1883, an American company, the Ponupo Mining and Transportation Company, was formed to exploit the mines in the Ponupo district. A narrow-gage railroad connecting with the Sabanilla and Maroto railroad at La Maya was built and 500 tons of ore were produced in 1895 (Hayes, Vaughan and Spencer, 1901, p. 62). Another narrow gage railroad was begun from El Cristo to reach the Boston mine but apparently was never completed. With the onset of the Cuban war of independence, nearly all mining operations ceased.

In 1898, development of the Ponupo mines was resumed and continued until 1905 when the company was dissolved. Another company, financed by American and Cuban capital, and called the Ponupo Mining Company, then operated the mines until 1907 when low prices put an end to activity. Mines in El Cristo district were in operation during this period, and new mines were opened in the Bueycito and Candelaria districts. La Gloria mine in the Candelaria district and the Costa mine in the Bueycito district produced small amounts of ore at this time.

From 1907 until 1915, mining was at a virtual standstill; during the four years from 1911 to 1914, no manganese ore was exported to the United States. In 1915, however, increased demand and higher prices due to the World War brought about a reactivation of mining, and in 1918 exports to the United States reached a maximum of 82,974 long tons, valued at $2,751,193 (Burchard, 1920, p. 103). Old mines were reopened and new deposits were discovered but the old districts continued to supply the greater part of the ore. By this time nearly all of the known districts and most of the mines of Oriente had been discovered and many deposits had been found elsewhere in Cuba. Several hundred tons of ore was mined from deposits on the south coast of Las Villas and a number of deposits had been located in Pinar del Río.

Because of the strategic importance of manganese ores during World War I, the U. S. Government sent E. F. Burchard of the Geological Survey and Albert Burch of the Bureau of Mines to Cuba in the spring of 1918 to locate, examine, and determine the character and quantity of manganese and chrome ores on the island in cooperation with the Cuban Government, which assigned Sr. E. I. Montoulieu, mining engineer, to the project. Burchard and Burch recommended appointment of umpire samplers and assayers at Santiago de Cuba to insure fair settlement of disputes, and urged the improvement of mine roads as a means of increasing ore production.

The armistice ended the abnormal demand for manganese ore, and cancellation of purchase contracts together with a great drop in prices brought mining again to a standstill. In addition, a multitude of claims were entered against the U. S. Government by mine operators who had sustained financial losses in attempting to develop mines and prospects. D. F. Hewett of the Geological Survey was sent to Cuba in 1920 to investigate and appraise the individual claims.

Between 1921 and 1926, a total of 71,588 long tons of ore was exported to the United States. About 50,000 tons of this total came from mines in the Bueycito district that had been operated during the war by Howard and Andrew Trumbo but which were then taken over, together with properties in the Manacal district in the western Sierra Maestra, by the Sun Development Company, a subsidiary of the Sun Oil Company. A large concentration plant was constructed in the Bueycito district; after about 150,000 tons of ore had been milled, the plant was shut down, apparently because of low prices and exhaustion of suitable ore.

Production declined in the next 6 years, during which only 27,447 long tons of ore was shipped. The Cuban Mining Company was organized during this period, and the mines of the Ponupo and El Cristo districts were reopened and brought into small scale production. In 1931 control of the Cuban Mining Company was obtained by the Freeport Sulphur Company. Intensive churn-drill exploration of the Quinto deposits in El Cristo district and of several deposits in the Ponupo district were undertaken by the company, and sufficient low-grade ore was "blocked out" to warrant construction of a 1,000-ton concentration plant utilizing flotation and sintering of flotation concentrates. The first successful application of flotation techniques in the concentration of manganese oxide ores was achieved with this plant, although many difficulties beset the company during the early years of operation.[1]

With the advent of the Cuban Mining Company, production increased rapidly and rose from a low of 2,071 long tons in 1930 to 105,936 long tons in 1939. Several properties were drilled by the Cuban Mining Company during this period, including deposits in the Jutinicú, Sabanilla, and Palmarito districts, but ore bodies proved to be too small to warrant large-scale mining operations. The company's purchase of ore from independent producers awakened interest in many small mines and the onset of the second World War in 1939 provided an additional stimulus.

During 1939 many mines in Oriente were reopened and by 1940 several new deposits, including the Corinto and the large high-grade deposits of the Taratana group, had been found. Several new ore buyers entered the field. Production rose to 130,645 long tons in 1940 and 243,405 tons in 1941.

With entry of the United States into the war in December 1941 the need for manganese ore became greater, shipping became scarce, and items necessary to mining, such as gasoline, tires, explosives, and trucks had to be rationed. The establishment of a central agency to purchase, ship, and stockpile ore, to ration supplies to mine operators, and to aid operators in any other practicable way became essential. Therefore the U. S. Metals Reserve Company Agency (later the U. S. Commercial Company Agency) of the U. S. Government entered the field and, with the consent and cooperation of the Cuban Government, set up an office at Santiago de Cuba in 1942 for the

---

[1] For a full discussion of the evolution of this pioneer nonmetallic flotation plant, see Norcross (1940).

purchase, stockpiling, and shipping of manganese ore during the war period. Production reached a maximum 306,298 long tons of metallurgical grade ore in 1943 and then declined to 253,791 long tons in 1944 and 194,875 long tons in 1945. With the end of the war in August 1945 production decreased rapidly. The sintering plant of the Cuban Mining Company ceased operation on December 31, 1946 with the exhaustion of open-pit ore after having produced more than 1,200,000 tons of sintered concentrate. Production of metallurgical grade ore during the years 1947–49 inclusive averaged only 39,070 tons per year.

Prior to 1946 practically all the ore produced in Cuba was of metallurgical grade, but in 1946 the Tennessee Eastman Corporation initiated the purchase of chemical grade ore, and from 1946 to the end of 1949, 25,651 tons of this ore was produced.

## MINES AND PROSPECTS

### PINAR DEL RÍO

Manganese deposits are known in four general areas of Pinar del Río: near Las Pozas, 15–20 kilometers southwest of Bahía Honda; La Jagua district, between La Palma and Viñales; the vicinity of Gramales, 30 kilometers west-northwest of the city of Pinar del Río; and at Mendoza, southwest of Pinar del Río. The most promising deposits are along the north side of the Sierra de los Órganos between Bahía Honda and Gramales. We did not see these deposits; the descriptions of mines and prospects that follow were compiled from field notes made available by C. F. Park, Jr., of the Geological Survey, who made a reconnaissance study of the deposits in 1941.

#### BAHÍA HONDA DISTRICT

##### ALTA GRACIA PROSPECT

Alta Gracia prospect is 4 kilometers southeast of Las Pozas and 19 kilometers southwest of Bahía Honda. A small cut in deeply weathered volcanic(?) rock shows thin streaks and veinlets of low-grade pyrolusite. Another pit 23 meters west shows 1.5 to 2 meters of streaky pyrolusite underlying thin-bedded chert(?), which strikes east and dips 70° N. Three other small pits in decomposed schist or argillite are barren.

##### BLANCA LUZ PROSPECT

The Blanca Luz prospect is on the Río Bahía Honda. A considerable amount of low-grade reddish manganese oxide occurs in dense hard gray or greenish-gray argillite. The ore contains much clay and silica. No work has been done.

### EL FIÑO PROSPECT

El Fiño prospect is near Bahía Honda. Several small cuts in clay expose 1 to 1.5 meters of low-grade pyrolusite. Considerable jasper and a little bementite and neotocite occur as float. The average ore contains about 20 percent manganese.

### HATUEY MINE

The Hatuey mine is near Las Pozas on the Río Cacarajicara. Country rock is crumpled thin-bedded red chert and argillite. A shaft and several adits are inaccessible. Except for a few lumps of manganese silicates(?) on a dump, no ore was seen. The mine produced about 300 tons of ore in 1941 and has a total production of about 2,000 tons.

### LA LIGERA PROSPECT

La Ligera prospect lies some 19 kilometers southwest of Bahía Honda. A small cleared area in heavy brush shows at least 1 meter of hard, probably siliceous manganese oxide. The country rock seems to be chert and argillite. Very little work has been done.

### SANTA TERESITA PROSPECT

Santa Teresita prospect is 7 kilometers northwest of Las Pozas. Boulders of hard glassy manganese oxide as much as 1 meter across are found on a low hill and in a nearby arroyo. No work has been done.

### VISTA ALEGRE PROSPECT

The Vista Alegre prospect is about 20 kilometers southwest of Bahía Honda. An outcrop of hard manganese oxide, at least 2 meters wide and 100 meters long, strikes N. 45° E. and dips 45° NW., nearly parallel to the surface of the hill on which the property lies. The results of an analysis of the ore show 46 percent manganese and 16 percent silica. Additional outcrops are said to occur along the strike. The prospect is one of the most promising in the province. Discoveries thus far made in the little explored region around Las Pozas indicate excellent possibilities for finding a considerable amount of ore.

## GRAMALES DISTRICT

### ANCÓN MINE

The Ancón mine is near the city of Pinar del Río, but the exact location is not known. Several shafts, now filled with water, have been sunk in red or chocolate-colored limy shale and limestone. A trench about 45 meters long exposes a bed of low-grade manganese ore striking N. 65° E. and dipping 55° NW. The hanging wall is red limestone, the footwall white limestone. The bed is about 45 centimeters thick and consists of streaks and patches of siliceous pyrolusite in reddish clay.

Some of the pyrolusite appears to have been derived from manganese silicates. A few tons of material averaging 20 percent manganese have been extracted.

### EL ARCANGLE MINE

El Arcangle mine is 8 kilometers north of the city of Pinar del Río. It was worked first in 1915. The lode of manganese oxide ore ranges in thickness from 0.3 to 1.5 meters and averages about 0.6 meters; it strikes N. 85° E. and dips 25° S. Country rock to the north is thin-bedded limestone; to the south, schist. Mine workings consist of an adit and a raise and several open cuts. About 1,000 tons of ore averaging 40 percent manganese and 2.5–3.5 percent silica was blocked out in 1941. Total production is said to be about 2,000 tons.

### CALIENTE PROSPECT

The Caliente prospect is on the north side of the highway, 1 kilometer west of Sumidero. A flat-lying bed of black and white spotted clay about 1 meter thick is exposed in a creek bottom. The bed can be followed about 30 meters and may be much more extensive. Although the material in sight is very low grade, a considerable tonnage might be obtained by stripping the thin cover.

### LA CERRA PROSPECT

La Cerra prospect is southeast of the Carretera Central, 14 kilometers northeast of the city of Pinar del Río. Several cuts and two adits show pockets and irregular stringers of soft sticky manganiferous mud in brown and white streaked mud. At one place there seems to be a bed of manganese oxide ore about 45 centimeters thick.

### FRANCISCO MINE

The Francisco mine is west of Gramales. Churn drilling has established the presence of a manganiferous bed that strikes N. 35° E. and dips about 15° NW. The bed ranges in thickness from 1 to 2 meters and has been followed about 2 kilometers along the strike. Streaks and patches of pyrolusite are scattered through reddish-brown clay. At one place near the west end of the ore zone the bed is composed of 60 centimeters of soft pyrolusite overlying 1 meter of hard pyrolusite containing much black chert. Locally the ore bed forms a dip slope. According to the operator, some 100,000 tons of ore averaging about 20 percent manganese has been proven by drilling. Two hundred tons of ore was shipped for metallurgical testing in 1941.

### GRAMALES PROSPECTS

A number of shallow shafts and cuts explore an extensive manganiferous area near Gramales. The country rock is thoroughly decomposed shale and limy argillite. Almost all the ore seen consists of fragments and nodules of pyrolusite, although the owners report several thin veins in inaccessible shafts and pits. At one place about 30 centimeters of fairly good ore was seen along a contact between red limy shale and fine-grained limestone. Most of the residual material contains about 10 percent granzón. A few tons of ore containing 30–35 percent manganese has been stockpiled. A churn-drilling program is said to have discovered some "concentrating" ore, but in general the prospect of finding ore is not good.

### LAS LEGUAS PROSPECT

Las Leguas prospect is about halfway between Las Acostas and Gramales. Some high-grade pyrolusite float is scattered on the surface, and a thin vein of high-iron pyrolusite in limestone was seen. No work has been done.

### LA MAMBISA PROSPECT

La Mambisa prospect is about 12 kilometers north of Consolación del Sur. A bed of low-grade iron-rich manganese oxide striking N. 75° E. and dipping 70° SE. is exposed in a large pit about 6 meters deep. Both walls are white limestone; the hanging wall contains much black chert. The ore is 1 meter or slightly more thick and, locally, is very siliceous.

### MATANZAS PROSPECT

The Matanzas prospect is on the northwest side of the Carretera Central, about 14 kilometers northeast of the city of Pinar del Río. Two cuts show 1 to 2 meters of black, red, and yellow clay, probably derived from a limy schist. The prospect has no value.

### EL MORADO PROSPECT

El Morado prospect is near Las Acostas and 20 kilometers north of Guane. The country rock is decomposed red shale(?) and cherty limestone(?). Several cuts expose layers of soft powdery pyrolusite and a psilomelane-type manganese oxide, 30 to 60 centimeters thick. An area 800 meters across is covered with granzón as much as 2.5 meters deep. Most of the granzón pellets are only a centimeter or so in diameter, but a few are as much as 15 centimeters across. The ore in sight appears to be of good grade and the prospect is near enough to the railhead at Guane to warrant further exploration.

### VALENTINE MINE

The Valentine mine is near Sumidero on the Matahambre mine road, 2 kilometers north of the Carretera Central. Several cuts have been dug in soft reddish-brown clay containing streaks of low-grade pyrolusite. One pit shows a bed of low-grade ore 1 meter thick. Another cut shows seams of pyrolusite in hard limestone. Two of the three shafts on the property are inaccessible; the third explores a bed of black and brown clay 60 centimeters to 1 meter thick enclosed in shaly limestone which strikes N. 40° E and dips 30° SE. A little siliceous granzón is scattered here and there. With the exception of some of the granzón, all the ore seen was of very low grade.

## LA JAGUA DISTRICT

### LA ANGELITA MINE

La Angelita mine is near La Jagua. An opencut exposes about 15 centimeters of low-grade pyrolusite along the contact of red limy shale (footwall) and massive red limestone, which strike N. 65° E. and dip 60° NW. Several other cuts have been made over a distance of about 450 meters. The ore zone lies approximately parallel to the bedding of the enclosing rocks. Most of the ore appears to be very siliceous. A considerable amount of low-grade granzón and hematite nodules are also present.

About 70 tons of ore was shipped in 1941. The mine is not promising because of the siliceous nature of the manganese oxides and the possibility that silicates will be found at depth.

### BAIRE MINE

The Baire mine is in the Viñales area. The principal mine working is an opencut 15 meters long, 3 to 4 meters wide, and 3 to 5 meters deep in decomposed thin-bedded sedimentary rocks that strike N. 45°–60° W. and dip 20° SW. Ore consists of layers of pyrolusite as much as 1 meter thick. Many small cuts and shafts are scattered over the mine area. Some expose small quantities of granzón, others are barren.

About 40 tons of ore estimated to contain 30 percent manganese and another 25 tons containing approximately 40 percent had been extracted in 1941. Much of the ore is high in silica and iron. The deposit is one of the more promising ones of Pinar del Río, but work thus far has been too haphazard to exploit fully its potential.

### LA CONSTANCIA MINE

La Constancia mine is 9 kilometers southeast of La Esperanza. The deposit is in thin-bedded black shale and limestone of the Cayetano(?) formation, which strike about east and dip approximately vertical. A trench on a low ridge along the strike of deeply weathered shale exposes streaks and seams of pyrolusite ranging from 15 to 60 centimeters in width. These seams appear to lie parallel to the bedding. Two adits were being driven south in 1941 to intersect the ore zone at a depth of about 8 meters. A 15-meter shaft has been sunk in shale and clay containing irregular masses of pyrolusite and opaline quartz.

Fifteen meters south of the trench a shaft 9 meters deep with a northeastward-trending crosscut 26 meters long explores what appears to be a faulted or folded segment of the main ore zone.

Surface workings extend over a distance of about 650 meters and the ore zone continues at either end. At the east end of the trench, two separate seams of pyrolusite about 15 centimeters thick are separated by some 60 centimeters of country rock; in another place, three similar seams occur over a width of 2 meters. A small amount of granzón has accumulated along the ore zone. About 200 tons of ore is said to have been shipped.

### CONSUELO DE LAS CUATRO HERMANAS MINE

The Consuelo de las Cuatro Hermanas mine lies about 3 kilometers northeast of La Palma. An ore zone about 1 meter wide is enclosed in deeply weathered thin-bedded argillite striking N. 75° E. and dipping 40° SE. Pyrolusite is scattered throughout the lode and must be hand-sorted to attain a grade of even 35 percent. A little better grade of ore was found in a new adit (1941). This mine may yield a considerable amount of ore if additional exploration is undertaken.

### LA CUCA PROSPECT

La Cuca prospect lies just east of La Constancia mine. There are no outcrops, but a few residual rock fragments in clay suggest that the country rock is probably shale and limestone of the Cayetano formation. A large amount of granzón has accumulated over an area nearly 800 meters long. The concentrate is reported to assay 32–43 percent manganese with low iron and silica, but much of the material seems to be hematite. One pit shows granzón to a depth of 2 meters. Washing of the crude ore should materially increase the grade of concentrate.

### LA ESPERANZA MINE

La Esperanza mine is 2 kilometers east of La Palma. A 9-meter adit cuts a layer containing streaks and pockets of siliceous pyrolusite. This layer strikes N. 80° W. and dips about 30° S; it may have been formed by weathering of a limestone bed. Another adit, 11 meters below, intersects the same bed, which is 3 meters wide here and contains some partly decomposed red limestone and hard white limestone. Several small cuts expose a little low-grade ore. A small amount of ore was shipped from the mine in 1949.

### EL FRANK PROSPECT

El Frank prospect is east of La Angelita mine. Two opencuts in limestone, shaly limestone, and argillite, which strike N. 75° E. and dip 55°–60° NW., expose 15 to 60 centimeters of siliceous iron-rich pyrolusite. Some of the ore is unusually heavy and may contain some hausmannite.

### LA GLORIA PROSPECT

La Gloria prospect lies halfway between San Vicente and La Jagua, about 1 kilometer east of the road. A shaft 13 meters deep is sunk on an ore zone about 2 meters thick lying in nearly horizontal beds of black shale. The ore is a very light weight black powder reported to contain 26–28 percent manganese.

### LA JUANA PROSPECT

La Juana prospect is on Finca San Andrés near La Siomara mine. A trench 15 meters long is cut in red limy shale or argillite and limestone along the south side of an outcrop of Viñales limestone. A small amount of pyrolusite has been recovered from soil. No ore was seen definitely in place but a bed about 15 centimeters thick may be present. The ore appears to have replaced black shale.

### EL MACEO MINE

El Maceo mine is reached by a dirt road extending 2 kilometers east from the power house at Viñales. A short adit and a 6-meter shaft leading to a drift explores a vein lying approximately parallel to the bedding of massive gray to pink limestone, which strikes N. 80° W. and dips 45° N. The vein is 30 to 60 centimeters wide and seems to be composed of manganese oxides near the surface and manganese silicates (bementite, neotocite, and piedmontite?) at depth. A little hausmannite may be present, and a few specks of malachite were seen. Locally, thin layers of pyrolusite alternate with limestone and may contain small lenses of limestone. The vein is broken in places and cemented with seams of calcite.

Two caved adits and a barren shaft are also on the property. A small amount of low-grade highly siliceous material was extracted in 1941.

### LA REINA MINE

La Reina mine adjoints La Esperanza mine on the south. Several cuts expose manganiferous jasper and a little pyrolusite; the general trend of the ore zone is N. 60° E. A little ore was shipped in 1949.

#### LA SIOMARA MINE

La Siomara mine is about 3 kilometers from La Constancia mine. A shaft 6 meters deep and a small trench explore a bedded ore zone 15 to 35 centimeters thick, which strikes N. 70° E. and dips 60° N. The hanging wall is blocky chert and argillite of the Cayetano(?) formation; the footwall seems to be massive limestone. A shallow shaft, 15 meters west along the strike, exposes about 15 centimeters of ore.

The ore is manganese oxide estimated to contain about 35 percent manganese; much of it appears to be highly siliceous and some has considerable amounts of black silica. Some of the ore is rather strongly magnetic.

#### TRINIDAD PROSPECT

The Trinidad prospect is east of La Angelita mine. A partly caved trench in decomposed red limy shale has yielded a small amount of pyrolusite, which probably occurs in beds. This ore zone is reported to have an extension of 10 to 12 kilometers. An unknown but small amount of ore was shipped from this property in 1949.

### MENDOZA DISTRICT

#### MARÍA CRISTINA MINE

The María Cristina mine is just south of Mendoza in western Pinar del Río. One old shaft at least 9 meters deep is sunk in dark blue limestone and phyllite, which strikes N. 75° E. and dips vertical. No manganese ore was seen. Just to the west another shallow shaft and adit expose a few narrow irregular patches of pyrolusite along a contact between crumpled limestone and phyllite. A little quartz and calcite is associated with the pyrolusite. The mine has not been worked for many years, probably since 1918–1919.

### ISLA DE PINOS

Descriptions of two prospects on the Isla de Pinos were taken from field notes of C. F. Park, Jr., who spent a short time on the island in 1941.

#### RENÉ PROSPECT

The René prospect is in the Sierra de Cañada west of Santa Fe. A prominent outcrop of mixed oxides of manganese and iron trends northward and seems to dip about 30° E. Country rock is mica schist. Three cuts and two shafts, one 11 meters deep, have failed to expose more than a trace of manganese ore.

#### ZENAIDA PROSPECT

The Zenaida prospect is 4 kilometers northeast of Santa Fe. The ore is siliceous and iron-rich granzón, scattered over an area of about 1 square kilometer. As much as 2 meters of residual manganiferous material was seen in an old shaft.

## LAS VILLAS

Manganese deposits near Amaro, in northwestern Las Villas, were examined by C. F. Park, Jr. Deposits at Quemado de Güines, in northwestern Las Villas, and near Trinidad on the central south coast were studied by Straczek.

### AMARO DISTRICT

A number of manganese prospects near Amaro were explored during 1940–41 without notable success. A few of the prospects will be described.

#### ANNE PROSPECT

The manganese lode of the Anne prospect is a discontinuous breccia of chert and argillite cemented by manganese oxide. This breccia zone trends N. 20° W. and appears to dip steeply westward. The country rock is crumpled shale and limestone. Two shafts, sunk more than 31 meters on the breccia, were abandoned and are inaccessible because of flooding. The ore zone apparently ranges in width from 1 to 3 meters and the manganese oxide is concentrated near the limestone hanging wall. Most of the ore averages only about 20 percent manganese.

#### CONCHITA PROSPECT

A series of trenches explores a zone of contorted and deeply weathered siliceous argillite, 100 to 300 meters wide, lying between limestone beds. Streaks, pockets, and thin films of manganese oxide cut the argillite, particularly near the limestone contacts. All the ore is very low grade.

#### EDELMIRA PROSPECT

A breccia of chert and jasper cemented by hard psilomelane-type manganese oxide crops out for about 60 meters in a northwestward direction on the Edelmira prospect. The breccia contains chert fragments as much as a meter or so across. The manganese oxide appears to be a surficial concentration.

#### LA FE MINE

La Fe mine was worked prior to 1941 and some 220 cars of ore were shipped to the Republic Steel Company at Birmingham, Ala. Crude ore was treated in a small mill consisting of a log washer, picking belt, and four jigs. In 1941 all the mine workings were caved and very little could be seen. The country rock is crumpled thin-bedded chert and argillite, stained here and there by films of manganese oxide. The ore bed was reported to be 1.3 to 3 meters wide and to average about 30 percent manganese. Exploration nearby in 1941 was unsuccessful, as only thin stringers of medium-grade ore were found.

#### LA LUCRECIA MINE

Several trenches and drill holes have explored crumpled thin-bedded siliceous sedimentary rocks on La Lucrecia claim, southwest of the Conchita prospect. The only ore in sight was thin seams of manganese oxide along fractures in argillite. A small amount of ore is reported to have come from two shafts, now inaccessible. According to Park (1942, p. 81) a sample of oxide ore from this mine contained 0.25 percent cobalt.

#### RITA PROSPECT

An extensive area, at least 300 meters across, on the Rita prospect is blanketed with granzón to depths of 1 meter. Many of the granzón pellets are less than 5 millimeters in diameter, and a large proportion of them are iron oxide. The granzón appears to be very low grade.

#### ROSA MARIA PROSPECT

The Rosa María prospect adjoins La Lucrecia mine. A trench 5 meters wide and 40 meters long has been cut in crumpled argillite and chert that trend N. 10°–20° W. Patches and concretions of dense hard psilomelane-type manganese oxide mixed with brown and red iron oxide spot the beds. One lenticular concretion was 30 centimeters across and 15 centimeters thick. About 15 tons of ore estimated to contain about 35 percent manganese was stockpiled in 1941, but the ore is said to have come from La Lucrecia mine.

### QUEMADO DISTRICT

#### DESCRIPTION OF THE DISTRICT

The manganese deposits of the Quemado district are near the north coast of Las Villas, largely in a triangular area bounded by lines connecting Quemado de Güines on the south, Caguaguas on the east, and the shallow-water port of Carahatas on the north. The principal manganese-bearing area is a zone about 13 kilometers long and 3 kilometers wide, lying parallel to a series of low ridges and broad valleys which trend about N. 65° W. A semi-improved road connects the towns of Caguaguas and Quemado de Güines, and the Ferrocarriles Unidos passes through the district. Most of the land and nearly all of the manganese denouncements are owned by the Compañía Industrial y Agrícola de Santa Clara, which operates the sugar mill of Central San Isidro. A network of unimproved roads and narrow gage railroads of the Central serves the area. The nearest deep-water port, La Isabela, lies 30 kilometers east of Carahatas.

The holdings of the company consist of 14 denouncements that cover an area of over 2,800 hectares. These include the Emilio, Lola, La Frontera, Rita, Inés, Rosa, Josefa, Sara, Elva, Carmela, Progreso, Luz, and a new large denouncement, La Promesa, which covers areas between and around the older denouncements. The Berta, a small denouncement, lies about 5 kilometers northwest of the above area. Several other denouncements, wholly or partly enclosed within the Promesa, are not owned by the company. Most of these denouncements, including La Victoria, Chichí, Ignacio (or San Ignacio) and La Rastra were examined in 1942 by M. W. Cox of the Geological Survey and contain manganese deposits similar to those discussed below. Claim boundaries are shown on the index map (fig. 35).

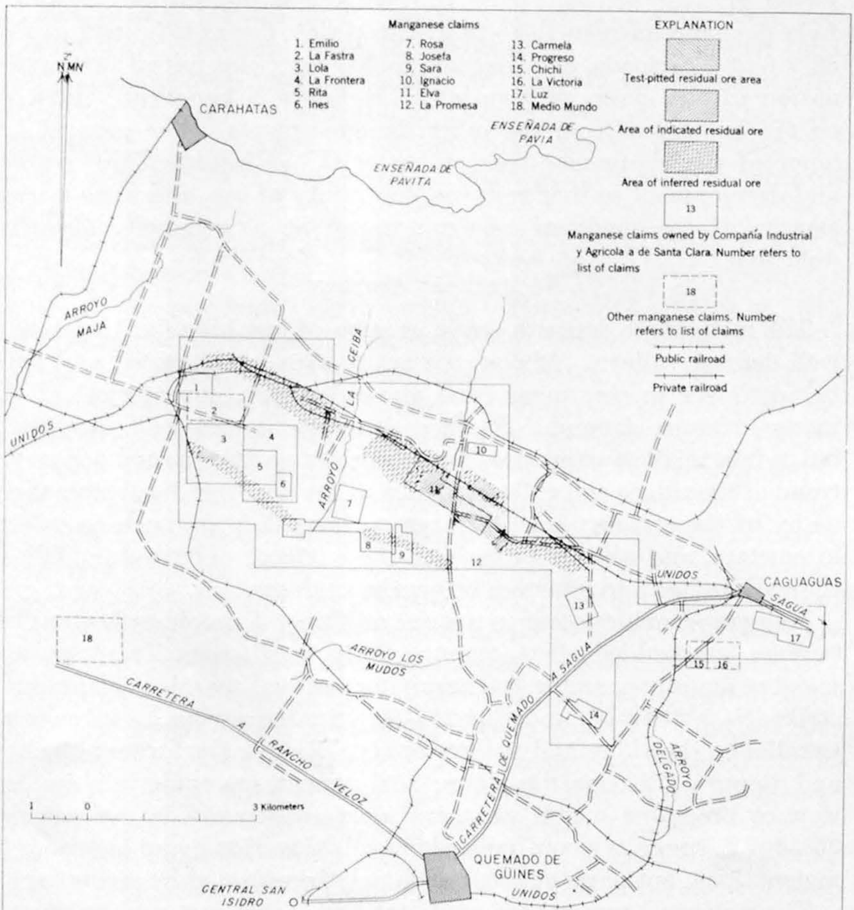



FIGURE 35.—Map of the Quemado district, Las Villas, Cuba, showing manganese claims and principal known areas of residual ore.

Detailed examinations were made of the Elva, Lola, Josefa, Sara, and parts of La Promesa denouncements; the Emilio, La Rastra, Rosa, and Carmela denouncements were studied only briefly. About 70 hectares of company land has been systematically test-pitted and sampled, and the results of this work, including assays and log-washing and jigging tests were made available to us by courtesy of the company. We acknowledge gratefully the assistance of Major Yonge, an official of the company who is familiar with the entire district.

## PRODUCTION

Although the manganese deposits of the Quemado district have been known for many years, little ore has been shipped because the nature of the deposits is such that ordinary methods of concentration are not effective. Several thousand tons of selectively mined and sorted granzón are said to have been mined and shipped from the Lola denouncement in 1930–1931, but Major Yonge informed us that only 6 or 7 carloads, or about 200 to 300 tons, was mined; an examination of the claim substantiates his figure. Apparently little or no ore has come from the other denouncements. The general low tenor of the manganese-bearing material has inhibited prospecting and development so that reserves, continuity of ore, and some critical aspects of the mode of occurrence can be ascertained only with difficulty.

## GENERAL GEOLOGY

The manganese deposits are in an area of low hills flanking broad, well-defined valleys. Almost the entire area is cultivated and little or no timber exists; sugar cane, the chief crop, covers most of the manganiferous ground. Surface drainage is not well developed, but a few small streams flow northward to northeastward across the trend of the ridges and valleys. Much of the drainage is subterranean; many of the streams head at large springs, flow as much as several kilometers, and disappear beneath the surface. The water table in the valleys lies 3 to 9 meters below the surface.

Manganese oxides occur in a series of Upper Jurassic or Lower Cretaceous interbedded chert, impure shaly to siliceous limestone, and massive limestone, and in the overlying residual mantle. These rocks strike N. 50°–80°W. and dip 25°–60° S.; the strike is, in general, parallel to the ridge and valley trends. Ridges are formed by chert and impure siliceous limestone; the valleys are underlain by less impure limestone which weathers more readily. The average dip 35°–40° S. suggests a continuous homoclinal section many hundreds of meters thick, but parts of the section may be repeated by strike faults.

The principal manganese oxide is hard, dense but porous cryptomelane showing well-developed colloform and stalactitic structures.

A wadlike oxide of indeterminate composition and minor amounts of pyrolusite are the other manganese minerals. In addition some iron oxides, chiefly limonite, are associated with the manganese-bearing material.

### ORE DEPOSITS

#### CHERT RUBBLE DEPOSITS

A breccia of angular fragments of porous white to gray chert and translucent yellowish-brown to dull-brown chert cemented by oxides of manganese and iron crops out along a more or less continuous ridge in the district. Fragments and boulders of breccia weighing as much as several hundred pounds are found on the surface of the chert-strewn ridges and in many small open pits. In pits on the Carmela, Rosa, and Emilio denouncements, boulders and large irregular masses of rubble breccia are embedded in chert rubble and red soil or clay formed by the weathering of calcareous chert and siliceous limestone beds. None of the observed pits was deeper than 5 meters and as none reached the base of the surface mantle the relation of the manganiferous material to the unweathered bedrock remains obscure. The chert rubble ore appears to form disconnected zones 3 to 9 meters in width and as much as 30 meters or more in length.

On the Carmela claim several partly caved pits, as much as 2 or 3 meters deep expose weathered chert rubble and red clay with irregular masses of manganiferous chert breccia. These pits explore an area less than 25 meters wide and 60 meters long. Some 10 tons of rubble ore was removed from one pit and lesser amounts from the others; a few of the pits were nearly barren. Several pits on the Rosa denouncement about 4 kilometers northwest of the Carmela showed similar material. On the Emilio claim, 3 kilometers farther northwest, several tons of rubble ore was removed from shallow open pits. Similar occurrences are known on the Progreso, Luz, Chichí, La Victoria, La Rastra, and La Frontera claims. None of the areas examined gave definite evidence on the probable width, continuity, or depth of the mineralized zones. However, it seems certain that the zones are narrow and that intensity of mineralization is extremely variable.

The chert rubble appears to be of supergene origin, formed by moving ground waters during weathering of calcareous cherts and siliceous limestones containing small amounts of manganese, possibly in the form of low-grade manganiferous carbonate. Most of the manganese oxides probably were deposited by descending or laterally moving waters, but some may have been deposited by ascending artesian waters. Mineralization is thought to be limited to the zone of deep weathering and leaching, about 6 to 12 meters thick.

The grade of the breccia as a whole will not exceed 5 to 15 percent manganese. The manganiferous material itself may average 10 to 20 percent and mining and hand cobbing might give concentrate containing as much as 30 to 35 percent manganese.

### RESIDUAL DEPOSITS

The residual or granzón deposits form an extensive surface mantle in the valleys or flat areas flanking the ridge on which the rubble deposits crop out. Although the residual accumulations are found throughout the valleys, only certain narrow discontinuous zones lying parallel to the ridge contain manganese in sufficient quantity to be classed as possible or potential ore. In these zones the manganese-bearing material ranges in thickness from less than 60 centimeters to a little more than 1.6 meters and consists of nodules, particles, and boulders of manganese oxides, iron oxides, and chert in a matrix of ferruginous red lateritic soil. The pebbles of manganese oxide range in size from a few millimeters to several centimeters in diameter. Most of the smaller pellets are well-rounded and concentrically banded; their centers commonly contain some iron oxide. The large fragments are irregular in shape and often are deeply pitted. Many of the large pebbles enclose fragments of white to brown chert and most contain considerable iron oxide. Chert fragments are similar to those observed in the rubble deposits. Many are coated with manganese oxides and except for their angular shapes resemble pebbles of manganese oxides. They range in size from small particles to irregular boulders over 30 centimeters in diameter. Nodules and fragments of iron oxide form part of the granzón; they appear to be composed of dense, hard, possibly siliceous limonite.

The manganese minerals of the pebbles are rather soft, dull-black oxides that may be classified as wad or impure pyrolusite. A small amount of psilomelane-type oxide, much like that in the rubble ores, is recognizable.

The ore-bearing mantle grades downward into red or yellowish-brown soil bearing little or no manganese. The maximum depth of soil cover in the valleys is not known; in places it is as much as 6 to 10 meters. On parts of the Lola claim residual ores are found in channels between pinnacles of limestone that crop out or lie very near the surface.

Systematic test-pitting and sampling was concentrated on and near the Elva denouncement where more than 1,800 pits were dug over an area about 1,400 meters long and 430 meters wide, or 70 hectares (165–170 acres) in all. Pits were dug first at 46-meter (150-foot) intervals and then on 16-meter (50-foot) centers in the more promising areas. According to Mr. Thomas, consulting mining engineer for the owners, the test pitting has indicated a total reserve of 580,000 tons of manganiferous material, averaging 8.95 percent of manganese. The average thickness of the ore-bearing mantle is about 1.1 meters. Material containing less than 6 percent manganese was not considered in the estimate. About 35 hectares out of a total of 70 was indicated as ore-bearing.

All accessible explored ground was examined and an attempt was made to correlate the surface appearance and test-pit data. Six test pits were dug in a selected area on the Elva denouncement. These pits were spaced about 30 meters apart and were located between those dug by the owners. Samples were obtained by retaining every other shovelful of material removed from the pits. The bulk samples were mixed, coned, and quartered on a steel plat in the field and then were further reduced by screening, crushing, and splitting in the laboratory at Central San Isidro.

The head samples were assayed by the United States Metals Reserve Company Agency at Santiago de Cuba with the following results:

| Sample No. | Depth of pit (feet) | Mn (percent) | $SiO_2$ (percent) | Fe (percent) |
|---|---|---|---|---|
| 10-11-J | 3.4 | 9.04 | 38.00 | 13.63 |
| 10-11-K | 3.5 | 8.92 | 39.60 | 12.41 |
| 10-11-H | 3.0 | 6.94 | 38.30 | 12.47 |
| 10-11-F | 2.5 | 7.49 | 38.90 | 13.35 |
| 6-7-K | 2.8 | 7.57 | 40.20 | 12.80 |
| 9-10-K | 2.0 | 4.22 | 43.10 | 12.27 |

These results checked reasonably well in grade and thickness with the results obtained by the owners.

The first five of the above samples were washed in a 2-meter hand-operated log washer at the central. The average concentration ratio was about 2.3 : 1, and 89 to 95 percent total manganese was recovered. One-half to two-thirds of the resultant concentrate consisted of chert fragments and the balance of nodules and pebbles of manganese and iron oxides. Over two-thirds of the manganese particles are 5 millimeters or more across. The log-washer concentrate was not assayed, but concentrate obtained by the company from comparable heads contained from 13 to 19 percent manganese.

Two generalizations, believed to be applicable to the other areas bearing residual manganese oxides, have come out of this study: First, the amount and size of manganese nodules and fragments on the surface seems to bear a general relation to the quantity of manganese present throughout the thickness of the mantle. Lower grade areas characteristically show well-developed, rounded pellets of medium soft to soft manganese oxide, generally less than 5 millimeters in diameter. Conversely, high-grade areas show many more and larger pebbles of oxides on the surface. However, layers of soil as much as 30 centimeters or more thick have been deposited locally by sheet wash and may conceal residual material of fair grade. Second, the better areas are characterized by many chert fragments and boulders. Large quantities of residual chert does not indicate necessarily a proportional quantity of manganese oxides, but areas containing little chert are likely to be low in grade.

The residual deposits appear to have been formed by the weathering and disintegration of the rubble deposits. The present deposits are believed to have accumulated by downward settling as the underlying limestone was dissolved or weathered away; transportation of manganese either in solution or as pebbles was probably of only secondary importance. The variable distribution of manganese probably reflects the original mineralization in the source rocks. It is possible that the rubble ores seen in place today are the source rocks from which the residual ores were derived, but other unexposed ore horizons may have furnished some of the manganese. Continued weathering of the disintegrated source deposits resulted in conversion of most of the original psilomelane-type mineral to the softer oxides of the residual ores. Weathering of the residual deposits in turn resulted in the leaching and removal of some of the manganese. The concentric banding of the smaller pellets suggests either reconstitution of the manganese nodules or the formation of pellets by reprecipitation of manganese from ground waters.

The extent of the residual manganese-bearing mantle was determined by a field study of the entire area. Indicated and inferred reserves are believed to be several times as large as the measured reserves noted on page 136, but the grade may be somewhat lower.

The average thickness of ore in areas containing indicated and inferred reserves is slightly less than 60 centimeters. Much of the reserve must be considered as doubtful until further test-pitting is done. Most of the areas of inferred ore show only fine pellets of manganese which in the test-pitted area indicated material generally containing less than 6 percent manganese. A considerable part of the ore on the Lola claim may not be readily available because of many limestone pinnacles that would make mining difficult and expensive.

If the residual deposits can be concentrated economically the effective reserve of the area will depend upon the concentration ratio and the recovery of manganese; the latter may range from 50 to 75 percent of the total contained manganese. The intimate association of manganese oxides, iron oxides, and chert fragments certainly seems to preclude concentration by any simple and inexpensive process.

## TRINIDAD DISTRICT

### MERCEDES MINE

The Mercedes mine lies about 10 kilometers west of Trinidad and 2.5 to 3 kilometers north of the coast. A road 11 kilometers long connects the mine with Trinidad, the shipping point on the Ferrocarriles Unidos de la Habana. The district is accessible only by rail or boat.

The manganese-bearing area is covered by six claims that were denounced in 1909–11; these include the Mercedes, Adela, Purita, Serafina, Hipólita, and San Juan. Apparently all the ore shipped was mined from the Mercedes claim. Most of the ore, approximately 300 to 400 tons, was shipped by the Trinidad Manganese Company during and prior to 1917; an additional 50 to 150 tons was reported shipped by the Patria Mining Company and may have been shipped by the former company. The mines apparently were not worked from the end of World War I to 1943. In 1943 the mine was not being worked but about 35 tons of ore had been mined and stockpiled on the Mercedes claim. About 55 tons of ore mined in World War I was shipped to the U. S. Metals Reserve Company Agency in February 1943, but failed to meet the minimum grade requirement of 40 percent manganese.

During World War I, ore was hauled by wagons to the coast at the mouth of the Río Guanayara, where a small and unprotected cove afforded anchorage for a small boat on which ore was shipped to the deep-water port of Casilda, south of Trinidad. Now ore could be trucked to Trinidad; the first 6 kilometers of road is unimproved but in fair condition and the last 5 kilometers is surfaced.

The claims are in the southern foothills of the extremely rugged Trinidad mountains, which rise to a height of more than 900 meters a short distance from the mine area. Mine workings on the Mercedes claim lie on the east side of the Río Guanayara at an altitude of about 85 meters. Outcrops are extensive, but much of the area is covered by almost impenetrable thickets.

The youngest rocks of the area, probably of Pleistocene age, form a narrow coastal belt of coral limestone. This limestone is underlain by gray, cavernous, generally massive limestone of Oligocene and Eocene age that dips gently southward and forms low-lying hills flanking the Trinidad mountains. The base of the older limestone is marked by coarse conglomerate and breccia of pebbles and blocks of mica schist and marble cemented by limestone. The Oligocene and Eocene limestone unconformably overlies a series of interbedded calcareous mica schist, schistose marble, and crystalline limestone of pre-Jurassic(?) age that are said to form the bulk of the Trinidad mountains. In the mine area the schistosity, which appears to coincide with bedding, strikes N. 60°–75° E. and dips 50°–70° S. Incompetent schist units between the marble beds are commonly highly contorted and locally contain veinlets of white quartz and calcite.

All the manganese deposits on the Mercedes claim lie in the metamorphic series, commonly as small lenticular bodies in fault zones. At one place manganese oxides occur in clay-filled joints or fractures in schistose marble. The manganese minerals include a soft, brownish-black, nondescript oxide with a little crystalline pyrolusite, psilomelane-type oxide, and ranciéite(?). Iron oxides, some calcite, and unreplaced country rock constitute the gangue.

The principal mine opening is an opencut 30 meters long, from 3 to 6 meters wide, and about 17 meters in maximum depth, which was sunk along a well-defined fault trending north to N. 15° E. and dipping 65°–75° W. The hanging wall of the fault is massive brown crystalline limestone of indeterminate attitude; the footwall is well-foliated contorted mica schist, that strikes N. 60°–70° E. and dips 55°–65° S. The west dip of the fault enters into the wall above the bottom of the pit, but the fault was cut again in a 3-meter crosscut driven westward from the pit bottom. Drifts extend 9 meters northward and 8 meters southward along the fault zone from the end of the crosscut. A winze sunk 9 or 10 meters on the fault gives a total explored depth of about 26 meters.

The fault zone ranges in width from 60 centimeters to 2.5 meters and consists of soft, brown, claylike material containing many flakes of mica and angular blocks of mica schist. Lenses of impure manganese and iron oxides are concentrated largely along the well-defined fault footwall; they range in thickness from a few centimeters to about 60 centimeters and average less than 30 centimeters in the exposed faces. Small irregular pockets of manganese oxides occur in the fault zone, along the hanging wall, and in the footwall schist.

The strike length of minable ore exposed in the winze and drifts is not more than 6 meters; only a few centimeters of low-grade ore are exposed at the ends of the drifts and at the bottom of the winze.

The total production from the above workings is not known, but 200 to 350 tons of ore may have been extracted from the open pit during World War I. The 35 tons of sorted ore stockpiled near the pit in 1943 was mined from the winze and drifts.

About 45 meters northeast of the main workings several shallow pits expose a very small amount of low-grade manganese oxide. Evidence of mineralization appears to be concentrated in a narrow zone, possibly along a fault parallel to that in the workings to the southwest.

The only other large workings lie about 300 to 450 meters west-southwest of the workings described above. These workings are said to be on the Mercedes claim but may actually be on the adjoining Adela claim. They consist of an opencut—about 25 meters long, 5 to 6 meters deep, and 6 to 9 meters wide—from which short drifts and inclines extend. The country rock is a gray schistose marble that appears to strike N. 65° E. and dip 45°–50° S. Manganese oxides occur in clay-filled solution-widened joints and cracks in the marble. Four steeply dipping, essentially parallel clay-ore zones about 1.3 to 2.5 meters apart are exposed in the south wall of the pit. These zones range in thickness from 15 centimeters to 1.2 meters and cut across the strike of the marble. Three of the zones terminate upward against a 30 centimeter layer of mica schist in the marble. Some manganese oxides extend along this schist layer. Neither the nature of the main ore body nor the possible amount of ore extracted could be ascertained. The 6 or 7 tons of ore stockpiled near the pit was mined many years ago.

Assays of three samples gave the following results:

| | Percent | | |
|---|---|---|---|
| | *Mn* | *$SiO_2$* | *Fe* |
| Main workings, average of 2 samples of stockpile | 38. 62 | 6. 86 | 11. 34 |
| 2-ton lot of low-grade ore | 30. 42 | 10. 05 | 3. 90 |
| Stockpile at western workings | 42. 11 | 7. 65 | 1. 56 |

The chief diluent in the main stockpile is evidently iron oxide. Hand-sorting of this ore would be a slow and tedious process, not only because of the intimate association of manganese and iron oxides, but because the iron oxide is commonly so very dark in color that it resembles surficially the manganese ore. Some iron may be chemically combined in the manganese minerals themselves. Considerable calcareous material is probably also present and much calcium may be chemically combined in the dull nondescript manganese oxide that is the chief mineral of the ores.

The grade of ore shipped in the past is not known, but an analysis of a 3-carload shipment in 1917 gave about 39 percent manganese and 5.25 percent silica. Analyses of the two carload lots shipped to the U. S. Metals Reserve Company Agency in February 1943 are given below:

| | Percent | | |
|---|---|---|---|
| | *Mn* | *$SiO_2$* | *Fe* |
| 30-ton lot | 36. 71 | 5. 31 | 2. 81 |
| 25-ton lot | 37. 83 | 8. 25 | 2. 58 |

The oxide ores appear definitely to be of secondary origin. Primary minerals, perhaps low-grade ferruginous and manganiferous carbonates occurring either along the same faults in which the present ore is found or in the subjacent calcareous country rock, were dissolved and the manganese and iron redeposited as oxides by lateral- and downward-percolating ground waters. No manganese silicates, such as might be expected in a metamorphic sequence, were identified but some may be present; Rogers reported rhodonite in pink schist in 1917. Little, if any, manganese oxide should be expected below the present ground water level, 30 to 45 meters below the surface.

Total reserves in the area studied are estimated at no more than a few hundred tons of ore containing 35 to 40 percent manganese. The ore occurs in small, irregular, discontinuous zones along or adjacent to rather widely separated faults or fault zones. Prospecting along these faults may uncover additional ore bodies but there is little reason to belive that they will be any larger or any better in grade than those found to date.

## CAMAGÜEY

Two manganese prospects in Camagüey were examined by T. P. Thayer of the Geological Survey.

### PROSPECT NEAR JARONÚ

A deposit of residual manganese oxide lies on the north slope of the Sierra de Cubitas about 2 kilometers west of Jaronú and 1 kilometer south of the Ferrocarriles del Norte line. The area is about 45 kilometers north of the city of Camagüey.

Lumps of manganese oxide weighing as much as 2.3 kilograms are scattered through red carbonate-cemented clay lying in solution cavities in Tertiary limestone. Both clay and manganese oxide apparently have formed by weathering of the limestone. The residual character of the ore is evident in a prospect pit about 3 meters deep.

### PROSPECT ON FINCA SANTA CLARA

Small manganese deposits are exposed on Finca Santa Clara, about 25 kilometers southeast of the city of Camagüey. Several shallow pits show small masses of high-grade manganese oxide in pockets in basalt. Rosettes of red fibrous piedmontite are associated with the manganese oxide. No minable ore was seen over an area of several acres.

## ORIENTE

### BONIATO DISTRICT

#### AUJALITA PROSPECT

The Aujalita prospect is about 2 kilometers northwest of Boniato. A shaft and old adit have been driven along a large mass of jasper enclosed in tuff. A little low-grade ore has been found.

#### CARIDAD PROSPECT

The Caridad prospect is near Boniato station. A shaft and cut reveal a little low-grade ore in tuff.

#### SANTA MARÍA PROSPECT

The Santa María prospect is east of the Aujalita prospect and adjoins it. Two cuts and an old adit explore three beds of manganiferous tuff interbedded with green and red tuff. The beds are 30 to 60 centimeters thick and locally contain considerable jasper. A few tons of low-grade ore (about 35 percent manganese) have been mined.

### BOTIJA DISTRICT

The Botija district is 10 kilometers southeast of Palma Soriano and 3 kilometers northeast of the settlement of San Juan de Wilson.

#### FORD PROSPECT

The Ford prospect was worked on a very small scale during 1941–42 and produced 6 tons of ore containing 46 percent manganese.

Thin beds of manganese oxide are scattered through a meter or so of tuff near irregular pods of jasper. The stringers of ore are less than 5 centimeters thick and pinch out laterally within 3 meters of the jasper. Pyrolusite and a little psilomelane-type oxide are the only manganese minerals. The prospect is not at all promising.

### BUEYCITO DISTRICT

#### BUEYCITO MINES

##### HISTORY AND PRODUCTION

The Bueycito district is near the west end of the manganese belt between the towns of Bueycito and Buey Arriba. An all-weather road connects the district with the Bayamo-Manzanillo highway, 19 kilometers north. The principal denouncements, including the Costa, Helen, Manuel, Oviedo, and Vicente, are owned by the Sun Development Company. A total of some 7,000 hectares is covered by the various claims.

A considerable but unknown amount of high-grade ore was produced during the first World War. In 1922 the Sun Development Company installed a concentration plant consisting of jaw crushers, rolls, a cone classifier, jigs, and tables. Narrow-gauge track was laid from the mill to many of the workings and to the railhead at Julia, 21 kilometers north-northwest. Seventy-three diamond-drill holes and 47 churn-drill holes were put down and ore was found in 30, most of them on the Manuel claim. The mill was operated from January 1923 to July 1926 and about 180,000 tons of crude ore averaging 25–30 percent manganese was treated. The tailings dump is estimated to contain about 40,000 tons of material averaging nearly 20 percent manganese.

The mines were shut down in 1926 and lay idle until 1942 when they were reopened by the Compañía Minera de Bueycito under lease from the owner. Although the rail facilities were in a state of disrepair, most of the track having been removed, the mill was reparable and was rebuilt to handle about 125 tons of crude ore per day. Operations began in February 1943. Ore was trucked to the railroad at Julia.

Production and grade of ore for the years 1923–44 are given in the following table:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| 1923–1926 | [1] 50, 000 | 45 |
| 1942 | 1, 864 | 47 |
| 1943 | 7, 526 | 46. 7 |
| 1944 | 3, 337 | 45. 4 |

[1] Estimated.

Mining in the Bueycito district has been beset by many difficulties, especially the discontinuous nature, small size, and wide scattering of the ore deposits. As many as 88 separate ore pockets were known in 1943, and 39 of them were being worked, but no systematic operation has been possible with so many disconnected ore bodies.

## GEOLOGY

Three kinds of rock are found in the region—agglomerate, tuff, and red to gray limestone (pl. 3). Outcrops and drill-hole data show that tuff underlies both agglomerate and limestone. The agglomerate has not been seen in contact with limestone, but fragments of both red and gray limestone in the agglomerate are physically identical with the nearby limestone and 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 that the agglomerate is a surface accumulation, which unconformably overlies both the tuff and limestone or that the agglomerate is intrusive into and through the tuff and limestone. Rounded fragments and the apparent gradation of agglomerate into conglomerate support the first idea, whereas the complete lack of bedding and the large size and angular character of many fragments suggest a mud flow near the vent that has spread over the surface locally and may be of intrusive character elsewhere.

Many of the agglomerate fragments are of enormous size; several that have been measured are more than 15 meters on a side. The fragments consist predominantly of tuff and other volcanic rocks, but include pieces of both gray and red limestone. In general they are mostly subangular, but rounded fragments predominate in places and the rock then resembles a coarse conglomerate. Many drill-hole records and old workings show that the thickness of the agglomerate in the northern and western parts of the mapped area is generally less than 30 meters.

The tuffs are generally bright green, but locally they are reddish and brownish with a tinge of purple. Fine-grained material grades into agglomeratic beds consisting mainly of fragments a few centimeters or more in diameter. The tuffs are in part water-laid and are similar to the water-laid fragmental rocks so abundant elsewhere in the Sierra Maestra.

The limestone beds are at least 30 meters thick on El Aura hill, in the northwestern part of the area. They are mostly gray; the red color, due apparently to fine particles of hematite, is seen only along the contact with the underlying tuff and close to the agglomerate. Several other nearby hills have conspicuous cappings of red limestone. The limestone contains poorly preserved fossils, a few resembling *Lepidocyclina* are supposedly of upper Eocene age.

The beds of tuff and limestone are generally almost horizontal although their dips in few places exceed 25°. No faults large enough to map have been recognized in these units, although 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 agglomerate and tuff, is shown in the underground workings southeast of the road at a locality about 300 meters east of the staff house (see pl. 3).

### ORE DEPOSITS

The ore deposits at Bueycito are in tuff and are similar to the tuff ores throughout the province. The unique feature of the Bueycito district is that the ore beds have been broken during formation of the agglomerate and now form widely dispersed and disconnected fragments in the agglomerate. This fact explains the erratic distribution and small size of the ore bodies, the largest of which contained about 5,000 tons. Practically all exploration has been directed toward the finding 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 at the time the agglomerate was formed. One small ore body at the contact between tuff and limestone was mined on the Daniel denouncement. Figure 36 shows small blocks of ore in agglomerate at the Volumen de Carlota working.


FIGURE 36.—Opencut at Volumen de Carlota workings, Bueycito district. Outlined areas are manganese-oxide-bearing tuff, encased in a rind of jasper. Matrix is chloritized agglomerate, strongly silicified at right side of large block of ore. Bedding in large block is nearly horizontal. Letter "a" shows a veinlet of limy tuff. All ore is low in grade, averaging about 30 percent manganese. Pick shows scale.

The most abundant ore mineral is a psilomelane-type oxide; there are smaller quantities of pyrolusite and scattered patches of manganese silicates, notably orientite (Hewett and Shannon, 1921). Pink and white zeolites are abundant and have been seen in veinlets cutting ore. Jasper is widely distributed in the bedrock, both as layers next to ore pockets and as isolated fragments in the agglomerate. It occurs also as boulders scattered over the surface.

Ore reserves are inferred to be 10,000 to 50,000 tons, averaging 25–30 percent manganese. In addition there are some 40,000 tons of tailings averaging about 20 percent manganese. Most of the reserves and all tailings could be utilized only by an improved method of concentration, such as flotation followed by sintering. The Manuel claim has been thoroughly explored by drilling and offers little hope of new ore bodies. Drilling along the southern, eastern, and northern edges of the agglomerate, where the ore-bearing tuff beds appear to be more continuous than in the central area, might be productive. However, the discontinuous character of the many known ore bodies presents a formidable obstacle to systematic exploration. The district seems to offer little promise of large future production.

### CUBEÑAS MINE

The Cubeñas mine is at Purial de Jibacoa on the Río Jibacoa, 25 kilometers south-southwest of Yara. A dry-weather road connects the mine with the railroad at Yara.

Production for the years 1942–45 is given below:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| 1942 | 58 | 50 |
| 1943 | 339 | 54. 0 |
| 1944 | 620 | 40. 2 |
| 1945 (1st half) | 57 | 52. 7 |

The mine is on the northward-trending scarp of an old terrace of the Río Jibacoa; most of the mine workings are near the base of the scarp. Interbedded tuff and agglomerate are the country rock. The agglomerate includes blocks of porphyritic dacite or quartz andesite, pyroxene andesite, and crystal latite or andesite tuff as well as blocks of tuff too much altered to be identifiable. Some blocks are as large as 1 meter across, but the average block is less than 15 centimeters across. The bedded tuffs are red, brown, purple, gray, or white and range in grain size from coarse to fine; some purple tuff underlying the ore body is shaly.

In the main mine workings at the north end of the area, the rocks dip 20°–25° SSE. In an opencut, 45 meters south, the dips are N. 30°–35° W. In the area between, the dips range from 17°–23° W., which would indicate that the north end is underlain by a syncline plunging west. At the south end of the area, 180 meters distant from the main workings, the only exposures are in an opencut and adit, where the rocks dip 25° WSW., and in a shaft, which shows tuff dipping about 19° S. The structure between the southern and the northern part of the area is unknown as there are no exposures.

The topography of the area is rather remarkable in that three cycles of erosion are distinctly shown. The mine is near the base of a terrace scarp 15 to 18 meters high. The terrace above is capped in places by sand and gravel as much as 3 meters thick. A recently abandoned flood plain extends westward from the base of the scarp about 90 meters to the Río Jibacoa, which is now entrenched 4 to 5 meters below the plain. Just south of the mapped area is a fine example of an abandoned semicircular meander scarp having a radius of about 120 meters. Toward the north the flood plain loses its identity and merges with the terrace in the impressively flat and extensive Manzanillo-Yara plain.

The Cubeñas deposit is a bed of manganese-oxide-bearing tuff interbedded with tuff, shaly tuff, and agglomerate. In places the ore bed is overlain and underlain by tuff; elsewhere the hanging wall or footwall may be agglomerate. Where the ore is overlain by agglomerate a thin layer of clay intervenes. The contacts of ore and country rock are sharp and show little or no gradation.

The ore itself consists of nodules of manganese oxide that are usually less than 2.5 centimeters in diameter but may be as large as 15 centimeters. Pyrolusite is the dominant mineral; in places it shows radiating sheaves of acicular crystals, which suggest pseudomorphism after some psilomelane-type oxide. In the deepest faces of the mine some nodules are composed of braunite, and it seems probable that at least some and perhaps nearly all of the pyrolusite has formed by oxidation of braunite. Inasmuch as the washed ore is nearly free of jasper, the average high silica content (7–9 percent) indicates the possible presence of braunite or of free silica in the oxidized material.

The nodules themselves have been formed by replacement of tuff. Evidence for replacement includes the irregularly rounded and embayed shapes of the nodules, indicating that they are not detrital pebbles; the presence of tiny tongues of oxide extending from the nodules into the surrounding tuff; and the common occurrence of crystals of pyrolusite radiating from a common center within the nodule. The tuff within the ore bed has been altered to a red or pink (zeolitic?) material that feels soapy. No unmistakably detrital manganese oxide was seen.

The main ore shoot, which yielded nearly the entire production, was 45 meters long and 18 to 21 meters wide. The ore bed ranged in thickness from a few centimeters to 2 meters and averaged about one meter. The line that marks the downdip limit of mineralization is almost exactly parallel to the strike of the rocks; this may be coincidental or may in some way be related to the relative competency of the ore bed during the folding which has affected the area, assuming that mineralization preceded folding. Although the mineralization could not be dated as preceding or following the folding, the majority of tuff-ore deposits in Cuba appear to have been formed during or soon after deposition of the tuff.

An adit, which begins 25 meters south-southeast of the main portal, shows soft tuff containing a few nodules of manganese oxide along its entire length of 17 meters. The tuff is at least 6 meters thick and overlies agglomerate; no ore was seen. This manganiferous tuff seems to be at the same horizon as the main deposit but may be above it.

The old mine workings, including two shafts and an adit, are now inaccessible, but M. W. Cox reported (January 1943) that 1.3 to 2 meters of tuff ore was exposed for 18 meters down the dip. These workings are 45 meters south of the main workings and the ore bed may be at the same horizon.

An opencut and short adit 75 meters south of the main workings expose agglomerate containing a small amount of disseminated manganese oxide. A few blocks of gray crystal tuff have been selectively replaced by manganese oxide that forms a thin rim around them. A few small rounded blocks appear to be a former crystal tuff or porphyritic igneous rock whose groundmass has been nearly completely replaced by manganese oxide, leaving crystals of feldspar, quartz, and hornblende imbedded in the oxide. These blocks were probably replaced prior to the formation of the agglomerate as their alteration is much more intense than that which has affected the rest of the agglomerate.

A shaft 180 meters south of the main ore body exposes tuff that contains a few scattered nodules of manganese oxide. The overlying soil shows a concentration of residual manganese oxide pellets at its base. According to the operator, a drill hole from the bottom of the shaft found good ore a meter or so deeper, and an adit was started (1944) to intersect this ore at depth.

The main ore body apparently was mined out by 1945. Reserves of the old ore body are not known but were reported by Cox to be several hundred tons.

The Cubeñas mine area offers possibilities for exploration by drilling both on top of the terrace and on the flood plain below. Drilling on the flood plain would probably tap considerable water. Exploration by drilling will of necessity be speculative because of the lenticular nature of the ore bodies and the lack of outcrops.

### DATIL MINE

The Dátil mine is 23 kilometers south of Bayamo and 3 kilometers east of San Pablo de Yao on the east edge of the Bueycito district. It is reached by trail from the Bueycito road. According to report, the mine was first worked in 1939.

Production data are as follows:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| Prior to 1943 | [1] 200 | ? |
| 1943 | 207 | 43. 5 |
| 1944 | 41 | 44. 2 |

[1] Estimated.

The mine is on the north slope of a low hill in an area underlain by tuff and agglomerate that strike northeast and dip northwest. In the immediate mine area a lens of tuffaceous limestone at least 210 meters in length and about 6 meters in maximum thickness is enclosed in tuff.

Pods, nodules, and veinlets of manganese oxide are scattered through a bed of tuff ranging from 30 centimeters to 1.5 meters in thickness. A unique feature of the Dátil ore bed is that it appears to overlie the limestone lens, whereas elsewhere in the manganese belt ore is found underlying limestone. No evidence indicating overturning of beds was found. Many small lenses of jasper are associated with the manganese-bearing tuff. Locally the ore-bearing tuff is in contact with limestone, and veinlets of manganese oxide cut the limestone, but in many places a thin layer of altered tuff lies between ore and limestone.

Pyrolusite is the most abundant manganese oxide, though a little psilomelane-type oxide occurs here and there. Mine-run ore contains 30 to 35 percent manganese.

The ore bed is explored by six opencuts and five shallow shafts, two of which have been productive. In the underground workings the ore bed attains a maximum thickness of 1.3 meters but minable ore is usually less than 60 centimeters thick. Ore was mined, hoisted, and sorted by hand, and recovery was low.

Reserves were low in 1944 and the ore bed had thinned considerably in some of the faces. Possible downdip extensions of the ore bed had not been explored adequately; the ore and underlying limestone dip slightly more steeply than the slope of the hill and therefore lie at greater depth to the northwest. A considerable amount of low-grade ore may be found downdip, but the ore bed is too thin and too low in grade in exploited areas to offer great expectations.

### JOSEFINA MINE

The Josefina mine is 9 kilometers southeast of Bueycito and 4 kilometers east of the Bueycito mining area. A total of 380 tons of ore averaging about 46 percent manganese was produced during 1942–44.

The ore deposit is a bed of manganiferous tuff lying between a tuff footwall and a jasper hanging wall. The beds strike N. 20° W. and dip steeply east. Ore is exposed underground for 25 meters along the strike and is faulted against jasper at both ends. The ore bed ranges in thickness from 60 centimeters to 2.5 meters. Mine workings consist of two shafts (one 13 meters deep), a drift, and a shallow winze.

The ore body was probably mined out in 1944, as reserves at the time of our examination (1943) were very small.

## CANDELARIA DISTRICT

### GLORIA MINE

The Gloria mine is on the Río Jagua, 2 kilometers west of Candelaria. It is linked to the private railroad of Central Miranda by 5 kilometers of dry-weather road. Although the mine was discovered in 1890, and worked on a small scale during the first World War, the major production dates from 1930. A washing plant to treat residual ore was installed by the Cuban Mining Company in the 1930's and a jigging plant was added in 1940 to exploit the bedrock ore.

Production prior to 1942 is not known but is estimated at 7,000 to 8,000 tons. Output for the years 1942–45 is given in the following table:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| 1942 | 1, 800 | 44 |
| 1943 | [1] 5, 200 | 44–53. 1 |
| 1944 | 1, 858 | 51. 7 |
| 1945 (first half) | 512 | 54 |

[1] Includes 4,857 tons of ore sold to Cuban Mining Company.

The mine area embraces two low hills underlain by Charco Redondo limestone, which strikes northwest and dips gently southwest. Thin-bedded platy limestone, at least 12 meters thick, caps the hills and is underlain by a more massive limestone. A bed of manganiferous tuff, ranging in thickness from a few centimeters to 2.5 meters, lies along the contact between the two limestone units and crops out around the hills. Toward the southwest this bed grades laterally into limestone conglomerate containing fragments of manganese oxide. The ore bed on the west hill is explored by many cuts; the ore shoot in the east hill, which was 165 meters long and 80 meters wide, has been mined out. A second very thin ore bed crops out on the north-east side of the east hill, about 30 meters stratigraphically below the main ore bed.

Manganese minerals include psilomelane-type oxide, pyrolusite, a dull black oxide of unknown composition, and a little neotocite; some of the oxides were probably derived from neotocite. A thin persistent layer of jasper underlies the thicker ore. The oxides form concretions or nodules along certain zones in the tuff.

Extensive deposits of residual ore flanking the hills on the north and south were the principal sources of ore prior to 1940 and during 1944–45; these granzoneras probably have been mined out. The residual ore was very high grade, averaging more than 50 percent manganese.

The Gloria mine area has been thoroughly explored by drilling and is considered to be essentially mined out. There are no likely areas for further exploration.

### ELVIRA MINE

The Elvira mine is in the shallow valley southwest of the Gloria mine. About 1,500 tons of ore averaging 52 percent manganese was shipped during the years 1942–45.

The ore deposit is an intraformational conglomerate composed of fragments of limestone and manganese oxide and is the downdip extension of the ore bed at the Gloria mine. Only where weathering of the conglomerate has freed the manganese fragments from their limestone matrix can the material be mined, as fresh conglomerate contains only about 15 percent by volume of manganese-oxide fragments. No large production can be expected.

### JESÚS MINE

The Jesús mine is on the south side of a steep-walled canyon about 1 kilometer northeast of the Polaris mine. It can be reached from the Palmarito-Candelaria road by truck in dry weather. Production is not known, as much of the ore has been shipped with ore from several other mines worked by the same operator; probably several thousand tons has been produced.

Manganese oxides occur in tuff and tuffaceous conglomerate lying 5 to 8 meters below a limestone bed, about 30 meters thick. The beds strike N. 85° E. and dip 35° S. One to two meters of conglomerate and a meter or so of the overlying tuff contain manganese oxide, but the ore-bearing zone averages only 1 meter in thickness. It is exposed on the surface and in inclines underground for 170 meters along the strike and 25 meters downdip. Ore minerals consist of fine-grained oxide of unknown composition, pyrolusite in stringers and nodules, and soft wad in radiating clusters of needles. Less than 20 percent of the ore particles are more than 1 centimeter across.

Reserves are small and low grade, and no sizeable extensions are expectable.

### POLARIS MINE

The Polaris mine is about one kilometer northeast of the Gloria mine. The denouncement and the farm on which it is located are owned by E. H. Kobler of Miranda. During 1941 and 1942 about

500 to 600 tons of ore containing 42 to 44 percent manganese was shipped. The mine was inactive during 1943–45.

The deposit is on an eastward-trending ridge about 600 meters south of and 90 meters above the Río Jagua. A bed of manganiferous tuff 0.3 to 1 meter thick lies at the base of a conglomeratic limestone, which is about 6 meters thick. The beds strike N. 35° W. and dip 10°–20° SW. Interbedded limestones and tuffs lie above and below the conglomerate. The ore bed crops out on the north side of the ridge, and is traceable along the strike for at least 120 meters, but ore has been mined only at the east end of the mineralized zone. Mine workings consist of two interconnected adits 15 to 18 meters apart and 25 to 30 meters long. The adits trend about S. 65° W. and are inclined 10 to 15 degrees downward. Stopes extend 50 meters eastward from the adits.

Manganese oxides, chiefly pyrolusite and a dull black oxide (pyrolusite?) with a small amount of psilomelane-type oxide are the chief ore minerals but manganese silicates, predominantly neotocite with subordinate bementite and braunite, are abundant in the lower levels. Ore minerals replace tuff at the base of the conglomeratic limestone; the contact with the limestone is well-defined, though the basal 0.3 to 1.6 meters of the limestone contains small irregular replacement nodules and pockets of manganese oxides, largely pyrolusite. A continuous jasper bed, ranging in thickness from 30 to 60 centimeters, underlies the ore bed. The jasper is brown, dense, massive, and fine grained; its contacts with mineralized tuff above and altered gray tuff below are frozen and sharp.

Manganese-bearing silicates are an interesting and economically significant feature of the ore. At the surface the ore is composed entirely of manganese oxides disseminated in pink to red zeolitic tuff. About 12 meters down the dip a thin layer of neotocite and bementite, with a little braunite, appears at the base of the ore bed in contact with jasper. The silicates increase in abundance with depth until, at the bottom of the workings, 90 percent of the manganese minerals are silica bearing and only 2.5 to 10 centimeters of oxides remain above the silicates. The contact between silicates and oxides is sharply gradational. At one point at the east end of the workings the entire 60 centimeters of ore bed was made up of neotocite containing irregular nodular masses of braunite 2.5 centimeters or so in diameter.

A variation in manganese oxides with depth is also evident. At the surface and for short distances down the dip considerable quantities of soft, blue-gray, crystalline pyrolusite are present. With increasing depth this mineral is superseded by a soft, black, lusterless oxide (microcrystalline pyrolusite?) and a negligible amount of psilomelane-type oxide. Specimens of neotocite, braunite, and the dull black oxide were assayed with the following results:

| Sample No. | Mineral | Mn (percent) | $SiO_2$ (percent) | Fe (percent) | Remarks |
|---|---|---|---|---|---|
| 43-5-206 | Braunite | 56.21 | 3.50 | 3.55 | Contaminated by small amount of neotocite. |
| 43-5-207 | Neotocite | 20.54 | 21.80 | 3.94 | Manganese silicate. |
| 43-5-211 | Manganese oxides | 46.95 | 6.75 | 1.55 | Dull black; contaminated by small amount of tuff. |

The general relationship of the various minerals suggests that the primary ore consisted of neotocite, braunite, psilomelane-type oxide, and bementite, in descending order of abundance, and that oxidation of these minerals converted them to the dull fine-grained oxide and pyrolusite(?) at the same time leaching part of the silica. Additional weathering and near-surface oxidation converted a part of these oxides to typical crystalline pyrolusite.

Several pits scattered over a strike length of more than 120 meters show erratic mineralization throughout the basal 1.6 meters of the conglomeratic limestone but very sparse mineralization in the ore bed itself. The same ore bed crops out on the south side of the ridge but is less than 15 centimeters thick and of very low grade.

About 6 meters below the main adits a small unexplored outcrop of ore probably marks a second ore bed but may be a downfaulted portion of the upper bed. Some exploration along this zone may be warranted, but it appears to be thin and the manganese oxides will probably give way to silicates at comparatively shallow depth.

About 500 meters to the northeast a shallow pit on the northeast bank of the Río Jagua exposes sparsely mineralized, altered tuffs containing manganese oxides. The mineralized zone is less than 3 meters stratigraphically below the base of a limestone unit, which lies 45 meters or so below the conglomeratic limestone at the main workings. The limestone is at least 9 meters thick and contains scattered rounded boulders of diorite as much as 30 centimeters in diameter. The limestone strikes N. 20° W. and dips 50° W; it is the continuation of the limestone above the ore bed at the Jesús mine, about 500 meters to the east. The mineralization at the Polaris extension may be related to that in the Jesús mine, and shallow shafts sunk in tuffs at the base of the limestone may discover some minable ore; but the marginal character of the Jesús ore body and the apparent decrease in grade of the ore zone toward the southwest are not encouraging.

Ore reserves total a few hundred tons containing 35 percent manganese. Additional prospecting may discover more ore but there is no likely chance to find any sizeable ore bodies.

## CHÉVERE DISTRICT

### CHÉVERE MINE

The Chévere mine is in the northern foothills of the Gran Piedra range at the headquarters of the Río del Indio. It may be reached by truck from El Caney over 42 kilometers of rough road. Production data are given below:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| 1941 | [1] 1, 000 | 44–46 |
| 1942 | 617 | 45 |
| 1943 | 108 | 45 |
| 1944 | 205 | 43 |

[1] Estimated.

The ore body is an irregular lens of partly oxidized manganese silicates enclosed in thin-bedded green tuff that is highly silicified near the ore. The lens strikes approximately east and dips steeply south, but in detail it is sheared and broken up by many small faults. It ranges from 0.6 to 2.5 meters in thickness and has a linear extent of at least 90 meters. The primary minerals are bementite and neotocite. Pyrolusite is the only abundant mineral in the oxidized ore. Figure 37 is a sketch map of the mine area.

Exploration over a vertical range of about 17 meters has shown that most of the oxidized ore lies within 3 meters of the surface; at greater depth manganese silicates become increasingly abundant. Practically all the high-grade oxidized ore was mined out by 1945. Several thousand tons of manganese silicates are surely available, but this material is not of saleable grade and the property, therefore, is not considered to be promising.

### JAVIER PROSPECT

The Javier prospect is just south of the Chévere mine. A lens of manganese silicates (mostly neotocite) and jasper is enclosed in fine-grained green and red tuff that strikes northwest and dips northeast. A little pyrolusite has formed by weathering of the manganese silicates, but little ore is in sight or expectable.

## EL COBRE DISTRICT

### SAN ILDEFONSO MINE

The San Ildefonso mine is near the town of El Cobre, about 150 meters from the junction of El Cobre road and the Carretera Central. A few tons of ore was shipped during 1917–18, but the bulk of the small production dates from 1941. A total of 257 tons of ore averaging 49 percent manganese was shipped from 1942 to 1945.

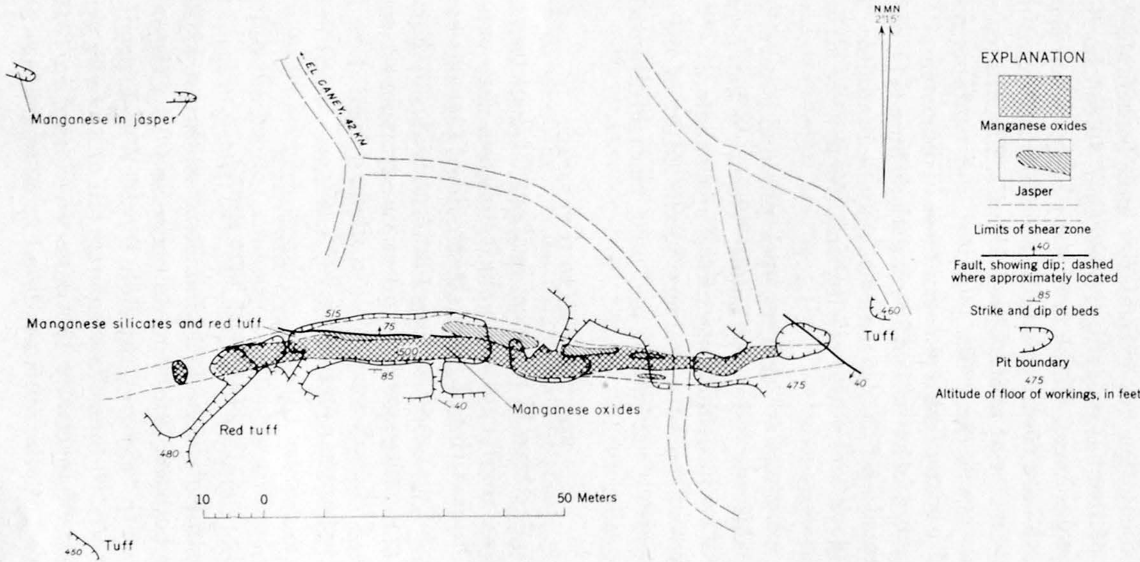



FIGURE 37.—Sketch map of the Chévere mine, Oriente, Cuba.

Country rocks are coarse-grained green tuff and limy tuff that strike east and dip 10°–50° N. Lenses and irregularly bedded deposits of manganese oxide occur in the tuffs, principally along one zone of steepened dips where four ore bodies have been found. Trenches show that these bodies either are lenticular or have been faulted apart. The ore in three of them is in stringers less than 40 centimeters wide and less than 3 meters long. In the fourth ore body, which is more than 60 meters long, the ore forms two beds, each about 60 centimeters thick, separated by 1 meter of white, bleached tuff. The altered country rock enclosing this ore is generally bleached and contains masses of red material with a soapy feel, a meter or more in diameter.

Most of the ore is hard, dull-black psilomelane-type oxide; 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 mine workings are shallow open pits and several shafts 6 to 9 meters deep. Mining is done by hand. The ore is hand-sorted because it is mixed with a large quantity of tuff and calcite.

The reserves of the mine are very small. Most of the ore averages less than 30 percent manganese and must be carefully sorted to reach a 40 percent grade.

#### VIENTE DE MAYO II PROSPECT

The Veinte de Mayo II prospect is about 8 kilometers northwest of El Cobre. Two small cuts and a shaft 3 meters deep expose tuff containing small quantities of manganese oxide. One cut exposes a thin veinlike body of manganese oxide that trends N. 30° E. and dips 70° NW. Some manganese oxide boulders and granzón are scattered over the surface. Although very little work had been done in 1942, the prospect did not appear promising.

### EL CRISTO DISTRICT

#### AUGUSTO LUIS MINE

The Augusto Luis mine is 2 kilometers southwest of El Cristo, on the highway between Santiago de Cuba and El Cristo. The claim was denounced in 1884 and, through World War I, produced an estimated 1,000 to 1,500 tons of manganese ore of 45 to 50 percent grade. After a period of inactivity the mine was leased in 1941. Between 1942 and June 1945 the mine produced 2,266 tons of ore averaging 46 percent manganese.

The Augusto Luis deposit is in well-bedded altered andesitic or basaltic tuff and minor tuffaceous shale of the Cobre formation. It is a manganese oxide and jasper bed conformably enclosed in green to brown, fine- to medium-grained tuffs, lying 300 to 350 meters stratigraphically below the top of the Cobre. The beds strike east in the main part of the mine area but at the east edge of the deposit trend northeastward to north. The entire section is overturned and the beds dip 16°–60° S. Plate 4 is a geologic map of the area.

Manganese oxides are closely associated with a single jasper lens that crops out conspicuously and forms the crest of an eastward-trending spur of Sierra de Boniato. The jasper-ore zone could not be traced beyond the ends of the jasper lens, which appears to pinch out within the limits of the mapped area. Limy tuffs and thin lenticular beds of tuffaceous limestone lie along the apparent strike prolongation of the west end of the zone where some foraminiferal limestone is partly replaced by jasper and manganese oxides.

The conformable jasper lens is about 300 meters long and has a maximum thickness of about 3 meters at the surface and 8 meters in the underground workings. It occurs, with enclosing tuff beds, in an overturned structural terrace; the northern edge dips 15 to 20 degrees south but the southern edge steepens to 60 degrees (see section, pl. 4). Eastward-trending normal faults of small displacement, commonly dipping steeply southward, and poorly developed shear zones roughly parallel to the bedding are exposed in the underground workings. Many irregular fractures, some mineralized, cut the jasper, but all fractures with observable displacement appear to be postmineralization.

Manganese oxides occur in a tuff zone along the jasper footwall; this zone ranges from a few centimeters to more than 2 meters in thickness and averages about 60 centimeters. The hanging-wall contact of the ore zone is very irregular and grades abruptly into jasper. Irregular stringers and veins of manganese oxides have penetrated the jasper to depths of a meter or more. The footwall contact of the ore zone is sharp and is usually marked by a bedding-plane fault. Locally, the footwall of the ore is marked by a thin layer of jasper. Manganese oxides are found also as apparently isolated pockets and irregular stringers within the jasper; some are of minable dimensions but most, even though high in grade, are too small to warrant exploitation.

Tuffs along both contacts of the jasper and manganese bed are strongly altered to nontronite and montmorillonite. The alteration zone along the barren hanging wall of the jasper is as much as 30 centimeters in thickness. In the footwall zone, where the tuffs are largely altered to green nontronite and contain small isolated lenses of jasper but no manganese oxides, the zone of alteration is more than 8 meters thick.

Pyrolusite, largely secondary after psilomelane-type oxide, is by far the dominant manganese mineral. The pyrolusite commonly forms irregular layers, with minor grains and patches of tuff, separated by thin and irregular layers of unreplaced red or brown tuff. A part of the ore consists of irregular replacement patches and nodules of pyrolusite in pink manganiferous montmorillonite. The masses of ore within the jasper are made up of pyrolusite with very little tuff and jasper gangue.

The ore zone has been mined over a strike distance of 135 meters and is developed by surface pits, shafts, and adits. Mine workings are shown on plate 5. Ore mined during and prior to World War I came largely from several open pits and short adits extending from them. A 100-meter adit, which cuts the ore zone at an altitude of 155 meters, is the principal mine entry. Drifts extend along the ore zone at this level, and winzes, sunk in jasper and ore, connect three drift levels below the main entry. The lowest drift shown on the underground map is 13 meters below the main adit, about 30 meters vertically below the surface, and about 21 meters long; it exposed an average thickness of 1.2 meters of ore containing an estimated 35 to 40 percent manganese. The lower level has been mined out since the mine was mapped early in 1943, the ore reportedly having pinched out about 8 meters below the level. Ore was mined in open underhand and overhand stopes and either hoisted by hand winch or hauled to the adit portal by wheelbarrow.

From the adit the ore was hauled by truck about 450 meters to the washing plant northeast of the mine workings, where the ore was screened, crushed, and jigged. The concentration ratio, estimated to be 1.5 : 1 to 2 : 1 using ore averaging 30 to 35 percent manganese, was relatively low for a jigging plant.

Ore reserves of a few thousand tons can be inferred in extensions along the strike and at depth. Extensions of ore at depth may well be found even though the ore on the lower level appears to have pinched out. Ore that pinches out locally is common in the upper levels, and exploration below the lower level should find small quantities of ore as long as the jasper lens with which the ore is closely associated can be followed. Thus far no minable ore has been found in the Augusto Luis mine area beyond the strike limits of the jasper lens.

### BOSTON GROUP

The Boston group includes the Boston and Pilar mines and the Edelmira prospect, all on adjacent claims covering the same manganese deposit.

#### BOSTON MINE

The Boston mine, operated by the Compañía Minera Boston, is 3.5 kilometers east of El Cristo, the shipping point with which it is connected by an all-weather road. The claim was denounced in 1885 and was one of the earliest producers of manganese ore in Cuba. Total production is unknown but has been reported to be as much as 50,000 tons; however, the size and extent of the old workings indicate that this figure is probably too high. The recorded production from 1942 to the end of August 1945 was 7,412 long tons of concentrate containing 44 to 46 percent manganese.

The mine is on a hill near the Río Guaninicún and the workings extend from the foot of the hill at about 120 meters above sea level to the hill crest at an altitude of about 230 meters. The rocks exposed in the Boston area are dominantly coarse- and medium-grained well-stratified tuff beds of the Cobre formation with which two or more beds of foraminiferal limestone are interbedded. The upper part of the section consists of brown, gray, reddish, and purple tuff deposits exposed on a steep ridge east of the mine. The lower part, in which the manganese occurs, is very poorly exposed and contains at least two beds of gray to green highly foraminiferal crystalline limestone, 3 to 5 meters apart. These limestone beds are exposed in shafts and in outcrops in the northern and southern parts of the mine area on the adjoining Pilar denouncement but no direct correlation is possible on the basis of present information. In places the limestone is conglomeratic or brecciose—a coarse green rock consisting of tuff, shale, and jasper(?) fragments as much as 5 centimeters across with many Foraminifera, all set in a limestone matrix containing much green nontronite. In places as much as one-third of the rock is composed of rock fragments or Foraminifera.

The mine appears to lie on the north limb of an eastward-trending anticline. The strike of the beds ranges from northeast to northwest; dips range from a few degrees to 60 degrees and are all toward the north, except on the adjoining Edelmira claim at the north edge of the area where the dip is 20° S. Faults were observed only in underground workings in the northern part of the mine.

The deposit is a conformable bed of manganese oxides in tuff associated with a large lens of jasper. It directly underlies a bed of foraminiferal limestone, in places as much as 3 meters thick, that contains seams of clastic material and is underlain by altered tuffs. The jasper lens crops out on the hill on which the mine is located and is a mass nearly 450 meters in length, about 150 meters in maximum width, and about 12 meters in maximum thickness. The eastern part of the jasper lens is on the Pilar claim. At the crest of the hill the jasper and underlying tuffs are nearly horizontal but the dip steepens to the north so that the poorly exposed hanging wall contact lies along the north-facing hill slope. The lenticular ore zone, which ranges in thickness from a few centimeters to as much as 3 meters, overlies the jasper, and some ore forms irregular lenses and pockets in the jasper. The bedded ore consists of layers of nearly pure manganese oxides, together with layers of tuff impregnated and partly replaced by disseminated and nodular manganese oxides, interbedded with red and brown altered tuff; the manganese-oxide layers are parallel to bedding in the tuff and range in thickness from less than a centimeter to 60 centimeters. Locally, the layers of manganese oxides and tuff in the upper part of the bed are cut by veinlets of manganese oxide, calcite, and by occasional clastic tuff dikes. Mineralization extends beyond the jasper but the grade and thickness decrease markedly away from it. In places the mineralized tuff abuts and pinches out against the steep side of the jasper lens. A psilomelane-type oxide and pyrolusite are the only observed manganese minerals (fig. 10). The former is the dominant mineral in the underground workings but pyrolusite becomes more abundant toward the surface and is the dominant mineral in the weathered jasper and ore zone on the crest of the hill.

Most of the early production came from shallow surface workings on the jasper outcrop, which is largely disintegrated into irregular blocks and boulders. Much of the ore is, therefore, detrital in these surface workings, but most of it retains the structure and texture of the primary ore that formed irregular pockets in jasper or settled down between the jasper boulders and blocks from the overlying manganese-oxide-tuff bed. The main old working is an opencut nearly 90 meters long, but there are also many small pits and prospect shafts.

The ore mined during 1942–45 came mainly from underground workings in the northern part of the mine area where there are two lenticular shoots separated by a jasper mass against which the ore beds pinch out.

The east ore shoot was explored by several shafts and adits at different levels. The ore bed, which dips about 40° N., was mined for 45 meters along the strike and 40 meters downdip; the average thickness mined was 2 meters. The ore is overlain by a 3-meter bed of limestone and is underlain by coarse red tuff and, in places, jasper. On the east and south the ore zone is cut off by postmineralization faults of unknown displacement; the east fault probably will be cut if mining proceeds downdip. Typical sections of the ore bed are given below:

*Section of ore bed near intersection of faults, southeast corner of stope*

| | Cm |
|---|---|
| Hanging wall not exposed. | |
| Tuff, manganiferous (30 percent Mn) | 30 |
| Tuff, red | 6 |
| Tuff, slightly mineralized | 27 |
| Tuff, red | 3 |
| Manganese oxide, solid | 9 |
| Tuff, red | 6 |
| Tuff, manganiferous; irregular rounded replacement masses of impure oxide (20 percent Mn) | 90 |
| | 171 |
| Footwall not exposed. | |

*Section of ore bed, main level, west end of stope*

| | |
|---|---|
| Hanging wall not exposed. | *Cm* |
| Tuff, manganiferous (20 percent Mn) | 6 |
| Manganese oxide and brown tuff, interbedded in thin layers | 12 |
| Tuff, coarse; fragments as large as 1.5 cm with matrix largely replaced by manganese oxide (25 percent Mn) | 27 |
| Tuff, manganiferous (15 percent Mn) | 27 |
| Manganese oxide and fine brown tuff, interbedded; layers as much as 2.5 cm thick | 45 |
| Tuff, red | 6 |
| Tuff, manganiferous; irregular rounded replacement masses of impure manganese oxide (20 percent Mn | 60 |
| | 183 |

The west ore shoot was explored by an inclined shaft, now abandoned, and a vertical shaft connected to the main adit by a level. The ore body was explored along the strike for 40 meters and averaged about 2 meters thick. Maximum thickness seen was 3 meters. The ore bed strikes east and dips vertically below the main level; above this level the dip flattens gradually to 65° N. Limestone of unknown thickness forms the hanging wall and the contact is faulted, probably essentially along the bedding. The footwall is jasper and tuff, the thickness of jasper being unknown. At the west end of the main level the hanging wall fault cuts across the bedding and limestone is brought against jasper, cutting out the ore bed. Exploration along the fault should pick up ore extensions to the west. At the east end of the level, and probably all along the east margin of the ore shoot, the stratigraphic position of the mineralized tuff bed is occupied by jasper and exploration here had ceased in 1944. The shoot has been explored updip to the surface, a vertical distance of 15 meters above the main level. Two small faults with an aggregate displacement of 3 to 5 meters were found. About 5 meters above the main level the limestone hanging wall is separated from the mineralized zone by tuff, which appears to thicken updip; no limestone is exposed at the surface.

Ore was mined entirely by hand and crude ore was hand-sorted before being trucked to the mill, where it was crushed, washed, sized in trommels, and then jigged.

Known ore reserves are largely exhausted, but several thousand tons of ore of 20 to 30 percent grade may be found in downdip extensions of the mined ore shoots in the lower levels of the underground workings. Exploration by drilling or sinking of prospect shafts should pick up faulted extensions of the ore bed. The unexplored ground to the north toward the Edelmira prospect should be tested, although it is possible that only low-grade ore not amenable to concentration in a jigging plant will be found, as the higher grade ore is found close to the jasper which seems to pinch out northward.

### EDELMIRA PROSPECT

The Edelmira claim lies north of the Boston mine. Apparently very little ore has been produced from the property. A shallow open pit exposes bedded rocks of the Cobre formation that strike east and dip 25° S. toward the Boston mine. The section exposed is as follows:

| | Thickness (cm) |
|---|---|
| Tuff, gray | ------- |
| Limestone, fossiliferous, brownish-white | 30–60 |
| Tuff, mineralized, very low grade | 120–150 |
| Tuff, red | ------- |

The ore is very similar to the lower part of the Boston bed, showing replacement masses of impure oxide interbedded with red tuff. All the ore is very low grade, containing an estimated 15 to 20 percent manganese, and is not amenable to concentration because of thorough dissemination of manganese oxide through the tuff. This same mineralized tuff bed is exposed in an arroyo 160 meters south and is probably the same bed found in a shaft 90 meters southwest at a depth of 9 meters. It seems probable that the Edelmira and Boston beds occupy the same stratigraphic position and that the valley between them is synclinal.

There may be a fair reserve of low-grade mineralized tuff on the Edelmira claim, but it could be utilized economically only if concentrated by some such process as was used by the Cuban Mining Company.

### PILAR MINE

The Pilar claim borders the Boston on the east and includes the eastward extension of the Boston deposit. Production from the property is not known. The mine was last worked in 1942 by F. Norton, who shipped 433 tons of ore, some that reportedly came from the nearby San Roque and Rosita prospects. The principal productive area is on the crest of the hill on which the Boston mine is situated. Tuffs of the Cobre formation are interbedded with a gray and green tuffaceous foraminiferal limestone, 1 to 3 meters thick, that overlies the eastern extension of the Boston jasper and manganese oxide bed. The beds strike a little north of east and dip about 15° N. Irregular blocks and masses of jasper and limestone cap the north dip slope of the ridge on which the mine workings occur. The ore consists of residual fragments of pyrolusite, or granzón, interspersed in weathered tuff in and around the boulders of jasper and limestone. It is mined in scattered small open pits. Reserves are small; the only possibility of extensions of ore is downdip under the limestone bed, but no jasper appears to be present there and the mineralized zone if present is not exposed.

About 230 meters southwest of the Pilar mine, on the south edge of the Río Guaninicún, is a small outcrop of jasper with small amounts of manganese oxides. The lens of jasper is as much as a meter thick and is traceable along the strike for more than 30 meters. It is interbedded in tuffs estimated to be at least 25 meters stratigraphically below the Boston and Pilar ore zone. The bed strikes north-northwest and dips about 15° W. Exposures are poor and the grade and thickness of the mineralized zone could not be determined. No exploration work has been done.

#### CARIDAD PROSPECT

The Caridad prospect, owned by Harold Simpson and others, is 2 kilometers east-southeast of El Cristo and is connected to the El Cristo-Quinto road by an all-weather road. The property has produced little ore. The deposit is in medium- to coarse-grained altered tuff lying some 300 meters below the top of the Cobre formation and consists of a bed of mineralized tuff overlying a 1- to 3-meter bed of gray, coarse, tuffaceous limestone. The mineralized zone strikes east and is traceable by means of old shallow prospect pits and short adits over a strike length of about 300 meters. The west end of the zone is vertical but the east end dips about 73° N. The mineralized tuff bed ranges in thickness from a meter to nearly 4 meters and is low in grade, containing an estimated average of 10 to 20 percent manganese. The chief manganese mineral apparently is a psilomelane-type oxide, in part altered to pyrolusite, which, for the most part, is so finely disseminated in the tuff that the ore is not amenable to ordinary methods of concentration.

A considerable reserve of low-grade ore may possibly be developed along the mineralized zone. Extensions of the zone to the east and west are concealed beneath alluvium but both ends of the bed apparently are cut off by a large southward-dipping reverse fault which has been traced from the upper Dos Bocas valley past the south side of the prospect and is inferred to trend northeastward to cut the mineralized bed and to continue into the Quinto mine area. However, beyond the west end of the zone the dip of the fault may be so low that the mineralized zone, if it extends westward as far as the fault, may not be far below the surface in the footwall block of the fault. Further prospecting would be warranted only if the low-grade ore could be economically mined and concentrated.

#### ESPAÑA MINE

The España mine is in the upper Dos Bocas valley, 1.5 kilometers south of El Cristo, the railroad shipping point. It is the most southwesterly of the group of producing mines that includes the Portugal, San Luis, and Tordera mines, all within 1 kilometer of the railroad and highway between Santiago de Cuba and El Cristo.

Production from the España mine since its discovery and denouncement in 1886 probably totals at least 10,000 tons but the production prior to 1942 can only be approximated by a comparison of the extent of old mine workings with the new developments. The bulk of the ore apparently was produced between 1942 and 1945, during which time a total of about 6,500 long tons of ore averaging about 47 percent manganese was marketed.

The España deposit extends eastward and westward into the Portugal claim, which completely encloses the España claim. To the west the deposit crosses the Portugal claim and extends into La Tinta claim. Surface geology is shown on plate 6.

The mine workings are near the foot of the steep part of the southeast side of Dos Bocas valley at altitudes ranging from 170 to 200 meters above sea level. The mine area is underlain largely by coarse-grained andesitic to basaltic tuff of the Cobre formation which strikes east-northeast to east and in general dips south from 5 to 40 degrees. Interbedded with the tuff are at least two and perhaps three jasper-manganese oxide beds. The manganese oxides are closely associated with large conformable jasper lenses; of the two principal jasper lenses the one that is stratigraphically lower is the more extensive, and virtually all the ore mined thus far has been found along its contacts with tuff or within the jasper. This lower jasper lens can be traced along the strike for at least 200 meters and attains a maximum thickness of about 6 meters. The upper jasper lens lies 6 to 9 meters stratigraphically above the lower and can be traced along the strike for about 60 meters. Its maximum thickness could not be determined but probably is near 6 meters. The jasper beds pinch out in both directions along the strike.

The principal mine workings are in a structural horst bounded on two sides by north-northeastward-trending faults. The western fault, here referred to as the España fault, follows a steep-walled arroyo cutting through the deposit and is exposed at only one place underground, where it dips 55°–60° W. Its presence is inferred elsewhere because of the dissimilarity of rocks on opposite sides of the arroyo and by the fact that west of the arroyo the main ore zone lies 15 to 18 meters lower than on the east side; the fault therefore has a normal displacement. The eastern fault, named the Portugal fault, was first found in the Portugal mine area; it apparently dips steeply and its east side is downthrown an estimated 15 meters. The Portugal fault is believed to extend up the deep arroyo between the España and Portugal mine areas, just east of the area shown on plate 6. That the España ore beds were once continuous with the adjacent Portugal and San Luis beds is indicated by the fact that there are two principal ore and jasper beds in each mine area, about the same stratigraphic distance apart, and by the fact that the tuff sections are similar: relatively massive coarse green tuff underlies the lowest ore zone and well-bedded finer grained tuff overlies the uppermost ore bed.

Manganese oxides occur in tuff beds ranging in thickness from a few centimeters to about 3 meters. The beds overlie the jasper lenses and also extend beyond the ends of the jasper lenses, although where jasper is absent the tuff beds containing manganese oxide are low in grade and in general are not minable. The highest grade ore occurs in pockets, layers, lenses, and stringers within the jasper.

Pyrolusite is the principal manganese mineral but in places there are minor amounts of a psilomelane-type oxide. The texture of the pyrolusite indicates that most of it is secondary. The only gangue is slightly ferruginous brown jasper and tuff that is altered, especially along the base of the jasper lenses, to white to gray montmorillonite and green nontronite. Pink manganiferous montmorillonite in places is intimately associated with the manganese oxides, and altered tuff beds near ore are red from disseminated iron oxides. Manganese oxides form thin parallel layers, from a fraction of a centimeter to several centimeters in thickness, or are disseminated in tuff. In many places masses of ore within the jasper consist of nearly pure manganese oxides in sharp gradational contact with the jasper.

The upper ore bed has been explored by many opencuts, short adits, and shafts. In the block east of the España fault pyrolusite has been found in small pockets and lenses in jasper and also in a thin low-grade manganiferous tuff bed overlying jasper. This bed has been explored about 20 meters beyond the east end of the jasper and appears to pinch out. Only a few hundred tons of ore has been mined from this zone.

In the block west of the fault the upper ore zone cannot be recognized with certainty because of lack of exposures and because the associated jasper pinches out on the east side of the fault. Several opencuts expose a thin bed of low-grade manganiferous tuff which may represent the upper ore zone; no minable ore has been found.

The lower manganese zone has been explored by many hundreds of meters of adits, inclines, and drifts, and by four working shafts. Ore has been mined on both sides of the España fault but the east block has been by far the more productive and contains nearly all the accessible workings. The main ore deposit is a bed of manganiferous tuff which throughout most of its extent overlies a large jasper lens. The bed ranges in thickness from a few centimeters to 1.3 meters and averages about 0.6 meters. Manganese oxide, largely pyrolusite but with minor amounts of psilomelane-type oxide, is found in thin beds in tuff or disseminated through tuff. Where the ore bed is in contact with jasper it is commonly of better grade than elsewhere; in fact, very little ore has been mined from the bed where it is not in contact with jasper. Throughout the mine the manganiferous bed is folded locally into small anticlines and synclines (see sections, pl. 6). Although exposures in the mine do not furnish conclusive evidence it is believed that, analogous to the similar Tordera and San Luis deposits to the northeast, the folds are original structures modified by differential compaction over small domes and ridges of sedimentary jasper.

Manganese oxide also has been mined from a more or less continuous zone within the jasper about 2 to 2.5 meters below the main ore bed. The zone consists of small irregular pockets, lenses, and veinlets of oxide which may form as much as 50 percent of the rock mined; the only gangue is jasper. Production from the mineralized jasper has not been large because of the thinness of the zone and also because of difficulty in drilling the hard jasper.

Ore was mined entirely by hand. Much of the ore came from irregular underhand open stopes which stand well and require little timber. Ore was hauled by wheelbarrow up the inclined adits or to the foot of shafts where it was then hoisted by hand winch. From the mine the ore was trucked to the mill where it was crushed, log washed, and jigged. Recoveries were low as the manganese oxide is soft and friable and gave a high percentage of fines.

Lack of development work ahead of mining and the irregularity of mineralization throughout the deposit preclude an accurate estimate of reserves of high grade ore containing 30 to 35 percent manganese. Possible extensions to the south and southeast of the lower main jasper and manganese oxide bed may be inferred to yield several thousand tons of concentrate.

Reserves of low-grade ore containing from 10 to 20 percent manganese may be greater than high-grade reserves but their exploitation would require a different method of concentration than that now used in order to get a reasonably high recovery.

### GUADALUPE PROSPECT

The Guadalupe prospect, 2 kilometers south-southeast of El Cristo on the southeast side of Dos Bocas valley, is reached by trail from the highway on the opposite side of the valley. The deposit is enclosed in fine to coarse tuff striking southeast and dipping 40°–45° SW. It consists of a single bed of tuff containing disseminated pyrolusite and psilomelane-type oxide. The manganese-bearing bed has been prospected by shallow pits over a strike length of about 300 meters and a vertical extent of over 50 meters. It ranges in thickness from about 60 centimeters to more than 2 meters and is estimated to contain 10 to 20 percent manganese.

Little, if any, ore has been produced from the property but several tens of thousands of tons of low-grade material might be developed. Further prospecting would be warranted if the manganiferous tuff could be economically mined and concentrated. The mineralized zone is on the southeast projection of the España and La Tinta ore bed and may be the same bed, but it is not known that mineralization is continuous from the Guadalupe to the España area.

### MIRÓN MINE

The Mirón mine, 5 kilometers east-southeast of El Cristo and about 900 meters in the same direction from the Pilar mine, can best be reached by trail from the Boston mine or by trail up the Río Guaninicún from the Quinto group of mines. In 1943, the mine produced 172 long tons of ore containing 47.4 percent manganese, but the total production is unknown. Shallow surface workings explore small pockets and lenses of pyrolusite and psilomelane-type oxide that replace limestone and the immediately underlying tuff. The limestone bed is a meter or more thick and is the continuation of the limestone above the ore bed at the Pilar mine. It strikes east and dips 10°–25° N. Further prospecting will probably disclose small amounts of additional ore.

### QUINTO MINE

The Quinto mine (Isabelita or Ysabelita of older literature) lies about 3 kilometers east of El Cristo. It is one of the oldest manganese mines in Cuba and was operated intermittently from 1890 to 1932 and continuously from then until the end of 1946. The geology of the deposit and the early operations are described briefly by Spencer (Hayes, Vaughan, and Spencer, 1901, p. 65–66, fig. 7) and Burchard (1920, p. 70–71). A sketch of the geology and a description of operations of the Cuban Mining Company from 1930 to 1940 are given by Norcross (1940, p. 2–13).

The Quinto mine has been the largest producer thus far discovered in Cuba, although it may be surpassed eventually by the Charco Redondo mine. Total production from the deposit is not known, but from January 1942 until August 1945 it yielded about 375,000 tons of sintered concentrate, or some 35 percent of the total Cuban production of that period. Output of concentrate during the period of greatest production, 1935–46, is estimated to be between 800,000 and 900,000 tons.

Most of the ore has been extracted by open-pit methods. By the end of 1946, when the Cuban Mining Company ceased operations at El Cristo, all the ore economically recoverable by open-pit mining was exhausted.

The geology of the deposit will be summarized only briefly, as a complete description will be the subject of a forthcoming separate article. The essential features of the deposit are illustrated by plate 7, which in part gives a reconstruction of the deposit as it was before large-scale mining operations began.

The Quinto deposit lies in pyroclastic rocks in the uppermost 10 to 50 meters of the Cobre formation and consists essentially of two very extensive beds of low-grade manganese ore, which strike approximately N. 60° E. and dip 13°–15° NW. (fig. 38). Ore was mined over an area of approximately 1,000 meters along the strike by 300–400 meters down the dip from the outcrop. The beds are

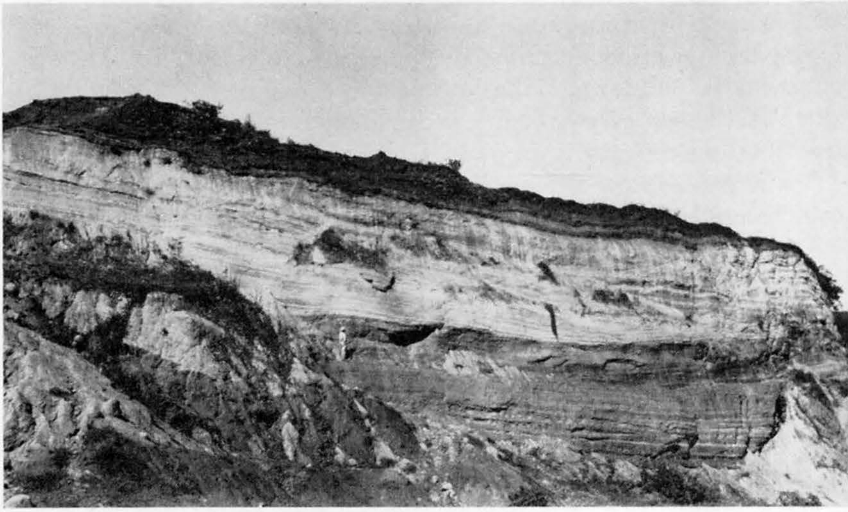


FIGURE 38.—Lower ore bed and base of upper ore bed, Quinto mine. The dark layer at the top of the cliff is the basal jasper zone of the upper ore bed. It is underlain by 7–8 meters of barren tuff. The lower ore bed, on which the man is standing, is more than 7 meters thick at this point but is of very low grade. Note the well-bedded character of tuff and ore and the interleafing of jasper and tuff at the upper righthand end of the cliff.

separated by a layer of altered tuff that ranges in thickness from a knife edge to as much as 15 or 20 meters; the tuff is thickest along the south (outcrop) edge of the deposit and disappears near or somewhat updip from the bottom of the present open pit. A third very thin bed is found in the southwestern part of the deposit a few meters below the lower ore bed.

The upper ore bed is overlain by a layer of barren tuff that ranges in thickness from a few centimeters along the north side of the deposit to 10 or 15 meters along the south side. This tuff is in turn overlain by the Charco Redondo limestone, which at Quinto is an impure white to yellow rock. Although the limestone is very rarely more than 5 meters thick, it is remarkably persistent and is found throughout the mine area. Above the Charco Redondo limestone lie brown calcareous shale and thin limestone beds of the San Luis formation.

The ore beds range in thickness from a few centimeters to a maximum of about 15 meters. Both beds are underlain over most of the mine area by sheets of jasper ranging from a few centimeters to as much as 15 meters in thickness. The ore beds as well as the jasper are extremely variable in thickness, and the variations may occur very abruptly. In addition, the strata are gently folded along axes that trend roughly east-northeast. The lenticular nature of ore and jasper, as well as some of the many minor folds, are shown clearly in plate 7. This lenticularity caused some difficulties during mining, as great flexibility in mining methods was required to cope with the abrupt changes in ore thickness, in dip, and in the amount of jasper that necessarily had to be extracted with the ore; draglines were found to be more useful than shovels because of their greater adaptability (Norcross, 1940, p. 4).

Tuff dikes cutting the ore beds are very abundant; several of them are exposed along the bottom of the pit on the north side.

The principal ore type at Quinto is what we have termed "replacement-stalacite" ore (pp. 82–85) and figs. 21–23). This ore, as mined, contained from 13 to 26 percent manganese (Norcross, 1940, p. 4) and probably averaged 16 to 17 percent during the life of the mine. The most abundant mineral is the psilomelane-type oxide characteristic of the "replacement-stalactite" type of ore; in addition, manganite is fairly widespread although not abundant and pyrolusite was plentiful during the early mining operations near the outcrop.

A number of steep-dipping normal and reverse faults with displacements of as much as 10 meters or more cut the ore beds within the area of the open pit. Most of these faults are shown on plate 7.

Along the north side of the open pit the dip of the ore beds and their enclosing rocks increases rather suddenly from 15 degrees or so to 45 degrees or even more; in places the dip approaches the vertical. The shale of the San Luis formation overlying the mineralized beds and exposed along the north wall of the pit is crumpled and sheared along a zone that strikes east-northeast at the west end of the pit and trends eastward at the eastern end; the sheared zone seems to dip almost vertically and is shown thus on plate 7.

The downdip extension of the Quinto deposit appears to be cut off by the fold-fault structure or at least to be carried by it to a considerable depth below the surface, as the few drill holes to the north of the structure, including one 110 meters (360 feet) deep, failed to intersect the top of the Cobre formation. At the line along which the dip begins to increase and along which open-pit mining consequently ceased, the ore bed is 6 to 8 meters thick and shows no decrease in manganese content. We believe, therefore, that the possibilities of finding a large tonnage of ore to the north of the fold-fault structure are good. The ore bed probably would lie at least 150 meters below the surface, so open-pit mining would not be feasible; for this reason among others the extensive potential ore-bearing area north of the Quinto pit was not drilled by the Cuban Mining Company.

### ROSITA SEGUNDA PROSPECT

The Rosita Segunda prospect, 3 kilometers southeast of El Cristo and about 1 kilometer southwest of the Boston mine, is reached by trail south from the end of the road at the mill of the Cuban Mining Company. It was prospected by F. Norton who worked the Pilar mine. Past production is not known but apparently was small. The workings consist of a shallow surface cut at the east end of a jasper lens intercalated in stratified tuffs. The reddish-brown jasper strikes east and dips 20°–25° N; it is exposed over a strike length of about 350 meters and is more than 3 meters in maximum thickness. A meter or more of mineralized tuff containing psilomelane-type oxide and pyrolusite overlies the east end of the jasper lens and extends beyond the end of the lens. Poor exposures and lack of prospect pits prevent determination of the extent of the mineralized zone. The jasper is cut by numerous fractures filled with white chalcedonic quartz. Barren tuff strongly altered to green nontronite underlies the jasper. The mineralized tuff is very low in grade; much of the soft manganese oxide is so finely disseminated as to preclude concentration by handsorting, and recoveries probably would be prohibitively low if the ore were concentrated in a washing and jigging plant. Further exploration would be warranted if the low grade material could be economically concentrated, but the prospect of finding a large tonnage of lowgrade ore is not good.

### SAN LUIS GROUP

#### GENERAL DESCRIPTION

The San Luis group, 1 kilometer south of El Cristo, includes three mines (San Luis, Portugal, and Tordera) and one prospect (El Papel) on adjoining claims. These properties are connected by an all-weather road leaving the Santiago-El Cristo highway 0.6 kilometer from El Cristo, the railroad shipping point. The Tordera mine covers most of the east half of the productive area shown on the surface geologic map (pl. 8), the San Luis mine covers most of the west half, and the Portugal occupies the extreme western end. El Papel claim borders the Tordera claim on the northeast and southeast and extends along the southwest side of the San Luis claim. Boundaries of the rectangular claims extend northwestward and northeastward but have not been placed on the map because of disagreement among respective mineowners and operators as to their locations.

Recorded production from 1942 to the end of August 1945 totaled nearly 55,000 long tons of concentrate of which the San Luis and Tordera mines produced more than 47,000 tons and the Portugal more than 7,000 tons. Grade of the concentrate ranged from 45 to 50 percent manganese and averaged about 46 percent. Production prior to 1942 is not known.

The same apparently continuous deposit is developed by interconnected workings of the San Luis and Tordera mines and the area forms, therefore, a natural geologic and economic unit. To avoid duplication the geology of the area as a whole will be described.

The mines are at the head of Dos Bocas valley and extend over the drainage divide of the Sierra Maestra. The terrain has moderate relief, with altitudes in the mine area ranging from about 180 to 250 meters above sea level. Coarse- to fine-grained bedded basaltic, andesitic, and dacitic tuff and minor agglomerate and tuffaceous shale of the Cobre formation are the country rock. Interbedded with the tuff are three manganese oxide-bearing beds associated with conformable lenses of jasper. The lowermost part of the section of pyroclastic rocks below the manganiferous beds consists mainly of thick-bedded, coarse, partly limy, altered green tuff. This coarse tuff, whose base is not exposed in the mine area, is overlain by about 15 meters of distinctly bedded, medium-grained, gray, brown-weathering tuff that underlies the lowest manganese oxide-jasper zone. From 5 to 25 meters of green to gray medium-grained and locally coarse-grained tuff lies between the lower and middle ore bed. In the southeastern part of the area, in the Tordera and Pilar mines, tuff immediately below and within the middle mineralized bed is very limy. Above the middle bed much fine-grained tuff and some brown tuffaceous shale are interbedded with medium- to coarse-grained well-bedded tuff; 3 to 6 meters of these rocks separate the middle and upper zones bearing manganese-oxide. The proportion of tuffaceous shale and fine-grained tuff increases above the upper zone of mineralization, and much of the tuff is distinctly limy.

The tuff and intercalated mineralized beds are irregularly folded and dip at low to moderate angles. The beds have a general north to northwest strike and dip about 10° E. In the western part of the area a broad open syncline plunges about 10° SW.

The entire section is part of the hanging-wall block of a great southward- to southeastward-dipping thrust or reverse fault that traverses Dos Bocas valley and apparently is continuous with the fault system in the Quinto group of mines. This fault lies just outside the area shown on plate 8, but several small faults, which converge toward and presumably end against the bordering thrust fault, displace beds within this area. Most of these faults are directly observable in the mine workings. The principal faults have moderate to steep dips and trend northward to northeastward, but small faults also trend westward and northwestward. Some of the faults appear to have normal displacements and some have reverse displacements, but striations along many principal faults and displaced folds reflected in the lower mineralized zone indicate a large horizontal component of movement.

The westernmost principal fault is on the Portugal claim, along the west side of the mine workings and is referred to as the Portugal fault; it trends northward and apparently dips steeply, but the direction of dip is unknown as the fault has not been directly observed. Massive coarse green tuff on the west side of the fault is in contact with fine-grained gray to brown tuffs on the east side, which is downthrown about 15 meters. The ore beds and tuffs of the San Luis and Tordera mines area apparently have been displaced along the Portugal fault and are believed to continue west of the fault to the España mine area.

The other principal faults form a subparallel set that trends northeastward through the San Luis mine area and passes to the north of the Tordera mine. These faults converge northeastward as they approach the thrust fault of Dos Bocas valley; the movement along them appears to be rotational as their displacement increases northeastward and the direction of dip changes along individual fault planes. The greatest estimated throw is 30 meters on the north side of the mine area near the intersection of the two main faults of the set, where ore beds and enclosing tuff are faulted against thick-bedded coarse tuff at least 30 meters stratigraphically below the lowest ore beds. The horizontal component of displacement is difficult to estimate but seems to be much less than the vertical component.

The ore beds consist of altered bedded tuff which encloses many lenticular masses of reddish-brown jasper and is replaced in part by manganese oxides. The three zones are mineralogically similar and differ only in their areal extent, thickness and grade, and relative proportions of jasper and manganese oxides. The lowest bed is the most extensive and has the greatest average thickness and grade; the proportion of jasper to manganese oxide in this bed seems to be the lowest of the three beds. The upper bed is the least extensive, thinnest, and lowest in average grade, and the proportion of jasper to manganese oxide is high, about as high as in the middle bed. The distribution, character, and relations of these beds can be seen on the surface map (pl. 8) and the isometric diagram (pl. 9).

Finely crystalline pyrolusite is by far the dominant manganese oxide. It is associated with rare psilomelane-type oxide and massive fine-grained manganite. The pyrolusite is in part massive, but commonly has fibrous and colloform textures suggesting that most, if not all of it, has been formed by alteration and oxidation of the primary psilomelane. Manganite probably is also secondary after psilomelane. Pink manganiferous montmorillonite is intimately associated with the manganese oxides, especially in the lower ore bed. Tuff near jasper lenses is altered to green nontronite and white, gray, or brownish-gray montmorillonite.

The manganese oxides occur as parallel solid layers from a fraction of a centimeter to several centimeters thick alternating with layers of barren tuff or altered tuff impregnated by manganese oxides; as replacement nodules; and locally within the lower bed in lenticular layers of intraformational conglomerate as angular fragments in a matrix of altered tuff. The manganiferous tuff zones overlie the jasper lenses and extend away from the jasper along the same stratigraphic horizon. Less commonly manganiferous tuff also underlies the jasper lenses. The grade of ore is almost invariably highest near jasper; the largest masses of ore are in contact with jasper and occur in the jasper as irregular pockets and lenses often consisting of nearly pure manganese oxide.

The lower ore bed has yielded almost all the ore mined and is the most intensively developed and explored of the three mineralized zones. The mined portion of this bed ranges in thickness from about 15 centimeters to about 3 meters; the average thickness is about 1.5 meters and the average ore contains 25 to 35 percent manganese.

Large lenticular masses of jasper separated by manganese-bearing tuff lie along this lower zone. The largest lenses reach a length of about 150 meters, a width of as much as 125 meters, and a maximum thickness of nearly 12 meters; the smaller lenses have a length of less than 30 meters and a maximum thickness of 1.5 meters. The jasper lenses are very irregular in shape, especially in thickness; the larger lenses are compound forms, consisting of steep-sided thick portions connected by thin zones. The thickest and best ore overlies the jasper on the flanks and edges of the thick portions and in the adjoining hollows.

The manganese-oxide-tuff beds and overlying tuff are conspicuously domed over the jasper lenses and commonly tuff and ore beds are squeezed and even faulted against steep flanks of jasper. That the domical structures have formed as a result of differential compaction of relatively incompetent tuff beds over resistant masses of jasper is supported by the following facts:

1. The domical structures and intervening sags or synclines do not appear in the tuff beds underlying the ore and jasper zone.

2. The folds die out upward rather abruptly and are not reflected in beds as high as the middle ore bed.

3. Faults along which tuff and ore beds are displaced are commonly peripheral to the jasper, curving with the curved flank of the lenses. They are crosscutting only at and above the flank of the jasper masses and become bedding plane faults down dip away from the jasper; many become bedding plane faults above the jasper.

4. Folds are nonsystematic over the area as a whole and domes are centered over the thick jasper lenses only.

The best ore is localized on the outer flanks of the jasper lenses; away from the jasper the grade of mineralized tuff beds almost invariably falls off so abruptly that the great bulk of the mining is confined to the jasper and to a peripheral zone 1 to 15 meters wide along the flanks and edges of the lenses. This fact and the fact that the jasper lenses are reflected as domes suggested the possibility that areas favorable for ore extensions might be determined if a structure contour map were made. More than 5 kilometers of underground workings were mapped and a structure contour map (pl. 10) was drawn on top of the lower ore and jasper zone. This structure contour map, superposed over the underground workings, illustrates well the close relation of minable ore and domical jasper lenses. It shows that the jasper lenses are irregular and have no systematic distribution, and indicates a crude northwesterly orientation of the longer axes of elliptically shaped lenses in the eastern half of the developed area but not in the western half. The reason for the orientation of the jasper lenses is not known but appears to be an original depositional feature at variance with the present regional structure and therefore bearing no relation to it.

The middle bed extends over most of the area but apparently thins out and disappears to the northeast. It differs from the lower bed in that the jasper lenses along it are thinner but more widespread, and the mineralized tuff is thinner and lower in grade.

Assuming that the jasper capping the small hills in the west and east-central part of the area was once continuous with adjacent main outcrops, only two or possibly three jasper lenses seem to lie along the middle zone. The largest lens was at least 450 meters long, but its maximum thickness is only 4 to 6 meters. Very low grade mineralized tuff containing disseminated manganese oxides extends away from the jasper and also forms a discontinuous zone at the top of the jasper. The low-grade tuff ranges in thickness from a knife edge to about 2.5 meters and contains an estimated 10 to 20 percent manganese. Very little ore has been mined from the middle bed, although prospect pits have been dug along it; however, residual fragments or granzón have been recovered from weathered parts of the outcrops, particularly on the erosional remnants represented by the jasper-capped hills.

A thin upper zone of mineralization apparently is present only in the southeastern part of the area on the Tordera and El Papel claims;

it is poorly exposed and is not traceable beyond the limits shown on the surface map. The zone contains lenticular masses of jasper, a meter or so in maximum thickness, overlain by low-grade manganiferous tuff as much as 60 centimeters thick. Similar thicknesses of poorly mineralized medium- to coarse-grained tuff extend away from the jasper. Commonly the mineralized tuff contains small nodules of jasper associated with much green nontronite.

Indicated and inferred reserves in the San Luis, Tordera, and Portugal mines area are estimated to total 25,000 to 50,000 tons of ore of 25 to 35 percent grade, most of which is on the San Luis and Tordera claims. Possibly more than 100,000 tons of low-grade manganiferous tuff containing 10 to 20 percent manganese could be developed in the middle bed and in low-grade extensions of the lower bed. However, this low-grade material cannot be concentrated by washing and jigging alone because the bulk of the manganese oxide is soft and finely disseminated.

### PORTUGAL MINE

The Portugal mine, denounced in 1887, is owned by Marcelino Alonzo (until at least 1945) and was operated under lease by Manuel Dumois and associates of the Compañía Minera La Llave, S. A. The productive area of the mine, 60 meters wide and 150 meters long, occupies the southwest flank of the hill shown on the west end of plate 8. Recorded production of concentrate is given below:

| *Year* | *Tonnage (dry long tons)* | *Grade (percent Mn)* |
|---|---|---|
| 1942 | 1, 259 | --------- |
| 1943 | 5, 577 | 47. 3 |
| 1944 | [1] 300 | --------- |
| 1945 | [1] small | --------- |
| Total | 7, 136 | --------- |

[1] Estimated, as the concentrates were mixed with those from the Tordera mine.

The lower and middle ore zones extend onto the Portugal claim but only the lower bed has been productive. This bed was developed by two principal adits. Ore was mined by hand and hauled by wheelbarrow to the surface, where it was loaded by hand on trucks and hauled to the Tordera concentrating plant.

The ore zone is almost completely mined out and minable ore extends only eastward onto the San Luis claim. However, as noted under the description of the España mine, the España ore body may extend onto the Portugal claim, which surrounds that of the España.

### SAN LUIS MINE

The San Luis mine, one of the oldest manganese properties in Cuba, was denounced in 1884. It was operated during 1942–45 under lease by Harold Simpson, who, together with María Ann Tejada owns the greater part of the mine. The claim covers the west-central part of the mapped area (pl. 8). Production of concentrate for the period 1942–45 is as follows:

| Year | Tonnage (dry long tons) | Grade (percent Mn) |
|---|---|---|
| 1942 | 4, 547 | -------- |
| 1943 | 10, 067 | 45. 0 |
| 1944 | 8, 520 | 45. 3 |
| First 8 months, 1945 | 2, 065 | -------- |
| Total | 25, 199 | -------- |

The lower and middle ore beds extend across the claim, but mining has been limited to the lower bed, which was developed by open pits, several adits, and many shafts. Ore was hauled in wheelbarrows from the stopes either to adit portals or to shafts where it was hoisted by hand windlass; small ore cars were used in the main adit. Mining was carried out in irregular open stopes. The ground stands well, although timber stulls and pillars must be used where the ore shoots are wide. Both hand drills and small air hammers were employed. Crude ore was hand-loaded on trucks and hauled about 6 kilometers to the concentrating plant at the Caridad prospect near the site of the Cuban Mining Company's concentrating plant. Here the ore was crushed, screened, and jigged. About 3 tons of crude ore containing 25 to 35 percent manganese was mined to obtain 1 ton of concentrate containing 45 to 46 percent manganese.

Known reserves in the San Luis mine area have been severely depleted so that the production rate in 1944 and 1945 declined markedly from the peak of over 10,000 tons of concentrate in 1943. However, possible extensions of the lower ore zone have not as yet been adequately explored. The north margin of the syncline in the central part of the San Luis mine area should be explored, either by deepening the several existing shafts or by exploring southward from the present mine workings. As shown on the structure contour map (pl. 10), the southeast side of jasper lenses at the head of the syncline has not been explored as yet, nor has any exploration been carried out on the northwest side in the area south of the small faults that displace the ore zone. Another inadequately prospected region is east and southeast of the old adit (shown as a narrow opencut on the north edge of pl. 8) where the structure contour map shows the ore zone to dip steeply northward.

### TORDERA MINE

The Tordera mine, denounced in 1887, covers nearly all the mapped area east of the San Luis mine, and includes the top of the hill in the east-central part of the area and the northwestward-trending arroyo at the margin of the area. Ownership of the mine is divided under the Succesión de Nicolás Morcillo among 15 people or groups of people, none of whom apparently owns more than 12 percent of the title. The Compañía Mineria La Llave, which operated the Portugal mine, also leased and operated the Tordera mine. Production of concentrate from 1942 to August 1945 can only be estimated inasmuch as recorded production includes some ore from the España and Portugal mines.

| *Year* | *Tonnage (dry long tons)* | *Grade (percent Mn)* |
|---|---|---|
| 1942 | 4, 904 | --------- |
| 1943 | 5, 500 | 47–48 |
| 1944 | 8, 000 | 48 |
| First 8 months, 1945 | 3, 800 | --------- |
| Total | 22, 204 | --------- |

All three ore zones have been recognized on the Tordera claim but mining was limited to the lower bed. As at the San Luis mine, some granzón has been recovered from weathered parts of the middle bed, but the upper bed is of too low grade to develop. The ore deposit was developed by many shafts and a few adits. Ore was mined by hand in open stopes supported by a few stulls and pillars and was brought to the surface by wheelbarrow and hand-operated hoist. Crude ore was trucked to a mill on the property where it was crushed, sized, and jigged. Selective mining resulted in a lower concentration ratio and a higher grade of concentrate than was attained at the San Luis plant.

Intensive mining from 1942 to 1944 depleted reserves to such an extent that the production rate of 1944 (about 8,000 tons of concentrate) could not be maintained in 1945. Possible extensions of ore shoots localized along the flanks of jasper lenses were indicated by underground mapping and the structure contour map, and shafts sunk on the basis of this information extended the productive ground to the hitherto unexplored area south and west of the concentrating plant. The ore zone is very thin and seems to be pinching out toward the north end of the property, but the possibility that minable ore extends east and southeast of the plant seems good. However, the large volume of water in the shaft from which mill water was obtained suggests that pumps will be needed. Reserves seem adequate for a few more years of operation at the 1945 rate and, moreover, fairly large reserves of low-grade manganiferous tuff might be developed in the lower and middle beds if this material could be mined and concentrated economically.

### EL PAPEL PROSPECT

El Papel claim was taken up in 1888; it borders the Tordera claim on the southeast and northeast. There is no known production; the 103 tons of concentrate shipped in 1943 is reported to have come from the adjoining Tordera claim at the southeast corner of the mapped area (pl. 8). The two prospect pits in the extreme southeast corner of the map, one on the middle bed and the other on the upper bed, are said to be on El Papel claim. The pits expose low-grade manganiferous tuff. However, it is possible that the lower zone extends this far southeastward and contains minable ore; it should be prospected, preferably by drilling, as there is likely to be much water in the lower zone.

### SAN ROQUE PROSPECT

The San Roque prospect, 5 kilometers southeast of El Cristo, is best reached by trail up the Río Guaninicún from the Boston mine area. Past production is unknown but apparently small. A number of shallow surface pits explore an exceptionally large jasper lens that caps the east slope of a ridge on the south side of the Guaninicún valley, where it overlies interbedded tuff and agglomerate. The jasper lens is about 650 meters long and has a maximum width of about 300 meters. It strikes north to northwest, and forms a dip slope inclined 25°–35° E. Surprisingly little manganese oxide has been found in this large lens; either the ore bed, which should overlie the jasper, has been eroded away or there never was much manganese associated with the jasper. Additional ore may be found downdip to the east, but little exploratory work has been done.

### SANTA ROSA MINE

The Santa Rosa mine is just off the Santiago-El Cristo highway, 2 kilometers southwest of El Cristo. From 1942 to 1943 the mine was operated by Enrique Grajales and in 1944 and 1945 by Pedro Luis Miguel. Production prior to 1942 is not known but was probably small; recorded production of concentrate and grade of ore is as follows:

| *Year* | *Amount (long tons)* | *Grade (percent Mn)* |
|---|---|---|
| 1942 | 200 | -------- |
| 1943 | 45 | 46. 4 |
| 1944 | 51 | 48. 2 |
| To August 31, 1945 | 77 | 50. 6 |

The deposit is a bed of altered manganiferous tuff that overlies the Charco Redondo limestone member of the Cobre formation. The resistant limestone, here about 6 meters thick, caps an eastward-trending ridge that continues westward as Sierra de Boniato; the limestone and the overlying tuffs form a dip slope on the north side of the ridge. Beds in the mine area strike east and dip 20°–45° N. Downdip they terminate against a major eastward-trending, southward-dipping fault that separates the folded and overturned beds of the Augusto Luis mine area on the north from the normal beds on the south. Just south of the crest of the ridge, bedded limy tuffs are folded into a small eastward-plunging anticline and syncline. The beds cropping out on the ridge terminate eastward against the great reverse oblique slip fault of Dos Bocas valley. Near the fault the Charco Redondo limestone and adjacent tuffs are intricately folded into a series of small tight drag folds.

The manganese-bearing zone is developed by shallow surface pits, short adits, and shafts over an area about 60 meters long and 30 meters wide. Maximum thickness is 2.5 meters. The ore consists of replacement nodules and small stringers and layers of pyrolusite and psilomelane-type oxide in soft medium-grained tuff that has been intensely altered to pink manganiferous montmorillonite. In places mineralized tuff alternates with white to gray montmorillonitic tuff containing some green nontronite, and locally the zone contains pods and small lenses of jasper lying parallel to bedding.

The ore is estimated to contain 15 to 25 percent manganese, although by selective mining a higher average grade may be maintained. Ore was mined by hand and concentrated in a small washing and jigging plant. Recovery was low as the manganese oxide is very friable. Reserves may total a few thousand tons, but much of the ore is too low in grade to be minable. There are no possible extensions of the zone either downdip or along the strike.

### THIERS MINE

The Thiers mine, owned by Srs. Adam and Piñeiro of El Cristo, is 2 kilometers southeast of El Cristo and about 750 meters southwest of the Boston mine. It can be reached by trail from the end of the road to the concentration plant of the Cuban Mining Company, 2 kilometers to the northwest. Total production from the deposit is not known; in 1942, 32 long tons of ore were extracted. The deposit consists of a weathered and disintegrated jasper and manganese-oxide lens on the crest of a small ridge and is explored by an old pit over 30 meters in length, as much as 15 meters in width, and 3 meters in depth. The zone strikes north of east and dips about 5° S. The ore consists of granzón of pyrolusite scattered among jasper blocks and boulders and embedded in reddish-brown weathered tuff. Some pyrolusite occurs in pockets and veinlets in the jasper. The deposit seems to be essentially mined out; the ore and jasper zone apparently extends only a short distance beyond the limits of the old pit, although exposures are poor and possible extensions may be concealed. The most recent work was the mining of small amounts of high-grade granzón from small pits dug in the floor of the old one.

## GÜISA DISTRICT

### ANTONIA GROUP

#### ANTONIA MINE

The Antonia mine is just northeast of Cobrero on the Río Güisa 11 kilometers southeast of Güisa and is reached from there by trail. During dry weather trucks can be driven within 8 kilometers of the mine. In 1943, the mine produced 44 tons of ore containing 44 percent manganese.

Disconnected pockets of pyrolusite are scattered through 20 to 25 meters of limestone breccia at the base of a limestone that caps the Alto de Cobrero. The largest pocket found was about 1.6 x 1.6 x 6 meters. A little brilliant-black material resembling neotocite is disseminated in the limestone.

Mine workings consist of about 215 meters of galleries, a few short raises and winzes, and several pits in a small area of granzón. Ore pockets are widely separated and mining is costly. The ore must be hand-cobbed but is high grade. Reserves total a few hundred tons.

Just to the east an adit 8 meters long explores a bed of manganese-oxide-bearing tuff ranging from 0.6 to 1.3 meters in thickness. The bed strikes N. 45° E. and dips 40° NW. Mine-run ore contains about 30 percent manganese and was hand sorted to a 42 to 45 percent concentrate.

#### DESPERTO PROSPECT

Veinlets of high-grade manganese oxide in limestone and at a limestone and tuff contact are exposed in several old cuts on the Desperto claim. The showings warrant additional prospecting.

#### JOSEFINA MINE

The Josefina mine adjoins the Antonia and is similar geologically. In 1943, 352 tons of ore containing 47 percent manganese was mined from thin stringers in limestone. The claim is probably the most promising one in the group, but no recent information is available.

#### SEVILLA PROSPECT

The Sevilla prospect is similar to the others in the Antonia group. An adit explores small pockets of manganese oxide in limestone. Very little ore was in sight in 1942.

### AURORA GROUP

The Aurora group of prospects is about 11 kilometers south of Güisa. It is reached by trail from the end of the Río Bayamo road at El Corojo. A maximum of a few hundred tons of ore has been produced.

At the Aurora prospect, two adits, an opencut, and a pit have explored a zone of stringers and pockets of manganese oxide and clay in solution cavities in white and pink limestone. The zone strikes N. 80° W. and dips steeply north. About 100 tons of ore containing 45 percent manganese has been mined. Just below the main ore zone, a drift 15 meters long has been driven in limestone breccia and clay cemented by manganese oxide.

Stringers of manganese oxide cutting conglomerate and subjacent agglomerate at the base of a thick bed of limy tuff are exposed in a 9 meter shaft at the Margot (or María Lola) prospect. Three short adits 15 meters stratigraphically below the ore horizon are in dense hard black silicified tuff and show no ore.

A pit and opencut expose irregular veinlets of manganese oxide in a limestone breccia overlying tuff at the Mercedes prospect. The contact of the limestone and tuff strikes N. 10° E. and dips 75° W. Fifty-three tons of ore containing only 37 percent manganese was shipped in 1943.

A little jasper and manganese oxide in limestone breccia can be seen in several badly slumped pits on the Morita claim.

### CÁDIZ MINE

The Cádiz mine is about 6 kilometers south of Güisa. The property, which covers 200 hectares, lies 2 kilometers south of the Río Güisa, about 13 kilometers above the confluence of the Río Güisa and the Río Bayamo. The mine was operated by Succesión de Emilio Bonich y Compañia of La Habana under a lease. The mine is reached by 11 kilometers of mule trail from Güisa or by a dirt truck road from the Río Bayamo. Ore was packed by mules to Güisa and then hauled 18 kilometers by truck to Bayamo; the road from the Río Bayamo was not used because the haul to Bayamo was over 35 kilometers long and the road was passable less than a third of the time. The Cádiz property was denounced 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 in 1941 a large pocket of ore was discovered which yielded about 10,000 tons of ore containing more than 45 percent manganese before being exhausted.

The mine workings are on the summit and north slopes of a flat-topped, heavily wooded hill, at an altitude of about 400 meters. Steep slopes lead north down to the Río Güisa, 180 to 210 meters below. Prospecting away from the mine workings has been superficial because of the dense forest cover. The shallow mine workings were dry, and water for mining and camp use was carried up from the river.

The Cádiz hill is capped by 30 to 90 meters of massive gray-white limestone, which overlies volcanic rocks. In the lower 15 to 25 meters of the limestone, lenticular conglomerate zones alternate with beds of platy limestone. Sections at points separated by as little as 150 meters differ greatly in detail, but in general the conglomerate is 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. Coarse green andesitic tuff, some limy, makes up the larger part of the volcanic section, but agglomerate interbedded with red tuff predominates near the limestone contact.

The entire Cádiz hill, in which the beds dip gently to the south, is part of a fault block between major faults that strike northwestward. A manganese-bearing zone on the north slopes of the hill parallels the fault trend and may extend along one of these faults. The limestone is cracked and brecciated along fracture zones that trend roughly north-south and east-west and generally have steep dips.

The main ore body, developed by a 12-meter shaft and several drifts, was a flat-lying zone about 25 by 20 meters in horizontal dimensions and from 3 to 12 meters thick. Most of the ore was in the lower part of the limestone and along the contact of the limestone and tuff. Ore in limestone was in stringers, pockets, and veinlets whereas the ore in tuff formed a well-defined bed. The ore consisted predominantly of pyrolusite with subordinate psilomelane-type oxide and was hard and massive. Flecks of black calcite and veinlets of white calcite were the principal gangue in the limestone ore. The walls contained pockets of iron oxide, but the ore was essentially free of iron. Red tuff was the chief gangue in the tuff ore.

The stringers of manganese oxides, which were generally from 2.5 to 5 centimeters wide, were persistent along certain fracture zones; the principal ore body was in one such zone. In this and other nearby zones the stringers dip 50 to 80 degrees, much more steeply than the bedding. Some stringers did not follow fracture zones and a few were parallel to bedding planes. The ore bed in tuff strikes N. 40° W. and dips 50° NE. It was rich enough to have been opened by pits for about 25 meters, but it grades along the strike in both directions into black manganiferous tuff. The ore was massive, high in calcite, and similar in general to the ore in the limestone but perhaps of lower grade.

The main ore body was exhausted by 1944 and little success had attended explorations for new ore. Probably the best place for exploration is along the eastward-trending zone in which the principal ore body was found.

## CHARCO AZUL GROUP

The Charco Azul group of claims embraces a large area just southeast of Santa Rita. Considerable exploration has been carried out along the several kilometers of contact between tuff and overlying Charco Redondo limestone exposed within the claims. Pods of manganese oxide in limestone breccia have been found on the Charco Azul, Labor, Vencedora, Adriana, and Celeste claims, and thin stringers and stains of manganese oxide occur in tuff just below the limestone on the Adriana, Celeste, and Tarafa claims. One shaft 6 meters deep has been sunk on the Charco Azul claim just northwest of the Lucía mine, and at least two drill holes have been put down. No good ore has been found anywhere in the group.

### CHARCO REDONDO GROUP

#### GENERAL DESCRIPTION

The Charco Redondo group of mines lies about 12 kilometers by road southeast of Santa Rita. It includes the Casualidad, Charco Redondo and Manuel mines. The area is drained by the Río Cautillo, a tributary of the Río Cauto.

Some of the claims were denounced as early as 1900, and a small amount of ore was extracted during 1917–20, when high prices stimulated mining. However, the important period of activity began in 1941 and continues to the present (1954).

Geology, topography, ore beds, and outlines of the principal mine workings are given in plate 11. The area is underlain by greenish tuff, agglomerate, and limy tuff of the Cobre formation which is overlain by the thin-bedded Charco Redondo limestone member. Locally a zone of limy tuff intervenes between pyroclastic rocks and limestone, but elsewhere, especially in the more strongly mineralized areas, the contact is sharp and in places is marked by a layer of tuff-agglomerate as much as 4 meters thick. The agglomerate may grade laterally into limy tuff. The limestone is at least 110 meters thick along the canyon of the Río Cautillo and is fossiliferous throughout; in places an abundance of algae heads gives the limestone a conglomeratic appearance.

In general the rocks strike east and dip gently north. Two major northward-trending faults are recognized in the area. The Río Cautillo crosses the westernmost fault just east of the Padrón and Solapa-Unitoria workings of the Charco Redondo mine, and the fault is believed to continue northwestward as that mapped by Woodring and Daviess (1944, pl. 68) between Santa Rita and the Lucía mine. It is a normal fault dipping 60°–80° W. and has a throw ranging from 18 meters at the southern end of the mapped area to at least 60 meters and perhaps as much as 100 meters west of the Casualidad mine. The east fault lies east of Loma Casualidad; its dip is not known, but the east side is downthrown at least 30 meters. A number of small steep-dipping faults have been recognized; several are shown in plate 11. A small thrust fault cutting limestone and ore will be mentioned in the description of the Charco Redondo mine.

Ore in the Charco Redondo district occurs in at least three main horizons at or just above the base of the limestone. The lowest zone, in the pyroclastic rocks just below the limestone, will be referred to as the basal ore bed or zone; the other two zones, lying 5 to 6 meters and 9 to 12 meters respectively above the base of the limestone, are known as the lower and upper ore zones. Both these zones are in tuff beds in the limestone. The lower ore bed has been the most productive of the three.

The basal ore zone consists of nodules, stringers, and thin beds of manganese oxides that replace thin beds of tuff or the tuff matrix of the agglomerate. It ranges in thickness from a few centimeters to 4 meters. Mineralization is usually spotty and low grade and shows notable lateral variation; the manganese content ranges from 15 to 35 percent.

The lower and upper ore beds consist of manganese oxides that almost completely replace tuff. The lower bed is from 15 centimeters to 1.1 meters thick and contains from 30 to 50 percent manganese. The upper bed attains a thickness of 1 meter but is usually less than 15 centimeters thick and is minable in only one part of the Charco Redondo mine. It contains 30 to 40 percent manganese and much calcite. One of these beds can be traced along the west flank of Loma Casualidad for more than 3 kilometers although it is nowhere more than 45 centimeters thick. These beds are probably equivalent to two of the three beds exploited at the Taratana mines several kilometers to the west. On the east bank of Arroyo Caridad one of the beds is overlain by 3 to 3.5 meters of manganese-bearing intraformational conglomerate containing fragments of limestone, tuff, and manganese oxide in a matrix of limestone (fig. 27). Foraminifera, shark's teeth (fig. 6), and algal heads are common fossils in the ore beds.

Manganese minerals include psilomelane-type oxides, pyrolusite, and subordinate manganite and black calcite; the psilomelane minerals are by far the most abundant. Gangue is predominantly altered tuff; calcite is abundant locally and jasper is found here and there, usually near the bottom of the ore beds.

The potentialities of the district are very great and it is unquestionably the most promising source of high-grade ore known in all of Cuba.

### CASUALIDAD MINE

The Casualidad claim covers essentially the east half of the area shown on plate 11. The mine was worked during World War I, when a small amount of ore was mined from the lower and upper ore beds. It was operated intermittently without notable success until 1941, when a mill was built to crush, screen, and wash the ore. In 1942, 6,458 tons of ore averaging 43 percent of manganese was produced. The mine was idle in 1943 and yielded only 1,361 tons in 1944 and 25 tons during the first half of 1945. Total production is estimated to be about 25,000 tons averaging 43 percent manganese.

Most of the ore mined in recent years has come from the basal bed, which crops out on a hill in the block between the eastern and western fault zones. The best ore body lies in a small swale on the western slope of the hill. The ore, which contains 20 to 35 percent manganese, averages 1.5 meters in thickness and in some faces is as much as 4 meters thick. It consists mainly of nodules of manganese oxide in a matrix of soft tuff, largely altered to chlorites, zeolites, and clay minerals (figs. 17, 18). 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. The contact of the limestone and tuff is mineralized elsewhere on the Casualidad hill and the chances of finding concentrating ore are fair.

South of the Río Cautillo and west of the western fault zone the contact is mineralized but the ore bed is thin and low-grade. One incline along tuff ore that contains pyrolusite stringers has yielded more than a thousand tons of high-grade ore and it is possible that a considerable tonnage of concentrating ore may be developed.

Reserves may be as large as several hundred thousand tons of ore containing 10–25 percent manganese. However, the low grade and nature of the crude ore presents a very difficult problem in concentration. The mine-run ore is very soft and yields a high proportion of fines by any of the ordinary concentration processes. Moreover, as may be seen clearly in figure 17, the manganese-oxide nodules themselves are very impure and would produce a low-grade concentrate even if they could be separated cleanly. Concentration ratios in the old mill were as high as 8 : 1, and mining was done largely by hand so that mining costs per ton of concentrate were very high. It seems certain that the great bulk of the Casualidad ore cannot be concentrated by any simple mechanical process; a process of flotation and sintering as developed by the Cuban Mining Company would appear to be a possible solution to the concentration problem.

### CHARCO REDONDO MINE

The Charco Redondo mine is the largest producer of high-grade manganese ore in Cuba and almost certainly will surpass the Quinto deposit in total production. A little ore was mined during World War I but, as with most of the manganese mines in Cuba, it was not until 1941 that any significant production was attained. Production data are given in the following table:

| Year | Tons | Average grade (percent Mn) | Year | Tons | Average grade (percent Mn) |
|---|---|---|---|---|---|
| 1942 | 11,836 | 43 | 1949 | 40,000 | [1] 44–45 |
| 1943 | 12,126 | 43.6 | 1950 | 52,850 | |
| 1944 | 12,482 | 45 | 1951 | 101,115 | ? |
| 1945 | 21,894 | ? | 1952 | 207,081 | ? |
| 1946 | 39,467 | ? | 1953 | 320,038 | ? |
| 1947 | 37,833 | 45 | | | |
| 1948 | 22,175 | [1] 45 | Total | 878,897 | |

[1] Estimated.

In 1943, the mine consisted of seven main workings with more than 3 kilometers of drifts, crosscuts, and inclines. The workings included K–6, Muñeco, Caridad, Solapa-Unitoria, Padrón, Socias, and Río 10; they are identified by Roman numerals on plate 11. Since then the mine has been developed by a number of inclined and vertical shafts in the area north-northwest of the K–6, Solapa-Unitoria, and Río 10 workings, and the lower and upper ore beds are known to extend for nearly 2,000 meters along the west side of the western fault zone. Minable ore is found over an area ranging from 300 to 600 meters in width and averages perhaps 2 meters in thickness.

Most of the ore was mined from the lower ore bed; the basal bed was productive only in the Socías and Padrón workings and possibly in the Caridad and Muñeco workings, and the upper bed was too thin to mine except in the Solapa-Unitoria workings.

In general the rocks at Charco Redondo strike east and have a northerly dip ranging from 5 to 15 degrees. North of the Río Cautillo the limestone has a constant and unbroken dip of 10°–15° N. This attitude is reflected in the K–6 and Solapa-Unitoria workings but dips are lower.

From the Solapa workings the ore beds can be projected without apparent offset to the Padrón workings on the south side of the river, but dips increase to 12 degrees. Apparently the hill in which the Padrón workings are located (Loma Caridad) is underlain by a broad northward-trending synclinal structure, as beds in the Socías workings to the southeast dip west to northwest at 10 to 25 degrees, and those in the Caridad workings 450 meters to the west dip 15 to 35 degrees east to northeast.

A thrust fault was traced along the north end of Loma Caridad, south of the Río Cautillo, from Caridad creek 450 meters to the east, at which point it appears to be offset by the western normal fault mentioned above. The thrust fault is believed to dip south at an angle between 10 and 25 degrees and is thought to have a displacement of a hundred meters or more. Although the trace of the fault is completely concealed its presence is indicated by repetition of the contact between the limestone and tuff and of ore beds, and by the fact that the beds in the Padrón workings, below the fault, dip 10°–12° N. whereas the beds in the workings 30 meters directly above the Padrón and above the fault dip 10°–20° SE. Exploratory work in the updip extensions of the Padrón workings showed (1943) a strong drag of the lower ore bed, which we believe is due to thrust faulting.

Northward-trending faults of small displacement cut the ore beds in the Solapa-Unitoria and Socías workings, but in the other workings no faults were observed.

Manganese oxides of the basal ore zone partly replace beds of tuff within or near the top of the tuff agglomerate zone or partly replace the tuff matrix of the agglomerate; very little replacement of the tuff blocks is evident. In the Socías and Padrón workings the basal ore bed ranges in thickness from less than 30 centimeters to more than 2 meters. Mine-run ore commonly contains more than 45 percent manganese, but in places unmined portions of the bed contain less than 40 percent. In these workings ore and tuff-agglomerate appear to die out toward the west. Many caved workings indicate that the area between the Padrón and Socías workings has been mined out; accessible workings expose only sparsely mineralized tuff.

Except at the Caridad workings, the base of the limestone is not exposed and the presence or absence of mineralization cannot be determined except by exploratory work.

Manganese oxides in the lower ore zone partly replace a bed of tuff in the limestone that ranges in thickness from less than 15 centimeters to slightly more than 1.1 meters. At some points the bed consists almost entirely of manganese oxides (figs. 14, 15) but at other places large amounts of tuff are present. The average grade of ore ranges from about 30 to 40 percent in the K–6 workings to nearly 50 percent in the Padrón and Socías areas.

The upper ore bed is exposed all along the north side of the Río Cautillo between the K–6 and Solapa-Unitoria workings and is seen also on the south side of the river in the workings above the Padrón, but only in the Solapa-Unitoria workings does the bed appear to be of minable thickness. Here the ore ranges from less than 15 centimeters to more than 2.2 meters in thickness and contains 30 to 40 percent of manganese. The presence of considerable white calcite in the ore necessitates much hand-sorting.

Mine workings are described separately. Inasmuch as most of our work was done in 1943 and 1944, it is apparent that the following descriptions cannot give a true picture of the mine at the present time, as it has yielded more than 700,000 tons of ore since 1944.

The K–6 workings, on the north side of the Río Cautillo (fig. 39) extended down dip a total distance of about 230 meters following a north-northwestward-trending ore shoot in the lower ore bed. At its outcrop the ore shoot had a length of about 60 meters but at the bottom of the workings a minimum strike length of more than 90 meters was indicated. The ore ranged in thickness from less than 15 centimeters to about 1 meter and averaged about 0.5 to 0.6 meters. Figures 14 and 15 show typical high-grade sections of the ore bed.

Stopes were open or back-filled in part and were supported by irregularly spaced pillars of various sizes supplemented by a few

FIGURE 39.—Sorting platform at portal of K–6 workings, Charco Redondo mine, looking northeastward across the Rio Cautillo. Opening is along lower ore bed, enclosed in blocky Charco Redondo limestone.

stulls. All ore was hauled in wheelbarrows to the foot of the 180 meter haulage incline along the ore bed. The mine-run ore, averaging 30 to 40 percent manganese, was intensively hand-sorted to bring it up to a shipping grade of 41 to 43 percent and excessive fines were removed by screening. The hand-sorting and screening operation used nearly as many men as were required in mining and haulage. Very little ore was developed in advance of mining and therefore extensions of ore were uncertain, particularly as outcrops of the lower ore bed show no minable ore for nearly 450 meters west of the portal of the workings and none between the K–6 and the Solapa-Unitoria workings.

The Solapa-Unitoria workings are about 150 meters east of the K–6 and covered an area about 135 meters long on the strike and 90 meters wide down the dip. Mining was limited to the upper ore bed, which ranged in thickness from a knife-edge to about 1 meter and averaged but 30 centimeters. Because of water seepage from the Río Cautillo many faces in the mine were flooded from time to time. The best and virtually the only minable ore was found at the bottom of the working over a strike length of 30 to 45 meters. Here the ore was from 0.3 to 1.0 meter thick, but the high calcite content made the ore difficult to sort by hand.

Two winzes were sunk to the lower ore bed. Both winzes showed ore similar in appearance and grade to the ore in the K–6 bed. No attempt had been made in 1944 to mine any quantity of ore from the lower bed, apparently because of its inaccessibility and the danger of flooding. Water seepage at normal river levels probably could be controlled by a pump in conjunction with a ditch and sump in the upper workings.

The basal ore horizon may be mineralized in this area, but the danger of excessive water seepage is great.

Mining in the Solapa-Unitoria workings was similar to that in the K–6. Ore was hauled updip in wheelbarrows to the mine portal, a distance of at least 90 meters.

The Padrón workings, directly across the river from the Solapa-Unitoria, explored the lower and basal ore zones. Workings on the lower ore bed covered an area about 55 meters long up the dip and 30 meters wide on the strike. The ore bed was between 2.5 centimeters and 1 meter thick and averaged about 0.5 meter thick where mined. Minable ore apparently was delimited in all but downdip extensions, where the river passes over the ore bed. To the south the ore is cut off by a thrust fault. East and west extensions of the ore were too thin to mine.

The workings on the basal ore bed indicate that minable ore covered an area about 25 meters square. Updip extensions of ore may exist, but limits of ore to the east and west appear to have been reached.

The Socías workings are about 150 meters south of the Padrón workings on the east side of the synclinal hill south of the Río Cautillo. The workings extended along the basal and lower ore zones, and possibly along the upper zone (pl. 12). Workings on the basal zone extended over a length of 90 meters and a width of 25 meters and on the lower (?) ore bed over a length of 110 meters and a width of 25 meters. Inaccessible stoped areas extended to the north along both zones.

Sections through the Socías workings (pl. 12) show that three distinct ore horizons are present. The basal zone is separated from the horizon immediately above it by a limestone stratum having a maximum thickness of 1.6 to 2 meters in the downdip extensions of the mine. This limestone disappears completely toward the upper part of the workings, so that it is not clear whether the upper of these ore horizons is part of the basal ore zone or whether it is the lower ore bed. A third ore horizon is present above the two lower beds; it may be either the upper or lower bed. However, the fact that the limestone thickens down the dip suggests that the three ore horizons present elsewhere in the Charco Redondo area are also represented in the Socías workings. Figure 19 (p. 82) shows an ore-bearing agglomerate of the basal zone.

All three ore beds in the Socías workings thin and become lower in grade at the west side of the workings. Inasmuch as the beds were mined and explored both north and south of the present workings, ore extensions appear to be definitely limited. Other ore shoots may be discovered by drifting westward on the ore zones. Intense local bedding-plane slip, apparently offsetting the northward-trending normal fault in the workings, seems to be responsible for some of the downdip thinning of the ore beds.

As in the Padrón workings, the average grade of mine-run ore was so high that little hand-sorting was required to produce ore containing more than 45 percent of manganese except in the lower grade portions of the basal ore bed.

The uppermost of the three ore beds was usually mined first, and the lower two beds were then mined together. The ground was heavy and much timber, supplemented by a few pillars, was used to support the back.

The Muñeco workings, across the Río Cautillo about 200 meters west of the K–6 portal, covered an area 135 meters long and 60 meters wide along what is thought to be the lower ore bed; the bed may be the basal ore zone, lying on interbedded limestone and tuff. The ore ranged from less than 30 centimeters to about 1.1 meters in thickness and contained about 30 to 35 percent manganese. Manganese oxides replace a tuff bed which is in part agglomeratic. Figure 30 (p. 93) shows the Muñeco ore bed, cut by a tuff dike.

Extensions of the present ore body had not been developed, but along all margins of the present workings the bed appears to be thinning somewhat.

Ore from the Muñeco workings was hauled 150 meters by tramway to a log washer on the north side of the river. Mine-run ore was washed and then was intensively hand-sorted to a shipping grade of 40 to 43 percent manganese. The concentration ratio was estimated at about 3 to 1. A jigging plant probably would have yielded a higher grade concentrate and would have eliminated most of the hand-sorting.

The Caridad workings are on the east side of Arroyo Caridad, about 300 meters south of the K-6 portal. Two small workings and outcrops show the ore zone to have a strike length of more than 90 meters but minable ore was found to extend only 10 or 12 meters down the dip. Minable ore has an average thickness of 0.5 meter and an average grade of 30 to 40 percent manganese. In downdip extensions the zone is less than 30 centimeters thick and the grade decreases to less than 30 percent. Figure 25 (p. 87) shows the Caridad ore bed, underlain by very impure tuffaceous limestone.

The Caridad ore bed appears to be in the basal zone; is is underlain by interbedded calcareous crystal tuffs and impure limestones. About 1.6 to 2.5 meters of limestone separates the ore horizon from an overlying conglomerate or agglomerate of limestone and tuff; this conglomerate contains numerous angular fragments of manganese oxide, and occasionally is partly replaced by oxide (fig. 27, p. 90).

Only a small amount of ore has been mined from the Caridad workings. Additional ore probably can be developed along the outcrop of the bed but the chances for downward extensions appear to be poor.

The Río 10 workings are about 180 meters north of the Solapa-Unitoria workings. Workings on the lower and upper ore bed covered an area of about 90 meters along the strike and 30 meters downdip. The workings were entered along an adit and down an incline along the west fault (pl. 11); ore was found 23 meters below the portal. The upper ore bed ranged in thickness from 0.6 to 2.2 meters and was very high grade for the Charco Redondo district.

None of the other exploratory workings was productive; a number of adits on the south side of the river between the Padrón and Muñeco workings are too far below the base of the limestone. The basal ore zone between the Padrón and Socías workings is too sparsely mineralized to be mined.

The principal ore reserves of the Charco Redondo mine are in the K-6, Solapa-Unitoria, and Río 10 block on the north side of the Río Cautillo; this block is known to extend nearly 2,000 meters north-northwest of the old workings. According to a study made in June 1954 by P. W. Guild of the U. S. Geological Survey and W. D. McMillan of the U. S. Bureau of Mines, estimated reserves are more than 2 million tons with an average grade of about 43 percent manganese. Of this reserve, about 1 million tons is in pillars and thin parts of the ore beds.

### MANUEL MINE

The Manuel mine is at the north end of the district and is similar geologically to the Charco Redondo mine. Both the lower and upper ore zones are present, but only the upper zone has been productive;

these beds pinch out toward the northeast. The upper bed is 0.3 to 0.5 meter thick and lies about 12 meters above the base of the limestone. Production in 1942 was 233 tons; the mine has been inactive since that time. Reserves are perhaps a few thousand tons of ore containing 30 to 40 percent manganese. No large production seems likely.

### EFFIE MINE

The Effie mine is at Pueblo Nuevo, 8 kilometers southeast of Güisa. It is reached by trail. In 1942, the mine yielded 381 tons of ore containing 44 percent manganese. Total production is estimated to be less than 1,000 tons.

Ore occurred as irregular pockets of manganese oxide in tuff that strikes N. 75° E. and dips 35° NW. A small amount of granzón was mined also. The mine appeared to be exhausted in 1942.

### JUSTA PROSPECT

The Justa prospect is 2 kilometers by trail west of El Corojo. About 60 tons of ore was shipped in 1941–42; no other production is known.

The ore deposit is in tuff-agglomerate about 60 meters stratigraphically below the base of the Charco Redondo limestone. A bed of manganese oxides and silicates 15 to 45 centimeters thick overlies a discontinuous zone of jasper that is parallel to the bedding of the agglomerate. Several centimeters of chlorite lies along the ore contacts. The jasper outcrop is about 60 meters long and hand-drill holes indicate a downdip extension of 90 meters. Both jasper and ore pinch out away from the outcrop.

The ore was hand-cobbed but contained a large amount of silica. Probably not more than a few hundred tons of shipping ore is available.

### LUCÍA MINE

The Lucía mine is near the Santa Rita-Charco Redondo road 7 kilometers southeast of Santa Rita. It was opened in 1941 and during 1942–45 produced 5,747 tons of ore containing 43 percent manganese. Apparently the mine was exhausted in 1945, as no ore was shipped during the first half of that year.

The Lucía ore body is a bedded deposit in the lower 3 meters of a tuff conglomerate that lies a few meters below the base of the Charco Redondo limestone. The ore bed strikes N. 45°–50° W. and dips about 40° SW.; the ore body plunges nearly due west.

The conglomerate consists of rounded to angular fragments of tuff ranging in size from fine particles to boulders more than 1.5 meters across and angular blocks of limestone as much as 2 meters across.

Some tuff fragments are fine grained, others are conglomeratic. Owing to variation in intensity of alteration, some tuff fragments are soft and others very hard; apparently the tuff was derived from several sources and had been altered before deposition in the conglomerate. The limestone is unfossiliferous fine-grained white rock very different from the Charco Redondo limestone. Figure 5 (p. 42) is a photograph of the conglomerate exposed on the sixth level.

The ore body ranged in thickness from 0.3 to 3 meters, and averaged about 1.5 meters. It had a maximum strike length of about 110 meters and extended down-dip for about 85 meters. Steep-dipping post-mineralization faults with a maximum displacement of 3 meters cut the ore bed; along two of the faults are thin andesitic dikes. A little brown jasper was found at or near the footwall of the ore bed in many places; it formed lenses usually less than 15 centimeters thick. A section through the mine workings is given in figure 40.

Several types of manganese minerals were found in the ore body. Psilomelane-type oxide, the most common manganese mineral, occurred in lenses as much as 0.6 meter thick and 6 meters long, and in irregular pods between tuff boulders. Veinlets of this mineral cut tuff blocks near the hanging wall. Most of the pods were in the lower part of the ore bed and in the lower mine workings. Pockets of soft wad were present only in the lower levels. Fine-grained tuff in the

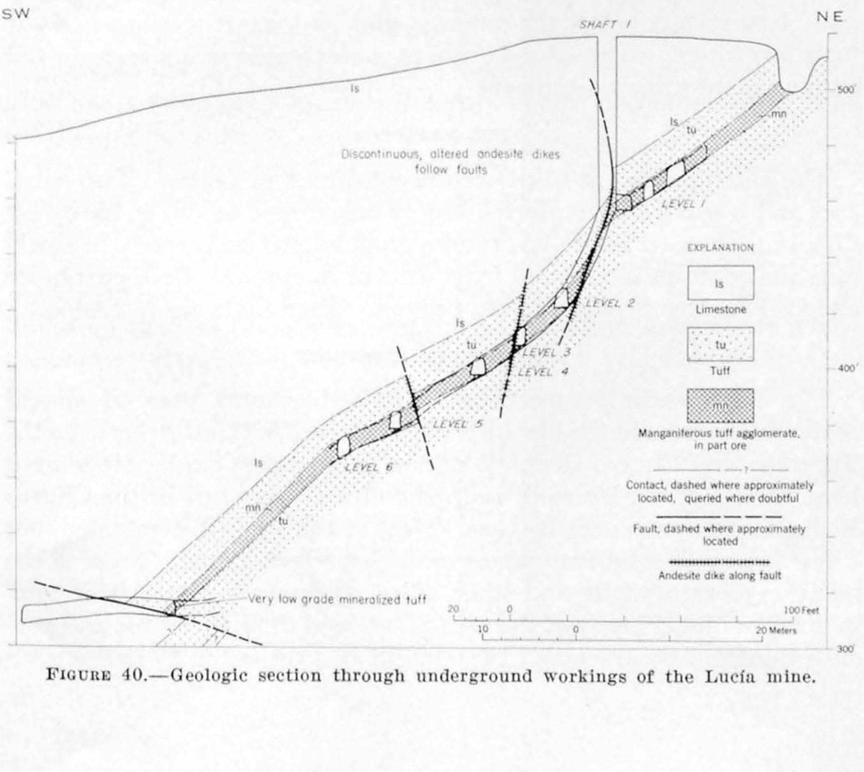



FIGURE 40.—Geologic section through underground workings of the Lucía mine.

conglomerate matrix was partly replaced by wad near the hanging wall. Pyrolusite was found throughout the mine but was most common in the upper levels. It was formed by alteration of psilomelane-type oxide and wad. Figure 13 (p. 72) is a photograph of coarse columnar pyrolusite, probably derived from psilomelane-type oxide.

The manganese oxide was probably deposited with the conglomerate on the sea floor. The "conglomerate" may be a mud flow formed near a volcanic vent; hot waters circulating through the unconsolidated material may have deposited manganese oxides. Except for a thin iron-stained rind on some pebbles, most tuff fragments show no alteration related to ore deposition. Limestone fragments are not replaced by manganese oxides even though they may be completely surrounded by ore. In three headings underground, thin veinlets of tuff cut across masses of hard psilomelane-type oxide (fig. 32, p. 107); one veinlet contains angular fragments of oxide. Figure 31 (p. 94) shows a veinlet of fossiliferous limestone.

On the 120-meter level, a lens of intraformational conglomerate about 3 meters long and 0.3 meter thick occurs in the ore bed. It is composed of subrounded fragments of tuff and angular fragments of hard psilomelane-type oxide in a matrix of white limestone. The lower contact of the lens is sharp, but on the upper side it grades into tuff.

The ore body was developed by drifts and inclines to a depth of almost 60 meters below the outcrop, and by a shaft southeast of the main workings. Most of the ore was concentrated in a screening and jigging plant prior to shipment.

### LUZ PROSPECT

The Luz prospect is 6 kilometers southwest of Güisa. Two small cuts and a short adit explore a bed of manganese oxides in hard reddish limestone. The ore bed ranges from 5 to 60 centimeters in thickness and contains blocks and fragments of limestone. Both pyrolusite and psilomelane-type oxide are present. Very little ore is visible.

### NEGLIGENCIA PROSPECTS

The Negligencia prospects are scattered over an area of several square kilometers in the low hills south of the Río Cautillo between the Taratana and Charco Redondo mines. Manganese oxides occur in at least five places in lenses or beds of tuff and limy tuff in the Charco Redondo limestone near its base. Most of the ore is disseminated, but a few layers of solid manganese oxide have been found. None of the many exploratory pits and short adits exposes any material of commercial grade. However, the area is believed to be favorable and possible downdip occurrences of ore might be prospected by drilling.

### SAN JOSE PROSPECT

The San José prospect is 4 kilometers by trail west of El Corojo. About 20 tons of ore, reported to have contained 42 percent manganese, was shipped in 1940; no other production is known.

Stringers and small blebs of pyrolusite occur in a deeply weathered tuff-agglomerate. The manganiferous zone trends N. 70°–75° W. and can be traced for about 90 meters. Three short adits and two pits show the zone to be 3 to 5 meters thick, but the material is very low grade and contains not more than 10 percent manganese. Several thousand tons of such material is readily available, but the ore would have to be concentrated, probably by jigging. The sparse nature of the mineralization and the lack of jasper suggest that the deposit is probably not a large one.

### TARATANA GROUP

#### GENERAL DESCRIPTION

The Taratana group of mines is 16 kilometers by road south of Santa Rita. It includes the Cañada and Lego workings (worked together and known collectively as the Taratana mine), the Gloria Segunda and Güisa mines, and the Caridad and Confianza prospects. The various claims were denounced in the early 1900's and a little ore was produced during World War I, but it was not until World War II that any appreciable amount of ore was produced. From January 1942 until August 1945, the Taratana mine was the largest producer of high-grade manganese ore in Cuba; it has been surpassed since by the Charco Redondo mine. Total production from the group during those years was more than 100,000 tons. Very little ore has come from the group since 1945.

Plate 13 is a geologic map of the area. Pyroclastic rocks and the overlying Charco Redondo limestone member of the Cobre formation are the only rock units. The beds in general strike northwest and dip gently northeast. The pyroclastic rocks are largely well-bedded water-laid green tuff with some agglomerate and a few flows. The limestone is more than 90 meters thick. Its lower 6 meters is a conglomerate composed of limestone boulders, tuff fragments, and algal heads. Locally the conglomerate becomes decidedly agglomeratic (fig. 4, p. 41). Above the conglomerate is 15 meters or more of dense limestone; the ore deposits occur as beds in the upper part of this limestone. A dense white platy limestone forms the rest of the section.

A northward-trending normal fault through the Taratana 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. Displacement along the fault ranges from 9 meters in the Cañada workings to at least 25 meters in the Lego workings. A similar northwestward-trending fault south of the Gloria Segunda mine brings tuff in contact with the ores, and is marked by a breccia zone 30 meters 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 were formed later than the ore.

Ore was found along two main horizons and two minor horizons in the limestone; no ore has been found in the underlying pyroclastic rocks. The lower ore bed lies 9 meters or so above the base of the limestone; the upper bed is 4 to 6 meters stratigraphically higher. These beds ranged in thickness from less than 15 centimeters to a maximum of about 1.7 meters. The lower bed was more extensive and had a greater average thickness than the upper bed. The minor ore beds were of little economic significance, although one of them, lying 1 to 2 meters above the lower bed, was locally of minable thickness.

All the ore zones follow beds of tuff or agglomerate in the limestone. In the Cañada and Lego workings ore may grade laterally into low-grade reddish manganiferous tuff; elsewhere, as in the Gloria Segunda mine and parts of the Lego, ore grades into black foraminiferal manganiferous limestone.

An intraformational conglomerate or breccia composed of fragments of manganese oxides, tuff, and limestone cemented by limestone is present both above and below the upper ore horizon throughout the Taratana mine (fig. 29, p. 91). Each zone of the conglomerate ranged from less than 1 meter to about 3 meters in thickness. Minor amounts of conglomerate were found in small areas in the lowermost of the two minor ore beds, but only one small lens (fig. 28, p. 90) was observed in the lower bed. The manganese-bearing conglomerate may grade laterally into limestone conglomerate.

Three types of ore were found at Taratana. The most abundant consisted of fibrous radiating psilomelane-type oxide forming nodules and layers in the tuff (figs. 7, 8, 9, pp. 67–68). The second consisted of dense powdery pyrolusite forming layers in the tuff. The third was the conglomeratic (mezclado) ore, which in few places contains sufficient manganese oxides to be mined. Pyrolusite and psilomelane were the only manganese minerals recognized. Near the Cañada fault and beneath the Cañada valley the ore was nearly solid pyrolusite, without conspicuous nodular and banded structures. It is believed that these solid ore beds were enriched by percolating waters, for they lie below a valley near a fault zone and are in permeable tuff beds that dip down the valley.

### TARATANA MINE

The Taratana mine, comprising the Cañada and Lego workings, yielded most of the ore produced from the group. Production data are summarized in the table below:

| *Year* | *Tons* | *Average grade (percent of Mn)* |
|---|---|---|
| 1942 | 7, 467 | 47 |
| 1943 | 31, 865 | 46. 5 |
| 1944 | 41, 947 | 46 |
| 1945 (First 8 mo.) | 17, 198 | --------- |
| 1946 | Not known | --------- |
| 1947 | [1] 3, 000 | 44. 7 |
| 1948 | Not operating? | --------- |
| 1949 | [2] 1, 000 | --------- |

[1] Minimum amount.
[2] Estimated.

Before the mine was shut down the Cañada and Lego workings had been connected and ore was stoped throughout the intervening area. The lower ore bed was mined over an area 600 meters long and a maximum of 130 meters wide; minable ore in the upper bed covered a somewhat smaller area but in general the bed itself was coextensive with the lower bed. A considerable quantity of ore was mined from a third bed lying 1 to 2 meters above the lower ore bed. A fourth bed was rather remarkable in that, although it averaged only a little more than 2.5 centimeters in thickness, it persisted throughout the mine (fig. 16, p. 80).

Both the Cañada and Lego workings are bounded on the west side by the Cañada fault. A block of ore 90 meters long and 35 meters wide was mined west of the Cañada workings in the upthrown block west of the fault.

The lower ore in the Cañada workings usually was in a bed of tuff, but in several places, especially near the southwest corner of the workings, a coarse agglomerate occupied the ore horizon. Some of the agglomerate blocks are very large; figure 20 (p. 83) shows one such block. Elsewhere, irregular lenses of limestone tuff-conglomerate are enclosed in the lower ore bed; a part of one of these lenses is shown in figure 28 (p. 90).

It is probable that the main ore bodies of the mine are exhausted. The limits of minable ore to the north and south had been reached in 1944, and the ore was thinning to the east along a line roughly parallel to the Cañada fault and the trend of the ore bodies. Other northward-trending ore bodies may lie east of the Taratana mine and this general area could be prospected by drifting east along the lower ore horizon and driving raises to the upper ore horizon. However, it is probable that much of the east part of the mine is inaccessible at present; we believe, therefore, that diamond drilling from the surface offers the most feasible means of exploration down the dip to the east of the old workings. Holes could be put down along Arroyo Cañada and up a southwestward-trending branch of the arroyo toward the Lego workings. Some difficulty probably would be experienced with diamond-drilling in the cavernous Charco Redondo limestone. Several churn-drill holes have been put down but results have not been satisfactory because of improperly cased holes and especially because of the difficulty in evaluating the thickness and grade of ore.

#### GLORIA SEGUNDA MINE

The Gloria Segunda mine is on the flanks of a limestone hill about 800 meters northwest of the Cañada workings (pl. 13). A total of about 2,000 tons of ore containing 43 percent manganese was mined in 1941–42.

The same three beds of the Taratana mine are found but they average less than 30 centimeters in thickness. Ore horizons are exposed for 450 meters along the outcrop and pinch out at both ends. Minable ore was found in two beds, each about 1 meter thick, which were separated by 0.3 to 1.2 meters of limestone. These beds were stoped for some 60 meters along the strike and 45 meters down the dip. Most of the ore was a mixture of manganese oxide, black calcite, and foraminiferal limestone and was hand-cobbed to yield a saleable product.

The ore beds have been explored thoroughly by several long drifts and many opencuts, but no good ore was found. There are practically no reserves, and prospects of finding any more ore are poor.

#### GÜISA MINE

The Güisa mine is just northwest of the Gloria Segunda mine. It is similar geologically to the latter but has produced practically no ore. The ore beds crop out for nearly 300 meters but in most places are too thin and low grade to mine.

#### YIYI PROSPECT

The Yiyi prospect is 5 kilometers south of Güisa. Three small pits have been sunk in a limestone breccia that trends S. 65° E. and dips about 35° S. Stringers and pockets af manganese oxide have been found in a zone as much as 1 to 1.2 meters thick. In one pit about 5 meters deep there are fragments of manganese oxide in what appears to be cave rubble. Some 40 tons of ore are reported to have been shipped in 1941.

### HOLGUÍN DISTRICT

A manganese mine and prospect in the Holguín district were examined briefly by T. P. Thayer of the U. S. Geological Survey in the course of a study of chromite deposits in the area.

#### PROSPECT NEAR CUEVITAS

Fragments of manganese oxide are found on the lower slopes of a limestone hill near Cuevitas, about 15 kilometers northeast of Holguín.

A road cut nearby has exposed two lenses of manganese silicates and oxides enclosed in gray limestone; one lens is about 3 meters long and 0.6 meter thick. No minable ore was seen.

#### SANTA ROSA MINE

The Santa Rosa mine is near Santa Rita, 30 kilometers east of Holguín, and is reached by an unimproved dirt road. Ore is trucked to Naranja Dulce on a United Fruit Company railroad and shipped by rail from there to Santiago de Cuba. Production in 1942 was 32 tons of ore containing 41.55 percent manganese. In 1944, 65 tons of ore averaging 49.21 percent manganese was shipped.

In the Santa Rita area, low eastward-trending ridges of serpentine are separated by valleys underlain by sedimentary rocks. Manganese oxides occur along a contact between massive white limestone and reddish-brown shale, which strikes N. 70° W. and dips steeply to the north. The contact zone is exposed in trenches, pits, and short adits over a length of some 300 meters. Ore consists of pockets and veinlets of pyrolusite and psilomelane-type oxide that are in part concentrated along surfaces of minor faults. The width of the ore zone ranges from a knife edge to about 5 meters but mineralization is very spotty. Some surficial enrichment probably has taken place.

Selective mining and careful hand-cobbing are necessary to maintain a grade of 42 percent manganese. Reserves appears to be small, not more than a few thousand tons, as present development indicates that only 60 to 90 meters of the contact is mineralized. A shaft was recommended to explore the ore zone at depth and to determine the extent of surface enrichment.

### IRIS-JOTURO DISTRICT

#### BRISEIDA GROUP

The Briseida group of mines is at and east of Iris on the Florida Blanca plateau. It includes the Briseida and Degarito mines and the Loló prospect. The area is reached by road from Jutinicú.

##### BRISEIDA MINE

The Briseida mine is 1 kilometer east of Iris. It was discovered in 1940 and was probably the largest producer of residual ore in the province. There has been no recorded production since 1945. Production figures are given in the following table:

| *Year* | *Tons* | *Average grade (percent Mn)* |
|---|---|---|
| 1940–1941 | [1] 3, 000 | 50 |
| 1942 | 4, 248 | 48. 5 |
| 1943 | 4, 146 | 45. 9 |
| 1944 | 2, 146 | 45. 3 |
| 1945 (first 8 mo.) | 516 | -------- |

[1] Estimated.

Most of the mine workings are clustered around and under a large mass of limestone that protrudes from the main limestone body to the southeast. The flat area around the limestone mass is covered with red laterite as much as 5 meters thick. Rounded fragments of manganese oxide as much as several centimeters across and numerous pellets of iron and manganese oxide, usually less than 2 centimeters in diameter, are found in pockets scattered through the laterite.

Most of the fragments are pyrolusite, which commonly retains a radiating structure inherited from the original psilomelane-type oxide. Many of the small pellets are composed of a brownish-black lusterless unknown mineral or mixture of minerals; they are concentrically banded concretions and contain about 35 percent manganese. Most of the granzón was mined from irregular workings driven from the edge of the flat and from raises to the surface on ore pockets; some ore was mined from open pits. Ore was washed and screened to eliminate all material less than 1.3 centimeters in diameter.

The manganiferous tuff at the base of the limestone is from 1.3 to 4 meters thick, but in most places minable ore is less than 1.3 meters thick. Layers of pyrolusite 0.5 to 5 centimeters thick and nodules of psilomelane-type oxide make up one-eighth to one-tenth of the minable ore. The bedded ore was explored by a haphazard network of galleries and several shallow shafts. Along the east side of the sink hole the tuff ore is too low grade to mine. From the Briseida mine north to the Corinto mine road, about 150 meters, the contact between the limestone and tuff is unexplored and unpromising. The bedded ore was washed and screened, and recovery was low.

Most of the high-grade granzón was mined out by 1945. Several thousand tons of fine-grained rejects are probably available, but they consist in large part of low-grade pellets. Reserves of bedded ore are unknown but may be considerable, especially if the predominantly low-grade tuff ore can be concentrated. In 1943 ore had been found over an area 60 meters long and 45 meters wide, and the limits of the ore body had not been reached at any place.

#### DEGARITO MINE

The Degarito mine is just south of the Briseida mine. It was operated from October 1940 to April 1943 and has a reported production of 1,500 tons of ore averaging 46 percent manganese, all from two granzón fields. Mineralized tuff below a limestone has been explored by short adits that expose thin stringers of manganese oxides and jasper. The mine is very similar geologically to the Briseida mine.

#### LOLÓ PROSPECT

The Loló prospect is at Iris. Several attempts have been made to mine three small granzón deposits, but the small pellets of ore generally contain less than 40 percent manganese. The largest deposit would yield probably only a few hundred tons of low-grade concentrate.

### CORINTO MINE

The Corinto mine is 2.5 kilometers east of Iris, on a lot of the Briseida claim. The road from Iris to the mine descended steep grades and was not passable in wet weather. The property was discovered in 1940 and from 1942 until 1945 produced 4,319 tons of ore averaging 46 percent manganese. Operations ceased in 1945, presumably because the deposit was mined out.

The mine lies just west of the Río Jarahueca in two steep-walled canyons separated by narrow, densely wooded ridges, which rise 120 to 215 meters above the stream bottoms. Arroyo Macagua, which runs through the mine area, contains sufficient water for mine and mill use. Country rock is thin-bedded calcareous tuff, tuff-agglomerate, and massive green andesitic tuff, overlain by 20 meters of Charco Redondo limestone and 45 meters or more of interbedded marls and tuffaceous limestone of the San Luis formation. Plate 14 is a geologic map of the mine area.

The regional dip of the limestone is 15°–20° E., but near the mine the limestone is broken by several northward-trending steeply dipping faults, and dips are rather erratic. The major faults are downthrown to the east; the combined effect of eastward regional dip and faulting is to drop the base of the limestone 250 to 300 meters below its position at the Briseida mine.

Low grade tuff ore containing a little jasper is found at the base of the limestone in many places along Arroyo Macagua and elsewhere (see pl. 14) but the main Corinto ore bodies, shown in plate 15, were in a tuff bed above the base of the limestone. Ore body 1 had a strike length of 105 meters and a width of 50 meters. Ore body 2 was 35 meters along the strike and 22 meters wide; it was faulted on its updip side. A third deposit in limestone along Arroyo Macagua is merely a small pod or lens.

The ore beds were lenses that range in thickness from a knife edge to somewhat more than 1 meter. In the north adit of the No. 1 workings, the manganese oxides diminished in quantity and tuff blocks took their place; in other faces the manganese-bearing bed pinched out into the enclosing limestone, but may reappear beyond the barren faces. In the south haulage adit of the No. 1 workings, a thin ore bed, probably at the same horizon as the bed in the main workings, suggests that the mineralized zone continues to the south. The ore beds were highly lenticular; for instance, in the No. 2 workings the original outcrop showed less than 8 centimeters of manganese oxide, yet this ore body proved to be as much as 1.7 meters thick. The footwall of both ore bodies was a smooth bedding surface, but the hanging wall was very irregular.

Pyrolusite, psilomelane-type oxide, and black calcite were the only manganese minerals recognized. The manganese minerals formed interconnected nodules, large dendrites, and pods in a matrix of red altered tuff and also formed massive layers parallel to the bedding. Irregular thin jasper pods occurred in the footwall of the ore in the northern part of the No. 1 workings. Massive layers were most common in the upper part of the ore bed near the center of the ore bodies; nodular ore occurred at the borders and in the lower 60 centimeters of the bed. The massive ore was dense, heavy psilomelane-type oxide with veinlets of pyrolusite. Masses of pyrolusite as much as a meter in diameter occurred in the thicker parts of the ore bed. Crude ore is estimated to have contained 25 to 40 percent manganese and had to be concentrated.

The Corinto ore deposits are similar in stratigraphic position and physical appearance to the deposits in the Taratana area, but they may have been formed after the deposition of the overlying limestone. The dendritic texture of the margins of the ore bed and the association of ore and altered tuff suggest that the ore bodies were formed by replacement of tuff lenses in the limestone. In the No. 1 workings, manganese oxides were found along a joint plane and formed a small pocket in tuff about 2 meters above the main ore bed. Although the ore was overlain by a conglomerate composed of tuff and limestone, the conglomerate contained no manganese pebbles.

Crude ore was sorted at the mine. Low-grade material was crushed to less than one inch in diameter, washed in a single log washer, and hand-sorted a second time. The mine apparently is exhausted and no reserves are known.

#### FEDERICO MINE

The Federico mine is just north of the Ibars de Urgel mine north of Iris, and covers part of the same granzón field. It was operated intermittently from 1939 to 1945. Total production is not known, but at least 2,400 tons of ore averaging about 46 percent manganese was shipped during 1943–45. Reserves are not known but are small.

### GUANABÁ GROUP

The Guanabá group of ore deposits, 5 kilometers northeast of Iris, includes the Guanabá (Los Laneros) mine and the Triunfo and Turquesa prospects. The area is drained by Arroyo Los Laneros to the west and Arroyo Portezuela to the south.

#### GUANABÁ MINE

The Guanabá mine is the largest in the area. It comprises, from north to south, the Amalia, Amelia, and Guanabá claims on the north flank of Los Laneros hill. Mining began in 1940 and continued until

1945; information later than 1945 is not available. Between January 1942 and August 1945, a total of 5,642 tons of ore averaging 45 percent manganese was shipped.

The mine area is underlain by the Charco Redondo limestone and tuff and calcareous tuff of the Cobre formation. The rocks dip gently northward and form a dip slope on the north flank of Los Laneros hill.

Manganese oxide occurs in tuff at the base of the limestone and as residual ore in weathered tuff.

Bedrock deposits are in two areas about 900 meters apart. The deposits are bedded manganese oxide and jasper replacements of tuff at the base of the limestone. The upper, or southern ore body covered an area about 180 meters long and 90 meters wide. It was limited on the north by a tabular mass of jasper near the crest of Los Laneros hill and on the south by limestone, although low-grade ore extends beneath the limestone for an unknown distance. Granzón covered the area and was underlain in places by manganese oxides in tuff. The oxides occur in irregular layers through a thickness of as much as 8 meters of tuff, but no single layer was more than 2.5 meters thick. Isolated pods of jasper are enclosed in the ore along the northern edge. Some of the manganese oxides are in small nodules and pellets, but adjacent to the jasper masses they form beds as much as 45 centimeters thick. A few veins of secondary pyrolusite cut across the decomposed tuffs. The mineralized zone is nowhere more than 8 meters below the original surface.

The ore body was worked first from shafts and open pits, but after most of the granzón cap had been removed, areas of barren tuff and soil overlying the ore were stripped with a scraper and tractor and the bedrock ore was mined by hand from open pits. Most of the ore body was abandoned, however, because fragments of tuff and jasper and pellets of iron oxide could not be removed by washing and a high-grade concentrate could not be produced.

The lower ore body was explored over an area about 150 meters in diameter. It is divided into two segments by a northward-trending fault that drops the ore 8 to 9 meters on the west side. Manganese oxides occur in pockets and discontinuous layers both in the tuff and in the base of the overlying limestone but no well-defined beds exist. Ore was mined in 1940 and 1941 from shafts and underground workings, but in 1942, the shallow eastern half of the deposit was stripped. Jasper lenses in the ore could not be moved by the scraper and consequently the ore body was only partly exposed.

Most of the ore shipped from the mine was granzón, which was found in at least six places covering areas as much as 300 meters across. Boulders of jasper as much as 3 meters across were scattered through the granzón, and much of the mining was necessarily done by hand.

Extensions of the southern ore body beneath the limestone to the southeast have been explored by a shaft, several adits, and an opencut 45 meters long. The shaft and one adit show good ore 0.3 to 1 meter thick. Impure masses of manganese oxide were found in the opencut through a thickness of as much as 1.2 meters of tuff; the overlying limestone is conglomeratic and contains small fragments of ore. This part of the mine was not explored adequately in 1944 and held considerable promise, although much of the ore was low-grade and would be difficult to concentrate by simple log-washing. Reserves were estimated at a few thousand tons, but a much larger amount might be considered as "geologically possible."

Reserves of granzón are probably negligible at the present time.

### TRIUNFO PROSPECTS

The Triunfo prospects include five claims (Sarah, Betsy, Lillian, Triunfo, and Campo Carmin) which lie around the borders of the Guanabá mine. In 1943, 95 tons of ore containing 46 percent manganese was shipped from the Sarah claim; no other production is known.

The granzón fields of the Guanabá mine extend north onto the Sarah claim and south onto the Triunfo, but the Triunfo granzón contains little ore that could be recovered by log-washing.

A contact of the limestone and tuff on the Betsy claim east of the Guanabá mine has been explored by opencuts but no ore was found. A few stringers of manganese oxide cut the basal part of the limestone.

None of the claims is promising, although the showing on the Betsy warrants additional prospecting.

### TURQUESA PROSPECT

The Turquesa prospect is west of the Guanabá mine across Arroyo Los Laneros.

A jasper mass from 1.3 to 1.6 meters thick and 12 meters long is enclosed in chloritized tuff lying about 3 meters below limestone. Near the jasper the tuff contains small stringers of manganese oxide; pockets of ore also are found within the jasper. The prospect has been explored by a pit and two short adits, but very little ore was found.

### IBARS DE URGEL MINE

The Ibars de Urgel mine is on the side of a steep hill just north of Iris. From 1942 to 1944, it yielded 526 tons of ore averaging about 43 percent manganese and 14 percent silica.

The ore deposit is in tuff at the base of a limestone that strikes N. 70°–95° E. and dips 20°–45° N. The mineralized tuff is from 0.3 to 2 meters thick and crops out for about 60 meters. Psilomelane-type oxide, pyrolusite, black calcite, and manganese silicates, principally bementite and neotocite, form irregular nodules and layers in the tuff; jasper and blue-white chalcedony are intimately mixed with the manganese minerals. The silicates are altered to pyrolusite and other oxides, and much of the silica has been leached.

Granzón above and to the east of the bedrock deposit is believed to be residual from it. The residual ore is similar to that at the Briseida mine, but is lower grade and less abundant. Reserves are small and much of the ore is very high in silica.

### MARÍA ANTONIA PROSPECT

The María Antonia prospect is a short distance southwest of Iris on the west side of the Iris ridge. An adit 8 meters long exposes a bed of very siliceous dense black manganese oxide striking northwest and dipping 20° NE. The bed averages 45 centimeters in thickness. Soft gray tuff forms the hanging wall and green tuff-agglomerate the footwall. An opencut 12 meters N. 20° E. of the adit shows similar material 30 centimeters thick.

The ore consists of irregularly banded jasper and pyrolusite; the presence of free silica within the pyrolusite bands and the peculiar shiny appearance of much of the pyrolusite suggests that it has been derived from the weathering of manganese silicates, probably neotocite or bementite.

Reserves are very small and the silica content of the manganese-bearing rock is high.

### TEJON PROSPECT

The Tejón prospect is near the Valle de Manganeso mine, about 2 kilometers west of the Río Jarahueca. It lies at the head of a small basin floored by tuff and rimmed by limestone cliffs. A bedded deposit of manganese oxide crops out at the contact between limestone and tuff. Two exposures, one east and one west of the valley floor, show from 2 to 2.2 meters of mineralized tuff that contains an average of about 20 percent manganese. The most common manganese oxide is a light-weight, porous, psilomelane-type mineral, which, because of its low density, would be difficult to concentrate by gravity methods.

Two short adits have been driven into the outcrops. The exposures warrant additional exploration, as a considerable tonnage of low-grade ore may be available.

### VALLE DE MANGANESO MINE

The Valle de Manganeso mine is 3 kilometers west-northwest of Joturo and 20 kilometers north-northeast of Jutinicú, the shipping point. From 1942 to August 1945, the mine produced 4,149 tons of ore containing an average of 44 percent manganese.

The mine is near the head of a narrow southward-trending valley bounded by vertical or nearly vertical limestone cliffs which in places are more than 30 meters high. Along the west side of the valley near the mine the limestone strikes northwest and dips 10°–21° SW; on the east side the limestone dips gently east. The limestone overlies coarse reddish and gray tuff that is exposed only in the vicinity of the mine; farther down the canyon the floor is limestone.

The limestone cliff along the west side of the canyon is terminated at its north end by a vertical eastward-trending fault having a minimum displacement of 18 meters, the south side being downthrown. Another eastward-trending fault cuts through the south workings of the mine; it is downthrown an unknown distance on the south side. The cliffs forming the canyon walls may be either faultline scarps or erosional scarps but available evidence, such as the sinuous course of the canyon, suggests that they are erosional features and that the valley itself has been produced largely by solution of limestone, perhaps controlled by joints. Geology and topography are shown on plate 16.

Manganese oxide has been mined from deposits on both sides of the canyon but the east-side workings are completely inaccessible.

The north ore body on the west side is in tuff at or near the base of the limestone. In places the manganese-bearing tuff is separated from the overlying limestone by as much as 1 meter of barren tuff; elsewhere the ore zone is in contact with limestone. The tuff strikes N. 10° W. to N. 30° E. and dips 12°–35° W. The manganiferous zone has been explored for 60 meters along the strike and 30 meters down the dip; it ranges in thickness from 1 to 6 meters (pl. 17). Although some small masses of solid manganese oxide are found, most of the mineralized zone consists of oxide containing considerable disseminated tuff that cannot be removed by jigging; the concentrate from such crude ore containing 30 to 35 percent of manganese is necessarily rather low grade.

Along the northwest side of the workings the ore body is cut off by a normal fault dipping 60°–75° E. Displacement of the fault is probably 3 to 5 meters. The upthrown side of the fault has not been explored, and there is an excellent chance of finding a good ore body on that side.

The south ore body is some 90 meters downdip from the north deposit. It is at least 45 meters wide along the strike and extends about the same distance down the dip (pl. 17). The rocks strike east and dip 25°–35° S. Between the two ore bodies the ore pinches out, but explorations in 1945 were not far enough advanced to show just where the ore limits lay. The ore bed ranges from 1.3 to 3 meters in thickness and is similar mineralogically to the north deposit. It is cut off along the south side by an eastward-trending normal fault and dropped an unknown distance on the south side of the fault. This down-faulted block is unexplored and almost certainly contains a sizable ore body.

Reserves are estimated at several tens of thousand tons in the two workings and in the faulted and unexplored extensions of the ore bodies. Possibilities of additional ore in the immediate vicinity of the known ore deposits are excellent.

An exploration shaft was being sunk (1944) in the canyon bottom 150 meters southeast of the main workings. The shaft was well located and will furnish considerable information about possible down-dip extensions of the mineralized zone. The canyon for 2 kilometers below the mine is excellent prospecting ground, but as the depth to the base of the limestone is not known anywhere except near the mine, any prospecting could best be done by drilling.

### JAGUA DISTRICT

The Jagua district covers a large area 15 to 20 kilometers north of Dos Caminos. It includes the Esperancita mine and the Cubanita, Raoulita, Esperanza, and Tres Josefas prospects.

#### ESPERANCITA MINE

The Esperancita mine is 20 kilometers north of Dos Caminos in the low limestone hills south of the Sierra de Nipe. It is reached by a dry-weather road. Ore was trucked to the railhead at Banabacoa, 12 kilometers south. Estimated production from 1941 to 1945, inclusive, was 4,000 tons of ore averaging 45 to 46 percent manganese.

The geology of the mine area is shown in plate 18. The oldest rocks are a strongly folded sequence of slate, shale, conglomerate, chert, limestone, acidic volcanic rocks, and lignitic beds of the Habana(?) formation. They are overlain unconformably by tuff, tuff-conglomerate, minor beds of sandstone, and the Charco Redondo limestone member of the Cobre formation. A tuff-conglomerate at the base of the Cobre is overlain by a massive green tuff that grades upward into a section of thin-bedded tuff and shale; the ore deposit is in the lowest thin-bedded tuff.

Both the Habana(?) and Cobre formations are intruded by irregular masses of andesite; one andesite body is along the unconformity between the two formations. Andesite crops out near the ore body and is exposed underground some 12 meters below the base of the ore, but no metamorphism of the ore was detected.

The regional strike of the Cobre beds is northwest; they generally dip southwest. South of the mine workings the strike is north and the dip is 30° or so west; the change in attitude may have been caused by intrusion of one of the andesite masses.

The Esperancita ore bodies are bedded deposits in tuff as much as 6 meters thick; the main ore body had an average thickness of 1.6

meters. A layer of jasper as much as 12 meters thick formed the footwall of the main ore body; the upper portion of the jasper contained variable amounts of manganese oxide. Jasper pods were scattered throughout the ore zone but were most abundant near the footwall. In the upper levels the jasper footwall was absent locally. In some places a series of small bedding-plane slips occurred in the well-defined hanging wall. Manganese oxide occurred as blebs, stringers, and fine disseminated particles; the ore mined contained from 25 to 35 percent manganese. Psilomelane-type oxide and a little pyrolusite were the only manganese minerals recognized. Gangue was tuff particles, zeolites, and a peculiar yellow-green chlorite.

The main ore body was developed by the Balbina and Salvador adits and the Prieto shaft (see pl. 19). The ore bed where first found in the Prieto-Balbina workings dipped gently south into the Esperancita hill. At the south edge of the workings the dip increased to 50 to 60 degrees and then flattened again to 10 to 15 degrees in the Salvador workings below.

Two outcrops that proved to be landslide blocks were explored by the Granada adit and the Cafetal shaft; very little ore was recovered in either block. Several other exploratory adits were driven but failed to cut any ore.

Ore was broken with jackhammers and hauled in wheelbarrows to a mill where it was screened, crushed, washed, sized, and jigged.

Most of the ore suitable for concentration in the old mill probably has been extracted. The remaining low-grade ore is not amenable to simple mechanical concentration and probably would need treatment by flotation and sintering. Reserves of all classes are estimated at several tens of thousand tons averaging 15 to 20 percent manganese.

### CUBANITA PROSPECT

The Cubanita prospect is on the divide between the Ríos Majaguabo and Jagua, 1.8 kilometers west of the road between Dos Caminos and the Esperancita mine. No ore has been shipped. A bedded manganese deposit in tuff about 6 meters below a platy limestone has been explored by an adit and several small pits. The adit, which trends N. 80° W. along the strike of the beds, exposes 0.6 to 1 meter of mineralized tuff; an incline south from the adit at an angle of 12 degrees follows the tuff for 12 meters. Manganese oxides form nodules that contain variable amounts of tuff. The average nodules probably do not contain more than 35 percent manganese because of their high tuff content. Although the nodules can be separated easily from the tuff, it seems doubtful that any method of gravity concentration can raise the grade of the individual nodules. The deposits contain at least a few thousand tons of mineralized rock and may contain much more.

#### RAOULITA AND ESPERANZA PROSPECTS

The Raoulita and Esperanza prospects are on the west side of the Jagua valley along the road between San Luis and Candelaria. A total of 60 tons of ore is reported to have been shipped from the properties.

On the Raoulita claim a bedded deposit of manganese oxides in tuff at the base of a thin platy limestone is explored by an adit 30 meters long. The mineralized bed strikes N. 60° W. and dips 5°–8° SW. It is overlain by thin jasper pods along the base of the limestone and rests on tuff altered to white clay. Most of the manganese oxide is disseminated in fine particles throughout the bed, but there are a few nodules and stringers. Because of the small size of the oxide particles, it seems doubtful that much ore can be recovered from this prospect.

At the Esperanza prospect, a bedded deposit occurs in the upper part of a flaggy limestone. Scattered blocks of nodular psilomelane-type oxides in tuff and jasper were seen on the old dumps. Although the workings are inaccessible and gave no information on the extent of the deposit, the mineralized area is believed to be rather large. Hand-drill holes in the probable ore-bearing area could explore the deposit economically.

#### TRES JOSEFAS PROSPECT

The Tres Josefas prospect is immediately west of the Cubanita prospect. Thin-bedded limestone that strikes east and dips 30°–45° S. is faulted against calcareous andesitic tuffs to the north. Manganese oxides form thin beds in tuff below the limestone south of the fault. The outcrop of the manganese-bearing tuff extends at least 120 meters down the west slope of a steep hill.

Three beds of manganese oxide, 0.3 to 0.6 meter thick, are found in a mineralized zone as much as 6 meters thick; the rest of the zone contains a little manganese oxide but is mostly clay and iron oxides. Five shallow pits and 2 short drifts have been driven along the ore beds and 60 tons of ore were shipped in 1942. The crude ore contains only about 15 percent of manganese and the beds are too thin to offer much promise of notable tonnage.

### JARAHUECA DISTRICT

The Jarahueca district is northeast of Jarahueca at the headwaters of the Río Jarahueca. It is reached by a dry-weather road from Alto Songo, 20 kilometers southwest.

#### LUIS ANTONIO-DONCELLA MINE

The only mine in the district known to have produced any ore is the Luis Antonio-Doncella, 7 kilometers northeast of Jarahueca. This mine was operated during 1942 and 1943 and produced about 500 tons of ore containing 47 percent manganese. Geology of the mine area is shown in plate 20.

The mine is on a steep hillside capped by 30 meters of limestone that overlies unconformably felsite and dolerite. The lower 5 meters of the limestone contains boulders and angular fragments of dolerite, felsite, and tuffs; tuff fragments are especially abundant in the conglomerate at the south end of the mine area. Above the basal conglomerate the limestone is a massive white rock containing a few felsite cobbles. The felsite is intruded by an irregular mass of coarse-grained dolerite, which baked the felsite at the contact. Stringers of quartz-bearing copper carbonates cut dolerite.

The limestone and felsite near the mine are broken by 3 steeply dipping normal faults. Pods of manganese oxide occur along the faults and in fractures parallel to them in both limestone and felsite.

An outcrop along the central fault was prospected by a shaft that cut ore at a depth of 4 meters and by an adit driven to intersect ore 9 meters below the shaft collar. In the mine, manganese oxides were found near the fault in felsite and in the lower few meters of the limestone-felsite conglomerate. The contact between limestone and felsite dips 45° NW. near the fault, less steeply farther to the north; it is irregular and offset by several small faults. A pocket 4 meters thick of massive manganese oxide in the hanging wall of the fault yielded 450 tons of ore. Stringers of oxides continue west from the pocket, but all of them so far discovered are less than 8 centimeters wide. No ore has been found in the footwall. The fact that the ore is located along the fault at the contact between limestone and felsite was shown as a winze was sunk 13 meters into barren felsite and a crosscut driven into barren limestone, both away from the fault. Future exploration should be concentrated along this and other faults that cut the contact.

The most abundant manganese mineral is pyrolusite, but psilomelane-type oxide and black calcite are also present. Most of the ore mined has been massive oxide. A few tens of tons of milling ore remained on the borders of the pockets in 1943.

There are almost no reserves in the deposit, but possibly other ore pockets may be found.

### JUTINICÚ DISTRICT

The Jutinicú district is 1 kilometer north of the village of Jutinicú, on the Ferrocarril de Guantánamo y Occidente. It is reached by road from Alto Songo, 7 kilometers southeast. Twelve claims have been denounced in the district but all the ore produced has come from the San Vicente, Omega, and San Andrés claims, known collectively as the Jutinicú mine. The district has been known since 1888 and was worked during World War I. Between January 1942 and August 1945, a total of 4,085 tons of ore containing 45 to 46 percent manganese was shipped.

### JUTINICU MINE

The Jutinicú mine covers the top and flanks of a small hill rising about 90 meters above the valley of the Río Guaninicún. The Jutinicú hill is a structural dome of tuff and tuff agglomerate capped by thin-bedded white limestone, which makes up the crest and flanks of the hill. Near the base of the hill the limestone is overlain by tuffaceous shale and thin marl beds of the San Luis formation. Tuff is exposed beneath the limestone cap in several valleys that breach the hill crest. A few faults cut the rocks but do not affect the symmetry of the dome. No faults cut the outcrop of the mineralized zone but the ore body may be dropped to the south along a fault following the trend of a jasper outcrop on the southern side of the mine workings.

Manganese oxide occurs in a coarse tuff bed underlying the limestone. Usually there is some barren tuff, in places as much as 2 meters thick, between the limestone and the mineralized zone; where this tuff is missing the limestone and ore bed may be separated by 8 to 15 centimeters of mixed jasper and chloritic tuff.

The main ore body crops out in a shallow valley on the east side of the hill and on the divide to the south. It has been developed by short adits and drifts over an area 215 meters long and as much as 60 meters wide. Although the ore zone is as much as 4 meters thick, minable ore is generally less than 2 meters thick. In the valley the ore body dips 10° N., parallel to the bedding of the enclosing tuffs; on the divide it is horizontal or dips slightly to the south. A jasper mass on the hill crest is believed to cut across the bedding; in the valley, however, the same jasper mass forms a layer in the footwall of the ore bed. The south bank of the valley is a dip slope underlain by the ore and jasper.

Manganese oxide forms nodules in tuff altered to red clay, and veinlets, blebs, pods, and layers in less altered tuff. Thicker ore zones are composed of bands of oxides alternating with layers of tuff. The ore is highly lenticular; both ore and jasper may pass laterally into manganiferous tuff, which in turn may grade into barren tuff. Figure 41 is a sketch of lenticular ore and jasper exposed in an opencut 280 meters southeast of the main cut. Some of the manganese oxide is pyrolusite that replaces psilomelane-type oxide, but most of the nodules are psilomelane. The average size of the manganese particles is 2 to 10 millimeters but some masses of solid oxide with a maximum diameter of 1.3 meters have been found. Much manganese oxide occurs in fine particles in the tuff matrix. The grade of the ore varies markedly from place to place and ranges from 10 to 25 percent manganese. The best ore is on the western side of the ore body.

The ore zone is explored by drill holes, open pits, and underground workings. It is exposed in several short drifts and adits south of the valley, along one adit north of the valley, and in several pits on the

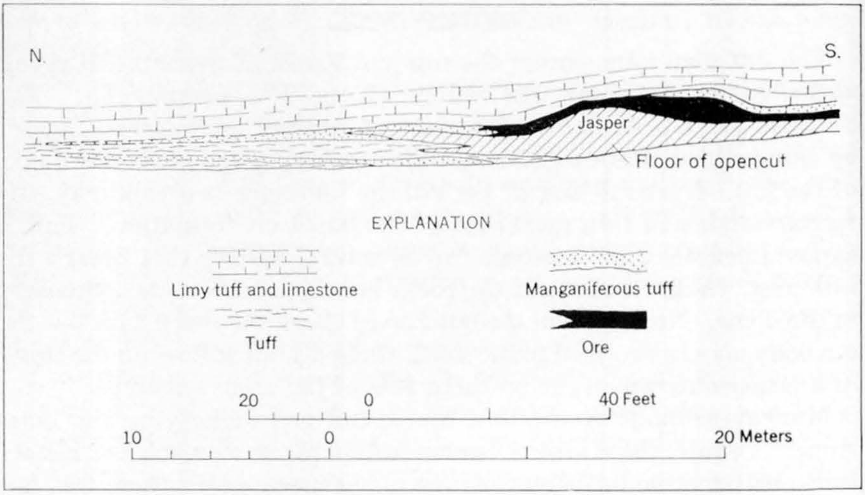



FIGURE 41.—Sketch of east wall of opencut, Jutinicú mine, showing lenticular character of the bedding.

divide to the south. In 1930 the Cuban Mining Company leased the district and put down 32 diamond-drill holes aggregating 3,000 feet of drilling in an effort to develop a large low-grade ore body. Seven of the holes are reported to have cut ore at depths ranging from a meter or so to 25 meters. In the area explored the ore is from 0.3 to 4 meters thick, and probably averages 1 to 1.3 meters.

Most of the ore is low grade and must be concentrated. During World War II ore was mined by hand and hauled by truck to a mill where it was crushed, sized, and jigged to a concentrate containing more than 45 percent manganese. Until April 1943, the plant treated 5 to 7 tons of crude ore to produce 1 ton of concentrate and the output of the mill seldom exceeded 15 tons per day. Much of the finer grained crude ore was lost. Revision of the mill flow sheet and enlargement of the crushing capacity of the plant, following suggestions of the engineer of the United States Metals Reserve Company Agency, lowered the concentration ratio to about 3.5:1 and increased production to nearly 25 tons per day.

Reserves are estimated at a few tens of thousand tons indicated and a similar amount inferred. The average grade of reserves is 15 to 20 percent manganese. There are probably few extensions of the known ore zone, because the drilling program of the Cuban Mining Company outlined almost completely the extent of the mineralized zone.

### MAFFO DISTRICT

The Maffo district is 2 kilometers southeast of Maffo, a small town south of the Carretera Central near Contramaestre. It includes two small mines, the Estrella and Sorpresa.

### ESTRELLA MINE

The Estrella mine is in gently rolling limestone terrain southeast of Maffo. A shaft 6 meters deep found an ore body in a tuff bed in limestone, which strikes east and dips gently north. The ore pocket was more than 45 meters long, about 8 meters wide, and had an average thickness of 2 meters. It was underlain by an irregular surface of limestone. Several thousand tons of high-grade ore was recovered before the ore was exhausted. Diamond drilling in the immediate vicinity of the mine has been unsuccessful in finding more ore. The base of the limestone beneath the old ore body should be explored.

### SORPRESA MINE

The Sorpresa mine is just west of the Estrella. Recorded production is 466 tons of ore averaging about 44 percent manganese. Manganese oxide occurs in two beds of tuff enclosed in limestone. The beds are 0.3 to 1 meter thick and are rather low grade.

### MANACAS DISTRICT

The Manacas district is about 10 kilometers southwest of Ramón de Guaninao and 20 kilometers southwest of Aguacate, a small settlement on the Carretera Central between Palma Soriano and Contramaestre. The road from Aguacate to Ramón de Guaninao is nearly always passable; the remainder of the road is usable only during dry weather. Ore has been shipped from the Amarito, Central, Guadalupe, Luis Segundo, Orión, and Pasaje claims. Production for the years 1942–45, inclusive, was about 13,000 tons of ore averaging more than 50 percent of manganese.

The district is in the rolling foothills north of the Sierra Maestra in the drainage basin of the Río Caney. Sufficient water for mining and milling operations is usually available.

The most conspicuous geologic feature of the district is the Manacas lava dome (pl. 21), an eastward-trending elliptical mass of gray dacite porphyry about 4.5 kilometers long and 3 kilometers wide. The dome has a relief of at least 120 meters. It consists of one or more plugs with related flow rocks and flow breccias. The dacite is a hard massive rock made up of phenocrysts of quartz and albite-oligoclase as much as 5 millimeters across, set in a groundmass of plagioclase laths, devitrified glass, chlorite, and iron oxide.

Pyroclastic rocks and overlying limestone of the Cobre formation lie parallel to the porphyry contact and dip 20 to 35 degrees away from the dome. The basal part of the pyroclastic sequence contains many rounded boulders of porphyry as large as 30 centimeters or so across. In places, particularly along the southwest flank of the dome, Cobre strata are upturned and faulted against the porphyry.

428472—58——15

The limestone bed along the north flank of the dome overlaps the pyroclastic rocks so that on the crest and south flank of the dome the limestone rests directly on porphyry; moreover, the limestone thickens noticeably to the north and west, away from the dome. It seems, therefore, that the dome was present as a positive area prior to the deposition of the overlying rocks. However, we believe that the present domical structure is due in part to differential compaction of the soft pyroclastic rocks over the massive, competent porphyry, which also caused the local upturning and faulting of beds along the porphyry contact.

Dikes are found throughout the area, especially in the dacite porphyry. Some are rhyolitic or dacitic; others, such as the large dike shown at the west edge of plate 21, are diabase.

Ore has been found at many places over a distance of more than 3 kilometers around the western half of the dome. It occurs in tuff beds in the basal 45 meters of the pyroclastic sequence and is similar to the tuff ore found elsewhere in Oriente. The ore beds range from 0.6 to 2.5 meters in thickness and average 1.1 to 3 meters. The total number of ore beds is not known, as correlations between the various occurrences of ore cannot be made with certainty, but at least 2 beds about 15 meters stratigraphically apart have been mined on the Guadalupe claim (pl. 22); the upper bed has been the more productive. Crude ore contains 20 to 30 percent manganese.

Psilomelane-type oxide is the most abundant manganese mineral; commonly it is partly or completely altered to pyrolusite. Braunite has been found in small amounts on the Amarito and Pasaje claims. Discontinuous lenses of jasper are found throughout the area, particularly near the hanging wall and footwall of the ore beds. Gangue includes chlorites, zeolites, and chalcedony.

Ore has been extracted from a great number of adits, inclines, pits, and shafts. A typical group of workings in the Guadalupe and Central claims is shown in plate 22. Mining during the early period of activity was poorly integrated because the various deposits were worked by different operators and concentration of ore was done at several widely separated small mills. All mining was done by hand. Ore was concentrated by the usual method of screening, washing, and jigging. The ore mills well and yields a high-grade concentrate.

Reserves of crude ore were estimated in 1946 to be a few tens of thousand tons indicated and several hundred thousand tons inferred. Reserves in terms of concentrate would depend on the efficiency of the concentration process; the concentration ratio in the former mills was 4:1 to 6:1 but almost certainly could be improved. Production since 1946 is not known but apparently has been small.

The Manacas district is one of the most favorable in the province. The known ore beds have a strike length of 1,200 meters on the

Guadalupe and Central claims alone and could be explored easily by inclined adits. The Amarito claim is also very promising, but mining has been hampered by large amounts of water. Of the remaining claims only the Pasaje and Orión have produced any considerable tonnage, and neither has been explored adequately.

### LOS NEGROS DISTRICT

Los Negros district embraces a large number of mines and prospects lying west, south, and east of the town of Los Negros. An all-weather road connects Los Negros with Baire on the Carretera Central, 10 kilometers north. Although several hundred prospects are known, only the Antonio, Montenegro, Pozo Prieto, Unica, and Yeya mines have produced notable amounts of ore.

#### AMY PROSPECT

The Amy prospect is about 3 kilometers southeast of Los Negros on top of a hill east of the Río Mogote. A cut about 30 meters in diameter is opened in granzón lying on a pitted limestone surface. From the bottom of the cut a shaft was started (1943) in limestone, and a short distance down the hill an adit, designed to undercut the granzón and connect with the shaft, was driven 35 meters in tuff and volcanic breccia. No ore was found in the underground workings.

#### ANTONIO GROUP

The Antonio group of mines and prospects is near Purial, 5 kilometers west-southwest of Los Negros. It includes the Antonio mine and the Esperanza, Gaceta, and Milán prospects. The area is reached from Baire on the Carretera Central over a road that is passable except after heavy rain.

##### ANTONIO MINE

The Antonio mine has been worked almost continuously since 1938 and most of the production of the group has come from it. It was denounced in 1901 and was worked for a time in 1917 and 1918, but most of the development has been done since 1938. Total production has been more than 10,000 tons of ore containing 40 to 45 percent manganese.

The mine is on the northern edge of a rugged karst area but most of the workings are in a region of low relief and shallow sinkholes. In the eastern part of the denouncement a few valleys are floored with tuff, and small streams furnish sufficient water for washing ores. Timber for the mines is hauled from the hills to the south.

The mine area is underlain by tuff and the Charco Redondo limestone member of the Cobre formation (pl. 23). The tuffs are well-bedded, water-laid, green andesitic rocks that are soft and form areas of low relief. Near the Antonio mine they do not contain manganese oxides, but mineralized tuff beds are found in some of the adjacent denouncements. The limestone is a dense, hard, white rock that weathers to a rough "dogtooth" surface with deep sinkholes and shallow undrained depressions. The contact between limestone and tuff is obscured in many places by blocks of limestone. A conglomerate composed of algal heads lies at the base of the limestone. It is overlain by 6 to 9 meters of dense platy limestone containing innumerable microfossils. In part of the area the platy limestone is overlain by 1–1.3 meters of manganese oxide in a matrix of tuff or tuffaceous limestone. Upon the ore bed rests an impure crossbedded intraformational limestone conglomerate as much as 1.5 meters thick, composed of small white limestone fragments in a gray fine-grained limy matrix. This rock occurs with the ore bed throughout the property and was used to correlate scattered outcrops of ore. At least 60 meters of platy white limestone interbedded with thin layers of algal conglomerate overlies the ore horizon. About 15 meters above the ore horizon is a coarse sandy limestone that contains many Foraminifera and megafossils.

The Antonio mine lies on the crest and the southwest flank of a northwestward-trending anticline that is cut by a zone of northwestward-trending faults (pl. 23). Near Purial, in the center of the mapped area, the faults have broken the ore bed into several blocks. West and south of Purial valley, tuff is faulted into contact with limestone, and limestone and ore are dropped to the southwest. Some of the faults are marked by red limestone breccia and many small caves.

Manganese oxide is found in and adjacent to the northwestward-trending faults, in caves formed by solution along the faults, in granzón patches on the surface, and in an ore bed. The bedded ores are mostly characteristic tuff ore—nodules and stringers of manganese oxide in altered tuff—but in 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 0.3 to 1.5 meters thick and is of considerable areal extent; it gradually pinches out to the southeast.

Stringers and pods of manganese oxide occur in or near many of the faults. The largest pods contain only a few tons each. Pyrolusite is the most abundant oxide. In one outcrop a mixture of pyrolusite and fine-grained black silica was seen; in another outcrop manganese oxides are mixed with copper carbonates. A cave along a northeastward-trending fracture in limestone 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 granzón are found as surficial blankets and in solution pits on the limestone. Most of the granzón deposits overlie outcrops of lode ores.

East of Purial the ore bed is explored by a large open pit from which two drifts followed the ore eastward for 30 meters. The ore bed is broken by several normal faults near the open pit. Galleries extending eastward and southward from the bottom of a 5-meter shaft show 0.6 to 1 meter of ore in a downfaulted block.

South of Purial, along the south side of the valley, the main ore bed crops out intermittently for more than 100 meters and is broken into small blocks by faults trending northeastward. Open pits expose 0.6–1 meter of ore, containing about 30 percent manganese, and an inclined drift, which follows the bed about 45 meters down the dip, exposes about 1.2 meters of ore. Near the faults (see pl. 23) ore has been mined from open pits.

Ore in a limy tuff bed continues for about a kilometer southeast of the area shown on plate 23. Ore has been mined also from shallow pits and galleries on all sides of a hill called Las Auras, but these workings are in a thin low-grade bed and mining was stopped because of the high cost of extraction.

Mining was done largely by hand 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 handcobbed; granzón and a little tuff ore were concentrated in a log washer.

Reserves as of 1946 were estimated at a few thousand tons indicated and several tens of thousand tons inferred, with an average grade of 35–45 percent manganese. Most of the indicated reserve is in thin beds that are costly to mine. The main ore bed can be explored near the mine by drifting and can be prospected away from the present workings by drilling; drill holes as much as 45 or 50 meters deep will suffice to explore a large area of potential ore-bearing ground. The Antonio mine area holds considerable promise for the development of moderate tonnages of medium-grade ore.

#### ESPERANZA PROSPECT

The Esperanza prospect is just west of the Antonio mine. A few shallow pits have been dug on outcrops of limestone breccia but little ore has been found. In 1943, 111 tons of ore containing 49 percent manganese was shipped from a mine called Esperanza, but it is uncertain whether it was the mine under discussion or a mine of the same name in the Jagua district.

### GACETA PROSPECT

A small patch of high-grade granzón was exploited in 1942 and 1943 on the Gaceta claim, northeast of the Antonio mine. Some ore was shipped also in 1945. Total production is unknown but small. Most of the workings are on limestone. In a few places, a limestone breccia is cut by irregular veinlets of manganese oxides. The granzón contains scattered boulders of jasper.

### MILÁN PROSPECT

The Milán prospect is just northeast of the Antonio mine (see pl. 23). A trench 30 meters long, 9 meters wide, and 0.6 meter deep has been opened up on a layer of fine-grained granzón. Granzón pellets are 3 to 6 millimeters across. The residual ore is about 150 meters from the nearest known outcrop of lode ore and its source is unknown.

Two small cuts on another part of the claim show a breccia of pink limestone, cut by irregular veins of pyrolusite as much as 1.3 meters across.

### ARCADIO MINE

The Arcadio mine is on the Río Mogote, 5 kilometers east of Los Negros. Production to 1945 is not known but is small; the 1945 production of 1,175 tons includes some ore from the Gaceta prospect. The ore contained about 44 percent manganese.

A cut about 30 meters long by 6 meters wide, trending S. 80° W., has been opened in limestone breccia just above its contact with the underlying tuff. Mineralization is irregular, but in general the ore zone strikes S. 80° W. and dips 30° N. Several small pockets of high-grade ore have been worked. The ore zone is explored also by an adit 60 meters long and a shaft; a layer of manganese oxide less than 15 centimeters thick is exposed in the shaft.

Surface showings at the Arcadio mine are good enough to justify a considerable amount of exploration, particularly along the contact between limestone or limestone breccia and tuff.

### BESSIE PROSPECT

At the Bessie prospect, a small cut explores a low-grade manganese-bearing limestone breccia on a ridge near the Mascota prospect on the Río Mogote, 3 kilometers east of Los Negros. A little ore was produced in 1942.

### BUENAVISTA GROUP

The Buenavista group of claims is near the settlement of Buenavista on the Río Cautillo, 15 kilometers southwest of Los Negros. It is accessible only by trail, either from Güisa, 18 kilometers northwest, or from La Tabla, 7 kilometers north.

Production until 1945 was small. About 800 tons of ore was shipped from the María Teresa claim in 1941, and some 290 tons was mined at the Lolita claim in 1943–44. A little ore has come from the Lola claim, 3 kilometers north of the María Teresa. The group is in very rugged limestone terrain and has not been prospected thoroughly.

Pyrolusite associated with jasper has been found in pockets in limestone along brecciated zones that probably mark faults. The pockets lie within 30 meters of the base of the limestone; 6 pockets containing from 10 to 300 tons of ore were found on the María Teresa claim. All the ore contains considerable calcite; on the Fortuna and Lolita claims it contains so much hematite that a saleable ore is difficult to produce.

The contact between the limestone and tuff is exposed for several kilometers along Arroyo Colorado and the Río Cautillo and warrants further exploration. Very little prospecting has been done between the María Teresa and Lolita ore pockets. Reserves in the area are negligible, but the possibilities of finding additional pockets of ore are good.

#### CANDAS PROSPECT

The Candas prospect is about 2 kilometers east of the Antonio mine. Several small cuts in limestone breccia expose small pockets and stringers of manganese oxide associated with pink clay; the largest pocket was 1 meter across.

#### DEFENSA PROSPECT

The Defensa prospect is 5 kilometers by trail south-southeast of Los Negros. Production has been less than 100 tons. A limestone breccia overlying altered tuff has been explored by several pits. One cut exposes a layer of manganese oxide about 0.6 meter thick. A small amount of granzón was scattered over the nearby surface.

#### DICHOSA PROSPECT

At the Dichosa prospect, 2 kilometers 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 nearly a kilometer along the strike. One cut showed a layer of high-grade pyrolusite about 30 centimeters thick, which strikes N. 70° W. and dips 65° N. A prospect adit 12 meters long, which was started about 8 meters below the ore horizon, was entirely in agglomerate that showed no obvious mineralization. Dikes of hard hornblende latite (?) were exposed in two cuts.

### DIDO PROSPECT

The Dido prospect is on the Río Mogote, 5 kilometers south of Los Negros. Production is not known, as ore was shipped with ore from the Pozo Prieto mines, but is certainly rather small.

Ore occurs in small irregular pockets in limestone and as small lenses roughly parallel to the bedding of the enclosing limestone. The largest ore body, exposed in a drift off a 5-meter shaft, was about 8 meters long and averaged about 0.6 meter thick. Reserves are very small and prospects of finding much ore are not good.

### EDUARDO PROSPECT

The Eduardo prospect, about 3 kilometers south of Los Negros, is developed by at least 5 cuts in a manganiferous limestone breccia that strikes N. 45° W. and dips 25° SW. The ore zone is very irregular but averages probably 1.3 to 1.6 meters in thickness. It consists of stringers and small pockets of manganese oxide with associated jasper and some hematite. Mineralization is extremely erratic and spotty.

### FORTUNA MINE

The Fortuna mine is about 5 kilometers airline northeast of Los Negros and is connected by road to the Carretera Central at Contramaestre. Workings on the property consist of an irregular glory hole, from which about 25 meters of drifting has been done, a new shaft that was 8 meters deep in 1941, two abandoned shafts, an old cut, and an inclined adit 9 meters long. These workings are in limestone, in fracture zones that trend nearly northward, normal to the bedding. In the glory hole the ore trends nearly eastward and appears to be breccia and cave filling. It consists of fragments of limestone cemented with travertine and cut by seams of manganese oxide; in places the oxide forms pockets as much as 1.5 meters wide. About 100 tons of ore is said to have been sold in 1941 and another 100 tons lay on the dump in the spring of 1941.

### MASCOTA PROSPECT

The Mascota prospect is on the Río Mogote, about 2 kilometers south of the Arcadio mine and 3 kilometers east of Los Negros. A thin flat-lying ore bed, 15–30 centimeters thick, in limestone breccia is exposed in a circular cut about 12 meters in diameter. Several other smaller cuts and a shaft reported to be about 15 meters deep show stringers of manganese oxide in limestone breccia. A small amount of ore has been shipped.

### MONTENEGRO-ADRIANA GROUP

The Montenegro-Adriana group is 12 kilometers south of Baire, on the Carretera Central, and 1 kilometer south of the settlement of Rihito. It is reached by a rough all-weather road from Baire.

The Montenegro mine was opened in April 1942, and to the end of 1944 produced 9,352 tons of ore averaging 41 percent manganese. Total production from the Adriana mine is not known. The mine was worked first in 1917–18 and is reported to have produced about 8,000 tons of ore containing 43–45 percent manganese. However, the size of the old stope suggests a considerably smaller production. A small amount of ore was recovered in 1941; since then the mine has been inactive. Some ore was shipped from the group in 1946 and 1949.

The Montenegro-Adriana group is in a steep-walled canyon typical of the Sierra Maestra karst country. Geology and topography are shown on plate 24. Massive limestone and limestone conglomerate form the canyon walls. The limestone is a dense creamy or gray rock containing innumerable microfossils. At the base of the limestone is a conglomerate composed largely of limestone boulders and fragments in a limestone matrix. Its thickness is unknown, but may be as great as 15 or 20 meters. Commonly, especially near and in the mines, the conglomerate contains a few angular fragments of manganese oxide.

A red, purple, or gray coarse agglomerate underlies the limestone. Fragments of the agglomerate are as much as 1 meter across and are composed of gray and purple andesitic tuff. The agglomerate wherever exposed is soft and deeply weathered. In the Montenegro mine and probably in the Ariana, a bed of tuff 0.6 to 1.5 meters thick separates agglomerate from the limestone; in the Montenegro mine the ore is found largely in this tuff.

The contact of the limestone and agglomerate along the northeast side of the valley is exposed in a short adit, where it dips 40° NE. A layer of gouge 1–1.5 meters thick separates the two rocks; near the portal a thin lens of mineralized tuff lies along the hanging wall. The contact is undoubtedly faulted, but it is believed that the fault is essentially parallel to the bedding and of small displacement. Farther southeast the contact appears to be offset by a fault trending north-northeastward, but both the location and strike of this fault are uncertain.

Along the southwest side of the valley the contact is exposed in many cuts, inclines, and shafts between the Adriana pit and the southernmost incline of the Montenegro mine. Farther south the contact is obscured by limestone float. The contact dips from a few degrees to 35° W. and appears to be a slightly sheared sedimentary contact. It can be traced southeastward 2.5 kilometers to the Progreso mine, but no other manganese deposits have been found. A 60-meter adit just southeast of the mapped area is entirely in agglomerate and is 15–18 meters below the limestone.

The manganese deposits are along the contact of the limestone and agglomerate. At the Montenegro mine, ore is localized in a thin tuff bed along the contact. The manganese-bearing rock at the Adriana mine is not exposed, as the main stope is badly caved, but a small outcrop of mineralized tuff on the south side of the Adriana pit suggests that perhaps the ore was similar to that at the Montenegro. A small stope in the limestone hanging wall of the main stope exposes a bed of manganiferous tuff, ranging in thickness from 15–60 centimeters; it is about 21 meters stratigraphically above the base of the limestone. Another thin tuff bed lies 1.3 meters higher. The limestone above and below the tuff is a conglomerate containing many stringers and irregular fragments of manganese oxide.

The Montenegro deposit was developed by three inclines driven 90–100 meters down the dip. The two north inclines were connected by a stope with a strike length of 120 meters. Limestone conglomerate containing fragments of manganese oxide formed the roof of all the workings; the floor was soft agglomerate. Between the limestone and the agglomerate was a tuff bed from 0.6 to 1.5 meters thick that carried the manganese ore. The ore commonly was banded and consisted of alternate layers of tuff and manganese oxide. Commonly the manganese oxide was concentrated near the hanging wall; as the footwall was approached the ore became leaner and graded into barren tuff. This gradational change was well shown about halfway down the north incline. In some places the entire bed was ore and in a few places massive psilomelane-type oxide formed bands parallel to the bedding or formed crosscutting veins as much as 5 centimeters thick. The massive bands usually were along the hanging wall.

The limestone hanging wall in general dips uniformly west-southwestward with dips ranging from 25 to 40 degrees. Many small faults, which commonly strike about northwest and are downthrown on the southwest side, cut the ore bed; their net effect is a slight increase in the apparent dip of the ore bed.

In general the mine-run ore was low grade, containing less than 30 percent manganese, and nearly all the rock mined had to be beneficiated to produce a saleable concentrate. Ore was broken by jackhammers and hauled up the inclines by gasoline-driven hoists. It was then hand-sorted, log-washed, and screened to eliminate excessive fines. The concentration ratio was probably as high as 5 : 1 or 6 : 1.

The Adriana workings consist of an open pit, 25 meters long and 18 meters wide, from which an inclined stope leads downdip at least 25 meters. The stope has a maximum strike length of about 40 meters. According to Burchard (1920, p. 89–91) the ore shoot was 50 feet (15 meters) wide, at least 90 feet (27 meters) long down the dip, and had an average thickness of 4 feet (1.3 meters). No ore was found in an exploration shaft 26 meters deep at the contact of the limestone and tuff and the shaft was abandoned.

By the middle of 1944 the downdip limits of ore apparently had been reached. The ore body probably is bounded along its southwest side by a northwestward-trending fault downthrown on the southwest side, as ore was brought into contact with limestone at several places along the fault. The downthrown block probably cannot be explored from the old workings because the back of the main stope was virtually unsupported and the stope itself was unsafe. Inasmuch as the portals of the inclines are only 6 to 9 meters above the valley floor, exploration would have to be carried out by long inclines in barren tuff or agglomerate.

Limits of ore to the northwest had not been reached in 1944 and this part of the deposit was the only immediate source of much additional production. The present (1953) status of the mine is not known. Reserves cannot be estimated with any assurance of reliability. However, several tens of thousand tons of ore containing 30 to 35 percent manganese may be found in the downthrown block southwest of the fault. The limestone and tuff contact from the Montenegro mine to the Progreso mine, 2.5 kilometers southeast, is an excellent area for further prospecting; it is a sedimentary contact for the most part and could be explored by shallow opencuts and inclines.

## POZO PRIETO GROUP

### GENERAL DESCRIPTION

The Pozo Prieto group of denouncements is in the rough karst country 10 kilometers southwest of Los Negros. It is reached by road from Baire by way either of Los Negros or the Antonio mine at Purial. The claims have been worked during World War I and later from 1938 until the present time. Production from 1942 to August 1945 is not known, as some of the ore credited to the group came from other mines operated by the same company, but probably some 5,000 tons of ore containing 45 to 47 percent manganese has been shipped.

The Pozo Prieto region is one of deep sinkholes and craggy forested uplands developed on the Charco Redondo limestone member of the Cobre formation, which in this area is massive and at least 90 meters thick. Below the limestone are tuff and agglomerate that form the floors of many sinkholes. Underground streams fed through caves are the principal means of drainage; except locally, there is no surface drainage. Geology and topography of the north end of the group are shown on plate 25.

The calcareous rocks include thin-bedded platy limestone, massive dense white limestone, and many lenses of algal conglomerate. At Pozo Prieto the basal part of the unit is a conglomerate containing fragments of andesite; the overlying thick-bedded limestone is coarse grained and near the tuff contact commonly is stained red from iron oxide.

Two fault systems cross the region, one trending nearly northward and the other northwestward. 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 form along them. Conversely, the northwest faults, although 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 basal contact, but the general relations of the two sets of faults indicate that they are due to deeper-seated forces.

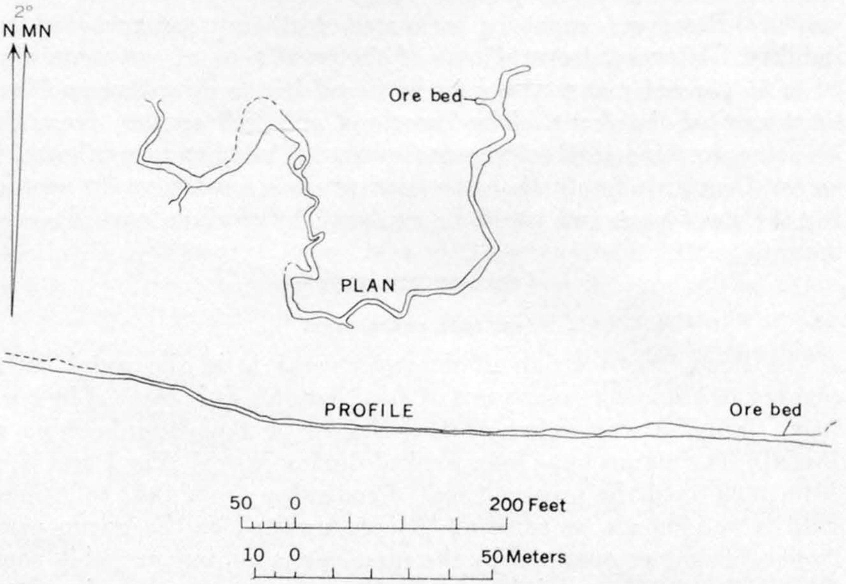



FIGURE 42.—Plan and profile of Pozo Prieto cave.

The Pozo Prieto cave, which carries the drainage from the entire valley (fig. 42), trends southeastward for about 180 meters then northeastward for an equal distance. The most distant accessible point in the cave is about 120 meters nearly due east of the entrance. The cave is at the base of the limestone and follows a system of northeastward and northwestward 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 slants steeply, so that the face of the cave is 27 meters lower than the mouth. A deposit of manganese-oxide-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.

Ore occurs in stringer lodes, beds, breccias, and pockets in the limestone; none has been found in the volcanic rocks. Residual accumulations of ore have been found on limestone and tuff in several places.

The lode ores consist of compact black psilomelane-type oxide with some pyrolusite. 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 present no problems in mining. Black and white calcite fill veinlets and cavities in the ore.

Breccia zones near Hoyo Zinzonte are cemented by manganese oxides and contain pods and veinlets of manganese oxide, some nearly a meter across. These breccia deposits are typical of the manganese ores in much of the sinkhole area; 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 Riñón ("Kidney"), the mineral is all iron oxide.

One of the largest ore pockets, about 18 meters long, 12 to 15 meters wide, and 1.5 meters 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 9 meters, a width of 5 meters, and a height of 3 meters, 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 indicate that pockets of manganese ore may still remain to be discovered.

Residual ore has been mined at a number of places, especially on the Prueba claim. The ore is in lateritic soil derived from the weathering of limestone and in decomposed tuff. Pellets and boulders of manganese oxide range from a few millimeters to a meter or more in diameter. The most abundant ore mineral is pyrolusite.

### ADELAIDA MINE

The Adelaida deposit is just south of the Antonio mine and is reached by trail from La Dalia or Rihito de Matías.

Mine workings are in an area about 45 meters long by 30 meters wide on a northward-trending limestone-capped ridge. Most of the ore has come from a shaft 5 meters deep connected to a short drift along an ore zone 9 meters or more above the base of the limestone. Apparently the ore follows the bedding of the limestone. A few small irregular pockets are found in the limestone immediately above the ore zone. The ore bed is essentially flat-lying; the drift along the ore horizon follows a reverse fault dipping about 65° S. The zone ranges in thickness from 0.3 to 2.1 meters and averages 1 to 1.3

meters. Ore minerals include typical psilomelane-type oxides and secondary pyrolusite.

Other workings east and north of the main shaft show little ore. A westward-trending pit 12 meters long and about 2.5 meters wide extending from the main shaft shows only small irregular pockets of ore. A shallow shaft, 23 meters east of the main shaft, cut only a thin low-grade extension of the ore zone. Other pits 30 meters to the east show small quantities of ore in limestone, but none has been deep enough to explore the ore horizon. No work has been done southwest of the main shaft, and possible ore extension in this direction is less than 90 meters.

### NEW YORK MINE

The New York mine is about 1 kilometer northwest of Pozo Prieto near the road between Pozo Prieto and Rihito de Matías. The workings are in the extreme northwest corner of plate 25.

The main adit is driven west about 30 meters in limestone along an ore zone which dips 40°–50° N. This zone is 35 to 45 meters stratigraphically above the base of the limestone and can be traced on the surface for about 60 meters west and 150 meters east of the adit. Ore follows a discontinuous zone of tuff with a maximum thickness of 1.3 meters. The footwall of the tuff-ore zone is highly sheared. Psilomelane-type oxide and pyrolusite replace part of the tuff and some oxides are found in irregular pockets in the overlying limestone. In the first 15 to 18 meters of the adit, ore forms discontinuous lenses as much as 30 centimeters thick; in some places ore or limestone occupies the entire zone. The best ore is found in the last 12 meters of the adit, where it ranges from 0.6 meters to more than 2.5 meters in thickness.

Pits on the outcrop of the ore zone show only small irregular pockets in the limestone hanging wall. The ore zone has been explored for 150 meters east of the adit by pits and one inclined adit. Very little ore has been found in these workings but most of them are poorly located. All the workings indicate a faulted tuff-ore zone with a footwall of massive limestone and a hanging wall of conglomeratic or brecciated limestone containing fragments of tuff. The conglomeratic and brecciated tuffaceous limestone grades upward into massive limestone through a stratigraphic distance of 6 to 9 meters.

A small amount of granzón has been recovered about 230 meters southwest of the main adit. Particles and boulders of manganese oxide as much as 30 centimeters or so in diameter lie in a residual soil derived from weathering and solution of limestone containing beds and irregular pockets of manganese oxides. The residual deposit is less than 3 meters thick. Only the larger pieces of ore were recovered. A log washer would probably separate the fine particles from the soil very efficiently but lack of water has prevented installation of a washing plant. However, with suitable storage basins the stream of water flowing in the nearby Pozo Prieto cave might furnish sufficient water for a limited operation.

PRUEBA MINE

The Prueba mine is about 750 meters southwest of the New York mine in a small tuff-floored sink surrounded by steep limestone hills.

Most of the production has been granzón, which was mined from an area about 25 meters wide and more than 45 meters long. The granzón area lies in the bottom of the sink at the base of a 15-meter cliff of limestone containing pockets of manganese oxide (see fig. 43). The

FIGURE 43.—Sinkhole and granzón area of the Prueba mine in Pozo Prieto mine group. This is a typical tuff-floored sinkhole in the rugged karst terrain of the Pozo Prieto area. Note the steep limestone cliffs in center background and heavy vegetation. Ore is in tuff and residual clay and is mined from pits in the foreground.

granzón fragments range in size from pebbles 2.5 centimeters or less in diameter to boulders weighing more than 100 kilograms. These fragments lie in tuff and clay as much as 5 meters thick; locally, manganese oxide boulders make up 50 percent of the material. Ore was mined and sorted by hand with minimum of loss, as small fragments are not abundant.

The chief ore mineral is pyrolusite, but psilomelane-type oxide is also found. A small amount of impure iron oxide also occurs as residual boulders in the granzón.

Three small ore bodies crop out in the limestone cliff adjacent to the granzón area. One small pocket is at the base of the cliff at the northeast end of the granzón area. Another pocket, 8 meters long and from 0.3 to 1 meter thick, was found in a pit at the top of the cliff 15 meters above the first. The ore strikes N. 25° E. and dips 20° SE. Some exploratory work has been done, and a small amount of manganese ore was recovered. The ore is largely psilomelane-type oxide and locally contains considerable calcite. Some iron oxide, similar to that in the granzón, was found adjacent to the manganese oxides. The third ore body, 30 meters to the southwest, is an irregular pocket a meter or so in diameter; it was not accessible and no work had been done on it. The ore in the granzón area probably was formed by solution and weathering of limestone containing pockets of manganese oxides similar to those in the cliff.

Measured and indicated reserves of the Pozo Prieto group have never been large, as practically no ore has been developed ahead of mining. None of the ore bodies thus far discovered has yielded as much as 1,000 tons. However, the possibilities of new ore discoveries are good, and inferred reserves are estimated at a few tens of thousand tons of ore containing 45 to 50 percent manganese.

#### PROGRESO MINE

The Progreso mine is in the karst terrain between the Ríos Mogote and Cautillo just north of Unión, 8 kilometers west-southwest of Los Negros. It is reached from Baire on the Carretera Central by 16 kilometers of road; the last 3.5 kilometers of road are very rough and almost impassable during the rainy season. Production from 1942 to August 1945 was 2,346 tons of ore averaging nearly 50 percent manganese.

The ore deposit lies near the base of a massive limestone. The contact of limestone with the underlying tuff-agglomerate is marked by a shear zone 3 to 5 meters thick. Apparently the limestone lies parallel to the shear zone, which strikes N. 45°–50° E. and dips 35° NW. in the lowest mine workings but swings to N. 15° W. in the higher workings to the northeast. Many steep-dipping small faults striking north to N. 25° W. are the latest structures.

The mine workings are reached by an adit 60 meters long and a lower haulageway 75 meters long. Stopes extend from the adit 45 meters eastward to the surface and about 30 meters downward to the west.

In the upper stopes, ore occurred in pockets that contained from 10 to 400 tons; the pockets were connected by irregular veinlets of manganese oxides. Pyrolusite was the most common mineral; one pocket of psilomelane-type oxide was found. Caves discovered during mining contained no ore, although some manganese oxide was found under a coating of calcite on the walls of the cave at the end of the main adit.

In the underhand stopes west of the adit manganese oxides occur in a zone as much as 3 meters thick, which lies parallel to the bedding of the limestone. Tuff remnants in the base of the ore zone suggest that the oxides have replaced a lens of tuff. Lenses of limestone as much as 12 meters long and 1.3 meters thick and irregular blocks of limestone are enclosed in the ore. The footwall of the ore zone is a smooth bedding plane but in the limestone hanging wall manganese oxides extend upward along fractures. Pyrolusite is the most abundant mineral, but there is considerable psilomelane-type oxide along the footwall. Mine-run ore contains 45 to 46 percent manganese and a small amount of hand sorting produced a high-grade shipping ore.

Reserves of the mine were very small in 1944, but additional small pockets of ore might be found north and west of the old workings. Reserves of all classes are estimated at a few thousand tons.

### RUISEÑORES MINE

The Ruiseñores mine is a short distance northwest of the settlement of La Tabla, 10 kilometers west-southwest of Los Negros and 17 kilometers by road southwest of Baire. The mine was one of very few discovered during World War II. It was opened in 1942 and to the end of 1944 produced 741 tons of ore containing 43 to 48 percent manganese.

The Ruiseñores area is in the karst country of the Sierra Maestra foothills, characterized by high limestone cliffs and tuff-floored valleys. An obsequent fault-line scarp of massive limestone, which in the neighborhood of the mine is 45 meters high, forms the northeast side of the Ruiseñores valley. This fault is exposed in the opencut at the mine portal, where it strikes N. 75° W. and dips 55° NE. It can be traced northwest for about 15 kilometers with only one small break, an offset near the Taratana mines, but appears to die out a kilometer or so southeast of the Ruiseñores mine. Southwest of the mine and across the valley is another prominent limestone cliff that appears to be in part a fault scarp and in part an erosional scarp. This fault strikes about north and appears to have localized the erosion of a deep valley which enters the Ruiseñores valley from the north a short distance west of the mine. The second fault has little or no effect on the main fault on the northeast side of the valley and is either earlier or of small displacement.

The valley is probably underlain by tuff although tuff is exposed only in the opencut of the mine.

The Ruiseñores deposit is in limestone at an unknown distance above the contact of the limestone and tuff. It is localized in part along a fault that is essentially parallel to the Ruiseñores fault. Mine workings are shown on figure 44. The deposit was developed by a drift on the 270 meter level and a shaft and drift on the 265 meter level. Manganese oxide was found in small irregular pockets in brecciated limestone where it replaced limestone and may have filled cavities in the breccia. The plan and sections of figure 44 show only the ore zone, as individual pockets were too small and irregular to map. There are probably two separate ore shoots, as no connection was found between the ore body on the 270 level and the deposit on the 265 level, although both lie along the same fault. The ore was soft fine-grained pyrolusite that powdered excessively during blasting and handling.

The limestone is cavernous and one open cave as well as several completely filled ones were discovered in the course of mining. These caves were all of small extent and were filled with calcite and red clay.

On the Milagrosa claim, which adjoins the Ruiseñores claim on the east side, a pocket of pyrolusite was found about 12 meters above the base of the cliff. The pocket was 5 meters long, 1.3 to 2.5 meters thick, and 6 meters high, and lay parallel to the cliff face. Several hundred tons of ore was removed.

The known ore bodies were nearly exhausted in 1944 and no ore was shipped in 1945. Exploration by diamond drilling along the base of the cliff east and west of the mine might discover other ore bodies, but in view of the small size of the Ruiseñores deposit the success of such a drilling program is doubtful. However, if the drill holes were deep enough to reach the base of the limestone and the underlying tuff, additional ore might be found along the contact; this contact zone has been very productive at the Montenegro-Adriana mine group, 4 kilometers northeast.

### SAN LORENZO PROSPECT

The San Lorenzo prospect is in the southeast corner of the district about 1 kilometer northwest of Filé. It may be reached by road from Contramaestre, 16 kilometers north.

A limestone conglomerate bed about 6 meters thick is interbedded with tuff below the Charco Redondo limestone member. Small amounts of manganese oxide are exposed in 3 pits. Some ore has been shipped but the prospect has little value.

### SANTA ANA MINE

The Santa Ana mine is 3 kilometers southwest of Bijagual and 6 kilometers east-southeast of Los Negros. It is connected to Contra-

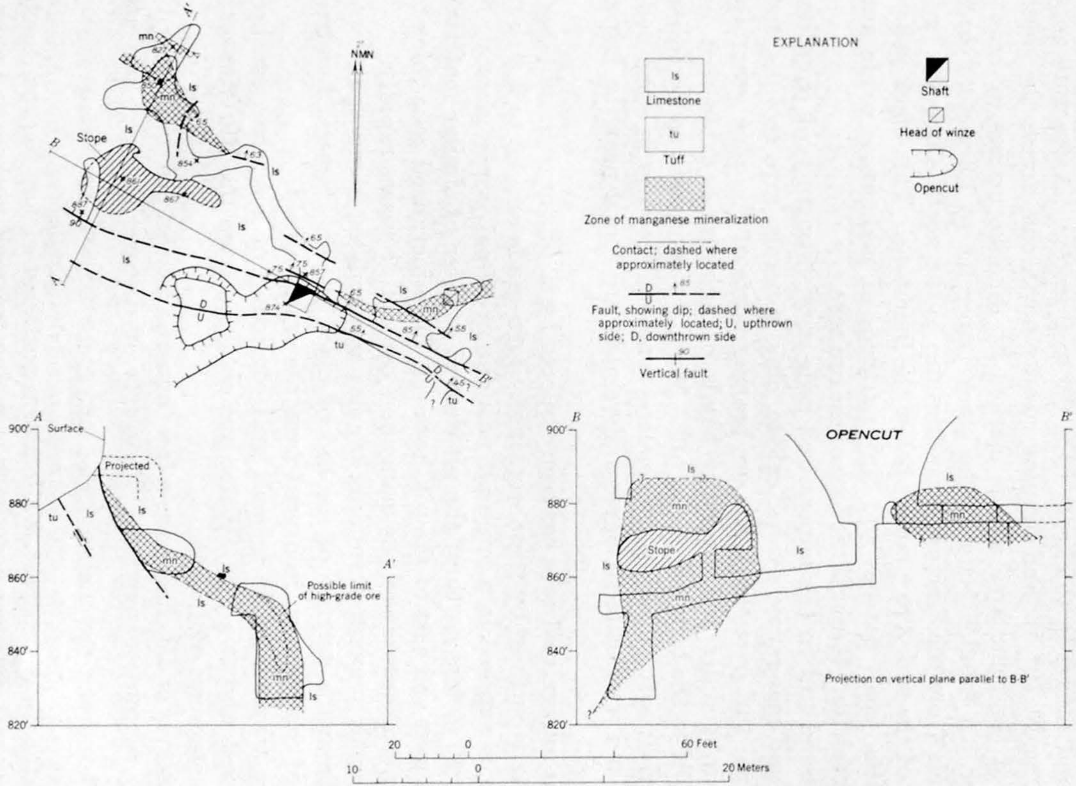



FIGURE 44.—Plan and sections of underground workings of the Ruiseñores mine, Oriente, Cuba.

maestre on the Carretera Central by 14 kilometers of dry-weather road. Production has been a few hundred tons of medium-grade ore.

The mine is on a small hill southeast of the Río Mogote in an area underlain by interbedded tuff and limestone of the Cobre formation that strikes N. 30°–70° W. and dips 10°–15° NE. Plate 26 is a geologic map of the mine area. Ore occurs just below a limestone bed and ranges in thickness from 0.6 to 2 meters. A fracture zone striking N. 70° W. and dipping steeply north cuts across the south side of the mine area and is marked by dikelike masses of brown jasper. A tabular body of the black jasper 0.6 to 1.3 meters thick extends from the fracture zone downdip to the north along the bedding of the tuff, 3 to 4 meters below the limestone. This black jasper contains small patches and tiny particles of manganese oxide and black calcite. It marks the base of the ore zone.

Altered tuff in the mineralized zone consists mainly of chlorites, iron and manganese oxides, calcite, clay minerals, rare zeolites, and residual tuff particles. The ore-bearing parts of the zone generally contain nodules and irregular bands of manganese oxide that lie parallel to the bedding of the tuff. Most of the ore is a soft wadlike material; soft radiating psilomelane-type oxide occurs in some nodules, and pyrolusite stringers and veinlets are found near the jasper masses.

The mineralized zone has been explored by 22 pits or short adits and is nearly outlined by these workings. Low-grade ore, 1.3 to 2 meters thick, is exposed in a large pit near the principal jasper masses. A shaft 40 meters north of the pit showed 1 meter of similar material. Both west and east of the pit, however, the mineralized zone thins to a few centimeters and the manganese content decreases rapidly.

A small amount of residual ore has accumulated along and downhill from the outcrop of the bed of black jasper. Several hundred tons of ore has been recovered from the granzón field.

Ore was treated in a small mill consisting of a washer, crusher, trommel, and two jigs. Water was obtained from the Río Manacas, 500 meters east of the mine.

Reserves of all classes are a few thousand tons of ore containing 15 to 20 percent manganese. Prospects of discovering more ore are poor.

### TONY PROSPECT

At the Tony prospect, 4 kilometers northeast of Los Negros, 4 cuts and a shaft 8 meters 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.

### UNICA MINE

The Unica mine is on the south side of the Río Brazo Seco, 11 kilometers airline south-southwest of Los Negros. It is reached from Baire via Los Negros and Matías by 27 kilometers of road; the portion of road between Los Negros and the mine is passable only in dry weather. A small amount of ore was produced during the first World War, but most of the output dates from 1939. Total production is estimated at 20,000 tons averaging 43 percent manganese.

The property is in the rugged foothills of the Sierra Maestra, in a heavily-wooded area drained by the Río Brazo Seco, a main tributary of the Río Mogote. Near the mine the river has cut a steep-walled canyon 60 to 120 meters deep.

The most widespread rock unit is the Charco Redondo limestone member, which in this area is a massive crystalline limestone at least 150 meters thick. Underlying the limestone are typical reddish-brown and green tuffs and agglomerates of the Cobre formation. The structure of the area is difficult to determine, as the massive limestone shows no bedding. A strong fault, called the Unica fault, crosses the mapped area just west of the mine. It is a normal fault that strikes N. 20° W. and dips 80° NE; the amount and direction of displacement are not known definitely, but the throw is about 25 meters. A few small fractures lie parallel to the fault.

The Unica ore body cropped out in a limestone cliff about 15 meters above the river. It was first developed by an adit driven into the cliff along the ore body and later by a haulage adit near the river level.

The ore body has the form of a flattened or roughly tabular pipe. The long axis of the pipe trends east from the outcrop and the flattened section dips steeply south. Near the outcrop the pipe plunges 10°–15° E.; as it is followed downward to the east, the plunge steepens gradually to more than 50 degrees in the deeper workings. In the lower levels the southern edge of the pipe is bounded by a clay-sealed slip. The country rock is brecciated or massive white limestone in which no planar structures have been recognized. The ore body grades into limestone through a zone of mixed limestone and manganese oxides less than 0.6 meters wide. Figure 45 is an isometric block diagram that shows the rather irregular shape of the ore body.

The principal ore mineral was psilomelane-type oxide. Small amounts of pyrolusite and braunite were also present. A peculiar finely fibrous mineral that occurred in furlike clumps associated with quartz in vugs in the ore proved to be manganite. Black calcite is abundant. Powdery red hematite and a little brown jasper were found along the border of the ore body. White calcite was the most abundant gangue mineral; a little black quartz occurred in vugs.

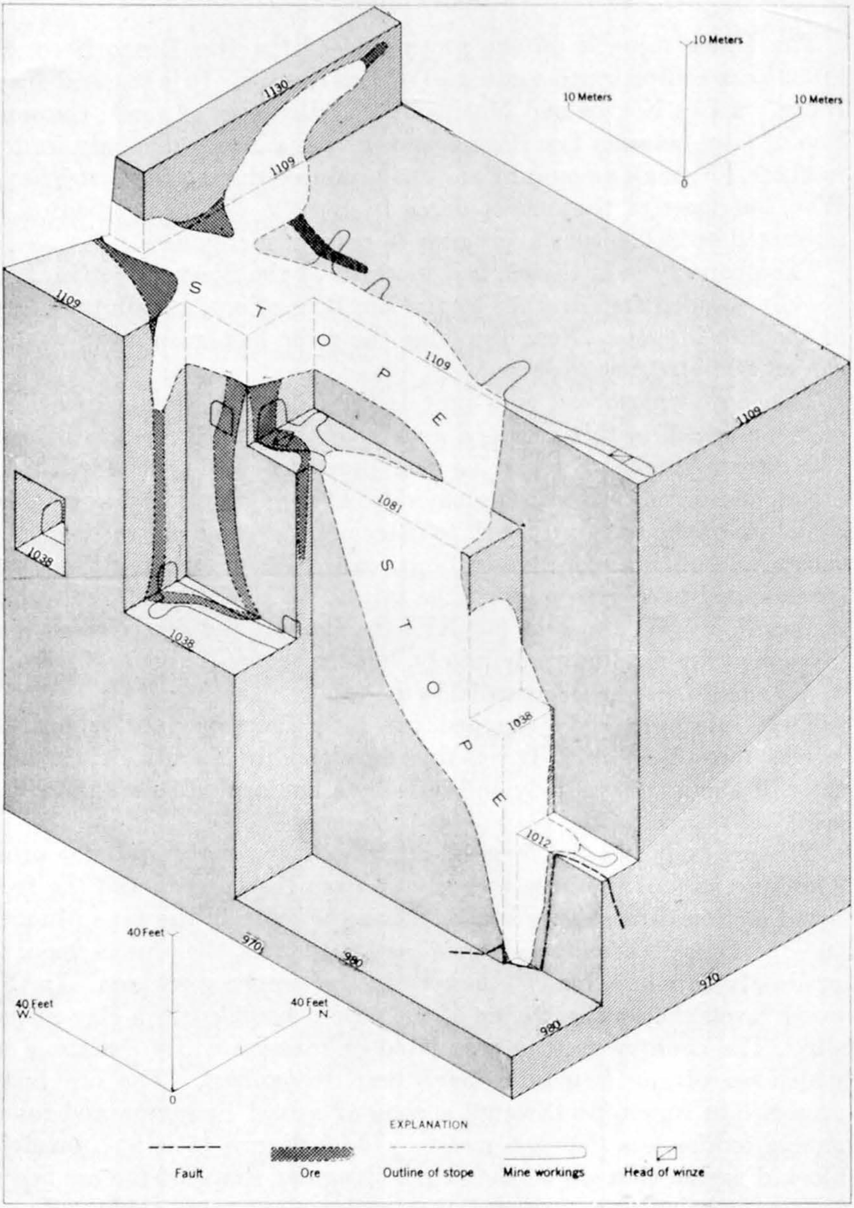



FIGURE 45.—Isometric block diagram of the ore body of the Unica mine.

The manganese minerals formed coalescent nodules with interstitial calcite. Along the borders of the ore body the nodules formed along small fractures in the limestone. Veinlike offshoots from the main ore body follow no consistent trend. Two of these stringers led to small ore bodies, but most of them pinched out away from the main pipe.

Ore was mined by hand and hoisted through winzes to the haulage adit. It was then trammed by a power winch about 60 meters up an incline to a sorting platform on the road. Mine-run ore was hand-cobbed; owing to a high calcite content, the sorted ore rarely contained more than 43 percent manganese.

The Unica ore body was practically mined out by the end of 1944. Reserves are negligible and no promising showings are known in the immediate vicinity of the mine. There are, however, many small outcrops of manganese oxides elsewhere on the Unica claim and the adjoining Angelina claim. Many of these outcrops were prospected during 1940–1945 without finding much ore.

### YEYA MINE

The Yeya mine is on the south bank of the Río Mogote, 4 kilometers southeast of Los Negros. It is reached by an all-weather road from Los Negros. The mine was opened in 1940 and to August 1945 produced about 15,000 tons of ore containing 48 percent manganese.

The mine area is underlain by interbedded limestone and tuff of the Charco Redondo limestone member. Geology and topography are given in plate 27.

Two limestone beds, each 3 to 12 meters thick, are traceable throughout the mine area, and several other thinner beds can be followed at least a hundred meters. The upper limestone is made up of angular fragments of white, medium-grained limestone and coarse green tuff cemented by limestone. The lower limestone is similar in appearance but is very fossiliferous and contains more rounded fragments. It lenses out northwestward toward the Río Mogote. At the main workings, the two limestone beds are separated by 55 meters of interbedded tuff and tuffaceous limestone; to the northwest the thinner limestone beds disappear and the tuff beds thin to about 30 meters. A short distance south of the main workings, the limestone beds end abruptly and probably are faulted against the underlying volcanic rocks.

Near the mine the rocks are folded and cut by many small faults having displacements of less than 15 meters. The folds seem to be broad warps whose axes trend eastward and northwestward; the axis of the most prominent warp trends approximately parallel to Arroyo el Gato. Dips in the limestone are less than 20 degrees.

Several small masses of fine-grained andesitic rocks intrude and metamorphose the limestone and tuff. The largest is roughly circular in outcrop and 9 to 12 meters in diameter. Adjacent to the andesite the limestone is recrystallized and both limestone and tuff are bleached. Northwest of the mine workings a metamorphosed zone in limestone about 90 meters long and 3 to 12 meters wide probably marks the trace of a dike that crops out at its northeastern end.

The Yeya ore body is in tuff-agglomerate in the lower limestone bed. Mine workings (fig. 46) show the agglomerate to be a lens at least 60 meters long from west to east, about 26 meters wide, and about 12 meters thick. Rounded fragments of tuff as much as 1.3 meters in

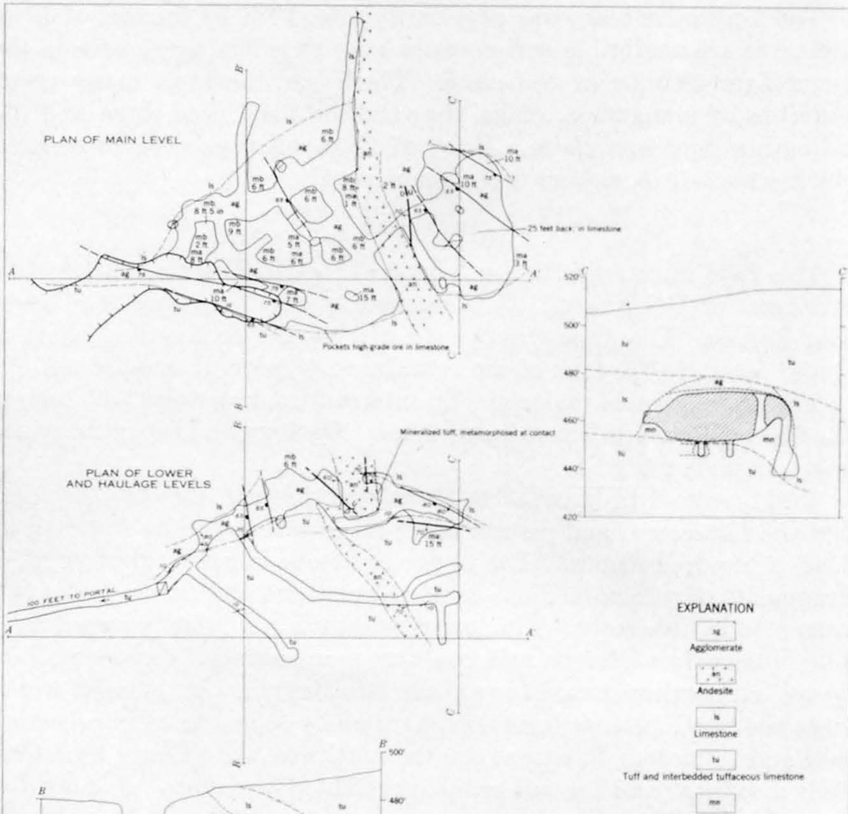



**Figure 46.—Geologic level maps and sections of underground workings of the Yeya mine.**

diameter make up most of the agglomerate, although isolated blocks of limestone also are included, particularly near the enclosing limestone. The agglomerate grades into limestone through a zone about 1.5 meters wide. The agglomerate matrix is manganese oxides and calcite in the ore zone and small tuff particles elsewhere. Agglomerate and limestone overlie well-bedded altered tuff. On the north side of the agglomerate lens, the limestone and lower tuff are warped downward along an eastward-trending axis. Postmineralization faults of small displacement and calcite-filled joints cut the ore; no premineralization faults were observed.

Ore is restricted to the tuff-agglomerate and the upper part of the underlying tuff. Manganese minerals include psilomelane-type oxide, ranciéite, pyrolusite, and soft wad. These oxides form solid masses in the lower 6 meters of the agglomerate and irregular nodules in the overlying 3 meters. The nodular ore grades upward into barren tuff-agglomerate. A few pods of manganese oxide are found in the underlying tuff, which consists mostly of clay minerals, calcite, and zeolites. An andesite dike, which trends N. 20° W. and dips steeply westward, has metamorphosed the ore to dense hard psilomelane-type oxide for several centimeters from the contact. The dense oxide also occurs in pods as much as 20 meters from the dike.

The Cafetal ore body is 165 meters northwest of the main Yeya workings and lies in the same limestone bed. At the Cafetal workings the limestone is about 2.5 meters thick and interfingers with tuff. The ore body trends N. 35° E. and is 9 to 11 meters wide, at least 60 meters long, and from 0.6 to 1.3 meters thick. Limestone marks the northern boundary of the ore and a normal fault trending N. 35° E. marks the southern limit; the limestone boundary and the fault converge near the east end of the ore body. The fault is believed to be postmineralization in age although a little secondary pyrolusite occurs along the outcrop. A decrease in the concentration of manganese oxide toward the fault suggests that little or no ore may be found on the footwall side.

Much of the mine-run ore was shipped without further treatment. Low-grade ore was hand-sorted during the early stages of mining; later a 70-ton mill, consisting of a log washer, crusher, trommel, and three jigs, was installed.

The mine was in operation as late as 1946 but more recent data are not available. Almost certainly the main ore body and probably the Cafetal deposit are exhausted. A few churn-drill holes near the mine failed to find ore but were not located in the most favorable places. Further exploration by drilling is warranted. In addition, an outcrop of agglomerate west of Arroyo el Gato should be prospected.

### PALMARITO DISTRICT

The Palmarito district is a few kilometers southeast of Palmarito. It is most easily accessible from Santiago de Cuba by railroad to Manganeso station but may be reached also by a dry-weather road from San Luis. Only the Abundancia and Llave mines have produced any appreciable quantity of ore, although at least 24 claims have been denounced.

#### ABUNDANCIA MINE

The Abundancia mine is about 300 meters west of Manganeso station, 4 kilometers south of Palmarito. A short loading spur leads onto the property. The mine is in open cultivated country on the east bank of the Río Guaninicún, about 9 meters above river level.

The property was operated during the first World War, when at least 14,000 tons of jigged concentrate was produced. In 1930 the Cuban Mining Company leased the claim and between 1930 and 1940 put down more than 60 churn-drill holes in an attempt to develop a large low-grade ore body. Several tens of thousand tons of ore averaging 21 percent manganese was indicated by the drilling. Between 1940 and 1944 the mine was worked on a small scale and yielded something more than 1,000 tons of ore containing 47 to 48 percent manganese.

The main, eastern ore body is in tuff at and near the base of a limestone bed. It strikes N. 50° W. and dips 20°–60° SW. An isometric fence diagram of the ore body is given in figure 47. The deposit is 300 meters long and at the southeast end extends downdip more than 60 meters. In section it is a double wedge tapering downdip to a thin point. At the northwest end of the ore body there are two zones—an upper zone, 1 to 1.5 meters thick containing an average of 10 percent manganese, and a lower zone, 1.5 to 6 meters thick containing an average of 20 percent manganese. To the southeast the two zones coalesce and include a thin wedge of tuff. No other ore bodies were discovered by drilling along the strike and down the dip.

Manganese minerals form nodules, stringers, and disconnected pods in a matrix of altered tuff. The footwall tuff and tuff horses within the ore zone are altered to white clay and zeolites. Pyrolusite, psilomelane-type oxide, neotocite, braunite, and black calcite have been identified and dull black oxides of unknown composition have been found. The silicates, especially neotocite, occur in irregular patches near the footwall of the ore body where they are mixed with brown jasper, veinlets of quartz, and large crystals of calcite. Most of the ore in the exposed part of the deposit is steel-gray pyrolusite. The silicates are not abundant enough to affect the commercial value of the deposit, but might increase in amount down the dip.

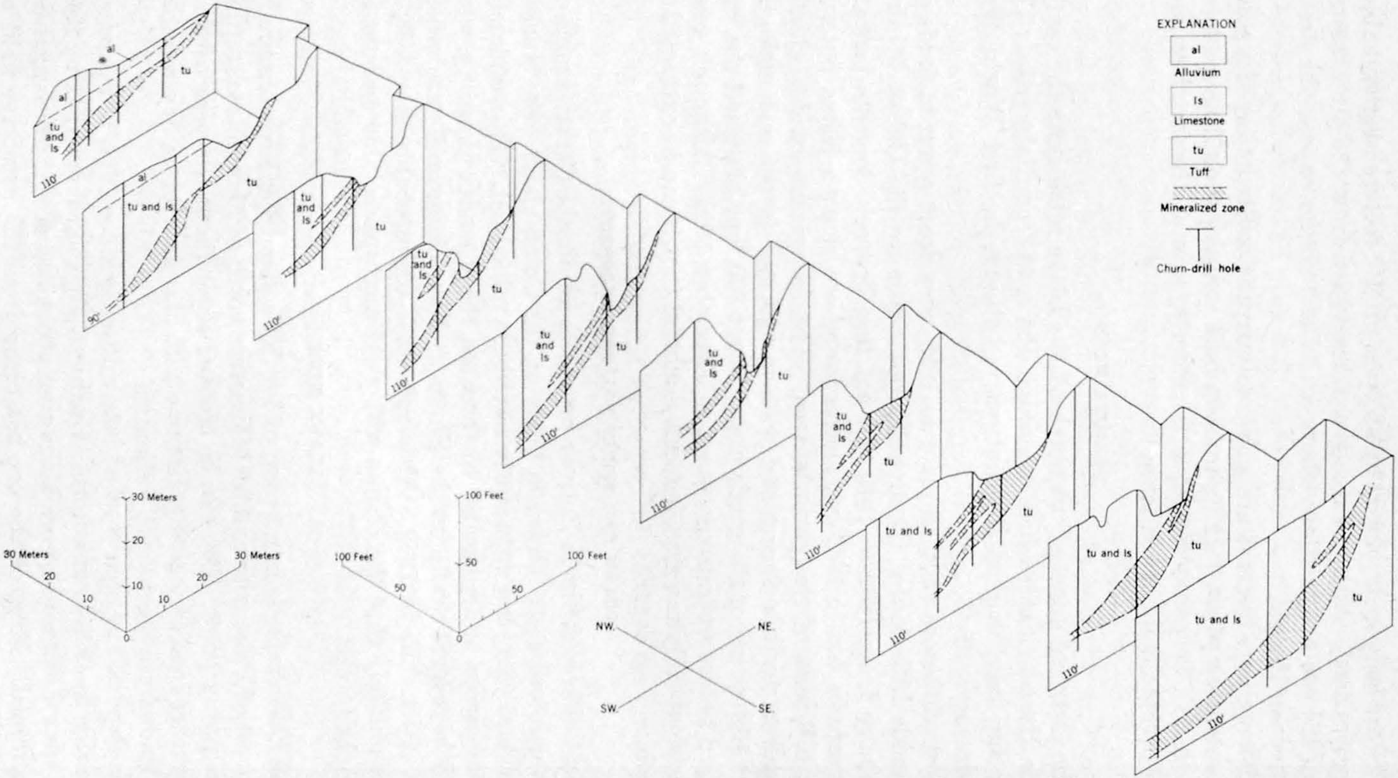



FIGURE 47.—Isometric diagram of sections of the Abundancia deposit, Oriente, Cuba.

The ore body is developed by an open pit 245 meters long and about 20 meters deep. An adit extends southeastward from the pit 45 meters along the ore body. Many short drifts and shafts expose the ore in the floor of the pit.

Although ore reserves are ample to warrant construction of a small concentrating plant, jigging tests on bulk samples should be made. If the ore can be concentrated satisfactorily, several thousand tons of concentrate should be available.

#### CARMITA MINE

The Carmita mine is just north of the Llave mine near the center of the district; it is reached by a rough dirt road from Palmarito. The mine has been worked intermittently, both in the first World War and during 1940–43.

Most of the ore shipped prior to 1942 came from granzón fields on two wide hill slopes. Drill holes put down by the Cuban Mining Company from 1932 to 1940 did not find bedrock deposits beneath the granzón, but in 1942 two shafts found ore along a jasper outcrop on a hill west of the granzón area. The manganese oxides, chiefly pyrolusite, form stringers and pods in tuff and jasper and make up about 10 percent of the crude ore. About 300 tons of sorted ore was shipped before operations ceased in December 1942. Although some ore undoubtedly remains, it seems doubtful that it can be extracted at a profit.

#### COLÓN AND SIMÓN BOLÍVAR PROSPECTS

The Colón and Simón Bolívar prospects adjoin the Carmita mine on the north and east. Granzón fields on the Colón claim were worked for several years but apparently have been mined out. Thin stringers of manganese oxide similar to those on the Carmita property were found in several shafts on the Simón Bolívar claim and were mined for a short time in 1942. Although some ore probably was left, it seems unlikely that the claims will yield any appreciable amount of ore in the future.

#### LLAVE MINE

The Llave mine is in a group of low hills about 2 kilometers south-southeast of Palmarito and 1.5 kilometers north of Manganeso station, the shipping point. Ore can be trucked throughout the year over an all-weather road connecting the mine with Manganeso. A dry-weather road leads from the mine to Palmarito.

The deposit has been worked intermittently since 1914, but production prior to 1942 is unknown. During the period from 1942 to 1945 more than 7,000 tons of ore averaging about 50 percent of manganese was shipped. Most of the ore has come from the extensive field of granzón that covers most of the claim but a small production came from underground operations on bedded ore.

The Cuban Mining Company kindly allowed use of data obtained during its churn-drill exploration of the Llave, Carmita, Colón, and Simón Bolívar denouncements. The rocks are largely green tuffs with subordinate brown and gray tuff. Limestone crops out along the Río Guaninicún and Río Cauto and on Mogote, a prominent hill 2 kilometers east of the mine, but none is found within the mine area. The tuffs strike north-northwestward to northeastward and dip 7°–21° W; the structure in the immediate vicinity of the mine is essentially a homocline dipping west. A considerable part of the Llave area is covered by jasper boulders that form a mantle as much as 5 meters thick. The boulders, some weighing many tons, are found on a low northward-trending ridge whose west flank is approximately a dip slope. Most of the jasper mantle carries residual ore that has been mined over an area of about 20 hectares, largely on the west flank of the ridge. These jasper boulders are thought to be remnants of a former almost-continuous stratigraphic zone that has been exposed by erosion and left as a residual capping; the present base of the cap is thought to coincide more or less with the original base of the zone.

A thin bed of manganese-bearing tuff crops out in a small canyon near the center of the mine area and has been explored on the ridge to the south by several adits and many shafts; the bed is known to extend at least 120 meters southwest, south, and southeast. About 230 meters south of the outcrop mineralized tuff, probably the same bed, was found in a shaft, and it seems possible that the manganiferous tuff is continuous between outcrop and shaft.

The strike underground ranges from north to northeast, the dip from 5°–25° W. Near jasper masses the dip increases to as much as 50 degrees where the mineralized tuff folds over the jasper. The ore zone is 12 to 15 meters below the surficial jasper mantle along the west side of the developed area but only 6 to 8 meters below along the east edge, the two mineralized zones apparently converging somewhat toward the east. That the zones may actually merge farther east is suggested by an exposure in an opencut about 90 meters northeast of the last shaft, where a manganese-bearing tuff bed is overlain immediately by jasper fragments and boulders. It is not certain, however, that this bed is equivalent to that exposed in the shafts.

The mineralized tuff ranges from 0.3 to 2 meters in thickness and averages about 1 meter. In several places small jasper masses underlie the ore bed or form lenses as much as 1 meter thick within the bed. Both footwall and hanging wall are tuff, which is occasionally agglomeratic, and commonly a thin layer of bright green chloritic tuff overlies the mineralized rock. Manganese mineralization is rather poor at best and is exceedingly spotty. Much of the mineralized zone contains only thoroughly disseminated particles of manganese oxide that cannot be concentrated; in places intimately mixed oxide and tuff form nodules 5 to 8 centimeters in diameter. The best ore consists of thin layers of psilomelane-type oxide along the bedding of the tuff and veinlets cutting tuff. Veinlets of tuff as much as 10 centimeters in width cut the ore bed throughout the workings. The tuff veinlets are invariably emplaced later than the oxide, indicating that ore deposition took place before consolidation of the tuff. As is common elsewhere in Cuban manganese deposits, the best ore is found adjacent to jasper masses, but the amount of jasper is negligible. No faults of any importance were found although in the south part of the developed area the hanging wall contact is faulted somewhat, essentially along the bedding. Neither silicification nor manganese mineralization are considered to be controlled by faulting; the major control is definitely stratigraphic.

Along the south boundary of the Carmita claim, about 430 meters north of the area described above, a mineralized zone was found in several shafts at depths ranging from 6 to 18 meters. All shafts were inaccessible in 1944, but tuff outcrops and reported depths of shafts indicate that the zone strikes about north and dips 15°–20° W. Dump material suggests that the mineral found was similar in grade to that being extracted farther south, and it seems likely that the two mineralized zones are stratigraphically equivalent.

Further north a mineralized tuff bed 1.3 meters thick is exposed in an opencut. The bed contains scattered concentrations of manganese oxide but considered as a whole is very low grade. Churn drilling by the Cuban Mining Company and dumps of several caved shafts indicate a northward extension of the mineralized zone.

Several exploration shafts were being sunk (1944) along the west edge of the Llave claim in an effort to find downdip extensions of the north ore zone. If the dip remains constant the shafts would have to be at least 30 meters deep to reach the zone.

The mantle of jasper boulders carrying granzón pellets covers 25 to 30 hectares, mostly on the Llave claim but extending eastward to cover parts of the Colón and Anita claims. At least 10 hectares was nearly or completely worked out by 1944 and another 10 hectares was worked quite thoroughly. Granzón may be found as deep as 5 meters but commonly the deposits were worked to depths of only 2 to 2.5 meters because of difficulty in moving large jasper masses and because the best ore usually was found near the surface. The pellets range in size from fine shot to masses weighing a kilogram or more; the average pellet was less than 2.5 centimeters across.

Crude ore was dry-screened first to remove fines and as much soil as possible, and then was log-washed, jigged, and hand-sorted to remove jasper fragments. The total concentration ratio, from rock in place to shipping ore, varies from 20:1 to 35:1, depending principally on the amount of large jasper masses in the original ground; the average ratio was 20 : 1 to 25 : 1.

Reserves of residual ore in terms of concentrate were estimated in 1944 to be several thousand tons. Inasmuch as the mine may have been in operation to the present time (1953) the actual reserves are not known. In addition it was estimated that the mine contained a few thousand tons of bedded ore containing 15 to 20 percent manganese; this figure may have been increased considerably if exploratory work was successful.

### PONUPO DISTRICT

The Ponupo mining district is 25 kilometers northeast of Santiago de Cuba. It may be reached from Santiago de Cuba by either automobile or train via El Cristo, Alto Songo, and La Maya. Roads, drainage, and locations of the various ore deposits are shown on the index map (fig. 48).

The district is covered by 12 mining claims aggregating 560 hectares. The most important of these claims were denounced in 1887 and 1888. Six manganese deposits are known: Ponupo 1 and 2, on the Vencedora and Serallo claims; Ponupo 3, on the Vencedora claim; Ponupo 4, on the Serallo and Vencedora claims; and Juanita, Sultana, and Balkanes, on claims of the same names. Four of these deposits, Ponupo 1 and 2, Ponupo 3, Sultana, and Juanita, have been mined by the open-pit method; the Balkanes deposit and Ponupo 4 deposit have been explored by drilling but not mined. All the deposits were worked by the Cuban Mining Company of El Cristo between 1940 and 1946.

#### HISTORY AND PRODUCTION

Very little is known of the early history of the district. A short description of the Ponupo 1 and 2 deposit was given by Hayes, Vaughan, and Spencer (1901). According to this report, the Ponupo Mining Company shipped 500 tons of ore to the United States in August 1895; by June 1901, the total production of the district, mainly from Ponupo 1 and 2 and possibly from Ponupo 3, had amounted to 60,000 tons. Exploitation continued until 1909, when low world prices for manganese forced a shutdown. Mining was resumed in 1915 under the impetus of increased consumption and demand brought about by World War I.

During 1939 and 1940 the district was explored and developed by the Cuban Mining Company in order to implement the production from its Quinto mine at El Cristo. An extensive program of churn-drilling outlined 5 ore bodies, and mining operations were initiated on 3—the Ponupo 1 and 2, Ponupo 3, and Sultana. From 1940 until 1946, when the mill at El Cristo was closed, the district provided a significant part of the crude ore treated by the company.

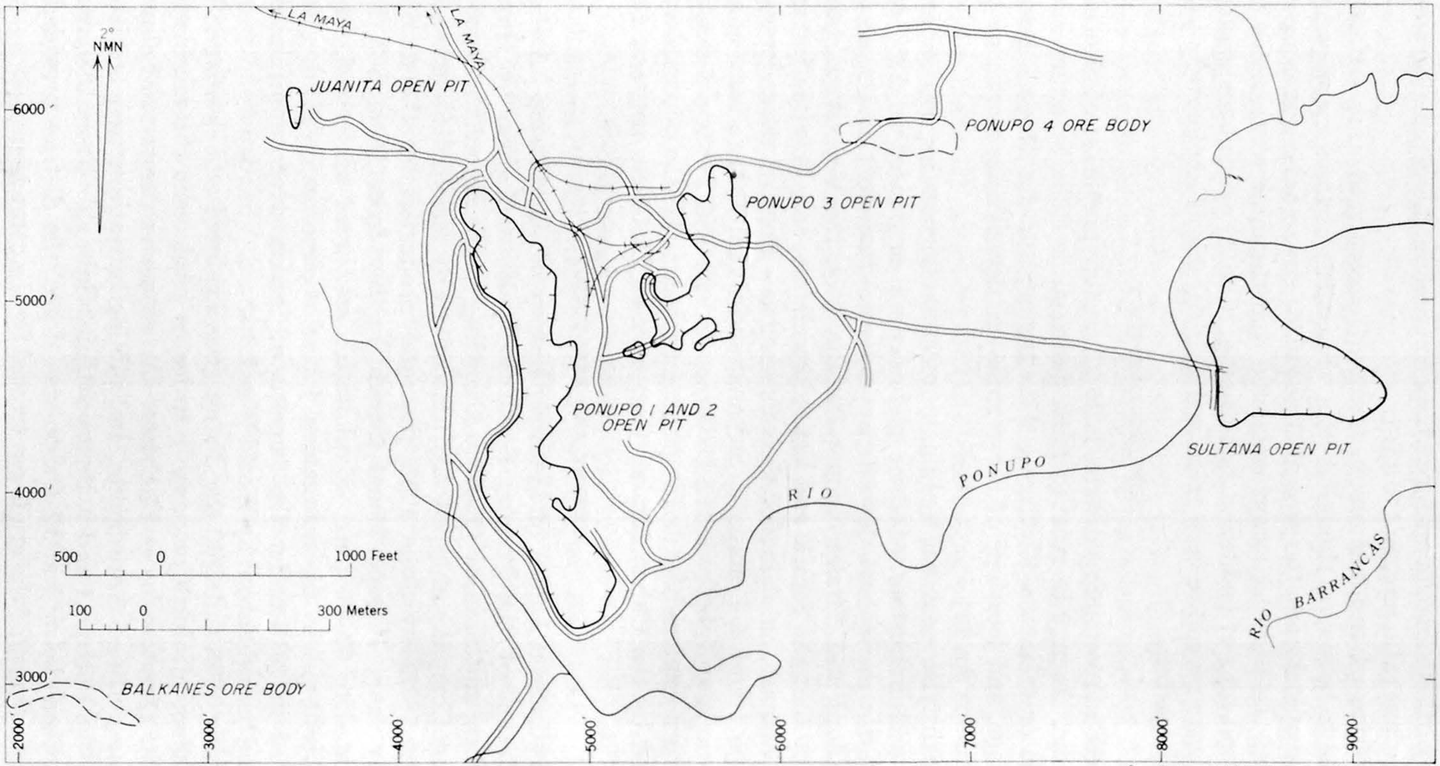



**Figure 48.—Index map of the Ponupo mining district, Oriente, Cuba.**

The total production from the district is not known, nor can it be estimated with any reasonable accuracy. It seems likely that several hundred thousand tons of ore was produced prior to 1940. The amount of crude ore extracted by the Cuban Mining Company between 1940 and 1946 may have totalled approximately 1 million tons.

### GENERAL GEOLOGY

Rock units in the Ponupo district are summarized in the following table:

| Age | Name | | Lithology |
|---|---|---|---|
| Recent or Pleistocene(?) | | | Fluviatile gravel, sand, and silt, unconsolidated, crossbedded, 15–18 meters thick. |
| | Unconformity | | |
| Middle Eocene | San Luis formation | | Pink marly limestone, pink and cream calcareous shale, and brown tuffaceous sandstone and shale; at least 18 meters thick. |
| | Cobre formation | Charco Redondo limestone member | Massive white foraminiferal limestone, highly lenticular; intraformational conglomerate locally at base; maximum thickness about 90 meters. |
| | | Pyroclastic rocks | Red and green coarse andesite tuff, some agglomerate. Includes manganese-bearing tuff and underlying jasper at top of formation. |

The district has been divided by faults into three blocks. The Balkanes block, at the southwest corner of the district, consists largely of limestone overlain by San Luis formation on the west, north, and east sides of the block. The Balkanes ore body lies along the south side of the block at the base of the limestone. The block is faulted down 15 to 25 meters against the Ponupo block along a fault striking about N. 35° W. Structure within the Balkanes block is domical. The doming of the San Luis formation probably is due in part to the initial lenticular character of the limestone, which thins to the east, north, and south.

The Ponupo block, which contains the Ponupo 1 and 2 and Ponupo 3 ore bodies, is a triangular-shaped wedge bounded on all sides by faults. It is faulted down against the Sultana block to the east along a fault striking approximately N. 25° E. This fault has a throw of at least 60 meters, as approximately that thickness of Cobre formation lies between the ore zone at Ponupo 3 and the equivalent ore zone at Sultana, 900 meters east. Both the Ponupo and Sultana blocks are bounded on the north by an eastward-trending fault whose north side is downthrown an unknown amount. North of the fault, only San Luis formation crops out; south of the fault, both San Luis and Cobre formations are exposed.

428472—58——17

Structurally, the Ponupo block is a dome whose core is a large jasper mass overlain by the manganese-bearing tuff beds of the Cobre formation and limestone and the San Luis formation. A few minor faults are found within the block; along one a dike of agglomerate 3 to 4 meters thick has been intruded.

The Sultana block, containing the Sultana ore body, lies east of the Ponupo block and is in fault contact with it. The block is structurally a poorly defined dome, faulted along the west side. The ore body itself is bounded along its east side by an eastward-dipping reverse fault striking slightly east of north; throw of the fault is 9 to 12 meters.

The entire Ponupo district may be considered a complex dome, entirely surrounded by gently dipping beds of the San Luis formation. We believe that all the known manganese deposits of the district are at or near the same stratigraphic horizon, and the present distribution is due largely to original ore deposition, modified to some extent by later faulting. We believe also that much of the doming is due to original deposition of large lenticular masses of both jasper and limestone over which the later San Luis formation has been compacted differentially.

### BALKANES DEPOSIT

The Balkanes deposit, in the southwestern corner of the district, was drilled by the Cuban Mining Company but was not being mined in 1944. Reserves are estimated at a few hundred thousand tons of ore containing 20 to 30 percent manganese. Much of this ore can be concentrated effectively by washing and jigging.

### JUANITA DEPOSIT

The Juanita open pit is about 500 meters northwest of Ponupo. The pit trends about N. 15° W. and is about 80 meters long by 30 to 40 meters wide. Only small-scale hand mining was going on in 1944.

The ore body and enclosing country rock vary greatly from place to place; the general relations are shown by a sketch map of the pit and sections along the pit walls (fig. 49). Country rock is tuff similar to that at the Ponupo 1 and 2 and Sultana deposits, but the ore is considerably different in appearance.

Three general types of ore are found: tuff ore and two varieties of limestone replacement ore. The tuff ore consists of irregular small nodules and stringers of dense featureless manganese oxide that replace red tuff. These nodules contain considerable unreplaced tuff. A small quantity of manganese oxide is disseminated through the tuff matrix. The mineralized rock is cut by many clastic tuff dikes and

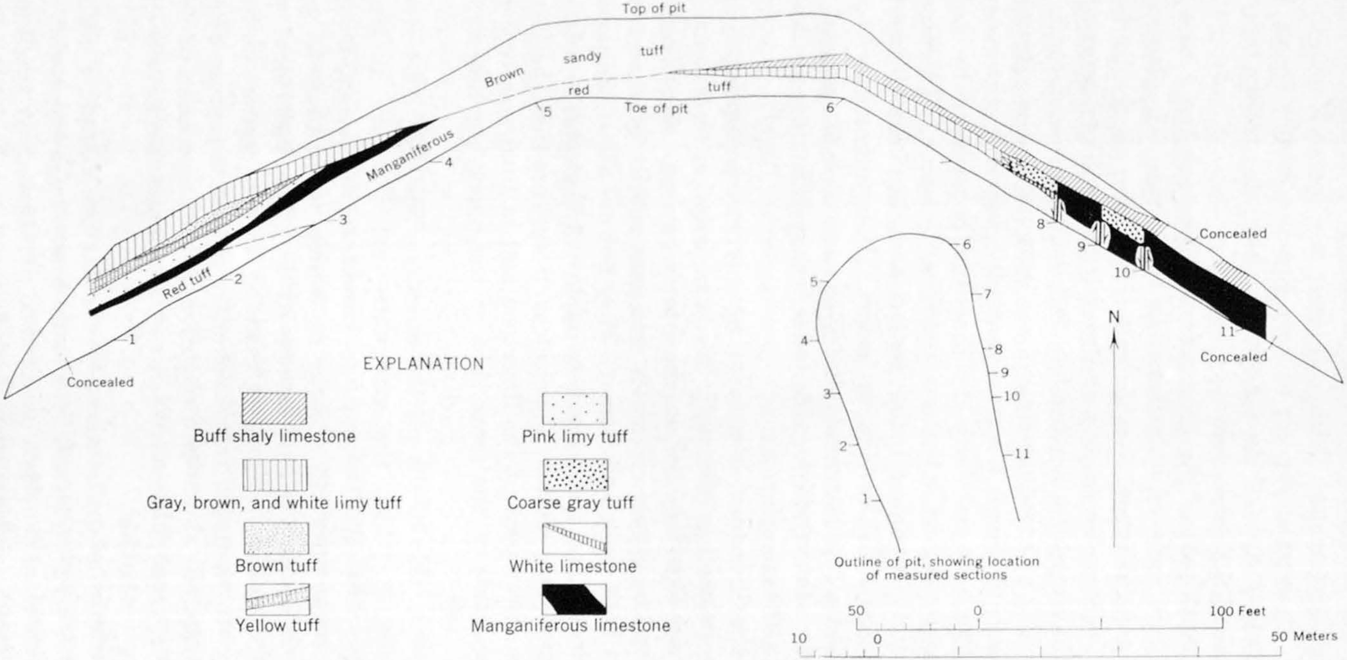



FIGURE 49.—Sketch of walls of open pit of the Juanita mine. Shows lenticular character of the bedding.

carries much jasper in its lower portion. The relation of jasper to ore could not be determined because of lack of exposures. Tuff ore is as much as 5 meters thick in places; the footwall usually is not exposed. In general the ore is very low grade, but in an adit at the southwest corner of the pit some high-grade ore has been found at the base of the limestone.

In the south part of the pit a massive limestone bed 1 to 4 meters thick has been replaced by psilomelane-type oxide. Replacement ore is of two general types. On the east side of the pit the limestone is replaced by irregular veinlets and rounded wormlike masses of oxide that cut the limestone in a random fashion. Masses of oxide rarely attain a width of 2 centimeters and are irregular in the extreme, with thin offshoots of the main masses penetrating several centimeters into the limestone. Occasionally the limestone is replaced by radiating fanlike aggregates of acicular crystalline(?) oxide. The limestone, presumably light colored before replacement, has been altered to reddish orange, reddish purple, or brown. It is rather coarse grained and contains a few Foraminifera. Not more than 30 percent of the rock consists of manganese oxide and it is very difficult to mechanically concentrate the material.

Below the limestone is a layer of manganese-bearing jasper in which the jasper has essentially the same relation to the manganese oxide as the limestone has in the overlying bed. However, a few thin veinlets of jasper cut oxide and one veinlet of limestone was seen to cut both oxide and jasper. Most but not all of the jasper was formed earlier than the manganese oxide. Although the relation between jasper and limestone is not clear, it appears that the jasper replaced the lower part of the limestone and in turn was replaced by manganese oxide at the same time as the overlying limestone was replaced.

On the west side of the pit the limestone has been converted to a peculiar ore in which the manganese oxide occurs as irregular feathery pencils. All stages of replacement are present, from mere incipient replacement to a stage in which more than 75 percent of the rock consists of manganese oxide. The individual pencils are roughly parallel, irregularly rounded in cross section, and almost invariably are separated from each other by a thin septum of calcite. Figure 24 (p. 86) shows two photographs of a specimen of the ore; this specimen resembles somewhat a coral whose tubes have been filled with manganese oxide.

Two varieties of psilomelane-type oxide are found: a light, apparently highly porous, soft type and a heavy harder material. Some of the psilomelane has been oxidized to pyrolusite. A small amount of the ore is a hard dense gray-black featureless material that has not been identified; it may be manganite or braunite. Small vugs lined with quartz and calcite crystals occur throughout the ore.

A few fossil gastropod shells, almost completely replaced by manganese oxide, were found at the top of the limestone bed.

Reserves of the deposit are not known as there has been practically no exploration beyond the limits of the present pit walls. The replacement ore being mined in 1944 contained so much calcite that a high-grade concentrate could not be obtained. Most of the tuff ore contains less than 15 percent manganese and probably only a few tens of thousands of tons are available. Reserves of high-grade tuff ore appear to be small. The deposit is not promising and large-scale work had been abandoned for some time.

#### PONUPO 1 AND 2 DEPOSIT

The Ponupo 1 and 2 deposit was worked formerly as an open-pit mine; from about 1943 on it was worked only by small-scale surface and underground operations. The pit is about 750 meters long in a general northerly direction, 60 to 215 meters wide, and 45 meters in maximum depth. In many places the pit walls have slumped so much that nearly all information on the thickness and distribution of ore and country rock had to be gained from study of churn-drill logs. The deposit was explored by the Cuban Mining Company, and 281 churn-drill holes aggregating a length of about 17,000 feet were put down. Geologic relationships are shown in an isometric fence diagram (pl. 28).

The general stratigraphic sequence is as follows:

Alluvium
Tuff
Foraminiferal limestone
Ore zone
Red and orange jasper
Green or yellow tuff

The upper tuffs are well-bedded coarse- to fine-grained varicolored rocks. They are andesitic or latitic in composition and are commonly calcareous. As the only exposures of these deposits are at the north and south ends of the pit, little is known of their variation along the strike. The tuff at the north end of the pit is grayish white badly decomposed and totally unlike the corresponding rock at the south end, which is purplish and conglomeratic grading upward into brown limy tuff.

About 245 meters from the south end of the pit, the basal portion of the upper tuff contains considerable jasper in thin irregular layers parallel to the bedding. Inasmuch as no definitely crosscutting jasper was seen, it appears that the jasper was deposited as sedimentary layers during deposition of tuff. The irregular nature of the jasper layers suggests a possible replacement origin, but no corroboratory evidence was found.

A massive white foraminiferal limestone overlies the ore zone everywhere except at the south end of the pit, where the limestone lenses out. The limestone ranges in thickness from about 2 meters at the north end of the pit to 12 meters near the middle; it lenses out about 120 meters from the south end. At the base of the thick limestone near the center of the pit an irregular bed of conglomerate overlies the ore zone. This conglomerate consists of angular fragments of manganese oxide and tuff cemented by limestone. It has an exposed lateral extent of only a few meters and lenses out both north and south. Just north of the last exposure of conglomerate, the limestone, which rests directly on the ore bed, has been replaced by manganese oxide for a distance of several centimeters above its base. The replacement very near the base is so complete that only the Foraminifera, apparently insusceptible to replacement, are left imbedded in a matrix of calcareous manganese oxide. A few veins of oxide cut and replace limestone.

A similar conglomerate overlies the ore bed in the north part of the pit. Elsewhere the limestone rests directly on the ore bed but is unaltered and nonconglomeratic.

In 1944, the Ponupo 1 and 2 ore bed was exposed at only a few places in the pit. At the north end of the pit the bed was about 2.5 meters thick and consisted of irregular nodules of psilomelane-type oxide that replace red tuff. These nodules range from a few millimeters to 15 centimeters across. Numerous stringers of oxide as much as 20 centimeters thick are found parallel to the tuff bedding. The basal part of the overlying limestone is conglomeratic and is cut by a few thin veinlets of manganese oxide. Most of the ore is very low in grade.

In the central part of the pit, under the thickest section of limestone, the ore consists of small nodules and highly irregular stringers of manganese oxide cutting agglomeratic red tuff. Most of the stringers are less than a centimeter thick and may be parallel to the bedding or may crosscut it. A few angular fragments of oxide are probably intraformational. The upper 0.3 to 0.6 meter of ore immediately underlying the limestone is of higher grade than the rest of the bed. Possibly the mineralizing solutions were trapped beneath the limestone and deposited a larger portion of their load there than elsewhere, but at no other place in the pit is such a concentration seen; inasmuch as the overlying limestone contains fragments of manganese oxide derived presumably from the bed below, the occurrence of the ore of highest grade just under the limestone may be entirely fortuitous.

A few short adits have been driven on the ore bed near the center of the pit on the west side where the main road leaves the pit. The bed is about 1.3 meters thick and consists of agglomeratic tuff replaced by manganese oxide. The oxide is disseminated sparsely through the upper meter or so of the bed and forms low-grade nodules in the lower part.

The best ore seen was in an adit on the west side of the pit at the extreme south end. Here the ore bed was as much as 2 meters thick and in places was nearly solid manganese oxide. Many tuff dikes as large as 30 centimeters wide cut the ore. Most of this ore has been extracted and exploration to the west was unproductive.

In the south half of the pit, the east wall is formed by a large jasper mass about 430 meters long and at least 300 meters wide. The jasper is at least 30 meters thick near the center of the outcrop and thins to the north and south. At one point, mining operations have uncovered a vertical jasper cliff 18 meters high. Although this cliff appears to be a fault scarp, drill holes on the west side of the supposed "fault" failed to find the offset body of jasper, and instead show only a few feet of jasper overlying the green tuff and agglomerate found at the base of the jasper throughout the deposit. We have no good explanation for the mode of formation of this cliff, although several theories suggest themselves as possible explanations.

1. It is a fault scarp.
2. It is an exhumed erosional feature.
3. The jasper was formed by replacement of some other rock, probably tuff, the cliff being controlled by a pre-existent fracture.
4. The cliff is an original depositional feature.
5. The jasper-bearing liquid was emplaced under pressure, lifting the now-eroded roof rocks along a preexistent plane of weakness (fault or joint), which plane is now represented by the jasper cliff.

The difficulty in the first theory has been discussed. No direct evidence is available to prove or disprove the second. However, drill records show manganese ore along the west side of the cut in such a position that it would have been deposited subsequent to the erosion of the jasper cliff; thus a considerable time gap would be inferred between jasperization and manganese mineralization. Such a gap is not confirmed anywhere in the Ponupo district nor in any of the Cuban manganese deposits, where, on the contrary, the intimate association of jasper and manganese mineralization suggests that the two are closely related in time as well as in space.

The apparently clean-cut face of the cliff is difficult to explain under the third theory, even if a fault did exist prior to jasperization, inasmuch as a large body formed by replacement might not be expected to end abruptly along a vertical surface but to finger out into the unreplaced rock. Moreover, there is evidence that the limestone bed cropping out near the base of the cliff was once present on the jasper surface above and east of the cliff, indicating that the limestone has been either faulted or folded but not replaced completely.

The fourth theory does not seem credible, inasmuch as even a vertical wall would not form ordinarily during sedimentary deposition of jasper; inasmuch as the rocks have been slightly tilted toward the east, the cliff originally would have been overhanging.

Theory five envisions a laccolithic type of emplacement of jasper, accompanied by faulting or monoclinal folding along one edge of the jasper mass. The mechanics of such a mode of formation are highly speculative. If, as we believe, the manganese deposition was syngenetic, the theory would indicate a considerable time interval between manganese deposition and jasper emplacement; objections to any prolonged interval were given in the discussion of theory two.

The lack of reliable information regarding parts of the deposit either mined out or partly mined out but now inaccessible precludes any very accurate estimate of reserves. Most of the reserve estimate is based on drill-hole data but all exposures of ore were mapped and measured and all accessible underground workings were examined.

Most of the reserves are in a narrow strip bordering the west side of the pit. This strip ranges from 15 to 45 meters in width and extends from about 150 meters north of the south end of the pit to slightly beyond the north end. The only ore remaining in the floor on east wall of the pit consists of small remnants that were being mined by hand. The huge jasper mass that forms much of the east wall of the pit undoubtedly contains additional pockets of manganese oxide, but these pockets are entirely unpredictable and are not considered in the estimate.

Reserves are estimated at several tens of thousand tons, more than half containing 10 percent manganese or less. A considerable part of the low-grade reserve is in beds that probably are too thin to mine economically.

### SULTANA DEPOSIT

The Sultana deposit is near the Río Ponupo about 1 kilometer east of Ponupo. It was the principal source of ore in the district during World War II. The deposit was worked as an open-pit mine with two draglines, one for stripping and one for loading ore. Ore was hauled to storage bins by tractor-drawn Le Tourneau carryalls. Additional stripping of soft rocks was done with Le Tourneau carryall scrapers. Most of the overburden had to be blasted prior to stripping.

The Sultana pit is roughly foot shaped, with the toe pointing east and the ankle north. It is about 330 meters long, 60 to 150 meters wide, and has a maximum depth of about 42 meters. The best exposures of country rock and virtually the only exposures of the ore bed are along the northeast wall of the pit. An isometric fence diagram (pl. 29) has been prepared to show the geology of the mine area.

The general stratigraphic succession is as follows:

Alluvium
Marl, white or yellowish, shaly
Marl, pink, fine- to medium-grained; occasionally tuffaceous
Tuff, red or white, coarse-grained; and (or) limestone conglomerate or coarse green tuff
Ore zone
Jasper, red or yellow
Tuff, green or yellowish; some agglomerate

A pinkish marl is found throughout the pit, from a few centimeters to 6 meters above the ore zone. The rock is fine grained and poorly bedded except at the southeast end of the pit, where it is slightly shaly and displays excellent bedding. The thickness ranges from 4 to 5 meters at the northwest end of the pit to 0.3 to 0.6 meter near the middle of the pit and 2 to 2.5 meters at the southeast end. The marl grades upward into a white or pale-yellow well-bedded marl. A similar pink marl is found in the Sabanilla district to the northeast, where it has the same relations to the ore zone.

Along the northeast wall of the northwest section of the pit the ore zone is overlain by a conglomerate that pinches out toward the southeast. This conglomerate ranges in thickness from a few centimeters to 1.5 meters and consists of fragments of tuff, limestone, and manganese oxide imbedded in a limestone matrix, which contains sharks teeth and many Foraminifera. The conglomerate fragments appear to have been derived, in part, from the underlying ore bed.

Between the conglomerate and the overlying pink marl is 0.6 to 1 meter of red, green, or white coarse-grained tuff. Toward the east this rock grades into a coarse green tuff that attains a maximum thickness of 5 to 6 meters and then lenses out completely before reaching the east end of the pit.

The rocks in general strike northwest and dip gently northeast. Sections of plate 29 reveal minor folds or possibly faults but only one fault and one probable fault of any appreciable magnitude were seen in the pit. In the east part of the pit a jasper cliff from 3 to 12 meters high was uncovered during mining operations. The cliff is about 105 meters long, is nearly vertical, and appears to die out along its strike in both directions. The ore bed in the east face of the pit is not offset. Although the cliff appears to be a fault scarp, most of the "displacement" probably has been caused by differential compaction of tuffs and marls over a resistant jasper hill. At the east end of the pit (fig. 50) a thrust fault that strikes north and dips 15°–17° E. is exposed in the walls. Drill records indicate a displacement of at least 180 meters (see pl. 29).

The Sultana ore bed was exposed at several places along the northeast wall of the pit in 1944. Maximum thickness observed was 4 meters near the center of the pit, but only at the northwest end was the base of the ore zone exposed. The maximum thickness of mineralized rock cut during drilling was 11 meters but the average thickness of high-grade ore mined was only 5 to 6 meters.

The ore in general consists of "stalactitelike" masses of fine-grained dense manganese oxide that appears to have formed by replacement of coarse-grained red tuff. The "stalactites" are composed of irregular oblate balls of manganese oxide, as much as 7.5 centimeters in diameter, connected by narrower necks; commonly the bottom of a

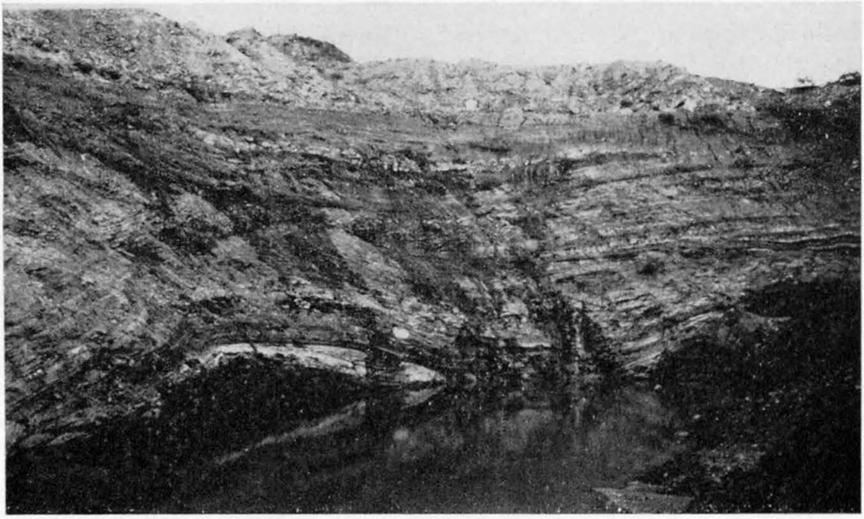


FIGURE 50.—East end of Sultana open pit in 1944. The footwall of the ore bed lies along the right-hand side of the photograph; the dark rock at right center is ore. A thrust fault is exposed just above the arched and crumpled marl beds to the left of center. In the core of the arch near water level is another exposure of the ore bed.

chain of nodules has a smaller diameter than the top, hence the rough resemblance to true stalactites. A few of the individual nodules have a concentric structure but most of them are apparently structureless. The "stalactites" are roughly perpendicular to the tuff bedding and almost invariably break along surfaces parallel to the bedding. The variation in diameter of the "stalactites" may be due to differences in ease of replacement of the various tuff layers. The upper part of the ore bed is usually higher grade than the lower part because the carrotlike masses of manganese oxide taper downward and because interstitial tuff in the upper part of the bed has been replaced more extensively.

Near the east end of the pit the ore is similar to other tuff ore deposits of Oriente and consists of bands of psilomelane-type oxide interbedded with tuff. About 90 meters from the northwest end of the pit the upper part of the ore zone is agglomeratic and contains many fragments of red tuff.

The great lateral extent of the ore zone and its apparent confinement to one series of tuff beds indicate that the mineralization was stratigraphically controlled and that the ore bed itself is a stratigraphic unit.

Throughout the pit and also over most of the area explored only by drilling, the ore bed is underlain by a layer of red or orange jasper ranging in thickness from a few centimeters to about 17 meters. In places the jasper is colored nearly black by disseminated manganese oxide. The relations between jasper and ore are not clear, as the contact was exposed for only a few meters at the time of our study. No veins of jasper were seen cutting the ore. A lens of jasper more than 100 meters long, enclosed completely in manganiferous tuff, was cut in drill holes just east of the pit.

The persistence of the principal jasper stratum over an area at least 430 meters long and 275 meters wide together with the consistent relation between jasper and the stratigraphically controlled ore bed suggest that the jasper too is a stratigraphic unit. The mode of origin of the jasper is not clear, but most of it appears to have formed prior to ore deposition. Jasper may have replaced a bed of tuff but no evidence points to such an origin and it seems more likely that the jasper was deposited as a highly siliceous sediment. That the source of the jasper may have been also the source of the manganese is suggested by the manganiferous character of much of the jasper.

There is no evidence that manganese minerals were deposited where mineralizing solutions rising or migrating laterally through the tuff were trapped against the overlying calcareous rocks. At every place where both marl and ore are exposed a layer of tuff, apparently very similar to the tuff in the ore bed, intervenes. Moreover, the conglomerate overlying the ore bed in the northwest part of the pit contains fragments of manganese oxide indistinguishable megascopically from the oxide of the ore bed; presumably these fragments were formed when the already existent ore bed was broken up by wave or current action.

It is believed, therefore, that mineralization was either essentially contemporaneous with or slightly later than deposition of the host tuff, and that mineralizing processes were completed entirely before deposition of the pink marl. Inasmuch as no manganese minerals other than oxides have been recognized, it is assumed that the oxides were deposited as such, although in places some psilomelane-type minerals were later oxidized to pyrolusite. The well-defined bedding of the mineralized tuffs and the presence of foraminiferal limestone a short distance stratigraphically above the ore bed indicates that the tuffs probably were water-laid in a marine environment.

The Sultana deposit has been churn drilled extensively by the Cuban Mining Company. One hundred and forty-three holes, ranging in depth from 18–130 meters (60 to 425 feet) were drilled; they aggregate about 28,300 feet in length. All holes cutting ore were drilled entirely through the ore bed.

The reserve estimate is based entirely on drill-hole data. Portions of the ore bed less than 1.5 meters thick have not been included, nor have barren zones within mineralized rock. Drill-hole data and geologic observation indicate that both manganese content and thickness of ore are rather uniform over relatively large areas. In 1944 the Cuban Mining Company contemplated stripping to a depth of 43 meters (140 feet). Therefore, only reserves of ore lying below the 43-meter level have been calculated.

Reserves are estimated at several hundred thousand tons of ore containing more than 15 percent manganese and a comparable tonnage containing 10–15 percent.

## SABANILLA DISTRICT

### SABANILLA MINE

The Sabanilla district is at and north of El Aura siding on the Ferrocarril de Guantánamo y Occidente, about 30 kilometers northeast of Santiago de Cuba. It may be reached by rail or by an unimproved truck road from Alto Songo, about 12 kilometers to the west. Most of the nine claims in the Sabanilla group were denounced in 1891 and 1892. Manganese ore has been produced intermittently from six of the denouncements.

The principal period of activity was during World War I, but production of that time is not known. From 1942 to August 1945 the district produced about 4,500 tons of ore containing 44 to 47 percent manganese.

The Sabanilla area has been divided into two parts, the north and south areas. The north area includes the manganese deposits on the María, El Aura, Altagracia, and Verdad claims; the south area includes those on the Dolores, Poder, and Arivas claims. Detailed study has been made of only the South area, although all of the deposits in the district have been examined. The entire Sabanilla area was churn drilled by the Cuban Mining Company in 1940 and 1941 and drill records have been made available to us through the courtesy of the company. A geologic map of the south area is given in plate 30.

The oldest rocks in the district are coarse-grained bedded tuff and minor amounts of agglomerate of the Cobre formation. These rocks are overlain by the Charco Redondo limestone member, which has a maximum thickness of about 14 meters. Throughout most of the area the limestone is less than 6 meters thick. Overlying the limestone is 15 to 25 meters of gray to pink marl and interbedded thin limestone of the San Luis formation. The youngest rocks are calcareous and tuffaceous greenish-gray to brown shale of the San Luis formation.

The principal structure is an elongate dome that trends north-northeastward and is about 2,250 meters long. Shallow synclines and anticlines are superimposed on the main structure. Both the south and north areas are on small subsidiary domes separated by a synclinal depression on the crest of the large dome. Dips are rarely greater than 10 to 15 degrees. No major faults have been recognized but several northeastward-striking small faults were seen in both areas.

Manganese ore occurs in tuff at distances of 1.5 to 14 meters below the base of the limestone. Manganese oxides are associated closely with lenticular and discontinuous masses of jasper and are distributed irregularly at or near the top of the jasper lenses. In the eastern half of the mapped area (pl. 30) the jasper occupies a roughly circular area about 300 meters in diameter. Locally within this area the jasper is as much as 9 meters thick, but in places it disappears completely; in general it is less than 3 meters thick. The contacts of the jasper lenses appear to conform with the bedding of the enclosing tuffs; the overlying beds merely are domed up over the thicker lenses. None of the observed faults were formed before the jasper but minor faults indicate movement after deposition of the jasper and the ore. Beds along the steep sides of the jasper lenses are thinner in places, and some of the contacts are marked by minor slips; these slips commonly flatten away from the jasper, parallel or nearly parallel to the bedding of the tuff. The footwall contact of the jasper is usually well defined but in places discontinuous small lenses and nodules of jasper occur along the footwall.

On the western edge of the south area thick jasper lenses crop out on both sides of a southward-trending arroyo. Apparently the lenses were once part of a connected mass now breached by the arroyo. Here, as well as in the north area, the ore and jasper zone appears to occupy the same stratigraphic position as it does in the eastern part of the mapped area. The apparent variation in distance between the ore zone and the base of the limestone may be attributed to local thickening or thinning of the intervening tuff (see pl. 30).

Most of the jasper is dense fine grained and reddish brown and forms prominent outcrops. In many places it is veined irregularly by white chalcedony and quartz. On the Poder claim in the western part of the south area and on the María claim in the north area, a greenish-gray jasper is found below the red type. The gray jasper apparently has replaced tuff, as it shows relict bedding. The contact between gray and brown jasper is sharp and is parallel to the bedding of the enclosing tuffs. The gray jasper attains a maximum thickness of 8 meters and grades out abruptly into unsilicified tuffs. No manganese oxides are associated with the gray type.

Part of the jasper in the eastern part of the mapped area appears to have replaced a conglomerate composed of fragments of impure manganese oxides, tuff, and tuffaceous shale cemented by pink, impure limestone. The contacts between jasper and conglomerate are frozen and very sharply gradational. In some places the jasper has a conglomeratic texture, which suggests that it may be pseudomorphic after the replaced rock. Replacement of conglomerate by jasper has resulted in the complete removal of the manganese oxides, tuff fragments, and other material present in the original rock.

An acidic, medium-grained tuff overlies the manganese zone in the south area. The rock is composed of feldspar, quartz, and minor amounts of a dark mineral, possibly augite. In places where there is no ore the rock is comparatively fresh and unaltered, but in the mine area it is altered locally to a white clay that retains none of the texture of the original rock. Float of the same type of acidic tuff on the María claim indicates that the bed may cover most of the north mineralized area.

Psilomelane-type oxide, pyrolusite, and a soft wadlike oxide of indeterminate composition are the only manganese minerals of importance. These oxides replace tuff adjacent to jasper and conglomerate. They form irregular nodules and particles separated by barren or sparsely mineralized tuff. The manganese minerals are commonly intergrown with pink zeolitic clay and tuff. Lumps of oxide often contain small disseminated particles of tuff that cannot be separated by ordinary methods of concentration. Oxidation of psilomelane-type oxide and wad (?) to pyrolusite has taken place for the most part only at and near the surface; in the deeper mine workings only a minor amount of pyrolusite is found. Chlorite is present in considerable quantity along the footwall of the jasper zone and locally is found above the ore. Nodules and lenses of jasper in the footwall of the main jasper zone commonly are surrounded and coated by chlorite. Unlike the pink zeolitic clays, chlorite does not occur in intimate association with manganese oxides.

The ore bed ranges in thickness from less than 0.3 meter to more than 2 meters and averages less than 0.6 meter; thickness of the ore is extremely variable over relatively short distances. Mine-run ore contains from 10 to 25 percent manganese.

Mining during and previous to World War I was done chiefly from open pits. The old pits, 7 in number, are concentrated in an area about 245 meters long by 180 meters wide (see pl. 30 for locations). Some of the pits are as much as 6 meters deep. Most of the ore produced during World War II was mined underground and extracted through shafts and adits. The principal underground working is an adit (B–30) at the southwest edge of the main pit area. The adit, which is about 45 meters long, develops a bed of medium-grade tuff ore from 1.3 to 2 meters thick. Several shafts have been sunk in and about the main mine area but few have disclosed minable ore. Churn-drill holes in the south area southwest and east of the main mine area have discovered as much as 4.5 meters of rock containing 12 to 15 percent manganese, but much of this material is probably limestone-manganese oxide conglomerate that may have little or no minable ore in or overlying it; shafts number 1–A, 5, C–22, 24, and C–24, which have been sunk in this area, show less than 0.6 meter of minable ore.

On the Poder claim on the western side of the mapped area, numerous shallow pits have been dug along the hanging wall of the jasper lenses and a small amount of ore has been recovered. However, the mineralized zone is thin and low in grade. Churn drilling as much as 90 meters west of the mapped area has indicated only sparse, low-grade mineralization.

Ore deposits in the north area are similar to those in the south area, but ore appears to be less extensive. On the west side of the María claim an open pit 30 meters long, 15 meters wide, and 3 meters deep is sunk on jasper, conglomerate, and tuff ore, which strike N. 80° E. and dips 30° S. The ore zone lies 3 to 5 meters below the limestone. Stopes extend downdip away from the pit over an area about 25 meters long by 15 meters wide. An adit about 23 meters long connects the south end of the stopes to the surface. The ore zone ranges from less than 0.3 meter to about 1.0 meter in thickness. Average ore on the west side of the María claim contains 25 to 30 percent of manganese.

About 300 meters to the east, low- to medium-grade tuff ore associated with jasper and manganese oxide in limestone conglomerate is exposed in an abandoned open pit, but it is probable that minable ore extends but short distances away from the stopes.

About 230 meters farther east, on the Altagracia claim, low- to medium-grade tuff ore crops out on both sides of Arroyo Sabanilla. The ore bed is 0.3 to 1.5 meters thick. Apparently it has yielded little ore.

On the Verdad claim, about 300 meters north of the Altagracia, a bed of tuff ore, 1 to 3 meters thick, lies at least 15 meters stratigraphically below the base of the limestone. The bed strikes N. 65° E. and dips 15°–20° N. The association of manganese oxide in limestone conglomerate with jasper suggests that this ore bed is the same as that on the María claim to the south; the greater distance below the limestone may be attributed to thickening of the intervening tuff to the north. Ore has been mined downdip and along the strike for about 15 meters; most of the workings are caved and inaccessible. Minable ore averages 0.6 to 1.0 meter in thickness and contains 20 to 30 percent of manganese. The ore bed possibly may extend east and northwest of the old workings.

Seven churn-drill holes were sunk in the north area near the jasper outcrops but none of them found minable ore. However, 3 holes were started below the ore horizon and 2 others may not have been sufficiently deep.

The potentialities of the Sabanilla district remain doubtful. The general low grade of the ore, which involves high concentration ratios, and the low average thickness of minable ore militate against any large production if only simple gravity concentration methods are used. More than half of the World War II production came from old mine dumps, which are now largely exhausted. The north area should be explored more extensively, as the average mine-run ore there may contain as much as 25 to 30 percent manganese.

Reserves of the Sabanilla district, calculated by using data from drill holes, underground workings, and outcrops are estimated at a few tens of thousand tons. The grade of ore is extremely variable, but will lie between 12 and 20 percent manganese. Virtually all the reserves are in the south area; much additional exploration is necessary in the north area before any reliable calculation of reserves can be made.

### AVISPA MINE

The Avispa mine is in the foothills of the Sierra de Nipe and Sierra del Cristal, 6 kilometers north of El Aura siding. It was explored in 1931, but no ore was extracted until 1940. Between 1940 and January 1943, about 1,250 tons of ore containing 30 percent manganese was mined and concentrated in a washing plant. The concentrate, containing 45 percent manganese, was trucked to El Aura over an unsurfaced road. Operations ceased in May 1943.

The Avispa ore body crops out in Arroyo Leonor, a steep-walled canyon 20 to 30 meters deep. Two mineralized tuff beds crop out at the base of a thin-bedded flaggy limestone. Only one of the beds contains much ore; this bed underlies the arroyo and a narrow gravel-capped terrace to the west and is exposed in several pits along the eastern bank of the arroyo. The ore body is explored by two shafts about 9 meters deep and by about 60 meters of drifts from the foot of the shafts. Workings north of the shafts are caved. Drill holes southwest of the ore body are reported to have cut ore, but nothing is known of the thickness or grade of the material.

Fine particles of soft, dull-black wad and stringers and pods of psilomelane-type oxide and pyrolusite are in a matrix of altered red tuff containing many small jasper pods. The ore zone is less than 1.3 meters thick and probably does not contain more than 20 percent of manganese. Ore exposed in pits along the northern border of the deposit is about 1 meter thick and contains less than 10 percent of manganese.

Measured and indicated reserves are at most a few hundred tons. If the drill data cited is reliable, a few thousand tons may be inferred. The prospect probably could be operated best as a feeder for a custom mill at Sabanilla.

### SIGUA DISTRICT

The Sigua district is on the crest of the Gran Piedra range about 55 kilometers east of Santiago de Cuba and 15 kilometers from the coast. The nearest town is Ramón de las Yaguas on the Río Baconao, 7 kilometers to the north. From Santiago de Cuba the district may be reached either by trail via El Caney and Ramón de las Yaguas or by road via Vinent to Chalía and thence by 8 kilometers of trail to the mine area. An alternative route from Vinent is by dirt road to Playa Sigua, 25 kilometers east, from which a truck road, 15 kilometers long, leads to the district.

The mineralized area is covered by the Graham, Hércules, Non Plus Ultra, Fantasía, and Capricho claims, denounced in the late 1880's. These claims cover an area of nearly 800 hectares. About 100 tons of ore was mined on the Graham and Non Plus Ultra claims in 1918, but no other production is known.

The mine area is one of steep-sided northwestward-trending ridges with a maximum height of 800 meters. Ample timber is available in the nearby forested areas, but water is scarce in the uplands. Any large supplies of water would have to be pumped from the Río Baconao, 2 kilometers east.

The principal manganiferous zone is known to extend 6 kilometers northwestward from the Rio Baconao and is said to extend 6 kilometers farther. The zone was studied in detail in two areas. The larger, shown in plate 31, covers part of the Graham, Hércules, and Non Plus Ultra claims; the smaller covers part of the Fantasía and Capricho claims 2 kilometers to the southeast. Areal studies were made by C. F. Park, Jr., and M. W. Cox.

Five rock units have been recognized. All the rocks appear to belong to the Cobre formation. The lowest unit is a coarse-grained green tuff at least 450 meters thick. The tuff is massive and forms prominent cliffs. Overlying the coarse tuff is about 150 meters of brown calcareous tuff, dense gray fossiliferous limestone, and a few layers of agglomerate. The Non Plus Ultra ore bed lies near the base of this unit. Rock types are rather variable, but in general the rocks become coarser and more agglomeratic toward the south-

428472—58——18

east. The uppermost unit of the volcanic section is a coarse agglomerate that consists of blocks of andesite porphyry as much as a meter or so across. A few beds of tuff and limestone and several andesitic(?) lava flows are intercalated in the agglomerate. Total thickness is probably more than 180 meters.

In the southern part of the district the bedded rocks are intruded by a massive dark-green diorite with a coarse diabasic texture. Clear plagioclase feldspar, biotite, and blebs of chloritic minerals, apparently derived from hornblende, can be recognized in hand specimen. Near the contact, the tuff is dense and flinty and some 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 zone is not known to crop out within 120 meters of the contact.

Agglomerate composed of scoriaceous andesitic fragments, which may have been formed in or near a vent, crops out on Loma Potrero. The upper part of the agglomerate shows bedding parallel to the enclosing green tuff, but the lower part is massive and cuts across bedding of the tuff. The manganese bed on the Hércules claim is in this rock.

In the area shown in plate 31 the green tuff and calcareous tuff trend N. 40°–50° W. and dip 45°–60° NE., except where the strike changes on minor cross folds. On Loma Cementerio tuff is horizontal and is assumed to be faulted against steeply dipping green tuff; this assumption is supported by the presence of float from the Non Plus Ultra ore bed to the north. Diorite occupies most of the region between the mapped area and the smaller Fantasía-Capricho area to the southeast. The manganese bed has the same strike and dip in both areas, but in the Fantasía-Capricho area the bed is cut by several small cross faults.

Very little work has been done on the deposits. The Non Plus Ultra ore bed is developed by a few small pits and two crosscutting adits 18 to 20 meters long. The Graham outcrop is opened by four pits, from which ore was shipped in 1918. The Hércules and Fantasía areas have not been explored.

The Non Plus Ultra claim contains the largest of the four occurrences of manganese-bearing rocks. On the Fantasía and Capricho claims there is a similar bed. At the Graham claim ore consists only of small pockets in and adjacent to a mass of jasper. The Hércules ore bed on Loma Potrero is thin and of small extent, but otherwise is identical in character to the Non Plus Ultra bed.

Two exposures of the Non Plus Ultra bed are known in the area studied. One is more than 400 meters long along the strike; the other, to the southeast, is 230 meters long. The bed is in limy tuff about 15 meters stratigraphically below the agglomerate. Its thickness probably averages 1 meter but ranges from as little as 15 centimeters to as much as 2 meters. Part of the outcrop forms a dip slope as much as 45 meters wide and makes available a considerable tonnage of ore on the surface. Unfortunately, the great breadth of this outcrop has led to a popular belief that the deposit is fabulously thick.

Typical mineralized rock is dull black or lustrous black, massive, hard, and brittle. Minerals tentatively identified include piedmontite, braunite, neotocite, psilomelane-type oxides, and pyrolusite. Probably the commonest 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, although some is known to be in fine-grained mixtures of silica and manganese oxides. Piedmontite locally gives a reddish color to both the Non Plus Ultra and Fantasía beds. Considerable lustrous black, brown, or yellow neotocite is found. Psilomelane-type oxide 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. In some outcrops the beds consist of black and red layers separated by lighter-red siliceous manganiferous tuff, which is the most common gangue and encloses the richer 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 shows veinlets and films of manganese oxide on broken surfaces.

Reliable analyses of outcrop samples show from 20 to 48 percent of manganese. A small part of the material from the Non Plus Ultra bed probably can be hand picked to produce an ore containing 40 percent manganese and 15 percent silica, but before the deposit could be utilized fully 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 calcareous tuffs at steep angles. Most of the ore came from a residual blanket of pyrolusite and psilomelane with some braunite.

Reserves are mainly in the Non Plus Ultra bed. At least a few tens of thousand tons of ore is in sight on the dip-slope exposure. 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. 31) it would contain several hundred thousand tons of ore averaging 20 percent of both manganese and silica. The Fantasía bed contains several tens of thousand tons of similar material. Reserves of the Hércules and Graham ore beds are negligible.

The Non Plus Ultra and Fantasía deposits can produce a large tonnage of manganiferous rock, but almost all the ore would have to be concentrated or used for special purposes requiring a high-silica ore. The problem of concentration is a formidable one and has not been studied to any appreciable extent.

### SOUTH COAST DISTRICT

A number of manganese prospects and one mine are found near the coast along the south flank of the Sierra Maestra, 120 to 150 kilometers west of Santiago de Cuba. Pilón, 72 kilometers by road from the nearest railhead at Manzanillo, is the only sizeable settlement in the district. Manganese deposits are along a narrow coastal strip about 30 kilometers long, extending eastward from Puerto Portillo, 13 kilometers by road east of Pilón, to Río La Plata. Trails leading to the various prospects may be reached either by launch from Pilón or Santiago de Cuba or by means of the main coastal trail between Portillo and Santiago de Cuba. The Ponupo de Manacal mine is connected to Puerto Portillo by 13 kilometers of dry-weather road.

Ore is shipped by boat from Puerto Portillo to Santiago de Cuba. No loading facilities were available at Portillo in 1944; all ore was loaded from shore by hand. Loading and shipping costs in 1944 were about $4.00 per ton.

#### PONUPO DE MANACAL MINE

The Ponupo de Manacal mine is in rugged terrain near the headwaters of the Río Portillo at an altitude of 360 meters. It is the most westerly manganese mine in the province.

Manganese ore was trucked from the mine to Puerto Portillo and then shipped to Santiago de Cuba on a boat of 100 tons capacity.

The Ponupo de Manacal group of claims includes the Ponupo and Amalia (Nenita) denounced in 1893, and the Serrallo and Sultana, denounced in 1925. The denouncements are controlled by the Sun Development Company.

The deposit was explored by the Sun Development Company in 1925 and 1926. Production during and prior to this period is not known, but probably was small. From 1926 to July 1942 the mine is believed to have been idle. The mine was reopened in 1942 and until August 1945 had yielded 6,963 tons of ore containing 43 percent manganese.

The mine area is underlain by brown or gray well-bedded tuff and calcareous tuff, massive tuff, and tuff-agglomerate. Impure limestone beds are conspicuous along the road south of the mine area but become less abundant toward the coast. The layered rocks are intruded by minor dikes of probable andesitic character. A stocklike fine-grained body of andesite or diorite cuts the bedded rocks above the confluence of Río Portillo and Arroyo Palenque. Geology of the mine area is shown in plate 32. The principal structure in the mine area is a tightly folded asymmetrical anticline that plunges westward at 10° to 20°. The limbs of the fold dip 60° to 80°. No major faults were observed in the mine area but several small flat-dipping postmineralization strike-slip faults cut the main ore zone and several minor bedding-plane slips are exposed in the underground workings.

Manganese oxides occur along stratigraphic horizons in tuff. A main manganiferous zone is overlain by at least two minor zones.

The main ore bed dips steeply southward and extends across the entire mine area south of the anticlinal axis. It is believed to be repeated on the north limb of the fold where the bed dips steeply northward. Massive, medium- to coarse-grained brown tuff underlies and overlies the ore zone. The massive tuff is highly jointed and locally is cut by small shears and slips. South of the fold axis the tuff above the main ore bed is 23 to 25 meters thick and is overlain by 75 to 120 meters of interbedded fine-grained tuff and medium- to coarse-grained agglomeratic tuff. The fine-grained tuff is overlain in turn by a gray tuffaceous limestone, from 3 to 6 meters thick; apparently this limestone lenses out on the west side of the mine area, but it is traceable for more than 300 meters eastward. Another bed of tuffaceous limestone about 11 meters thick is separated from the lower limestone by about 40 meters of tuff. Both limestone beds contain Foraminifera of middle Eocene age.

The stratigraphic equivalents of the limestone beds have not been found definitely on the north limb of the anticline, although they may be represented by discontinuous and poorly defined zones of very impure brown limestone and calcareous tuff.

Manganese oxides are associated with lenticular masses of reddish-brown slightly ferruginous jasper. The deposits are similar in appearance to those in El Cristo, Jagua, and Iris-Joturo districts north of Santiago de Cuba. Jasper masses in the main ore zone have a maximum thickness of about 12 meters and attain a length of as much as 150 meters. Along eastward and westward extensions of the main ore zone and along the minor zones, the jasper lenses are small; individual pods a meter or so in length are very common. The long axes of the jasper lenses parallel the bedding of the enclosing tuff, although here and there some shearing has taken place between soft tuff and hard competent jasper.

Manganese oxides replace tuff adjacent to the jasper lenses. The largest concentrations of oxides are invariably near the larger jasper masses, commonly along one contact and near the ends of the lenses.

Ore appears to be concentrated in distinct steeply-plunging shoots, 25 to 50 meters long, that grade into low-grade mineralized tuff and (or) black manganiferous jasper along the strike. Ore zones are as much as 6 meters thick but average only about 2 to 2.2 meters. Although jasper may be found at both contacts of the ore-bearing tuff, the main masses of jasper always lie along the footwall.

Beds of barren tuff from 0.3 to 1.5 meters thick occur within the ore beds or between ore and jasper. Contacts between ore and barren tuff commonly are gradational within a relatively narrow interval. The tuff immediately adjacent to the ore commonly is highly altered and pink, white, or dark gray. Clay minerals and fine-grained zeolites(?) appear to make up the alteration products. Tuffs as far as 6 meters from the walls of the manganese-jasper zones commonly are highly chloritized. The chlorite is disseminated through the tuff and concentrated along certain beds. Although small pods of jasper are common within chloritized tuff, and chloritic tuff is in contact with the larger masses of jasper in many places, no chlorite was seen in intimate association with manganese oxides.

The main manganese-oxide-jasper zone, from which almost all the ore has come, is traceable for at least 500 meters along the strike. Jasper forms an almost continuous outcrop nearly 300 meters long and 6 to 12 meters thick. The zone thins to the east and is marked by sparse irregular masses and nodules of manganese oxides, with small pods and disconnected lenses of jasper. To the west, lenses of jasper as much as 5 meters thick that finger out into mineralized tuff mark the position of the zone.

Minable ore is concentrated in at least three and possibly four distinct shoots. The shoots are developed by three adits. The easternmost shoot, which overlies adit 3, is about 23 meters long and 1.3 to 2.2 meters thick. This shoot has been mined to a depth of about 12 meters below the outcrop and continues in depth. The main ore shoot of the mine has been developed from adits 1 and 2; it is 30 to 45 meters long and has a maximum thickness of 6 meters. The minimum vertical length is nearly 30 meters. Two other ore shoots, each 30 meters or more in length, lie 90 meters and 150 meters, respectively, west of the main shoot. Lower limits of ore had not been reached in any shoot in 1944. Low-grade ore and black manganiferous jasper separate the ore shoots; locally some of this material is minable.

Two minor manganese-bearing zones are exposed in surface and underground workings on the south limb of the anticline above the main ore zone. One zone lies 25 meters stratigraphically above the main horizon and the other more extensive zone lies about 22 meters higher. The higher zone is traceable across the entire mine area for a distance of more than 600 meters. The lower ore zone crops out near the mine road in the center of the mine area and is exposed in the adit 60 meters to the southeast. The manganiferous beds range in thickness from 0.3 meter to about 3 meters and are associated with jasper lenses 3 to 5 meters thick. Minable ore has not been found at any place along either zone.

The minor zones are not exposed on the north limb of the anticline. However, jasper float may mark the trace of minor manganiferous horizons. One old pit, now caved, may be on the lower zone.

The ore at Ponupo de Manacal is composed chiefly of a dark-brown to black wad, with variable amounts of pyrolusite and very small amounts of psilomelane-type oxides. The composition of the wad is uncertain; according to analyses, it appears to be made up of manganese oxides intimately associated with appreciable amounts of iron oxides and silica. In places much of the wad is a dark-brown to black material of very light weight that has a shiny luster peculiar to oxides derived from manganese silicates. Selected specimens of this material assayed 45.07 percent manganese, 12.70 percent iron, and 3.87 silica.

Because of the high iron content, the analysis does not suggest very strongly that the mineral is an oxidation product of manganese silicates. No manganese silicates have been recognized on even the lowest mine levels, and no free silica can be seen in the ore, although the silica content of washed concentrate ranges from 7 to 11 percent.

Pyrolusite occurs as a soft, blue-gray mineral that forms small masses and veinlets in the wad. It is most abundant near the surface, but some is found at the lowest mine level, 30 meters below the surface. Pyrolusite is believed to be a secondary mineral derived by oxidation or reconstitution of manganese oxides in the wad.

The gangue is unreplaced tuff, pink to white clay minerals that are probably alteration products of tuff, and variable amounts of brown to black manganiferous jasper.

The ore deposits of the Ponupo de Manacal mine, like other deposits of similar type in the districts north of Santiago de Cuba, are believed to have been formed by replacement of waterlaid tuff at shallow depths below the surface of deposition. This replacement probably took place at essentially the same time that the tuff was deposited. The deposits differ in mineralogic composition from those observed elsewhere, but psilomelane-type oxides are common to all.

Mine-run ore contains 20 to 40 percent manganese. Until 1943, ore was sorted by hand and screened to remove tuff particles and clay; late in 1943, a log-washing plant was installed to treat all of the ore mined, including material containing less than 25 percent of manganese.

Ore reserves are estimated at a few thousand tons indicated and several tens of thousand tons inferred. The grade of reserves is 30 to 35 percent manganese. Concentration ratios in the washing plant were 4:1 or 5:1; it seems unlikely that these ratios can be improved very much if only a log washer is utilized.

Downward continuations of ore offer the best and virtually the only means of increasing the reserves of the mine. The completion of adit 4, which may develop a few thousand tons of ore below the 350-meter level, is essential. Additional ore may be found if the west drift from adit 2 is extended at least 90 meters to determine if the ore shoot in the new pit above continues downward. If the drift is driven along the zone of mineralization, enough ore may be recovered to pay for much of the cost of exploration.

### PROSPECTS BETWEEN PORTILLO AND RÍO LA PLATA

A number of manganese prospects in rocks of the Vinent(?) and Cobre formations have been denounced in the coastal strip between Puerto Portillo and Río La Plata. Production from this region has been about 3,300 tons of ore containing 39 to 46 percent manganese. Apparently ore has been shipped from only the Concha, Magdalena, Subur, and Venecia deposits.

The manganese deposits may be grouped into two general types. In the area between the Río Portillo and Río Camarón, manganese oxides and silicates are associated with lenticular masses of jasper. Psilomelane-type oxides, braunite, and manganese silicates replace tuff along contacts between jasper and tuff and also form small pockets in jasper. The largest concentration of ore is along the hanging wall of the jasper lenses, usually near or at the ends of the larger lenses. Low-grade ore may extend along the strike of the tuff for some distance from the jasper masses. These deposits resemble many deposits elsewhere in the province.

Between Río El Macho and Río La Plata, manganese silicates and minor amounts of oxides occur in beds of red argillaceous and tuffaceous limestone and calcareous argillite of the Vinent formation(?). A little dark manganiferous jasper is found in the deposits. Braunite, several unidentified manganese silicates, and a little psilomelane-type oxide replace the calcareous rocks. The manganese-calcium silicate inesite is a minor mineral at the Estrella del Norte prospect. In some deposits an entire bed may be replaced, in others the manganese minerals are enclosed in the thicker sections of the red rocks. The ore deposits form lenticular masses as much as a hundred meters or so long and ranging from a few centimeters to more than 1.5 meters in thickness.

The various prospects will be described by groups from west to east.

## PUERTO PORTILLO

### ISELA PROSPECT

The Isela prospect is about 2 kilometers north of Portillo. An ore zone in tuff, striking N. 60° W. and dipping 25° SW., is exposed in two small pits. Fragments of manganese oxide and jasper cover the top of a nearby hill. Insufficient work has been done to determine the value of the prospect, but the outcrops are encouraging.

### RAQUEL PROSPECT

The Raquel prospect is about 5 kilometers by trail north of Portillo bay at an altitude of 445 meters. A small opencut exposes 2 meters of manganese-oxide-bearing red tuff. A psilomelane-type oxide is the only manganese mineral; it forms irregular beds in the tuff and probably has replaced tuff to some extent. The footwall of the ore zone is jasper, which can be traced more or less continuously for 180 meters in a northerly direction.

Some of the crude ore carries as much as 35 percent manganese, but the average ore contains only about 25 percent. The prospect merits additional exploration, especially along the steep hillside on which the ore crops out, as the considerable extent of the jasper suggests that mineralization may be extensive also. The operators of the Ponupo de Manacal mine planned to explore the deposit.

### VICTORIA PROSPECT

The Victoria prospect is on land of Central Cabo Cruz near the town of Pilón. A ledge of tuffaceous sandstone containing small patches of manganese oxide and a little jasper trends N. 25° E. along the side of a hill. It is overlain by red argillite and tuffaceous limestone. The ledge seems to dip southeast. Five small cuts show the ledge to be 0.6 to 2 meters thick. Although a part of the ore is fairly high grade, most of the manganiferous material is too low in grade to mine.

## RÍO CAMARONCITA

The Camaroncito group of claims on the lower Río Camaroncito includes the San Juan, Pittsburgh, Concha, Antonia, Recompensa, and Abundancia. Only the first three of these claims were examined as apparently they are the only ones with outcrops of manganese-bearing material. Two other claims, the Carlos and Archie, at the headwaters of the Río Camaroncito, were not visited.

### CONCHA PROSPECT

The Concha prospect is 2 kilometers from the coast on a spur between the first main forks of the Río Camaroncito. The only recorded production is 120 tons of ore shipped in 1943. This ore contained 42.6 percent manganese and 9 percent silica.

A zone of jasper and manganese enclosed in tuff crops out for about 75 meters along the side of a steep hill. The zone strikes about N. 50° E. and dips 20° NW. Reddish-brown jasper forms a singe continuous lens 60 meters long and about 9 meters in maximum thickness. Thin-bedded gray to red tuffaceous shale underlies the jasper and a whitish-gray massive tuff overlies it. Both jasper and manganese ore pinch out at either end of the outcrop.

Manganese oxides, largely pyrolusite pseudomorphic after psilomelane-type oxides, and unidentified manganese silicates form small scattered pockets within the jasper throughout most of the zone. At the southwest end of the jasper lens 0.4 to 0.6 meter of manganiferous jasper and manganese silicates extend for 8 or 9 meters along the bedding of the tuff. A lens of medium-grade ore, 9 to 11 meters long and 1.3 meters in maximum thickness, is exposed in a pit 15 meters from the northeast end of the outcrop; it is overlain by about 4 meters of jasper. The ore contains 35 to 40 percent manganese and consists of pyrolusite in a gangue of tuff. A northwestward-trending adit 15 meters long was driven through the ore zone.

About 40 meters west-southwest of the first adit, another adit, now caved, was driven in jasper containing small irregular pockets of manganese oxides. The jasper is 4 meters thick. An incline 14 meters to the southwest was sunk 9 meters along the footwall of the jasper. One short drift extends eastward on jasper. Only small irregular pockets of low-grade ore are exposed in both surface and underground workings.

The only minable ore is near the northeast end of the zone. Reserves total only a few hundred tons.

### PITTSBURGH PROSPECT

The Pittsburgh prospect is near the trail between Río Camaroncito and Río Camarón about 1 kilometer from the coast. The deposit may actually be on the Antonia or the Recompensa claim.

A low-grade ore bed forms an outcrop 30 to 45 meters long. The bed strikes north to N. 15° E. and dips 25° W., parallel to the bedding of the enclosing tuffs. This ore zone conceivably could be a continuation of the San Juan ore zone (see below) although mineralization between the outcrops is probably not continuous. One inclined adit is driven 9 to 12 meters westward on the mineralized zone.

Unidentified impure manganese silicates, braunite, and black calcite are present in the mineralized zone but all of the material is too low in grade to mine. No ore has been produced.

### SAN JUAN PROSPECT

The San Juan prospect is on the west side of the Río Camaroncito valley less than 1 kilometer from the coast. A jasper and manganese zone enclosed in well-bedded tuff crops out along the north side and top of a southeastward-trending spur. The tuff strikes N. 20° E. and dips 30° W. Lenses of hard reddish-brown jasper as much as 9 meters thick are traceable from the lowermost exposure on the north side of the spur at an altitude of 45 meters to the top of the spur 120 meters south at an altitude of 90 meters.

Several pits along the ore zone show impure manganese silicates, braunite, and some psilomelane-type oxides along the hanging wall contacts of the jasper, mainly at or near the ends of the larger jasper lenses. In general the ore is thin and low grade, possibly containing 30 to 40 percent manganese.

The first pit, at the north end of the zone, exposes a jasper mass 10 meters thick, that apparently lenses out completely on the west wall of the pit in a distance of less than 6 meters. The overlying tuffs are domed up over the jasper; some of the tuff beds are cut out over the jasper lenses along small faults caused apparently by differential compaction. Less than a meter of low-grade manganese ore and manganiferous tuff is concentrated where the jasper pinches out. An adit has been driven 9 meters in a southerly direction approximately along the strike of the mineralized bed.

Surface exposures near the pit indicate that the mineralized tuff pinches out a short distance downdip, but to the southeast the jasper zone appears to be more or less continuous. Another pit, now partly caved and about 12 meters southwest of the first, exposes a thin low-grade mineralized zone on the hanging wall of the same jasper mass. A third pit about 70 meters farther east shows a lens of jasper 6 meters thick that contains a few small pockets of ore. A small amount of low-grade ore lies on the dumps of several other small pits on the hanging wall of the jasper zone.

Reserves are only a few hundred tons of siliceous and calcareous ore containing 30 to 40 percent manganese.

### RÍO CAMARÓN

The claims on the Río Camarón, 3 kilometers east of Río Camaroncito, include the Belén and the Bruja (0.7 and 1.5 kilometers respectively from the coast) and a third denouncement about 3 kilometers from the coast. Apparently no work has been done on the Belén and Bruja claims.

### CAMARÓN PROSPECT

The Camarón prospect is on the southeast side of the large basin at the head of Río Camarón. The deposit lies at an altitude of 430 meters above sea level and is reached by a steep trail up the east side of the Río Camarón valley. As far as is known, no ore has been shipped from the property although some exploration work has been done.

One small pit exposes large boulders of red jasper, black manganiferous jasper, and low-grade manganese oxides and silicates, in a rubble of tuff; none of the rock is in place. Another pit, 30 meters S. 15° E. and 12 meters higher, shows similar material. Apparently the deposit is a typical jasper and manganese bed that does not crop out. The attitude of the ore zone could not be ascertained. Float of ore and jasper is traceable for 90 to 100 meters east of the pits and jasper can be traced for 60 meters more. Scattered float indicates that the country rock is tuff.

About 10 tons of manganese-bearing material consisting of black partly oxidized manganese silicates, black calcite, pyrolusite, and manganiferous jasper is piled near the lower pit. The material is estimated to contain 30 to 35 percent manganese. An additional 5 to 10 tons of very siliceous ore is estimated to contain 15 to 20 percent manganese.

About 150 meters northwest of the area described above, a jasper zone more than 90 meters long crops out in a westward-trending arroyo. The jasper strikes northwest and dips 20°–30° NE. A small amount of siliceous manganese oxide float was seen. The country rock is probably tuff, although no outcrops were seen near the jasper. No work has been done on the outcrop.

All the ore on the property is of low grade and the primary manganese minerals appear to be mainly silicates. The relatively small amount of float on the surface and in shallow pits does not indicate a large reserve of even low-grade material.

## RÍO EL MACHO

El Macho group of claims is on Río El Macho and along the coast east to Río Magdalena. Fifteen claims have been denounced in this area but work has been done on only five.

### BRAZO DE FELIPE PROSPECT

The Brazo de Felipe prospect is near Río El Macho about 2 kilometers from the coast. A bed of manganiferous red limestone striking northeast crops out near the crest of a ridge. The bed is at least 1.3 to 2 meters thick. Country rock is tuff. No work had been done when the claim was seen in 1940.

## ESTRELLA DEL NORTE PROSPECT

The Estrella del Norte prospect is about 2 kilometers east of Río El Macho and 1.5 kilometers from the coast. Two and possibly three beds of manganiferous red calcareous argillite crop out along a southward-trending gully known as Arroyo Zorrito. These beds and the enclosing metamorphosed tuff lie to the north of a small mass of diorite.

A pit on the east side of the arroyo at an altitude of about 230 meters exposes a poorly defined zone of red argillite in metamorphosed tuff. Float and material on the dump near the pit indicate that braunite and manganese silicates, possibly bementite or neotocite, partly replace the red argillite. The small amount of manganiferous material on the dump is estimated to contain only 10 to 15 percent manganese.

Another pit on the west side of the arroyo 105 to 120 meters to the north is on red limestone and argillite which strike west and dip 43° S. The red rocks are 2.5 to 3 meters thick and are enclosed in well-bedded metamorphosed tuff. A zone lying about 0.6 meter below the top of the red beds is sparsely mineralized through a thickness of 1.3 meters; it is underlain by a layer of red impure hematite 30 to 45 centimeters thick. The manganiferous zone is of very low grade and is mineralogically similar to that in the first pit. About 3 meters stratigraphically below is another very sparsely mineralized zone of red argillite and agglomerate about 1.3 meters thick.

A third pit on the west side of the arroyo about 300 meters N. 30° E. of the second pit exposes a low-grade manganiferous bed 0.6 to 1 meter thick. The bed is underlain and overlain by well-bedded red impure limestone that strikes N. 85° E. and dips 43° S. Medium- to coarse-grained tuff crops out in the arroyo above and below the pit. The mineralized zone contains small irregular pockets of braunite-silicate ore. A small sample of some of the better material from the dump assayed 38.50 percent manganese, 10.90 percent silica, and 1.57 percent iron.

Manganese minerals include a finely crystalline bluish to steel-gray mineral identified tentatively as braunite, lavender-pink to brownish-pink inesite in clusters of radiating acicular crystals, and a dense brown unknown manganese silicate.

The prospects of finding any quantity of saleable ore on the Estrella del Norte claim appear to be very poor, although several thousand tons of manganiferous material containing less than 20 percent manganese may be present in the area.

### IGUALADA PROSPECT

The Igualada prospect is 2 kilometers east of Río El Macho and about 250 meters north of the coast. No ore has been produced from the property but some exploration work has been done along a sparsely mineralized bed of red limestone and hematite intercalated in tuff. The strata strike N. 85° E. and dip 58° S. Black calcite, together with a little pyrolusite possibly derived from the calcite, occurs in very small amounts near the footwall of the ore zone. The primary manganese minerals are not known.

One pit about 2.5 meters deep shows sparse manganese oxides and calcite at the base of a layer of siliceous red hematite about 2 meters thick. The hematite is overlain by red hematitic limestone at least 3 meters thick and is underlain by medium- to coarse-grained brown tuff. Another pit 30 meters to the east is on the continuation of the same zone but likewise shows no minable ore.

### EL MACHO PROSPECT

El Macho prospect is near the coast about 1 kilometer east of Río El Macho. A wedge of red to chocolate-colored manganiferous limestone lying between two intersecting fractures is exposed in a small cut. The limestone is underlain by decomposed coarse-grained diabase. Considerable red jasper is associated with the limestone. No ore was seen.

### MARTÍ PROSPECT

The Martí prospect is near the coast 3 kilometers east of Río El Macho. A considerable amount of manganese oxide float and a small outcrop of jasper cut by veinlets of manganese oxide were seen. No work has been done.

### PALITO PROSPECT

The Palito prospect is about 750 meters northeast of the Igualada prospect at an altitude of 150 meters above sea level. No production is recorded but a small amount of ore may have been mined and shipped.

Low-grade ore occurs along two zones of red argillite in tuff and agglomerate, which strike N. 30° W. and dip 60° SW. A trench about 45 meters long on the lower zone exposes 1 to 1.3 meters of red argillite that is partly replaced by braunite and manganiferous jasper. The footwall of the manganese-bearing zone is a greenish-black highly sheared agglomerate; the hanging wall is a greenish-gray indurated tuff. Near the west end of the pit an incline of unknown depth has been sunk on the mineralized bed.

The upper bed is separated from the lower by about 5 meters of tuff. It is about 2 meters thick and is similar in character to the lower bed. It has been explored by a short trench.

A few pockets of fair ore were seen in both mineralized zones but the prospects of finding any considerable tonnage appear to be poor.

#### VENECIA MINE

The Venecia mine is on the southwest side of Río El Macho about one kilometer from the coast. Total production from the mine is 260 tons. According to report 240 tons of the ore contained an average of 18 percent silica; the manganese content is not known. In November and December 1942, 20 tons of ore containing 39 to 42 percent manganese and 11 to 13 percent silica was mined and shipped.

The ore deposit crops out at an altitude of 60 meters above sea level and 30 meters above the floor of El Macho valley. The manganiferous zone is developed by pits and adits along a total outcrop length of 85 meters. It appears to be a fairly continuous bed ranging from 0.6 to 2.2 meters in thickness. The bed lies parallel to the enclosing tuffs beds, which strike approximately north and dip 27° W.; toward the north end the strike trends northeast. Well-bedded tuffs and massive coarse agglomeratic tuffs underlie and overlie the manganiferous bed.

The chief ore mineral is braunite. Small amounts of a black to brown manganese silicate or manganiferous jasper also are present, with a little blue-gray crystalline pyrolusite which is probably secondary. A hard brown calcareous material is the chief gangue of the ore; the manganese minerals occur as bands and irregular nodules within the matrix.

The mine workings consist of pits and adits. An adit 25 meters long is driven northwestward from a large pit at the southwest end of the ore zone. From 0.6 to 1.0 meter of low-grade calcareous and siliceous ore is exposed in the pit and throughout the length of the adit. A 6-meter shaft sunk in the floor of the pit near the portal of the adit is in tuff. A section in the pit from bottom to top consists of: soft massive gray tuff, 1.0 meter of low-grade calcareous and siliceous ore, 18 centimeters of hard manganiferous tuff, 0.5 meter of red and gray platy tuff, 0.5 meter of silicified, calcareous, and manganiferous tuff, 1 to 1.3 meters of red and gray bedded tuff, and coarse agglomeratic tuff.

The second pit, 25 meters northeast of the first, was dug about 3 meters below the level of the lowest manganiferous bed; an adit trending N. 75° W. from the pit apparently intersects the northwestward-dipping zone. The manganiferous bed is about 1.0 meter thick.

A third pit 40 meters N. 20° E. of the second was driven northwestward through surface rubble to the ore zone. An adit of unknown length explores a manganiferous bed 1.5 meters thick. Only 0.3 meter of the bed at the hanging wall is ore. A normal fault, striking N. 10° W. and dipping 55° W., cuts the manganiferous zone at the portal of the adit; the displacement on the fault is not known but is believed to be small.

About 15 meters farther north a pit, 6 meters long and 8 meters wide, exposes a low-grade manganiferous bed, which is 2.3 meters thick near the middle of the pit but only 0.6 to 1.0 meter thick at the sides. A westward-trending adit was driven in green tuff below the ore bed to intersect the downdip extension of the bed 5 or 6 meters from the portal. The ore is overlain by 1.6 to 2 meters of greenish-gray tuff and thin-bedded limy tuff.

Reserves are estimated at several hundred tons indicated and a few thousand tons inferred. Mine-run ore will contain 25 to 30 percent manganese. Some of the ore can be hand sorted and cobbed to give a concentrate containing about 40 percent manganese and 10 to 15 percent silica, but such an operation probably would not be economic. Because of the intimate association of ore and gangue, concentration by milling probably would be difficult and expensive.

### RÍO MAGDALENA

Only one claim was examined in the Río Magdalena area. Other claims are said to be denounced, but whether or not manganese occurs on them could not be ascertained.

#### MAGADALENA MINE

The Magdalena mine is on the east side of the Magdalena valley, about 1 kilometer N. 30° E. of the river mouth. According to confirmed report, 3,000 tons of ore containing 40 to 45 percent manganese was shipped from the property in 1926–27. Since then the mine has been idle and all of the principal mine workings are caved and inaccessible.

Surface and underground workings indicate that ore is localized in one and possibly two red argillite beds in tuff. The rocks strike N. 20° W. and dip 35°–65° NE. The main workings, from which all of the ore is reported to have come, are in the bottom of a small gully. They consist of a caved pit and a caved and inaccessible adit that was driven northeastward to intersect the downdip projection of the ore zone below the pit. Manganese minerals in the dump near the adit include braunite, coarsely crystalline hausmannite, and some unidentified manganese silicates. Gangue is calcite and calcareous red to brown argillite. A considerable quantity of reddish steel-gray crystalline specularite is associated with the manganese minerals.

A sample of ore from the dump assayed 39.92 percent manganese, 16.84 percent silica, and 1.51 percent iron.

About 90 meters northwest of the arroyo, a pit 8 meters long and 5 meters deep follows a very sparsely mineralized bed of brecciated red argillite 1.0 meter thick. The bed strikes N. 40° W. and dips 35° NE. An adit at the south end of the pit follows the ore zone.

Another open pit 30 meters to the southwest has been sunk on a bed of red argillite that strikes N. 40° W. and dips 60° NE. The argillite bed is 0.6 to 1.0 meter thick and is enclosed in tuff. It contains a small amount of very low grade manganiferous rock in which a little braunite can be recognized. This bed may be the faulted extension of the bed to the northeast but more likely is a second parallel bed. An adit at the north end of the pit is inaccessible; another west of the pit, apparently driven to intersect the downdip extension of the manganiferous bed under the pit, is likewise inaccessible.

The extent and character of the original deposit cannot be determined and no ore reserves can be estimated. Inasmuch as the mine produced a considerable amount of fair ore, it may well merit additional exploration to determine if ore extensions exist.

## RÍO LA PLATA

### SIGLO VEINTE PROSPECT

The Siglo Veinte prospect is the only known occurrence of manganese on Río La Plata. The deposit is about 4 kilometers from the coast on a steep ridge between Arroyo Manacas and Arroyo Grande on the east side of the river. A hematitic jasper zone crops out at an altitude of 440 meters on the west side of the ridge near the top. The jasper is 1.5 to 3 meters thick and is traceable for 40 meters along the outcrop. Massive fine-grained andesitic flow rocks crop out above and below the deposit, but the rocks at the contacts are concealed.

Manganese oxides and silicates, including braunite(?), bementite or neotocite, and impure secondary oxides, are concentrated in small irregular pockets near the base of the jasper. At one place 1.3 meters of very siliceous ore, containing possibly 25 percent manganese, crops out at the hanging wall of the jasper zone. A lens of jasper about 3 meters thick and 15 meters long crops out on the southeast slope of the ridge about 60 meters from the outcrop described above. The two outcrops of jasper probably lie along the same horizon. Very little manganiferous material is exposed. Practically no ore is in sight or expectable anywhere on the claim.

428472—58——19

## LITERATURE CITED

Allende, Roque, 1923, Estudio técnico de los yacimientos minerales de Isla de Pinos: Dirección de Montes y Minas, Habana, Bol. Minas no. 7, p. 51–67.

——— 1927, Yacimientos minerales de la República de Cuba; cobre: Dirección de Montes y Minas, Habana, Bol. Minas no. 11, 148 p.

——— 1928, Yacimientos piritosos de la Sierra de Trinidad, Mina "Carlota": Dirección de Montes y Minas, Habana, Bol. Minas no. 12, p. 50–58.

——— 1935, Breves noticias del cobre en Cuba *in* Copper resources of the world, p. 425–433: Internat. Geol. Cong., 16th sess., Washington, D. C.

Andersen, R. and Flett, J. S., 1903, Report on the eruptions of the Soufrière in St. Vincent in 1902 and on a visit to Montagne Pelée in Martinique: Royal Soc. London, Philos. Trans. ser. A-200, p. 353–553.

Bennet, H. H. and Allison, R. V., 1910, The soils of Cuba: Tropical Plant Research Foundation, Washington, D. C., 410 p.

Bermúdez, P. J., 1950, Contribución al estudio del Cenozoico Cubano: Memorias de la Sociedad Cubana de Historia Natural, v. 19, No. 3, p. 205–375.

Brown, B. and O'Connell, M., 1922, Correlation of Jurassic deposits of Cuba: Geol. Soc. America Bull., v. 33, p. 639–664.

Buddington, A. F., 1926, Submarine pillow lavas of southeastern Alaska: Jour. Geology, v. 34, p. 824–828.

Burchard, E. F., 1920, Manganese ore deposits in Cuba: Am. Inst. Min. Met. Engineers Trans., v. 63, p. 51–104.

Calvache, Antonio, 1944, Historia y desarrollo de la minería en Cuba: Habana, 170 p.

Cooke, C. W., 1921, New names for West Indian Tertiary pectens: Nautilus, v. 34, p. 137.

Darton, N. H., 1926, Geology of the Guantánamo basin, Cuba: Washington Acad. Sci. Jour., v. 16, p. 324–332.

DeGolyer, E. L., 1918, The geology of Cuban petroleum deposits: Am. Assoc. Petroleum Geologists Bull., v. 2, p. 133–167.

Dickerson, R. E. and Butt, W. H., 1935, Cuban Jurassic: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 116–118.

Fenner, C. N., 1923, The origin and mode of emplacement of the great tuff deposit in the Valley of Ten Thousand Smokes: Natl. Geog. Soc., Tech. Paper, Katmai Series, no. 1, 74 p.

Fernández de Castro, D. Manuel, 1865, Estudio sobre las minas de oro de la isla de Cuba: Habana, 105 p.

Fleischer, Michael and Richmond, W. E., 1943, The manganese oxide minerals: a preliminary report: Econ. Geology, v. 28, p. 269–286.

Flint, D., Albear, J., and Guild, P. W., 1948, Geology and chromite deposits of the Camagüey district, Camagüey province, Cuba: U. S. Geol. Survey Bull. 954–B, p. 39–63.

Hayes, C. W., Vaughan, T. W., and Spencer, A. C., 1901, Report on a geological reconnaissance of Cuba: Civil report of Brig. Gen. Leonard Wood, Military Governor of Cuba.

Hewett, D. F., and Shannon, E. V., 1921, Orientite, a new hydrous silicate of manganese and calcium from Cuba: Am. Jour. Sci., 5th ser., v. 1, p. 491–506.

Hoffmeister, J. E., Ladd, H. S., and Alling, H. L., 1929, Falcon Island: Am. Jour. Sci., 5th ser., v. 18, p. 461–471.

Imlay, R. W., 1942, Late Jurassic fossils from Cuba and their economic significance: Geol. Soc. America Bull., v. 53, p. 1417–1477.

Jaggar, T. A., 1931, Volcano letter no. 332: Honolulu.

——— 1947, The origin and development of craters: Geol. Soc. America Memoir 21, 508 p.

Kania, J. E. A., 1929, Precipitation of limestone by submarine vents, fumaroles, and lava flows: Am. Jour. Sci., 5th ser., v. 18, p. 347–359.

Keijzer, F. G., 1945, Outline of the geology of the eastern part of the Province of Oriente, Cuba (E. of 76° W. L.) with notes on the geology of other parts of the island: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks ser. 2, no. 6, p. 1–239.

Kemp, J. F., 1915, The geology of the iron-ore deposits in and near Daiquiri, Cuba: Am. Inst. Min. Engineers Trans., v. 53, p. 3–39.

Koto, B., 1916, The great eruption of Sakurajima in 1914: Imp. Univ. Tokyo, Jour. Coll. Sci., v. 38, Art. 3, p. 1–287.

Kuenen, Ph., 1935, Submarine slopes of volcanoes: Snellius expedition in the eastern part of the Netherlands East Indies, v. 5, pt. 1, 124 p.

Lewis, G. E., and Straczek, John A., 1955, Geology of south-central Oriente, Cuba: U. S. Geol. Survey Bull. 975–D, p. 171–336.

Lewis, J. W., 1932, Geology of Cuba: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 533–555.

Lindgren, W. and Ross, C. P., 1916, The iron deposits of Daiquiri, Cuba: Am. Inst. Min. Engineer Trans. 53, p. 40–66.

MacGillavry, H. J., 1937, Geology of the province of Camagüey, Cuba, with revisional studies in rudist paleontology: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks, no. 14, 169 p.

Marrero, Levi, 1946, Elementos de Geografía de Cuba: La Habana, 540 p.

——— 1951, Geografía de Cuba: La Habana, 736 p.

Massip, S., and Ysalgue de Massip, S., 1942, Introducción a la geografía de Cuba: La Habana, 250 p.

Meinzer, O. E., 1933, Geological reconnaissance of a region adjacent to Guantánamo Bay, Cuba: Washington Acad. Sci. Jour., v. 23, p. 246–263.

Metcalf, R. J., 1932, Discussion of Cuban Jurassic: Am. Assoc. Petroleum Geologists Bull., v. 16, p. 555.

Norcross, F. S., Jr., 1940, Development of the low-grade manganese ores of Cuba: Am. Inst. Min. Engineers Tech. Paper 1188, 13 p.

Page, L. and McAllister, J., 1944, Tungsten deposits, Isla de Pinos, Cuba: U. S. Geol. Survey Bull. 935–D, p. 177–246.

Palmer, R. H., 1934, The geology of Habana, Cuba, and vicinity: Jour. Geology, v. 42, p. 123–145.

——— 1945, Outline of the geology of Cuba: Jour. Geology, v. 53, p. 1–34.

Park, C. F., Jr., 1942a, Manganese deposits of Cuba: U. S. Geol. Survey Bull. 935–B, p. 75–97.

——— 1942b, Manganese resources of the Olympic Peninsula, Wash., a preliminary report: U. S. Geol. Survey Bull. 931–R, p. 435–457.

——— 1946, The spilite and manganese problems of the Olympic Peninsula, Wash.: Am. Jour. Sci., v. 244, p. 305–323.

Park, C. F., Jr., and Cox, M. W., 1944, Manganese deposits in part of the Sierra Maestra, Cuba: U. S. Geol. Survey Bull. 935–F, p. 307–355.

Perret, F. A., 1935, The eruption of Mt. Pelée, 1929–1932: Carnegie Inst. Washington Pub. 458, 126 p.

Roesler, M., 1917, Geology of the iron-ore deposits of the Firmeza district, Oriente Province, Cuba: Am. Inst. Min. Engineers Trans., v. 56, p. 77–127.

Ross, Clyde P., 1935, Copper in the West Indies and Central America: Copper resources of the world, p. 435–441: Internat. Geol. Cong., 16th sess., Washington, D. C.

Rutten, L. M. R., 1934, Geology of Isla de Pinos: Proc. Kon. Akad. Wetensch. Amsterdam, v. 37, p. 401–406.

Rutten, M. G., 1936, Geology of the northern part of the province of Santa Clara, Cuba: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks, no. 11, 60 p.

Sagra, Ramón de la, 1842, Historia física, política, y natural de la isla de Cuba: v. 1, p. 60–76, Paris.

Schuchert, C., 1935, Historical geology of the Antillean-Caribbean region, or the lands bordering the Gulf of Mexico and the Caribbean Sea: New York, John Wiley & Sons, 811 p.

Singewald, J. T., Jr., and Miller, B. L., 1916, The genesis and relations of the Daiquiri and Firmenza iron-ore deposits: Am. Inst. Min. Engineers Trans., v. 53, p. 67–74.

Spencer, A. C., 1903, Manganese deposits of Santiago, Cuba: U. S. Geol. Survey Bull. 213, p. 251–255.

——— 1908, Three deposits of iron ore in Cuba: U. S. Geol. Survey Bull. 340, p. 318–328.

Spencer, J. W. W., 1895, Geographical evolution of Cuba: Geol. Soc. America Bull., v. 7, p. 67–94.

Stearns, H. T., 1926, The Keaiwa or 1823 lava flow from Kilauea volcano, Hawaii: Jour. Geology, v. 34, p. 336–351.

Taber, S., 1931, The structure of the Sierra Maestra near Santiago de Cuba: Jour. Geology, v. 39, p. 532–563.

——— 1934, Sierra Maestra of Cuba, part of the northern rim of the Bartlett Trough: Geol. Soc. America Bull., v. 45, p. 567–619.

Thayer, T. P., 1942, Chrome resources of Cuba: U. S. Geol. Survey Bull. 935–A, p. 1–74.

Thayer, T. P., and Guild, P. W., 1947, Thrust faults and related structures in eastern Cuba: Am. Geophys. Union Trans., v. 28, p. 919–930.

Thiadens, A. A., 1937, Geology of the southern part of the province Santa Clara, Cuba: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks, no. 12, 70 p.

Torre, Carlos de la, 1910, Investigaciones paleontológicas realizadas en las Sierras de Viñales y Jatibonico: Acad. Cienc. Méd. Habana, An. Rev. Cient. 47, p. 204–217.

——— 1912, Comprobation de l'existence d'un horizon jurassique dans la région occidentale de Cuba: Internat. Geol. Cong., 11th sess., Stockholm, Compt. Rend., p. 1021–1022.

Vaughan, T. W., 1918, Correlation of the Tertiary geologic formations of the southeastern United States, Central America, and the West Indies: Washington Acad. Sci. Jour., v. 8, p. 268–276.

——— 1919, Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent coral reefs: U. S. Natl. Mus. Bull. 103, p. 189–524.

——— 1922, Stratigraphic significance of the species of West Indian fossil Echini: Carnegie Inst. Washington Pub. 306, p. 105–122.

Vermunt, L. W. J., 1937, Geology of the province of Pinar del Rio, Cuba: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks, no. 13, 60 p.

Vletter, D. R. de, 1946, Geology of the western part of middle Oriente, Cuba: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. ser. 2, no. 8, 101 p.

Washington, H. S., 1909, The Submarine eruptions of 1831 and 1891 near Pantelleria: Am. Jour. Sci., v. 27, p. 131–150.

——— 1926, Santorini eruption of 1925: Geol. Soc. America Bull., v. 37, p. 349–384.

Weld, C. M., 1909, The residual brown iron ores of Cuba: Am. Inst. Min. Engineers Trans. 40, p. 299–312.

Wentworth, C. K., 1926, Pyroclastic geology of Oahu: Bernice P. Bishop Mus. Bull. 30, 121 p.

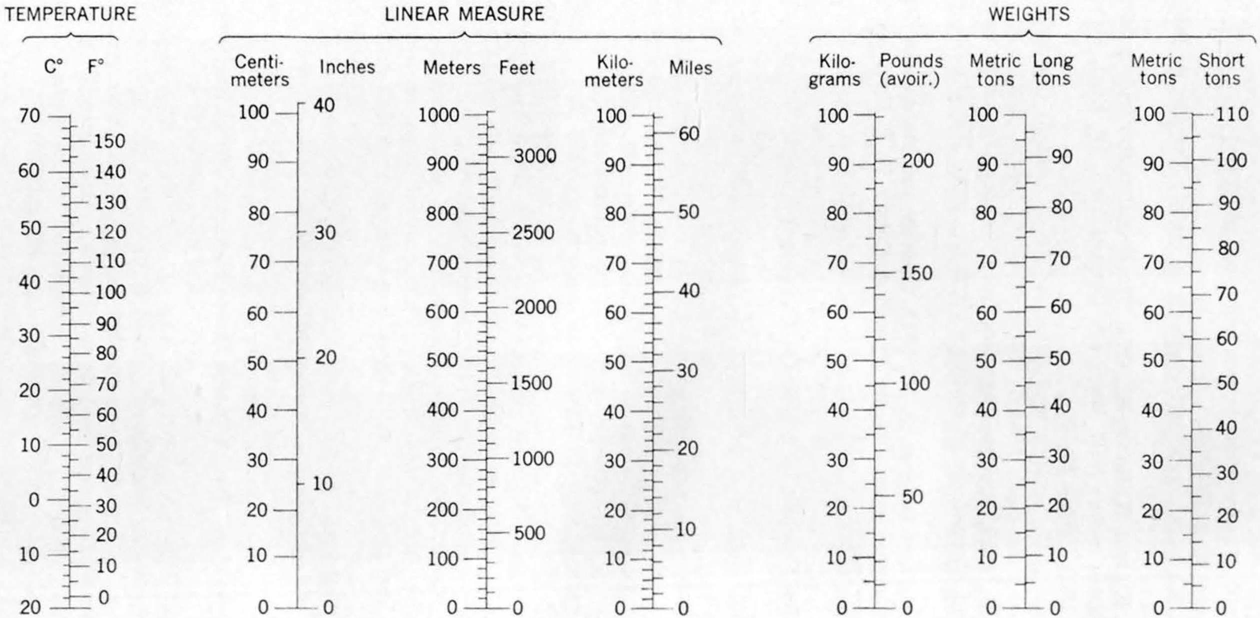
Wentworth, C. K., and Williams, H., 1932, The classification and terminology of the pyroclastic rocks: Natl. Research Council Bull. 89, Rept. Comm. Sedimentation 1930–1932, p. 19–53.

Wessem, A. van, 1943, Geology and paleontology of Central Camagüey, Cuba: Utrecht, Geog. en Geol. Meded., Physiog.-Geol. Reeks, Ser. 2, no. 5, 91 p.

Woodring, W. P., 1928, Miocene mollusks from Bowden, Jamaica; part 2, Gastropods and discussions of results: Carnegie Inst. Washington Pub. 385, p. 1–564.

Woodring, W. P., and Daviess, S. N., 1944, Geology and manganese deposits of Guisa-Los Negros area, Oriente Province, Cuba: U. S. Geol. Survey Bull. 935–G, p. 357–386.

# METRIC EQUIVALENTS




1 cm = 0.3937 inch
1 inch = 2.5400 cm

1 meter = 3.2808 ft
1 ft. = 0.3048 meter

1 km = 0.6214 mile
1 mile = 1.6093 km

1 sq. meter = 1.20 sq yd
1 hectare = 2.47 acres
1 cu. meter = 1.31 cu yd

1 kg = 2.2046 lb
1 lb = 0.4536 kg

1 metric ton = 0.9842 long ton
1 metric ton = 1.1023 short tons
1 metric ton = 2205 lb
1 long ton = 1.0161 metric tons
1 short ton = 0.9072 metric ton

# INDEX

U. S. GOVERNMENT PRINTING OFFICE: 1958