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W. E. Wrather, Director

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GEOLOGIC INVESTIGATIONS IN THE AMERICAN REPUBLICS 1941–43

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PREFACE

By W. C. Mendenhall

The Eighth Pan American Scientific Congress met in Washington in the spring of 1940. In that Congress, representatives of the various American Republics found a medium for the exchange of ideas and a common ground for the cementation of friendships. The State Department of the United States, acting through the Interdepartmental Committee on Scientific and Cultural Cooperation, recognized the role of science in pan-American relationships and sought a means for continuing the scientific intercourse fostered by the Congress. In the fiscal year of 1941, the Geological Survey, United States Department of the Interior, was allotted $25,000 for geologic investigations in cooperation with the other American Republics.

The possibility that the United States might become involved in the European war was strongly felt at the time of the Scientific Congress, and informal discussions by geologists from Argentina, Brazil, Uruguay, and Venezuela had focused attention on the strategic minerals that might be obtained from our fellow Republics to the south. It was natural, therefore, that the Geological Survey's initial move should be an evaluation of how the cooperative geological program could best serve in the procurement of strategic minerals.

In the fiscal year 1942 the allotment from the Interdepartmental Committee on Scientific and Cultural Relations was increased to $50,000 and in 1943 to $96,500. In 1943 the funds available for this work were further supplemented by allotments from the newly formed Board of Economic Warfare. As each field assignment was completed the results were immediately made available to our war agencies.

This Bulletin includes reports based upon field work done in in the years 1941-43. Later reports have been published as chapters of similar bulletins, under the same general title.

In order that the reports may be useful to the citizens of the countries in which the deposits are situated, the maps and charts carry bilingual legends—Spanish and English for Cuba, Mexico, and Costa Rica, and Portuguese and English for Brazil. Chapter C has been translated into Spanish and published as Boletín 8 of the Comité Directivo para la Investigación de los Recursos Minerales de Mexico and Chapter E has been translated into Portuguese and published as Boletin 64 of the Divisão de Fomento de Produção Mineral of the Departamento Nacional da Produção Mineral of Brazil.

In Bulletin 935 are assembled reports on nickel deposits in Brazil, manganese in Costa Rica, chromite, manganese, and tungsten in Cuba, and tin in Mexico. Of these, the chromite and manganese in Cuba were of vital importance to our Nation's war economy. Other reports represent critical evaluations of the geologic factors upon which possible productive capacity might be based. Though some deposits were found to hold little promise of important production, it was imperative that such facts be known as a basis for arriving at an over-all procurement plan. Such information forms part of the record to guide us in the economy of peace that now follows the economy of war.

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UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

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CHROME RESOURCES OF CUBA

BY

T. P. THAYER

Geologic Investigations in the American Republics, 1941–42
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CHROME RESOURCES OF CUBA

By T. P. Thayer

ABSTRACT

Total imports of Cuban chromite into the United States, (which are the best index of Cuban production), amounted to 710,069 long tons up to the end of 1940. Of this amount, about 600,000 tons came from the Camaguey district, about 100,000 tons from eastern Oriente, and about 10,000 tons from Matanzas Province. Approximately 100,000 tons was of metallurgical grade, the remainder being of refractory grade. Cuban production in 1941 filled more than half of the United States requirements for refractory ore.

The chromite deposits are irregular masses containing from a few tons to over 100,000 tons of shipping-grade ore in belts of serpentinized peridotite along the north coast for nearly the entire length of Cuba, but production has been limited to the eastern half of the island. Gabbro, troctolite, and anorthosite are associated with the peridotite, and form large masses in the Camaguey district. The chromite is closely associated with dunite, and to a lesser degree with troctolite; it is commonly cut by dikes of banded troctolite and more or less pegmatitic gabbro. Workable deposits of residual or float ore have been formed in some areas of low relief.

Pure chromite from Cuba contains from 22 to 57 percent chromic oxide (Cr_2O_3); and 9.7 to 14.4 percent iron. The high-chrome chromite therefore makes excellent metallurgical ore, with a Cr:Fe ratio of about 3.4, and the low-chrome chromite constitutes good refractory ore. Refractory ore from the Camaguey district averages 30 to 32 percent Cr_2O_3, 28 to 32 percent Al_2O_3, and about 5 percent SiO_2. The grade of the chromite is fairly constant in most districts; massive ore from Matanzas Province and the Mayari district of Oriente is consistently of metallurgical grade whereas the best massive Camaguey ore is only of refractory grade. In the other districts the massive ore is intermediate in grade, with the exception of the Sagua de Tanamo district, where the composition of the chromite varies greatly from one deposit to the next.

Shallow chrome-ore reserves are of such size that underground mining has not been necessary, and probably will not be necessary for another year or two at the present rate of production. The reserve of shipping-grade lode ore within 100 feet of the surface in the Camaguey district probably approaches 500,000 tons; the district also has a large tonnage of recoverable float ore, and an unknown but very large amount of milling ore. The known reserves of eastern Oriente are about 200,000 tons of milling and shipping-grade ore. This part of the island has not been prospected thoroughly, and new discoveries are reported from time to time. With improved methods of treatment

and underground mining, Cuban chrome production probably can be maintained at its present rate for several years.

INTRODUCTION

History and production

Chromite, also known as chrome-iron ore, was probably first mined in Cuba between 1840 and 1850 from deposits a few miles northeast of Holguin, where the old workings may still be seen. The mineral was believed to be iron ore, and when its true nature was discovered, interest in it waned. The first recorded shipment of chromite from Cuba to the United States consisted of 34 tons, exported in 1916. Under the stimulus of high war-time prices, exports to the United States jumped from 17 tons in 1917 to 14,461 tons in 1919. Although shipments fell during the postwar slump, since 1922 they have averaged about 45,000 long tons annually except in 1932, when no ore was shipped. Most of the ore shipped prior to 1926 came from the Caledonia mine, which was discovered in 1917. Mining in the Camaguey district began in 1923, and since 1926 most Cuban chromite has come from that district.

The best available statistics on production of chromite in Cuba are the figures on imports of Cuban ore into the United States, which are published by the Bureau of Mines, United States Department of the Interior, in the annual volumes on Mineral Resources of the United States, or currently in the Minerals Yearbook. These figures do not indicate the amount of ore in stock at the mines, the amount of ore consumed in Cuba, nor ore exported to other countries, but these quantities are believed to be small. Total imports of Cuban chromite into the United States up to the end of 1940 were 710,069 long tons. Of this amount, the Camaguey district yielded about 600,000 tons, Oriente Province about 100,000 tons, and Matanzas between 9,000 and 10,000 tons.

The Caledonia mine, perhaps the best known chrome mine in Cuba, was developed in 1918 and yielded about 94,000 tons before being abandoned about 1926. The Victoria mine in the Camaguey district, the most productive mine in Cuba, has yielded between 95,000 and 100,000 tons, and was still in operation in March 1941. Several mines in the Camaguey district have yielded more than 50,000 tons of shipping ore each, and about a score are credited with 10,000 or more each. Most of the ore from the Caledonia mine was of metallurgical grade, whereas ore from Camaguey is of refractory grade. The accompanying table shows the shipments of chromite from Cuba, or imports of Cuban ore into the United States.

Imports of Cuban chrome ore, in long tons, into the United States, 1916-40 1/

1916	34	1929	52,949
1917	17	1930	40,982
1918	8,821	1931	14,957
1919	14,461	1932	......
1920	710	1933	23,772
1921	600	1934	49,370
1922	1	1935	47,743
1923	10,420	1936	69,963
1924	8,145	1937	93,098
1925	29,830	1938	39,529
1926	36,020	1939	66,002
1927	16,983	1940	51,955
1928	33,707	Total	710,069

1/ **From Minerals Resources U. S. and Minerals Yearbook.**

Previous work

Geological investigations in Cuba have been mainly economic. They have been concerned directly with individual mines or mining districts, and comparatively little is known of the general geology of the island outside of those districts. Most of the results of geologic work done in the island since 1920 are unpublished.

The principal source of information on the general geology of Cuba is a reconnaissance report published in 1901 by Hayes, Vaughan, and Spencer.1/ In that report the serpentine masses along the northern coast of the island were recognized as forming the cores of eroded domical folds from which the cover of sedimentary rocks had been removed. Spencer reported chrome ore, apparently in laterite, from Moa Bay, and mentioned lode chromite associated with gabbro cutting the serpentine in Camaguey.2/ He indicated a belief that large deposits of chromite would probably be found in Camaguey, and might also be discovered in other parts of Cuba.

In 1918 Burch and Burchard 3/ studied the chrome and manganese deposits in Cuba for the United States Government to determine the possible production of these minerals during the war period. Their report was restricted to economic problems, and except for descriptions of individual deposits gave little general geologic information, though it gave an excellent account of the state of development of chrome mining in Cuba at the time it was published. The principal mines operating in Camaguey in 1928 were briefly described by Allende,4/ and in 1938 a complete list of mining denouncements in Cuba 5/ was published by the Cuban Government.

Field work and acknowledgments

This report is based on a reconnaissance of the chrome deposits in Cuba made as part of the program of investigation of

---

1/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., Report on a geological reconnaissance of Cuba: Civil Report of Brig. Gen. Leonard Wood, Military Governor of Cuba for 1901. Translation into Spanish with annotations by Pablo Ortega y Ros, Cuba Dir. Montes, Minas y Aguas, 4a Edicion, 1938. When references to both English and Spanish editions are given, the reference in Spanish will be indicated in parentheses, for example: (pag. 96).

2/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., pp. 84-85 (pag. 96).

3/ Burch, Albert, and Burchard, E. F., Chrome and manganese ores in Cuba: Cuba, Direc. Montes y Minas, Bol. Minas No. 5, pp. 57-70, 1919. Translation, Minerales de cromo y de manganeso en Cuba: idem, pp. 41-56.

Burchard, E. F., Chrome-ore deposits in Cuba: Am. Inst. Min. Met. Eng. Bull. No. 153, pp. 2523-2546, 1919.

4/ Allende, Roque, Los depositos de cromo de Camaguey: Cuba, Direc. Montes, Minas y Aguas, Bol. Minas No. 14, pp. 11-22, 1929.

5/ Estadistica Minera: Cuba, Direc. Montes, Minas y Aguas, Bol. Minas No. 17, 1938.

strategic and critical minerals, which was initiated in the United States in 1938. In 1940 this program was expanded with funds allocated by the State Department, to include similar investigations in the other American Republics. The past production and the proximity of the Cuban deposits to the United States clearly indicated that a survey of the chrome resources of Cuba should be made.

The field work for this report was done between November 15, 1940 and March 5, 1941, by the writer, who was accompanied by W. D. Johnston, Jr., of the Geological Survey, until December 8. In all, about 5 weeks were spent in the Camaguey district, and several of the larger accessible deposits were mapped in detail. Visits to most of the other districts and mines were restricted to two or three days each. The detailed maps of deposits were made on a field scale of 40 feet to an inch.

The Direccion de Montes, Minas y Aguas extended every courtesy to the writer, who takes this opportunity to express his gratitude to Sr. Jose I. Corral, Director, for making the facilities of the organization available; to Sr. Enrique Cayado, Ing. Jefe del Negociado de Minas, for maps and other information; and to Sr. Enrique Schumann, Ing. Jefe de Minas del Distrito de Oriente, whose help facilitated visits to the mines in Oriente. The writer enjoyed the full cooperation and hospitality of the mine owners, among whom officials of the Juragua Mining Co., the Compania Cubana de Minas y Minerales, the Cuban Ores Co., the Cuban American Mining Co., and Sr. J. A. Silva of Holguin deserve special mention. The kind services of Mr. R. H. Palmer as guide on trips to the mines in Matanzas and mentor in the general geology of Cuba were greatly appreciated. Space does not permit thanking individually the many Cubans whose hospitality speeded the work and made it more enjoyable, and the sugar companies who furnished transportation gratis. For discussion of geological problems and criticism of the manuscript the

author is greatly indebted to W. D. Johnston, Jr., and H. G. Ferguson of the Geological Survey. Credit is due Miss Jewell J. Glass of the Geological Survey for determination of the minerals in several specimens. Unless otherwise indicated, all chemical analyses quoted were made in the laboratory of the Geological Survey by R. E. Stevens.

Scope of the report

The purpose of this investigation was primarily economic, specifically, to secure first-hand information on the amount and grade of chromite that might be available for export from Cuba in the immediate future, and for the duration of the present world conflict. This entailed examination of all the more important known chrome districts and deposits of the island. Because time permitted detailed studies of relatively few mines, this report is chiefly reconnaissance in nature, and might be regarded as an up-to-date revision of the report by Burchard.[6] The opening of many mines and especially the development of the Camaguey district, since 1918 afforded the writer a much better opportunity to study relations of the chrome deposits, and a good deal of new information has been obtained. Only a few of the more important mines in the Camaguey, Sagua de Tanamo, and Holguin districts are described in this report, and it is hoped that these districts may be studied in more detail in the near future. A few observations on the general geology and physiography of the eastern part of Cuba are included.

GEOLOGY

General features

The chrome deposits of Cuba, like those in all other parts of the world, occur in altered ultramafic rocks, which are collectively recognized by the miner and prospector as "serpentine."

6/ Burchard, E. F., op. cit.

MINES AND DISTRICTS DESCRIBED IN TEXT

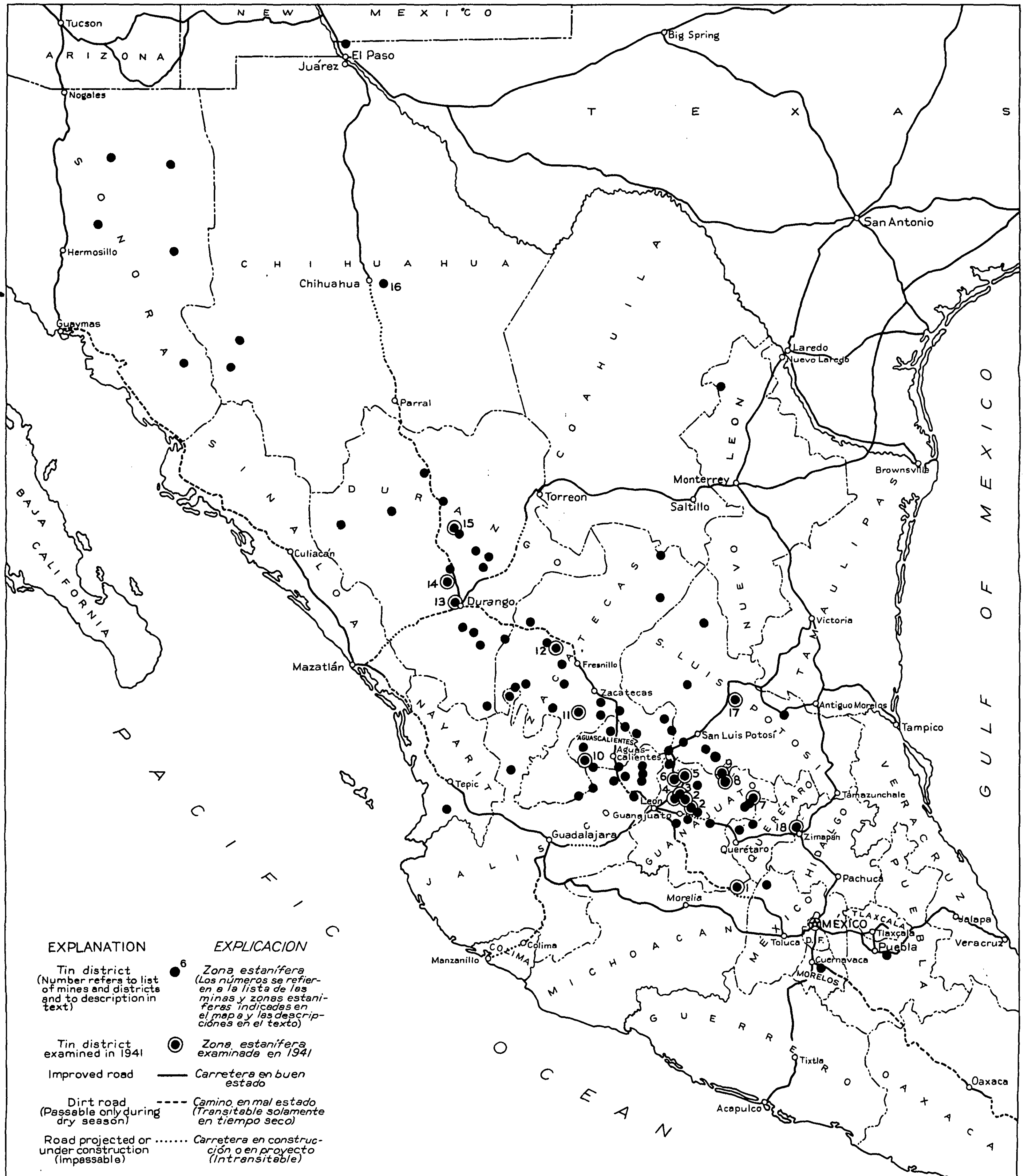
(See also table 5 in pocket)

1. Los Cabires mine
2. Dolores Hidalgo district
3. Tlachiquera district (east side)
4. Tlachiquera district (west side)
5. San Felipe district
6. Queensland mine
7. El Santín mine
8. Sauceda district
9. Jaula district
10. Calvillo district
11. La Quemada district
12. Sain Alto district
13. Cerro de los Remedios district
14. Cacaria district
15. Potrillos district
16. San Antonio mine
17. Guadalcázar district
18. Zimapán district

MINAS Y DISTRITQS DESCRITAS EN ELTEXTO

(Véase tambien la tabla numero 5, que esta en el receptaculo en el posterior parte del libre)

1. *Mina Los Cabires*
2. *Distrito de Dolores Hidalgo*
3. *Distrito de Tlachiquera (Lado oriental)*
4. *Distrito de Tlachiquera (Lado occidental)*
5. *Distrito de San Felipe*
6. *Mina Queensland*
7. *Mina El Santín*
8. *Distrito de Sauceda*
9. *Distrito de Jaula*
10. *Distrito de Calvillo*
11. *Distrito de La Quemada*
12. *Distrito de Sain Alto*
13. *Distrito de Cerro de los Remedios*
14. *Distrito de Cacaria*
15. *Distrito be Potrillos*
16. *Mina San Antonio*
17. *Distrito de Guadalcázar*
18. *Distrito de Zimapán*



MAP OF MEXICO SHOWING DISTRIBUTION OF REPORTED TIN DISTRICTS

MAPA DE MEXICO QUE INDICA LA DISTRIBUCION DE DISTRITOS DE ESTANO

50 0 50 300 Miles

100 0 100 400 Kilometros

U. S. GOVERNMENT PRINTING OFFICE: 1942 O - 480115 (faces p. 102)

The deposits are extremely irregular masses scattered at random, and fall in the category of "sack-form" deposits, which differ in many ways from the layered or "stratiform" deposits. Many examples of "sack-form" deposits along the Pacific coast of the United States have been described,[7/] and recently a description of the "stratiform" type of deposit, exemplified by the Stillwater complex in Montana, was published.[8/]

Serpentine is found throughout the entire length of Cuba in irregular belts roughly parallel to and near the north coast. It follows that the chrome deposits are in the northern part of the island. Although chromite has been reported from Pinar del Rio and Las Villas (Santa Clara) Provinces, most intense prospecting and all mining of chromite has been restricted to Matanzas, Camaguey, and Oriente (fig. 1).

The serpentine is exposed in the central portions of northwest-trending domical or anticlinal uplifts from which a cover of sedimentary rocks has been eroded. The preserpentine crystalline complex comprises schists, volcanic rocks, metamorphosed limestone, and gneissoid dioritic rocks. The serpentine also cuts slightly altered sedimentary rocks. The serpentine was formed by alteration of several intergradational yet readily recognizable types of ultramafic igneous rocks, namely, dunite, peridotite, pyroxenite, anorthosite, troctolite, and gabbro. These rocks in turn are cut by later dikes, some of which are closely associated with gold and silver deposits. Sedimentary rocks ranging in age from Upper Cretaceous to Recent [9/] lie

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7/ Strategic Minerals Investigations, 1940: U. S. Geol. Survey Bull. 922, chapters D, J, O, P, 1940-41.

8/ Peoples, J. W., and Howland, A. L., Chromite deposits of the eastern part of the Stillwater complex, Stillwater County, Montana: U. S. Geol. Survey Bull. 922-N, 1940.

9/ Rutten, M. G., Geology of the northern part of the Province of Santa Clara, Cuba: Geog. geol. Mededeel., Phys.-geol. Reeks, No. 11, p. 14, 1936. Translation by Enrique V. Perez y Jorge Brodermann, Cuba, Direc. Montes, Minas y Aguas, Bol. Minas No. 16, p. 15, 1938.

Brodermann, Jorge, Determinacion geologica de La Cuenca de Vento: Revista de la Soc. Cubana de Ing., vol. 34, No. 2, p. 310, 1940.

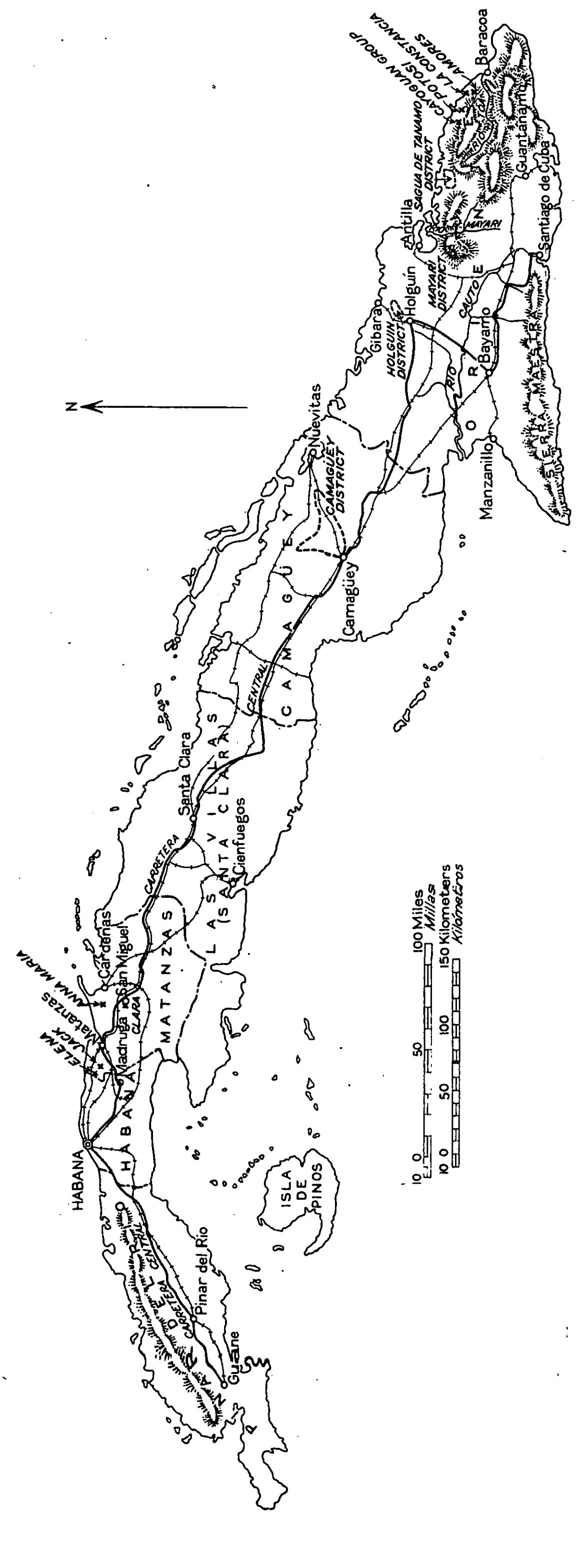

Figure 1.—Principal chrome mines and chrome-producing districts in Cuba.

unconformably on the ultramafic rocks. The serpentine masses form hills, partly because they are more resistant to erosion than the sedimentary rocks and partly because of relatively recent elevation along the axes of late Tertiary folds. In eastern Oriente relief of the warped erosion surfaces is measured in thousands of feet, and dissection of the high portions has produced very rugged topography.

Basement complex

Serpentine forms part of the crystalline basement on which the later rocks of Cuba were deposited, but, because it is the host rock of the chromite, the serpentine and allied rocks will be described separately. The sedimentary cover is so extensive and the serpentine masses so large that few exposures of the preserpentine rocks were seen in place.

Preserpentine rocks

In road cuts on the Central Highway east of Madruga in Havana Province, serpentine has been intruded into highly siliceous rocks that in places resemble altered volcanic porphyries. Along the southwestern edge of the Camaguey district the country rock is mica schist. Hayes, Vaughan, and Spencer considered "dense metamorphic and igneous rocks" in the west side of the Sierra de Nipe (see pl. 18) and in the southwest slope of the Sierra Cristal near Mayari Arriba as probably older than the serpentine.[10/]

The most extensive area of older rocks seen by the writer lies south of Navas Bay and is crossed by the trail to the Amores mine. Brecciated fine-grained diorite forms the low hills right at Navas, and metavolcanic rocks extend at least 2½ miles (4 km.) south of the bay to the north contact of the

10/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., p. 28 (pag. 30).

serpentine. About midway between Navas Bay and the serpentine contact a belt of coarse-grained dioritic-appearing rock and pegmatite half a mile (0.8 km.) wide cuts the volcanics. These volcanics consist almost entirely of massive fine-grained dark lava, and show little resemblance to the volcanic rocks of the Sierra Maestra.

Inclusions of older rocks in serpentine are extremely abundant in the Holguin district, and also occur along the northern edge of the serpentine belt southeast of Hershey, in western Matanzas. They consist of gneissic dioritic rocks, sheared volcanic rocks, hornblende and chlorite schists, crystalline limestone, and highly metamorphosed rocks of uncertain origin. The inclusions appear to have undergone very little alteration, even though the original enclosing rock has been altered to serpentine. The principal visible effect of alteration in the dark-colored dioritic inclusions is bleaching and loss of gneissic texture within a few inches of the serpentine contact, and development of veinlets of white tremolite. Microscopic study shows that in the light-colored parts diopside, tremolite, and colorless chlorite have replaced the feldspar and hornblende of the original rock. A few rounded grains of diopside were seen in the tremolite veinlets. Fine-grained hornblendic schists and volcanic rocks appear to be unaltered. One inclusion of schistose chloritic rock on the In Time denouncement in the Holguin district contains abundant native copper, a small amount of pyrite, and finely divided iron oxide. Serpentine is intrusive into crystalline limestone at the Nuevo Potosi gold mine near Holguin, and inclusions of light-colored diopside-feldspar rocks on the Angelita Silva denouncement may be altered limestones. One specimen of this altered rock was found to consist of irregular aggregates and grains of nearly pure diopside in a mosaic of fine-grained albite ($Ab_{96}An_4$), and another sample is very similar except for the presence of scalloped laths of anorthite

(Ab_5An_{95}). The albite in these rocks is clearly secondary. The close association of intrusive dioritic rocks and albitized metamorphic rocks as inclusions is regarded as good evidence that the peridotite came up through a complex of igneous and metamorphic rocks, and that some of the dioritic and granitic rocks in Cuba may be much older than the serpentine.

Ultramafic rocks or serpentine

The intrusive igneous rocks in which the chrome deposits occur may be classified collectively as ultramafic, for they contain a much higher proportion of magnesium and iron than most igneous rocks. Olivine and pyroxene are the essential primary minerals of these rocks, and chromite, magnetite, and feldspar are the most common accessory minerals. Gabbro and troctolite, which contain large amounts of feldspar, and anorthosite, which is composed entirely of feldspar, are not ordinarily regarded as ultramafic rocks. These feldspathic rocks, however, are subordinate in amount to, and very intimately associated with the true peridotitic rocks in Cuba. For convenience in description, therefore, the gabbro, troctolite, and anorthosite will be treated as varieties of ultramafic rock.

Olivine and pyroxene alter to minerals of the serpentine group, and rock in which the alteration is complete is properly called serpentine. Rocks in which the alteration is only moderately advanced are also commonly called serpentine, and it is in this broad sense that "serpentine" is used as an all-inclusive term for the true ultramafic and closely related feldspathic rocks in Cuba.

For the purposes of this report seven types of ultramafic rocks may be recognized, namely, dunite, peridotite, pyroxenite, troctolite, gabbro, anorthosite, and serpentine. Gradational variations among all these types may be found, as might be inferred from the following table:

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Essential mineral composition
of the principal ultramafic rocks found in Cuba

Rock type	Essential minerals
Dunite	Olivine.
Peridotite	Olivine, enstatite, and/or diallage.
Pyroxenite	Pyroxene, enstatite, and/or diallage.
Anorthosite	Plagioclase.
Troctolite	Olivine and plagioclase.
Gabbro	Olivine, plagioclase, and pyroxene.
Serpentine	Serpentine, formed by alteration of olivine and pyroxene.

The chrome deposits of commercial interest are most closely associated with dunite and troctolite, though accessory chromite is scattered through all the rocks.

Dunite is a uniformly dense rock which where fresh is dark gray, and where weathered ranges from reddish brown to pale yellow-green. Although little structure is visible in fresh rock, the typical mesh-structure of serpentinized olivine is usually well-defined on weathered surfaces. In this report, rocks containing 95 percent or more olivine and serpentine derived from olivine are classed as dunite.

Peridotite, although similar in appearance to dunite, is readily distinguished from it by the presence of pyroxene crystals or pseudomorphs of pyroxene that show cleavage faces and stand out on weathered surfaces. Even where all the pyroxene has been serpentinized, as at the Caledonia mine, pseudomorphs of bastite, a variety of serpentine, clearly show that the original rock was peridotite. In this report, rocks containing 5 to 95 percent of pyroxene and olivine and not more than 5 percent plagioclase are called peridotite.

Pyroxenite is a tough rock containing 95 percent or more of pyroxene, which usually is readily recognized by its prismatic form and good cleavage. The weathered surface of pyroxenite is normally very rough, and commonly resembles a mass of wood chips. Pyroxenite apparently is not abundant in Cuba, and it is found mostly as water-worn pebbles in streams.

Anorthosite was noted principally in the Camaguey district, though it also was found in eastern Oriente, and doubtless occurs elsewhere. It is a light-gray, granular, medium- to coarse-grained rock made up almost entirely of plagioclase feldspar (variety bytownite, An_{85}). The accessory minerals, which constitute 5 percent or less, consist of olivine, pyroxene, chromite, magnetite, and sulfides. Usually the ferromagnesian minerals are so alined that the rock has a banded appearance similar to that of some coarsely crystalline marbles.

Troctolite ranges in composition between anorthosite and dunite and with addition of pyroxene grades into gabbro. It therefore varies greatly in appearance. (See pls. 1 and 2.) The most common varieties are light to dark gray, depending upon the ratio of feldspar to olivine, and medium- to coarse-grained with definite gneissic structure. In places the gneissic structure is very striking, and large feldspar aggregates cause the rock to resemble augen gneiss (pl. 2, A). The very coarse grained troctolite contains feldspar grains up to an inch (2.5 cm.) across, with olivine grains of comparable size, and is analogous in its occurrence to pegmatite in more acid rocks. The pegmatitic facies show little or no gneissic structure. (See pl. 2, B.) Troctolite dikes, which cut many of the chrome bodies in the Camaguey district, usually show well-developed banding parallel to the walls, even where only a few inches wide (pl. 6). Weathered surfaces of troctolite are commonly very rough and cavernous, because the olivine breaks down rapidly whereas the feldspar remains almost unaffected by weathering processes. In this report only rocks composed essentially of olivine and plagioclase, containing less than 5 percent pyroxene and more than 5 percent each of olivine and plagioclase, are classed as troctolite.

Gabbro associated with ultramafic rocks in Cuba shows variations similar to those in troctolite, for the two rock types differ only in pyroxene and olivine content. Most gabbros, however, may be recognized readily by the presence of green diallage or other pyroxene with good cleavage or parting. Pegmatitic gabbro commonly contains crystals of pyroxene 5 centimeters or more in length.

The field work done so far in Cuba does not permit an accurate estimate of the proportions of the various ultramafic rock types, but it is safe to say that partly serpentinized peridotite originally containing between 15 and 25 percent of pyroxene is the predominant rock. Gabbro, troctolite, and anorthosite, in order of decreasing abundance, are very common and form large masses in the Camaguey district. Dunite is widely distributed, though the size of the bodies is known in but few places. Pyroxenite seems to be rare.

Most of the ultramafic rocks are partly and some are completely altered. Anorthosite and some gabbro are the only really fresh rocks. Residual olivine was found in most of the rocks, and pyroxene, especially diallage, normally is fairly fresh. Serpentine is the principal secondary mineral in dunite and peridotite, and on the average forms well over half the rock. The feldspathic rocks alter to serpentine and chalky-white material consisting of a mixture of colorless amphibole probably near edenite in composition, zoisite, zeolites, and some anthophyllite. In troctolite alteration of the feldspar commonly is much more advanced than serpentinization of olivine.

In most places primary igneous structures are so well preserved that the original rock type can be recognized. At the Caledonia mine, for example, the contact between dunite and peridotite may be traced without difficulty even though much of the country rock has been completely serpentinized.

Most of the ultramafic rocks are massive and homogeneous. The peridotite in the Sierra de Nipe is remarkably uniform, shows relatively little shearing, and is as massive as many granites. Banding indicative of rude layering is usually revealed in feldspathic facies by variations in the proportion of feldspar and dark minerals, and in parts of Camaguey and eastern Oriente it is conspicuous. In Camaguey the minor banding in troctolite and gabbro is parallel to the trend of zones of anorthosite and dunite, and the lateral contacts of major zones and minor bands alike are gradational. Folding and contortion of bands has occurred in a few places.

Feldspar-free ultramafic rocks occur throughout the length of Cuba, but gabbro, troctolite, and anorthosite appear to be more restricted in distribution. Hayes, Vaughan, and Spencer found gabbro at several localities in Las Villas (Santa Clara), in Camaguey, and in the Sierra de Nipe in Oriente.11/ They indicated that the gabbro is considerably younger than the serpentine.

From brief perusal of the literature and cursory inspection of the serpentine belts in Matanzas, it seems probable that gabbro and related calcic rocks occur mainly as dikes and not as large masses in the three western Provinces. In Camaguey gabbro and troctolite are widely distributed, and pieces were found on the dumps of nearly all the mines in the Camaguey district. Troctolite is probably more abundant than gabbro in Camaguey, whereas in Oriente gabbro seems more common. Comparatively speaking, gabbro is rare in the Holguin, Mayari, and Sagua de Tanamo districts in Oriente, but in the vicinity of the Cayoguan, Potosi, and La Constancia mines exposures of gabbro and troctolite are numerous.

The writer believes that the various rock types were intruded essentially simultaneously, and that the banding is a result of magmatic flow. Prevalence of troctolite and gabbro dikes shows that some of the feldspathic rocks were the last to crystallize, though the presence of pegmatitic facies and

11/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., pp. 25-28 (pag. 26, 30).

absence of chilled margins indicates that the dikes were intruded while the main mass was near the temperature of crystallization of calcic plagioclase, pyroxene, and olivine.

Postserpentine dikes

Dike rocks that cut the serpentine include diorite, gabbro, diabase, and many varieties of volcanic rocks. The close relationship of the gabbro to the ultramafic rocks has been indicated, and only two other rock types will be mentioned here.

Irregular dikes and masses of white, medium-grained albitite were noted on the Guaco and La Caridad (La Caridad near Cromo) denouncements in Camaguey, and other masses undoubtedly will be found. This rock is composed of nearly pure albite and contains a few wisps of actinolite. The masses on La Caridad denouncement are as much as 50 feet (15 m.) across, whereas the occurrence on the Guaco is a sinuous irregular dike at least 150 feet (50 m.) long, ranging in width from 1 to 3 feet (0.3 to 1 m.).

The gold deposits at the Reina Victoria mine near Holguin, which are reported to have produced about a million dollars in gold, occur in dikes of dacite porphyry that cut the serpentine. These dikes are very numerous; they are as much as 300 feet (100 m.) in width, and individual dikes have been traced for distances of 4 to 5 kilometers. They dip 45° to 70° N. and strike N. 60°-70° E., parallel to the trend of other regional structures. The rocks are millimeter-grained medium- to light-gray porphyries containing labradorite and pyroxene phenocrysts in a fine-grained matrix of oligoclase and quartz. Augite apparently was the only pyroxene in the lighter facies whereas the darker facies contains many pseudomorphs of anthophyllite, probably after hypersthene. All the ferromagnesian minerals are partly altered to chlorite. The gold mineralization accompanied silicification and pyritization which was apparently localized within the dikes and had very little effect on the serpentine.

These dikes, unlike those of gabbro, have dense fine-grained chilled margins.

GEOLOGY OF THE CHROMITE DEPOSITS

The only economic source of chromium is chromite, a mineral which is black in hand specimen, is usually nonmagnetic or weakly magnetic, and which yields a brown powder when scratched. In Cuba, workable chromite deposits are of two kinds: (1) Primary deposits in dunite or closely related rocks, and (2) secondary accumulations of chromite on the surface, left principally by chemical weathering of serpentine.

Primary ore may range from almost pure massive chromite to country rock containing a small percentage of chromite. Residual or float ore usually contains a certain amount of lateritic soil and weathered serpentine. The character of crude chrome ore, whether primary or float, is therefore based on a combination of three factors, namely: (1) Composition of the chromite, (2) composition of the gangue, and (3) proportions of chromite and gangue. These three factors must be considered carefully in any systematic attempt to devise methods for treatment and utilization of chrome ore.

Primary deposits

Mineralogy

Although in most mineralogical texts the chemical composition of chromite is given as $FeCr_2O_4$ or $FeO.Cr_2O_3$, the formula of commercial chromite is best written $(Fe,Mg)O.(Cr,Al,Fe)_2O_3$. Pure iron chromite ($FeO.Cr_2O_3$) is very rare in nature, if it occurs at all, and probably should be regarded primarily as a theoretical end member of the spinel group. Analyses of Cuban chromite (tables 1 and 2) indicate both a wide variation in content of Cr_2O_3 and Al_2O_3 and a complementary relation of these two oxides. Although the percentage of Cr_2O_3 ranges from 22.31

to 56.89, and the percentage of Al_2O_3 ranges from 13.77 to 44.73, the total weight percent of the two oxides ranges between 65.97 and 70.66. The percentages of MgO and total iron oxides are approximately equal, regardless of the variation in content of Cr_2O_3 and Al_2O_3. Cuban chromite may be regarded as consistently rich in the spinel ($MgO.Al_2O_3$) molecule, and deficient in the magnetite ($FeO.Fe_2O_3$) molecule. For this reason pure Cuban chromite is admirably suited for refractory use, even though the Cr_2O_3 content only averages about 35 percent. The high-grade chromite from Matanzas and Oriente is very desirable for metallurgical use because of its low iron content when the amount of admixed gangue is not excessive.

Table 1.--Analyses of chromite concentrates and chrome ore from Cuba

	1	2	3	4	5	6
Cr_2O_3	56.89	41.78	35.60	35.21	22.31	36.20-36.53
Al_2O_3	13.77	26.70	30.37	32.21	44.73	28.29-28.84
Fe_2O_3	1.27	3.16	3.65	2.83	7.04	Not det.
FeO	13.44	11.33	13.04	12.11	7.22	14.63-14.92
MgO	14.42	16.15	16.14	16.89	17.04	16.06-16.30
MnO	.17	.11	.15	.13	.16	Not det.
TiO_2	.13	.31	.63	.31	.20	Not det.
CaO	.12	.14	.28	.28	.14	.24- .38
SiO_2	.32	.68	.52	.24	.60	2.25- 2.57
H_2O	Trace	Trace	Trace	Trace	.86	.61- .99
	100.21	100.36	100.38	100.21	100.30	
Cr	38.93	28.59	24.37	24.10	15.26	24.9
Fe	11.34	11.01	12.68	11.39	10.53	11.5
Cr:Fe	3.44	2.60	1.92	2.12	1.45	2.2

1. Concentrate from Caledonia mine, Mayari district. R. E. Stevens, analyst.
2. Concentrate from Clemencia mine, Holguin district. R. E. Stevens, analyst.
3. Concentrate from Guillermina mine, Camaguey district. R. E. Stevens, analyst.
4. Concentrate from Aventura mine, Camaguey district. R. E. Stevens, analyst.
5. Concentrate from float ore from Carne Soltas mine, Camaguey district. R. E. Stevens, analyst.
6. Maximum range in composition of four shipments of ore totalling about 8,500 tons from the Narciso mine of the Cayoguan group. Sampled and analyzed by Booth, Garrett, and Blair.

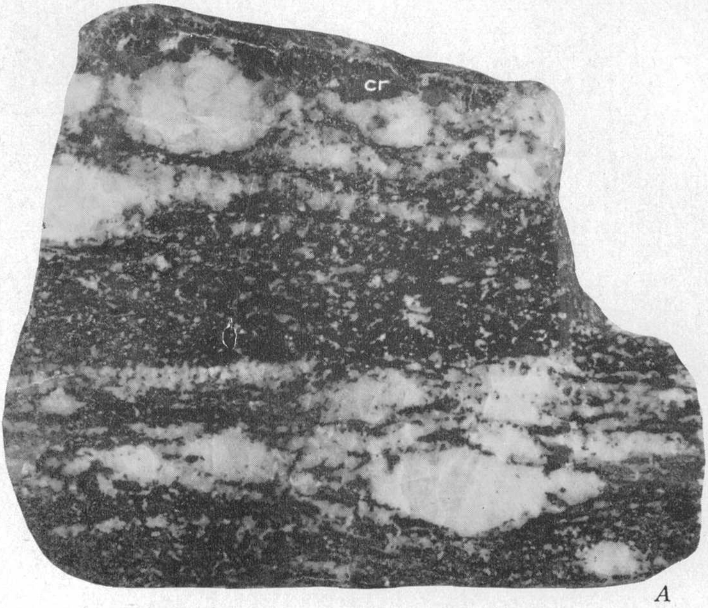
As most chrome deposits are in serpentinized dunite, serpentine is the most common gangue mineral. Serpentine, olivine, and bytownite form the gangue at the Guillermina mine, and dikes

A

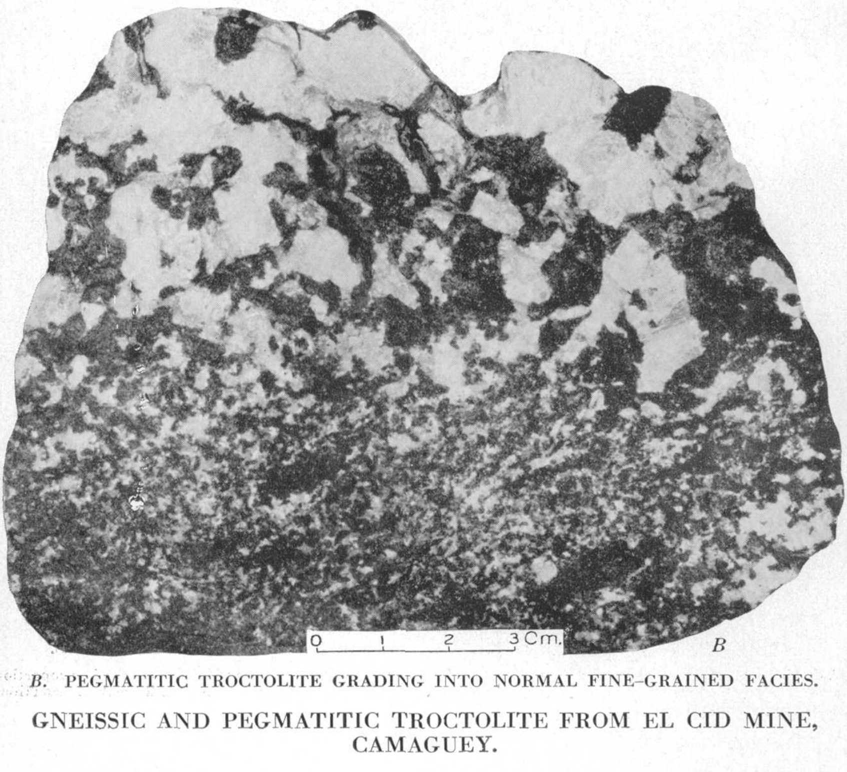
B

LIGHT AND DARK FACIES OF TROCTOLITE SHOWING GNEISSIC STRUCTURE.

With increase in proportion of olivine the dark facies grades into dunite, and with increase in proportion of feldspar the light facies grades into anorthosite. *A*, from El Cid mine; *B*, from hill south of Las Niñas mine, Camaguey.

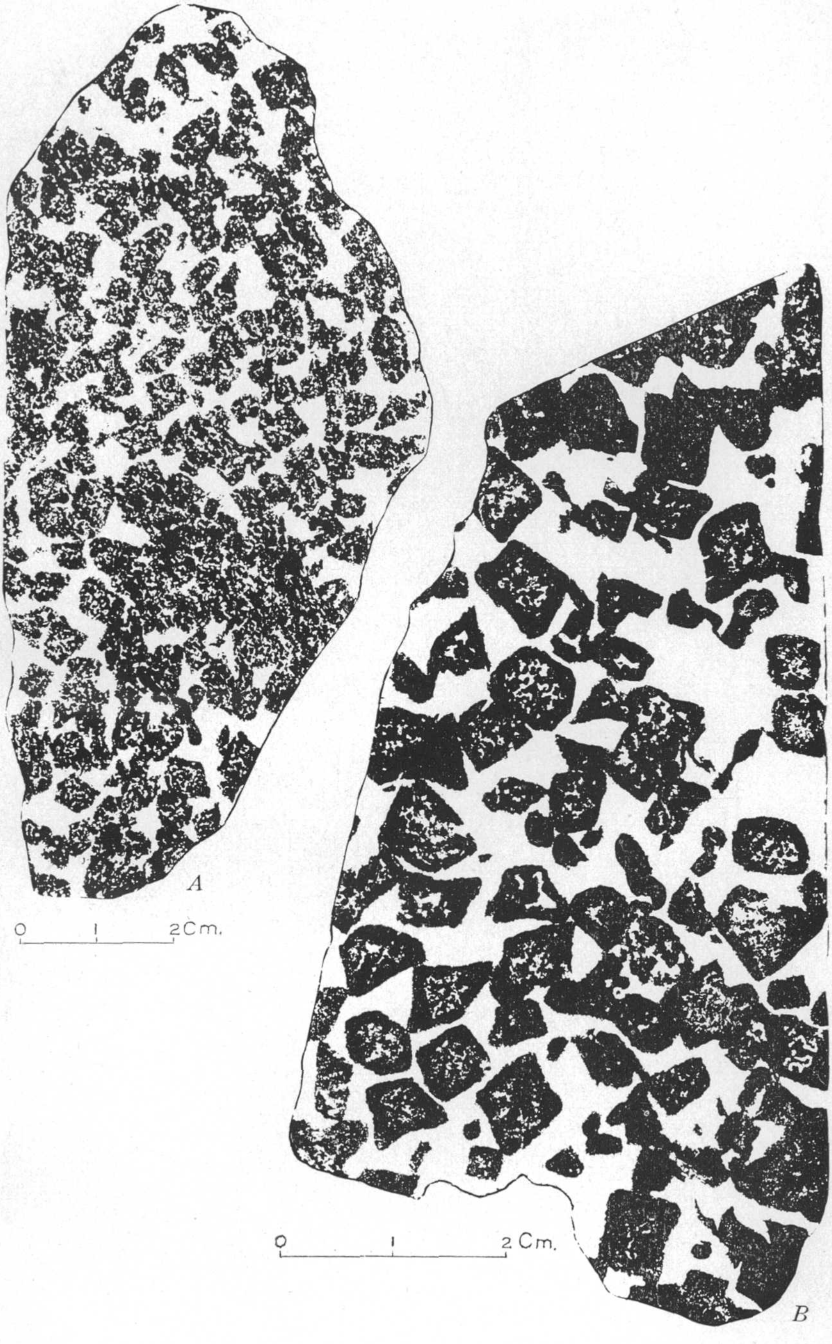


A. GNEISSIC TROCTOLITE CONTAINING LARGE FELDSPAR AUGEN.
Dark band at top mainly chromite (Cr).



B. PEGMATITIC TROCTOLITE GRADING INTO NORMAL FINE-GRAINED FACIES.

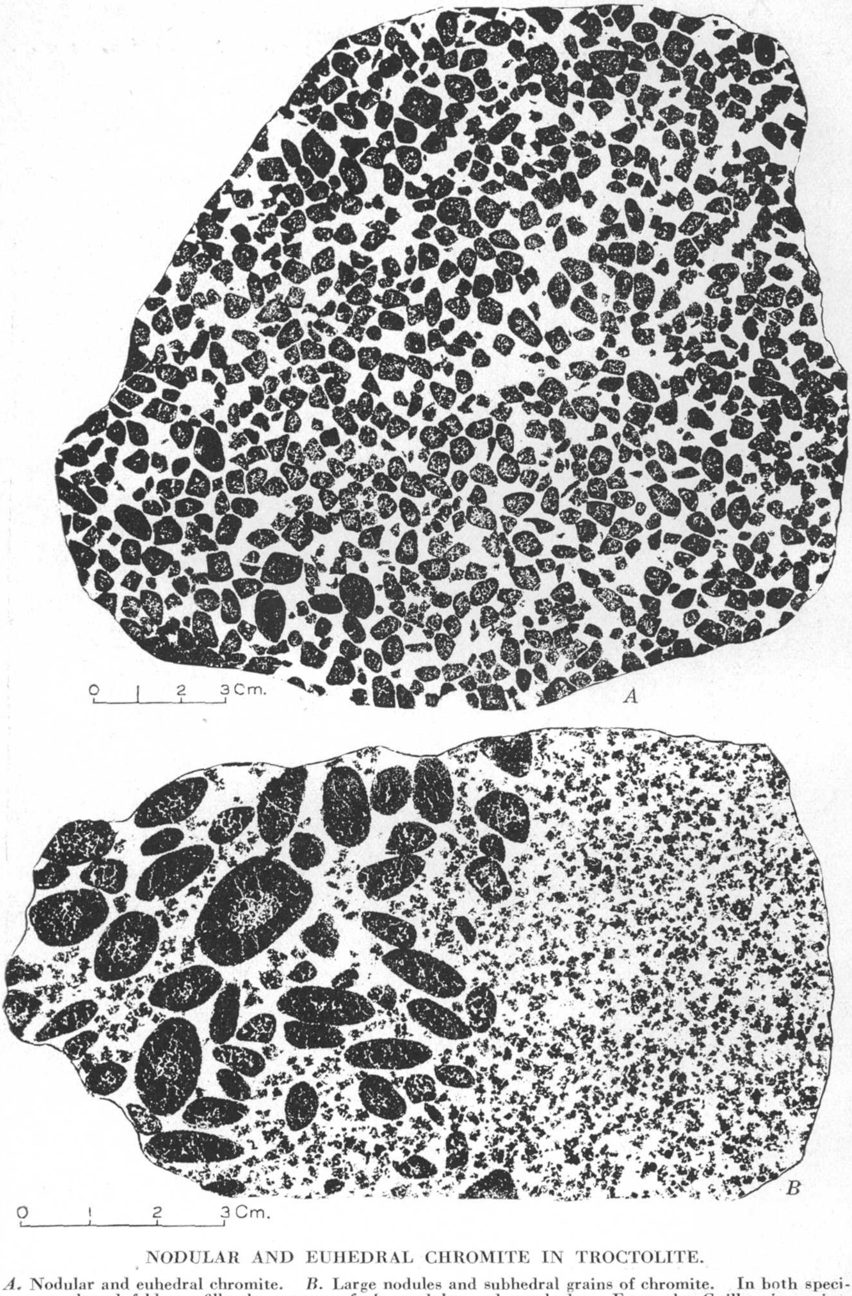
GNEISSIC AND PEGMATITIC TROCTOLITE FROM EL CID MINE, CAMAGUEY.



OCTAHEDRA OF CHROMITE IN SERPENTINIZED DUNITE.

A. Loose texture reveals the granular character of the octahedra and suggests incipient disruption. Fractures filled with serpentine. From Bad Luck mine, Holguin district.

B. Irregular octahedra in specimen from Guillermina mine, Camaguey. The centers of the octahedra consist of altered plagioclase.



NODULAR AND EUHEDRAL CHROMITE IN TROCTOLITE.

A. Nodular and euhedral chromite. *B*. Large nodules and subhedral grains of chromite. In both specimens altered feldspar fills the centers of the nodules and octahedra. *From the Guillermina mine, Camaguey.*

Table 2.--Partial analyses of chromite from Cuba
[R. E. Stevens, analyst]

District and deposit	Type of ore sample	Concentrate in sample (percent)	Analysis of concentrate: Cr_2O_3 (percent)	Fe (percent)	Cr:Fe
Camaguey:					
Aventura.....	Massive.....	1/87.4	1/35.53	1/10.13	1/2.40
Jose.........	....do......	87	35.51	11.32	2.15
Lolita.......	....do......	96	35.80	10.77	2.28
Ofelia.......	Disseminated	76	35.52	11.73	2.07
Rafael.......	Float ore...	......	2/25.88	2/17.77	2/1.04
Romanita.....	Massive.....	82	29.29	....	......
Holguin:					
Bad Luck.....	Disseminated	66	38.46	11.96	2.21
Mayari:					
Estrella.....	Massive.....	83	56.91	11.00	3.54
Loma Alta....	....do......	95	56.57	11.30	3.42
Sagua de Tanamo:					
La Tibera....	Disseminated	68	37.88	10.26	2.53
La Victoria..	High-grade dissemi- nated.	87	55.54	11.37	3.34
Cayoguan group:					
Narciso......	Massive.....	97	38.59	10.00	2.64
Cayoguan:					
Ore body No. 1....	....do......	98	38.40	9.73	2.70
Ore body No. 2....	....do......	97	39.35	9.72	2.77
Baracoa:					
Potosi.......	....do......	95	39.9	14.35	1.90
Amores:					
Tunnel 7...	High-grade dissemi- nated.	86	35.3	12.06	2.0
Tunnel 8...	....do......	87	38.4	11.10	2.4

1/ Average of 7 grab samples. 1.92 percent CaO in one average sample.
2/ Analysis of crude ore from 4-foot vertical channel sample.

of gabbro, troctolite and anorthosite, or any one of these rock types, are very common in the lode chrome deposits of Camaguey and eastern Oriente. Other minerals associated with the chromite include chrome diopside; uvarovite, the green chrome garnet; kammererite, a pale-purple to reddish chromiferous chlorite; magnesite; aragonite; and rarely, garnierite, a green nickel silicate.

Although chromite crystallizes in the isometric system, and usually occurs as small octahedra in the stratiform deposits, crystals are commonly poorly formed or wanting in the sack-form deposits. Octahedra were found in serpentinized dunite in the Holguin district and in troctolite and serpentinized dunite at the Guillermina mine in Camaguey (pl. 3). The crystals from Holguin appear to be partly disrupted solid octahedra, whereas the octahedra from Camaguey enclose small irregular masses of feldspar. The octahedra from Camaguey have somewhat concave faces, range in size from about 2.5 millimeters to nearly 2 centimeters across, and are made up of an aggregate of irregular grains. These distorted octahedra, which no longer are unit crystals, are intermingled with nodules that show similar range in size and like internal structure. Many of the grains making up the nodules are anisotropic, for they show distinct birefringence in thin section. The nodules and octahedra from Camaguey have essentially solid rims, surrounding a core of granular chromite and altered plagioclase. Genetic relationship between nodules and octahedra is indicated by their close association and similarities and especially by the fact that all gradations between sharp octahedra and perfect ellipsoidal nodules may be found (pl. 4, A). The nodules in serpentinized dunite at the Caledonia mine (see pl. 5, A), like the octahedra from Holguin, have the appearance of partly disrupted solid masses. Complete disruption of the nodules results in a uniform mixture of anhedral chromite grains and serpentine, or disseminated ore (pl. 5, B).

Almost all ore of shipping grade is massive black chromite containing less than 10 percent of gangue by weight. With moderate increase in amount of gangue massive ore grades into disseminated ore similar to that shown in plate 5, B; with excessive increase in amount of gangue disseminated ore grades into barren serpentine. Gradation between massive and nodular ore is shown in many places by close packing and coalescence of nodules.

A variety of ore that is very common in Cuban chrome deposits is a breccia (see pl. 8) consisting essentially of fragments of chromite in a matrix of troctolite or gabbro. The chromite fragments range in size from minute specks to pieces an inch

(2.5 cm.) or so across, and in form from angular splinters to rounded pieces resembling stream-worn pebbles (pls. 6-8). The smaller grains commonly show crystal faces, and many of the largest fragments reflect light uniformly from polished surfaces as if they were parts of single crystals. The proportion of gangue and chromite ranges from minute stringers of feldspar in chromite to occasional chromite fragments in gabbro or troctolite. As a rule, the fragments are nearly equidimensional and unoriented, but in the Aventura ore body the pieces of chromite are somewhat elongated and show rude orientation.

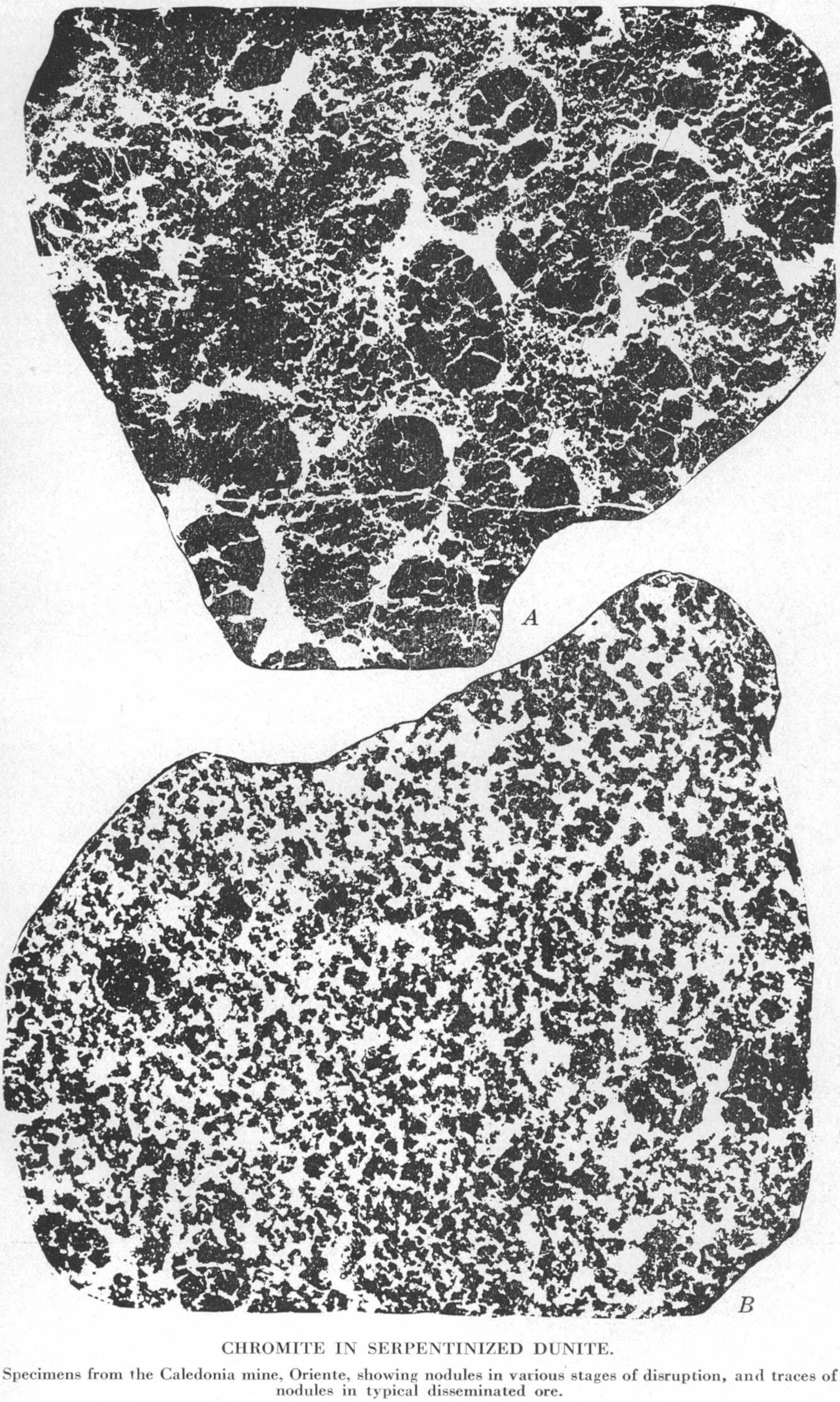
Although noteworthy amounts of breccia ore were seen at the Teide, La Constancia, and Potosi deposits, the relations were shown best at the Aventura mine. The gabbroic dikes at the Aventura mine are for the most part sharply defined (see pl. 6), but in places the contacts are obscure and the chromite wall rock is permeated by feldspathic material (pl. 7).

The field relations show clearly that the breccia ore was formed by shattering of massive chromite and mechanical injection of gabbroic magma. The origin of the other varieties of ore, however, is obscure. The octahedra must have once been crystals since they exhibit crystal form. Their present granular make-up may have resulted from some inversion that occurred during cooling of the peridotite. The relations between octahedra and nodules at the Guillermina mine suggest that the nodules are imperfectly formed crystals or crystals that have suffered resorption. Several minor features of the nodules indicate that they were not formed by mechanical rotting or abrasion of crystals. Gradations between nodular and massive ore suggest that some of the chromite may have separated from the peridotite magma as globules which settled to the floor of the magma chamber. The coalescence and flattening of nodules indicate that they were subject to plastic deformation at an early stage in their history. The apparent mechanical disruption of nodules and octahedra may be interpreted as evidence that the chromite was solid when the peridotite was intruded, so that it fractured when subjected to stresses accompanying intrusion. Remnants of nodules in disseminated ore are believed to indicate that at least some of this variety of ore was formed by breaking up of nodules and mixing of their fragments with dunite magma by differential flow. A process of this type would also account for the gradations between massive and disseminated ore, and the prevalence of linear structure in the latter. The rarity of crystals in most disseminated ore might also be explained by this hypothesis.

A brief explanation of the method of preparing plates 3 through 8, which are retouched photographs, seems advisable. As the discussion is primarily concerned with the relations between chromite and gangue, all chromite is shown in black, and all gangue in white, even if the gangue comprises dark serpentine and pyroxene. Because chromite and dark serpentine cannot be distinguished in photographs, the specimens were treated with hydrofluoric acid which attacks the silicates and coats them with a white deposit of fluorides. On some specimens to which acid was applied several times, the white deposit overlapped onto the chrome, giving false relations when photographed. This condition was remedied by shaving off the excess deposit with the edge of a glass slide. The treated specimens were photographed to obtain maximum contrast, or black and white prints. A certain amount of retouching was necessary, especially on pictures of rough specimens in which there are undesirable shadows or reflections. All the photographs except those in plate 7 are of cut and polished specimens.

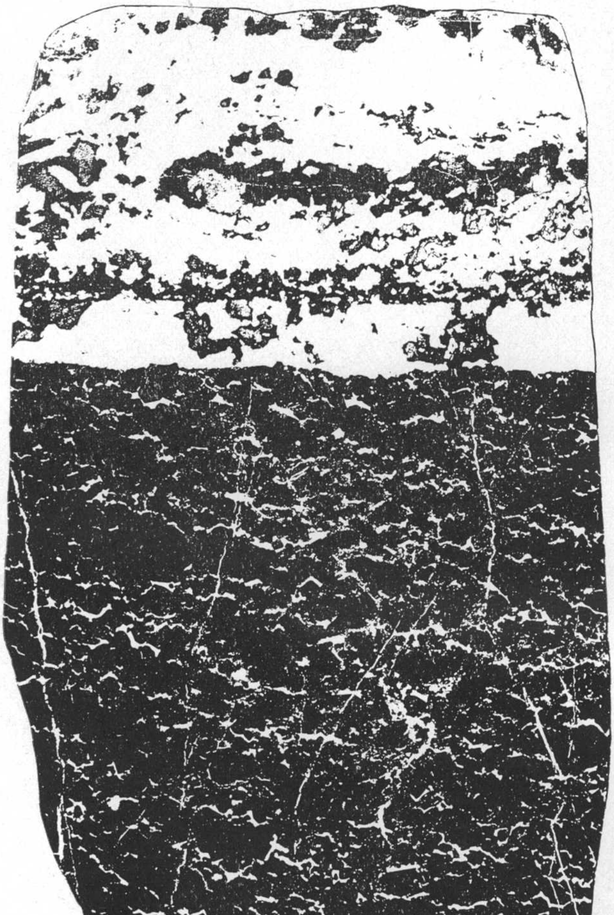
Form and structure

Chromite deposits of the sack-form variety are notable for their variation in size and shape. Those in Cuba range from a



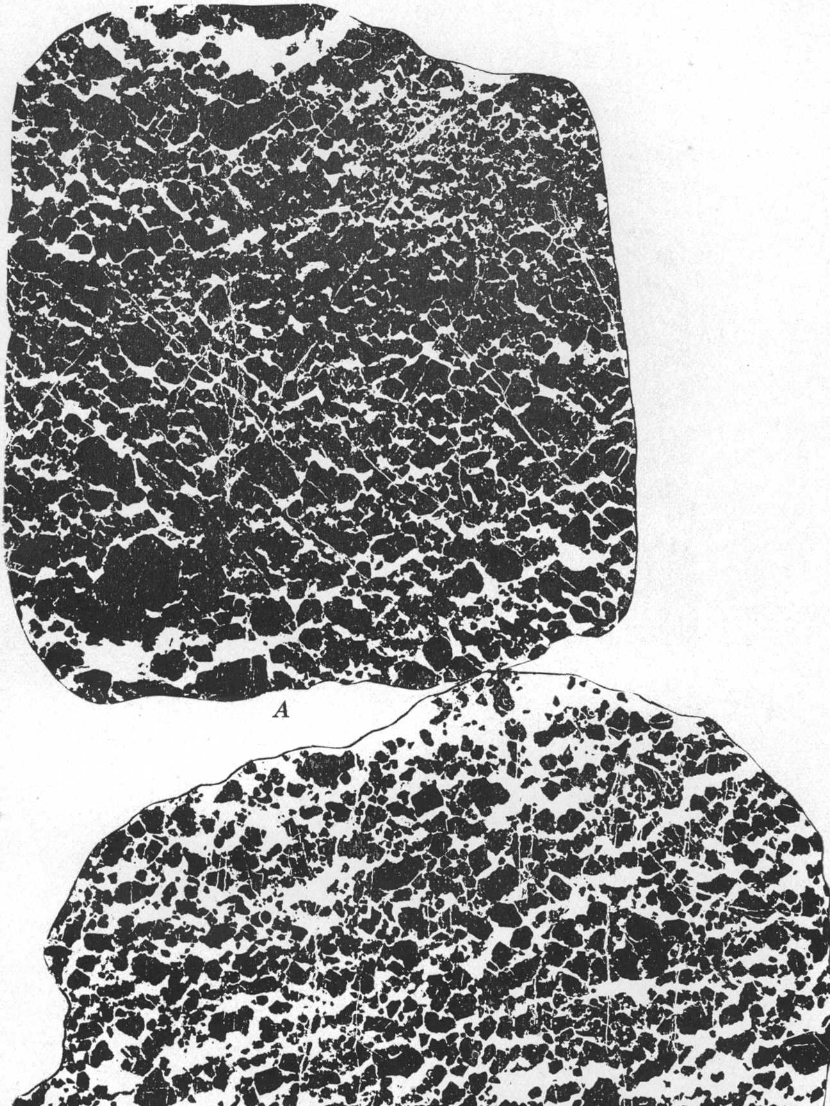
CHROMITE IN SERPENTINIZED DUNITE.

Specimens from the Caledonia mine, Oriente, showing nodules in various stages of disruption, and traces of nodules in typical disseminated ore.



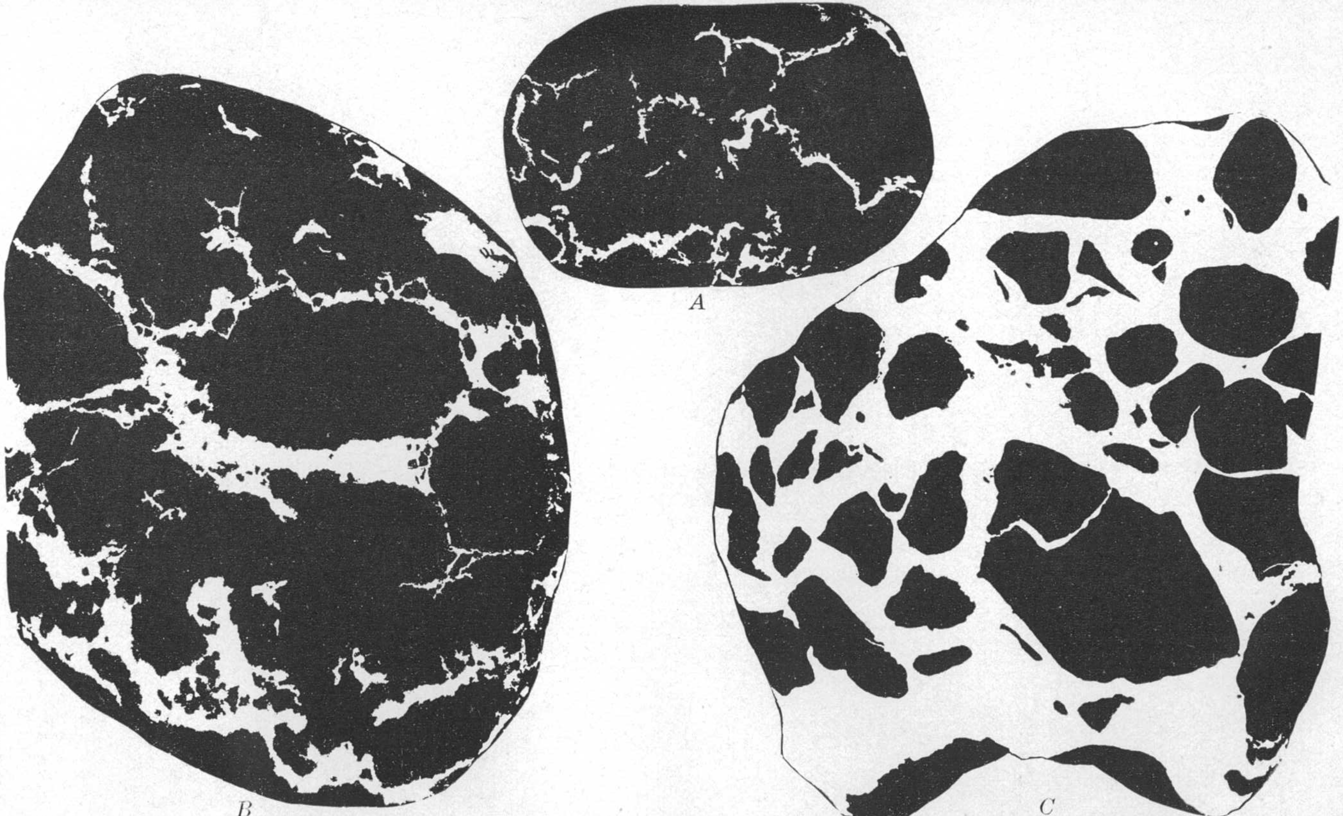
HIGH-GRADE CHROMITE ORE WITH OLIVINE AND FELDSPAR GANGUE CUT BY DIKE OF BANDED TROCTOLITE.

Black mineral in lower part of photograph is chromite; black minerals at top in troctolite dike are serpentine and olivine; white minerals chiefly feldspar. From Aventura mine, Camaguey.



BRECCIATED CHROMITE ORE SHOWING STAGES IN INTRUSION OF TROCTOLITE.

The original orientation of chromite grains and fragments derived from massive ore is still evident (compare pl. 6). The very thin veinlets are composed of edenite and other hydrothermal minerals. From Aventura mine, Camaguey.



DEVELOPMENT OF BRECCIA FROM MASSIVE COARSE-GRAINED CHROMITE THAT HAS BEEN FRACTURED AND INTRUDED BY OLIVINE GABBRO.

In specimen *C* many of the fragments have been rounded, apparently by chemical attack. Cobbles from the Rio Yamanigüey below the Potosi deposit.

few pounds to somewhat over 100,000 tons; most of the production has come from deposits that contained more than 10,000 tons. The majority of deposits might be termed lenses or pods, as their length greatly exceeds their width. Others are more nearly kidney-shaped, being wider in comparison to their length and having rounded ends. A few are tabular, having two dimensions many times as great as the third; some deposits of this type resemble veins. Many deposits, especially those of disseminated ore, are irregular masses.

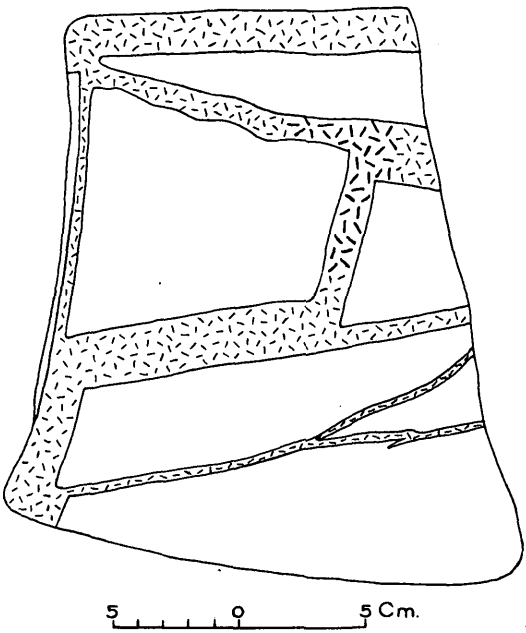


Figure 2.--Troctolite dikes in block of massive chromite from the Aventura mine, Camaguey. The grain size of the troctolite is unrelated to the width of the dikes.

Bodies of massive high-grade chromite show little internal structure, possibly because of the absence of contrasting materials that would reveal structure. The chromite is rarely distributed evenly in disseminated ore, which commonly has a banded appearance due to planar or linear structure. Planar structure is shown by alternating layers of high- and low-grade ore, or layers of ore and barren rock. Linear structure is revealed by arrangement of the chromite grains in lines rather than layers, and ordinarily is not as prominent as planar structure. Both linear and planar structure impart a banded appearance to the ore. Planar structure is well shown by interlayering of ore and gangue in the Progreso mine in Camaguey and the Angelita mine in the Holguin district, and by orientation of flattened nodules at the

Guillermina mine. Linear structure was noted in several of the disseminated deposits in Camaguey.

The most prominent features in many Cuban chromite deposits are dikes and irregular masses of gabbro and troctolite. The dikes range in width from a few millimeters (see fig. 2) to a meter or more and generally intersect the ore bodies at random. At the Aventura mine the large dikes follow a well-defined system of parallel fractures, and an unusually thick dike forms part of the footwall of the quarry. (See sec. A-A', pl. 10.) Irregular knots and bunches and anastomosing masses of gabbro may be many feet across and commonly are pegmatitic (fig. 4).

Relations of ore bodies to enclosing rocks

All of the chromite bodies seen by the writer in Cuba are closely related to serpentinized dunite. With the exception of the Guillermina mine, where much of the gangue is troctolite, the primary gangue in the chromite, disregarding the later injected feldspar, is olivine partly or completely replaced by serpentine. A narrow selvage or zone of dunite surrounds most ore bodies, although in places peridotite containing a small percentage of pyroxene forms the wall. The dunite selvage at the Caledonia mine is truly remarkable, for although the country rock was originally rich in enstatite and the ore body was nearly 50 feet (16 m.) thick in places, the selvage probably does not average more than 3 to 5 feet (1 to 1.7 m.) in thickness, and in places is only about 6 inches (15 cm.) thick. Any valid theory for the genesis of chromite must account for this close association of chromite and dunite, a relation which, except possibly in the stratiform deposits, seems to be worldwide.

The primary structures in the chromite, namely planar and linear structure, appear to bear little relation to the form of the ore bodies. At the Progreso mine in Camaguey and the

Angelita Silva mine in Holguin, prominent planar structure trends nearly at right angles to the length of the ore bodies and is cut off by unfaulted igneous contacts with dunite. The long axes of ore bodies, on the contrary, in places are parallel to the trend of major structures in the ultramafic rocks, as for example on the Cayoguan denouncement. This relation is true chiefly of ore bodies bounded by primary igneous contacts; where the contacts are faulted no consistent trends are evident. The lateral contacts of massive ore bodies are likely to be sharp whereas the ends may grade out through low-grade ore. The borders of disseminated deposits are predominantly gradational and therefore indefinite; in these deposits the boundary is determined arbitrarily as the limit of minable ore.

Possibly half of the large chrome deposits are bounded wholly or partly by faults, and therefore have well-defined contacts. Occasionally a single fault extends the entire length of a deposit and forms one wall, as at La Victoria mine in Camaguey, but this is unusual. As a rule, faulted contacts follow a number of intersecting fractures, and therefore are very irregular. It is obvious that estimates of reserves in deposits of the types indicated may be very misleading when based only on surface indications.

Distribution

The distribution of most chrome deposits is haphazard, and apparently not subject to definite structural control. The index map of the Camaguey district (see pl. 9) shows random distribution on a large scale, and some of the smaller maps (see pl. 16) show it in more detail. The chrome deposits may be compared to plums in a pudding, in which the plums are scattered vertically as well as horizontally. Like plums, the chromite bodies are not evenly distributed, and in places occur in groups, as in the vicinity of the Teide and Lolita mines. Although the deposits in the Holguin district might be considered exceptions to this rule, because chromite is often seen near or actually in contact with inclusions of old rock, actually many of the deposits are far from inclusions, and innumerable inclusions occur without chrome. The relation between chrome deposits and inclusions is best explained by analogy to plums and raisins in a pudding; a certain proportion of plums and raisins will be found together, just as a number of chrome lenses and inclusions are found. The ore bodies at the Amores mine dip at low angles and are distributed in a manner suggesting the presence of some sort of ore-bearing zone, though it cannot be definitely demonstrated (see p. 74).

Origin

The intimate relation of chromite, dunite, and troctolite, and the coarse-grained gabbro and troctolite cutting the chrome bodies, show that the chrome deposits in Cuba were formed early in the ultramafic magmatic sequence. The intergradation of gabbro, troctolite, and anorthosite with peridotite is considered prima-facie evidence of essential contemporaneity of the feldspathic and nonfeldspathic rock types. The crosswise trend of planar structure in some disseminated ore both with respect to the long axes of lenses and the trends of structures in the surrounding rock, suggest that, like the schistosity in inclusions of old rocks, some of the structure in the ore may be inherited. The large number of sharp unfaulted contacts between massive ore and barren rock, and the lack of correlation between size of serpentine masses and contained ore bodies are construed as evidence against differentiation of the chromite in place after intrusion of the peridotite. The very coarse grained chromite in some of the Cuban ore indicates that the chromite was segregated at great depths under conditions much more favorable to crystal growth than in any of the stratiform deposits where differentiation is presumed to have occurred after intrusion. These considerations, plus the random distribution of the chromite deposits, lead the writer to believe that the chromite was segregated at great depth before intrusion of the peridotite, and was carried up as solid inclusions, comparable to masses of schist and gneissoid diorite, during emplacement of the ultramafic rocks. Though the chromite itself was solid and subject to granulation under differential movements, the dunite matrix was sufficiently mobile to flow and penetrate minute fractures in the chromite.

Reserves

The reserves of chrome ore in Cuba are undoubtedly large. Burch and Burchard, who had to base their studies almost entirely on outcrops, conservatively estimated the reserves of marketable chrome ore in Cuba in 1918 to be between 92,500 and 170,000 long tons, 72,500 to 130,000 tons of which was in eastern Oriente.[12/] Exploration since 1918 has revealed large reserves in Camaguey, and has more than doubled the known reserves in eastern Oriente, in spite of the fact that in the meantime more than 760,000 tons of chrome ore have been shipped to the United States. Because the eastern part of Oriente has not yet been thoroughly prospected and development work in western Oriente and Camaguey has not been extensive, estimates of reserves made at this time will be changed by future exploration.

The Camaguey district contains more chromite than any other comparable area known in Cuba. Up to the end of 1940 this district had produced about 650,000 tons of shipping-grade refractory ore from open pits 80 feet (24.5 m.) or less in depth. Many of the pits that were abandoned because of comparatively high mining costs or excessive water still contain ore. By a

12/ Burch, Albert, and Burchard, E. F., op. cit., p. 65 (pag. 50).

conservative estimate the known reserves of shipping ore in the district are at least 350,000 tons. With past production this is sufficient to bring the total amount of shipping-grade refractory ore obtainable or already obtained from workings less than 100 feet deep to 1,000,000 long tons. This estimate does not include extensive deposits of mill ore, nor workable deposits of float ore, for which figures are not available. As the ore bodies probably are distributed uniformly in depth, the reserve of shipping ore alone would probably be increased by 1,000,000 or more tons for each 100 feet (30.5 m.) of depth below the surface.

The known reserves of shipping and milling ore in Oriente are about 200,000 tons, mostly in the Cayoguan group, the Potosi, and the Amores mines. All ore so far discovered east of the Sagua de Tanamo district is the high alumina type best suited for use in refractories. Massive ore in the Mayari district is of metallurgical grade, and the low-grade deposits will yield concentrates of metallurgical grade; the chromite in the Holguin and Sagua de Tanamo districts appears to be intermediate in composition, and concentrates from these districts would probably be of refractory grade. Exploration now in progress will undoubtedly greatly modify these estimates.

The deposits in Matanzas Province were small, high-grade lenses that have been mined out. The reserve of indicated ore at most amounts to a few hundred tons.

Float deposits

Nature and occurrence

The amount of chromium in the lateritic iron ores in Cuba is enormous, for these deposits contain at least 2 billion tons of iron ore having an average chromium content of about 1.5 percent.[13] This chromium content and a somewhat smaller content of nickel have been used to advantage in making so-called Mayari steel. The average chromium content is too low, however, to permit commercial extraction, so that most of the laterite must be considered chromiferous iron ore, rather than chrome ore. The chromium occurs in the form of chromite that was originally an accessory mineral in the serpentine from which the laterite was formed by chemical weathering. Therefore, where the original serpentine contained an unusually large amount of chromite the laterite is correspondingly rich in chromite, and in places constitutes minable chrome ore.

Float chromite, or "mineral flotante," has formed an important part of the production from the Camaguey district in the last few years. The largest and richest deposits occur as a surface blanket ranging in thickness from 6 inches to 3 feet (15 cm. to 1 m.) around large lode deposits. As the lodes commonly occupy the summits of low hills, the float ore on the slopes lies directly on the serpentine bed rock and is usually washed rather clean. The lower surface of the blanket is normally very irregular, and is characterized by pockets where the serpentine has been deeply weathered (fig. 3). Some of these pockets are as much as 10 feet deep and contain many tons of ore.

Normally, the float chrome deposits, like the chrome-poor laterite, support only a sparse growth of grass. The uppermost layer, though it superficially resembles common soil, contains a large proportion of very finely divided chromite, and may be nearly as rich in Cr_2O_3 as washed lump ore. Below the top layer, which is rarely more than 6 inches (15 cm.) thick, the ore is a mixture of angular to rounded lumps of massive chromite, fine-grained chromite, and lateritic clay. Fragments of fresh or partly weathered serpentine are generally present near the

13/ Kemp, J. F., The Mayari iron-ore deposits, Cuba: Am. Inst. Min. Met. Eng. Bull. No. 98, pp. 129-131, 1915.

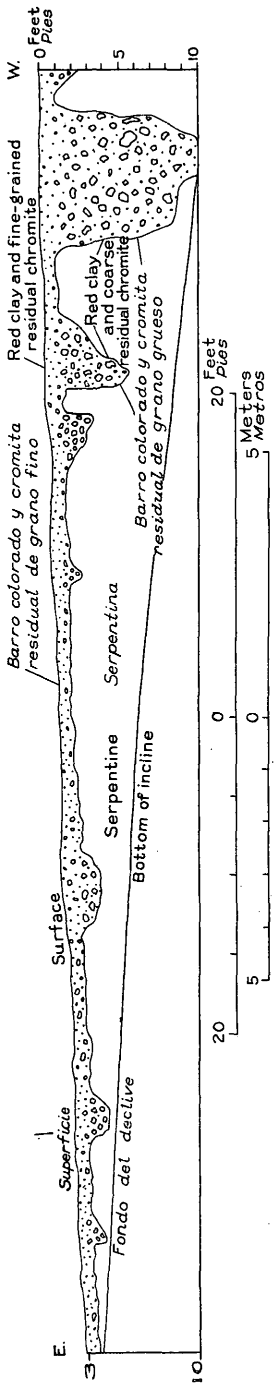


Figure 3.--Float chromite exposed in incline at La Victoria mine, Camaguey. Length of section 80 feet (24.5 m.). Sketched by W. D. Johnston, Jr.

bottom of the deposit. Fine-grained float ore derived from evenly disseminated primary chrome deposits may be distinguished from ordinary red or yellow laterite by a dark purplish color grading into black.

Float ore is subject to the same variations in composition as lode ore, for chromite is very stable and is not appreciably altered by weathering processes. On the whole, float ore free of serpentine fragments is somewhat better than lode ore, because of removal of the serpentine gangue during weathering.

Reserves

The principal known reserves of float chrome ore in Cuba lie on the rolling savannah of the Camaguey district, where the lateritic cover is comparatively thin. Other deposits of this type may be discovered on some of the gently sloping uplands in eastern Oriente. The amount of ore in a thin layer may seem small, but the following simple calculation shows that it can be considerable. If it is assumed that the blanket is 1 foot (30 cm.) thick and that 50 percent of the crude ore is recoverable as washed ore having an apparent specific gravity of 3, the deposit will yield approximately 1,850 long tons per acre or about 4,650 metric tons per hectare. Although the reserve of float ore in the Camaguey district has not been estimated, it must amount to many thousands of tons.

USE, MINING, AND TREATMENT OF CHROME ORE

Factors affecting use of chromite

Chromite ore is divided into three commercial classes: Metallurgical, refractory, and chemical, in order of decreasing consumption.

Ore of metallurgical grade ordinarily is used to make ferro-chrome, for use in alloying steel, although chromite can be smelted directly with scrap steel. Because standard grades of ferro-chrome contain 60 to 70 percent chromium and as much as 35 percent of the Cr_2O_3 in the ore may be lost in smelting, metallurgical ore must have a high ratio of metallic chromium to metallic iron. Specifications for high-grade metallurgical lump ore purchased by the Metals Reserve Co. under the Strategic Minerals Act in 1940 were as follows:

Cr_2O_3 (minimum).......	48 percent
Fe (maximum)..........	1/3 of Cr content
S (maximum)...........	0.5 percent
P (maximum)...........	0.2 percent

All lumps had to pass a 6-inch screen, and not more than 10 percent could pass a ½-inch screen. In normal times ore meeting these requirements is readily obtainable, but when foreign sources are shut off by war, lower-grade ore can be used. For example, in October 1941 the Metals Reserve Co. was buying lump ore containing at least 45 percent Cr_2O_3, not more than 11 percent SiO_2, and having a Cr:Fe ratio of 2.9. The cost per pound of chromium in ferro-chrome is greatly increased when low-grade ores are used.

The value of chromite as a refractory depends upon its behavior at high temperatures rather than upon its composition, and some of the best refractory chromite contains less than 40 percent Cr_2O_3. The minimum specifications for lump refractory chromite purchased by the Metals Reserve Co. in October 1941 were as follows:

Cr_2O_3 (minimum).....	32 percent
Al_2O_3 (minimum).....	25 percent
Fe (maximum)........	11 percent
SiO_2 (maximum)......	5 percent

Commercial purchasers sometimes stipulate that CaO must not exceed 1 percent.

Low-grade chromite rich in Al_2O_3 can be used as a refractory because the Al_2O_3 is itself refractory. Iron reduces the fusion point, and is therefore deleterious. Silica is not contained in the chromite, as is iron, but is generally combined in serpentine or other silicates which melt at temperatures far below the softening point of chromite. The amount of silica is therefore a measure of the amount of silicates, which should be kept at a minimum. Although serpentine, olivine, and pyroxene form the gangue in most chrome ore, feldspar is commonly present in Cuban ore. In commercial practice excess MgO is added to chrome ore to convert all serpentine and pyroxene to olivine, which is a good refractory, during firing. Since feldspar melts at a comparatively low temperature, and cannot be converted to more refractory material, bricks made from ore containing much of it fail quickly in use. Ore containing 1 percent of CaO contains approximately 5 percent of calcic plagioclase; some crude Cuban ore contains as much as 5 percent CaO.

Ore for use in the chemical industry should be nearly as rich in Cr_2O_3 as metallurgical ore, but is not subject to the same restrictions in iron content. The Metals Reserve Co. in October 1941 specified a minimum of 48 percent Cr_2O_3 and a maximum of 6 percent SiO_2 in first-class chemical ore, and not less than 44 percent Cr_2O_3 with not more than 5 percent SiO_2 in second-class ore. Iron-rich chromite breaks down more readily than aluminous types, and is more desirable. The use of low-grade ores greatly increases the cost of production of chemicals such as chromates and dichromates.

Lump ore works best in ferro-chrome furnaces, and when crushed yields nearly the proper proportion of various grain sizes needed in making dense refractory brick. Therefore specifications for chromite, until very recently, have called for lump ore. As a result, soft ores that crumble during shipment and fines produced during mining have not been readily salable. However, the process of smelting chromite directly with scrap steel to make stainless steel requires concentrates or crushed ore, and other smelting techniques adapted to the use of concentrates have been developed. A large proportion of refractory chromite is ground for use in cements, in ramming mixtures, and in daubing material for protecting brickwork. In the chemical industry, chromite is finely ground for effective mixing with reagents, so concentrates should be acceptable. It therefore seems probable that, although lump ore is better for some uses than concentrates and will continue to be in demand, the market for chromite concentrates and mixed ore will improve.

Sampling of chrome deposits

Chromite deposits that will yield ore of shipping grade can be effectively sampled by ordinary methods. Sampling of disseminated ore requiring concentration should show not only the average grade of the deposit, but also the amount of concentration necessary and the grade of concentrate that may be produced. The possible variation in composition of chromite is so great, even in neighboring deposits, that careful sampling entails at least one analysis of pure chromite from every deposit from which ore is to be milled. For example, analyses of two bulk samples from La Victoria and La Tibera mines in the Sagua de

Tanamo district might show 25 percent Cr_2O_3, yet the chromite content of the samples would be about 45 and 65 percent, respectively. Although these deposits are only about 1½ miles (2.2 km.) apart, clean concentrates from La Victoria should contain about 50 percent Cr_2O_3, whereas similar concentrates from La Tibera would not contain more than 35 percent Cr_2O_3 (table 2). The experience of the Geological Survey in sampling many chrome deposits indicates that the composition of chromite within a single ore body of the sack-form type is nearly constant, regardless of the grain size or other variations in the texture of the ore. If the composition of the chromite in a deposit is known, the ratio of concentration may be calculated from analyses of channel samples. Determination of the Cr:Fe ratio in a channel sample is apt to be misleading, because of the iron content of the gangue minerals.

Concentration of low-grade ores

Low-grade deposits of disseminated chromite and impure float ore constitute a large part of the chrome reserves in Cuba, and several thousand tons of milling-grade ore discarded during mining of high-grade lenses are ready for milling. The large amount of readily available residual ore in the Camaguey district attracted attention a few years ago, and a major part of the recent production from Camaguey has consisted of washed ore. Log washers are used to remove very fine grained chromite and lateritic clay from the ore, leaving a clean pebblelike product ranging in diameter from about ½ to 6 inches (1 to 15 cm.). Because the washers do not remove pieces of unweathered serpentine, mining is limited to thoroughly weathered material, and a great deal of ore is left on the ground. Moreover, all the fine-grained chromite is left in the tailings, some of which contain 25 percent or more Cr_2O_3, or about 70 percent of chromite. The recovery of residual ore probably could be greatly improved by installation of plants using jigs so that partly weathered material made up of a mixture of barren serpentine fragments, pieces of massive chromite, and laterite could be mined cheaply on a scale that is not possible with the present methods. A large part of the chromite in the tailings could be recovered by adding concentrating tables. The difference in specific gravity of the chromite and serpentine or laterite is so great that simple gravity concentration should be very effective.

Low-grade lode ore has been milled commercially at the Pilliken mine in California since 1937. This mine has produced between 6,500 and 7,000 tons of concentrates containing between 43 and 50 percent Cr_2O_3, and 4 to 6 percent SiO_2, from ore containing about 20 percent of chromite or 10 percent Cr_2O_3.[14/] Cuban chrome ore in general is similar to that at the Pilliken mine, but richer in chromite, and should be amenable to the same type of treatment. The use of jigs where practicable should yield products of different grain sizes that would be more acceptable to refractories makers than uniformly fine concentrates. The type of equipment needed to treat chrome ore by gravity methods is comparatively simple and cheap, and plenty of water for milling operations in the Camaguey district is available from abandoned open pits. The Juragua Mining Co. was reported to have a small mill in operation late in 1941.

Mining methods

Float ore in the Camaguey district is mined by hand digging of the weathered surface layer rich in chromite. The pockets of well-weathered material are removed, and intervening areas in which the chromite layer is thin or serpentine fragments are

14/ Wells, F. G., Page, L. R., and James, H. L., Chromite deposits of the Pilliken area, Eldorado County, Calif.: U. S. Geol. Survey Bull. 922, pp. 419, 439, 1940.

Ridgeway, R. H., and Melcher, N. B., Chromite: U. S. Bur. Mines, Minerals Yearbook, Review of 1940, p. 589, 1941.

abundant are left. As a rule float ore less than 6 or 8 inches (15-20 cm.) deep is not mined, and several inches of partly weathered material is left in stripped areas. The total recovery is probably between 50 and 75 percent.

Lode ore is mined entirely in open pits served by one or more inclines. The maximum depth of the pits is about 80 feet (24.3 m.). Power equipment is used for hoisting cars of ore and waste up the inclines, for pumping, and for drilling in a few mines where the ore is very hard. All ore and rock is moved by hand except at La Caridad mine near Altagracia, where a steam shovel and drag-line are used in stripping a large ore body. In most mines the ore is broken down with hand picks, then sorted on the quarry floor. Removal of gabbro and troctolite dike rock from ore is a major item of expense in working some deposits because thin dikes do not break away from the ore readily and must be chipped off. Mines are usually abandoned when the walls, which in most pits are very steep, become dangerously high, or when the cost of mining, including pumping, seems excessive.

Mine owners and operators

The principal owners and operators of chrome mines in Cuba are the Compania Cubana de Minas y Minerales, a subsidiary of E. J. Lavino & Co., and the Juragua Mining Co., a subsidiary of the Bethlehem Steel Corporation. These companies own all of the important mines in the Camaguey district, and cooperate closely in operations.

The Cayoguan mines are operated under lease by the Cuban American Mining Co., a Cuban company, of which G. D. Aulet is president. All ore from these mines is sold to the Harbison-Walker Refractories Co. under an exclusive contract, and an engineer has been sent down by the refractories company to assist in mining operations. The Harbison-Walker Co. also owns the Potosi deposit a few miles to the east. The deposits in the

Sagua de Tanamo district are owned by several individuals. It is said that all the owners have been organized by the superintendent of the Commercial Department of Central Cayo Mambi, so that negotiations may be conducted for the deposits in the entire district. The deposits in Matanzas, many of the smaller ones in the Camaguey district, and a few deposits in the Mayari district are held by various individuals.

DESCRIPTIONS OF DISTRICTS AND DEPOSITS

Matanzas Province

Two main belts of serpentine extend into Matanzas Province from Habana Province, and the chrome deposits are therefore similarly distributed. The deposits in the northern belt, which extends nearly east-west through Cardenas and Matanzas, were described by Burchard,[15] and as little mining has been done since his visit, the deposits need not be described again. The southern serpentine belt extends about S. 80° E. from Madruga, in eastern Habana Province, to a point about 5 kilometers southeast of San Miguel de los Banos. The serpentine occupies the central part of the Madruga anticline, which was named and mapped by Palmer, and forms a chain of hills that reach a maximum height of about 750 feet in the vicinity of San Miguel.

Clara mine

The Clara mine, the principal chrome deposit of the southern belt, lies near the base of a southerly slope, about 2 kilometers by trail west from San Miguel de los Banos. The mine has produced 2,000 tons or more of shipping-grade ore; accurate production figures are not available.

The main opening is a pit 150 feet (45 m.) long, 50 feet (16 m.) wide, and 25 feet (8 m.) deep, trending about N. 60° W.

15/ Burchard, E. F., Chrome-ore deposits in Cuba: Am. Inst. Min. Met. Eng. Bull. No. 153, pp. 2527-2530, 1919.

The ore occurs as irregular lenses of massive and disseminated chromite in dunite lenses in peridotite. Chromite is visible at the northwest end only, where an east-west chromiferous zone that is about 12 feet (4 m.) wide pinches within 20 feet (6.5 m.) to 4 feet (1.3 m.) of disseminated ore at the edge of the pit. A number of small pits located on small lenses west of the main opening were filled with debris. The amount of ore indicated is on the order of a few tens of tons, and, although several prospects have been opened in the vicinity and some placer chromite has been found, the future of the district does not seem promising.

Camaguey district

The Camaguey mining district, as shown in plate 9, is rudely triangular in outline, with its southwest apex at the city of Camaguey. The southeastern edge of the district lies about 3 miles (5 km.) south of, and parallel to, the Camaguey-Nuevitas branch of the Cuban Railroad. The district is bounded on the north by the Sierra Cubitas, a low range of limestone hills, and on the northwest by a laterite-covered mesa described by Cumings and Miller as the San Felipe iron district.[16] The western boundary of the district, like the southeastern, is indefinite and follows the limit of chrome mines or prospects.

The productive portion of the district covers an area of about 125 square miles (32,500 hectares), though the total area underlain by serpentine is much larger. The district is characterized by a gently undulating savannah with lateritic soil that supports a sparse growth of scrubby palms and coarse grass. Several hills of limestone, peridotite, and gabbro rise above the plain, which ends at the foot of the Sierra Cubitas. The laterite soil in places contains workable chrome deposits, but

16/ Cumings, W. L., and Miller, B. L., Characteristics and origin of the brown iron-ores of Camaguey and Moa, Cuba: Am. Inst. Min. Met. Eng. Bull. No. 51, pp. 147-268, 1911.

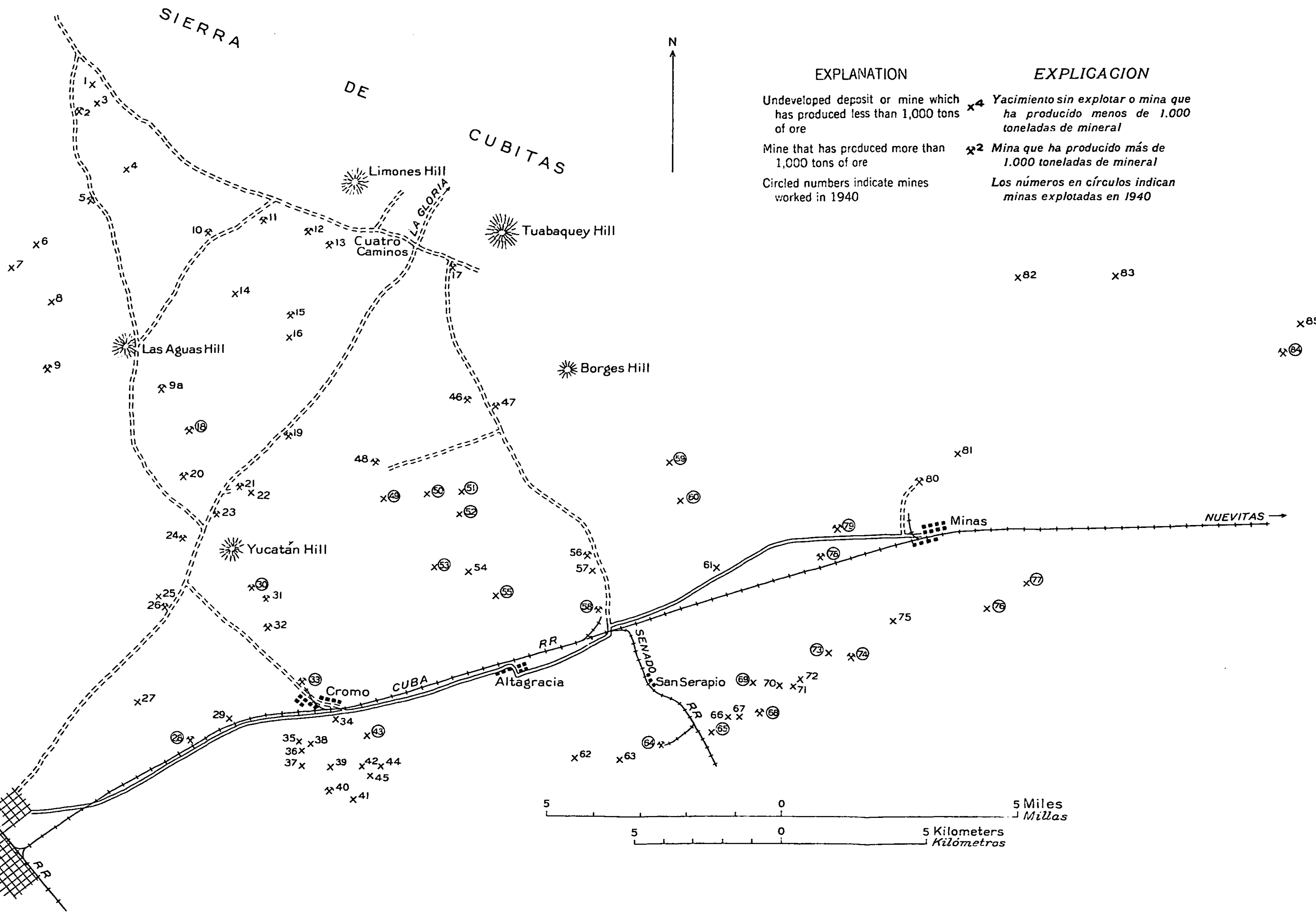
PARTIAL LIST OF MINES AND PROSPECTS

LISTA PARCIAL DE LAS MINAS Y LOS YACIMIENTOS

1 San Fernando
2 Margarita
3 Trinidad
4 Habana
5 Eloina Florat
6 Urbalina
7 Rincón Bellaco
8 La Imperial
9 La Rosalina
9a Avan
10 Guillermina
11 El Cid
12 Los Amigos
13 Nuevos Amigos
14 El Indio
15 La Delicia
16 Princesa
17 Tuabaquey
18 Las Niñas
19 Lola
20 Teide
21 Ofelia
22 Bertoldina
23 Angelina group
24 Buck
25 Ellen
26 Walfrido
27 Cyclo
28 El Próximo
29 Aventura Switch
30 Aventura
31 Portentosa
32 Roma
33 Rafael
34 Zoila
35 Eloísa
36 Rosario
37 Aurora
38 Elvira
39 Digna
40 Isabel group
41 Elsa
42 El Volumen
43 La Caridad (Robles)
44 El Consuelo
45 Peñón
46 Pedro
47 Estelnita
48 La Nona
49 Carnesoltas
50 Romanita
51 La Iguanita
52 Altagracia
53 Juanita
54 Suevia
55 Gertrudis
56 La Victoria
57 George
58 Victoria
59 Santa Cruz
60 Beta
61 Guanal
62 La Entrada
63 La Camagüeyana
64 Camagüey
65 Desprecio
66 Almendares
67 Casi Reina
68 Virtudes group
69 Reina
70 Pimentel
71 Porvenir
72 Ferrolana
73 Burgos
74 La Caridad (Juragua)
75 Boquina
76 Lili
77 Redención
78 La Juanita
79 Progreso
80 Lolita
81 Cayo del Medio
82 Papino
83 Mamina
84 José
85 Constance

NOTE: Compiled from data supplied by the Juragua Mining Co. and Compañía Cubana de Minas y Minerales. More than 200 denouncements or claims have been omitted, and only a few main roads are shown.

NOTA: Compilada de datos presentados por la Juragua Mining Co. y la Compañía Cubana de Minas y Minerales. Se han omitido más de 200 denuncios. y se han indicado solamente algunas de las carreteras.



INDEX MAP OF THE CAMAGUEY DISTRICT, CUBA, SHOWING DISTRIBUTION OF CHROME DEPOSITS AND PRINCIPAL PRODUCING MINES

MAPA DEL DISTRITO DE CAMAGUEY, CUBA, INDICANDO LAS UBICACIONES DE YACIMIENTOS DE CROMO Y DE LAS PRINCIPALES MINAS PRODUCTIVAS unimproved roads made on it are bad in wet weather. Serpentine from mine dumps has been used extensively for roads, even though it crumbles rapidly under heavy traffic; limestone and gabbro are available when needed for construction of first class roads. At the present time 1½-ton trucks are used for hauling ore to the Cuba Railroad for shipment to Nuevitas.

The large chrome deposits commonly form the summits of low rounded hills whose slopes are covered with chromite float. Many of the small deposits show no topographic expression and are revealed only by unusually heavy accumulations of float. Owing to the low relief, all mining is done in open pits, which rapidly fill with water when abandoned. For this reason, detailed study is impossible in nearly all abandoned pits in the district, and very few of them are described in this report. A few representative mines are described to illustrate the geological relations of the chromite and to indicate the economic problems involved in exploitation.

Chrome ore shipped from the Camaguey district in the past has been of satisfactory refractory grade, although some difficulty has been experienced in keeping the silica content below 5 percent. The average Cr_2O_3 content of shipping ore ranges between 30 and 32 percent. Pure chromite from Camaguey probably averages 35 to 36 percent Cr_2O_3; some may contain more Cr_2O_3, but some contains much less, and approaches chrompicotite in composition. On the whole, the chromite in the district seems quite uniform. The probability of finding deposits of metallurgical ore in this district is very small.

Magnesite deposits have been found in many parts of the Camaguey district, and many denouncements have been made for this mineral. Analyses indicate that most of the magnesite contains 10 percent or more CaO and therefore is of doubtful value. However, about 3,000 tons of high-grade magnesite was mined from shallow pits on the Zoila denouncement, near Cromo, and is now stored there. The magnesite is the dense, so-called bone variety, forming irregular cauliflower-shaped masses and apparently has replaced serpentine in which it occurs, though the pits from which it was mined are less than 15 feet deep and afford poor exposures. Small veins of magnesite, some of which show polished slickensides, were seen at a depth of 50 feet (15 m.) in La Caridad mine.

Aventura mine (30)[17/].--The Aventura mine is 2.1 miles (3.5 km.) by road northwest of the railroad siding at Cromo station. The ore body occupies the crest of a low hill on the eastern slope of which the Portentosa pit is located a few hundred feet away. The workings consist of three principal openings, including the main pit, and a few smaller pits, not all of which are shown (pl. 10). The main pit is 360 feet (110 m.) long, about 90 feet (27.5 m.) wide, and had a maximum depth of about 50 feet (15.2 m.) in March 1941. The ore body seems to be irregularly canoe-shaped, so it becomes narrower and shorter as mining progresses downward. The over-all length of the ore body was about 330 feet (104 m.) and the maximum width about 65 feet (19.[illegible] m). Pure chromite from this mine contains 35 to 36 percent Cr_2O_3, about 30 percent Al_2O_3, and has a Cr:Fe ratio of about 2.2 (tables 1 and 2). Ore as shipped contains 31 to 32 percent Cr_2O_3, 4 to 5 percent SiO_2, and 0.25 to 1 percent CaO.

Most of the ore in the Aventura mine is nearly massive black chromite containing a small amount of feldspar and serpentine, distributed as shown in plate 6. This ore is cut by dikes and irregular masses of gabbro and troctolite from a few millimeters to a meter (see figs. 2 and 4) in thickness. The well-defined dikes trend N. 40°-45° E., and dip 60°-70° NW., as if they had been intruded along a system of parallel fractures. Removal of dike material probably represents one-third to one-half the total cost of mining ore. In places the walls of the dikes are

17/ Numbers in parentheses refer to those used on the map (pl. 9).

poorly defined and the injection of troctolitic magma into the ore has produced the texture shown in plate 7, A and B; this type of ore must be concentrated and is sorted out. The thick dike in the southeast corner of the mine has been followed as the footwall in mining, although this entails leaving several feet of ore in the wall behind the dike. All contacts of the main ore body are well-defined. The entire northwestern boundary of the deposit is defined by faults, one of which extends continuously from the line of section A-A' to the southwest end of the ore body. The southeastern boundary is in part a primary igneous contact, and in part faulted. The small ore body in the deep pit crossed by section B-B' consists of massive high-grade

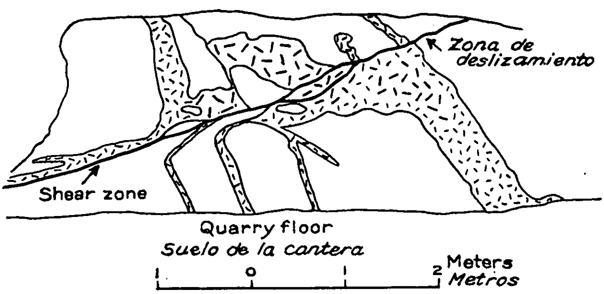


Figure 4.—Gabbro in chromite at the Aventura mine, Camaguey. The smaller dikes follow parallel fractures, and are cut by a later fault. Variation in grain size shown diagrammatically.

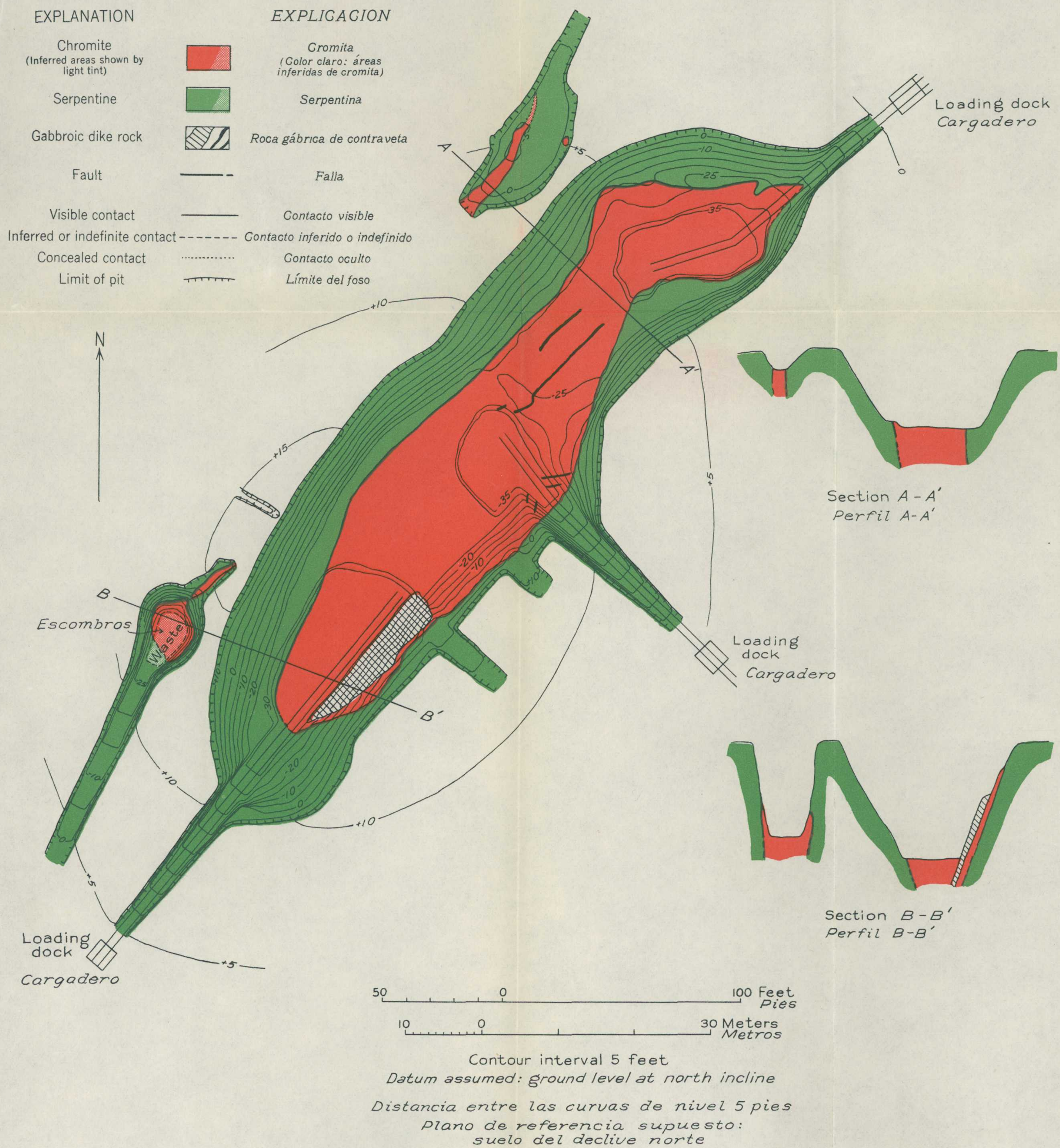
ore bounded by steep faults. The ore in the northern small pit is mainly disseminated, bounded in part by faults and in part by gradational borders. The small lenses seem to be distinct ore bodies separate from the main deposit.

El Cid mine (11).--El Cid mine is about 10.5 miles (17 km.) north of Cromo in a straight line, not far from the base of the Sierra Cubitas. The mine is said to have produced about 6,000 tons of ore averaging about 34 percent Cr_2O_3. The workings consist of six principal pits 10 feet (3 m.) or more in depth and a number of shallower scalping pits scattered over an area of several acres. The principal ore bodies are alined roughly in a westerly direction and distributed over a length of 1,000 feet (305 m.).

The form of the ore bodies is shown on the accompanying map (pl. 11). The ore is massive and high grade, and nearly free of gabbroic dikes; one 2-inch (5 cm.) anorthosite dike was noted in ore. The contacts of the ore bodies against the serpentinized dunite country rock are well-defined, and faulted in many places. The ore body in the westernmost pit is bounded by igneous contacts, except where cut off at the west end by a fault zone along a gabbroic dike. The eastern end of this body resembles a vertical dike 1½ feet (45 cm.) thick, with clearly defined parallel walls and unfaulted contacts. The ore body in the pit crossed by section A-A' is bounded by faults that diverge downward. The easternmost pit was partly filled with water, and no ore was seen in place. There is unusually well developed layering in troctolite and dunite, dipping about 65° W. Some of the best specimens showing pegmatitic troctolite, troctolite-dunite relations, and inclusions of chrome ore in troctolite were obtained from the dumps at this mine.

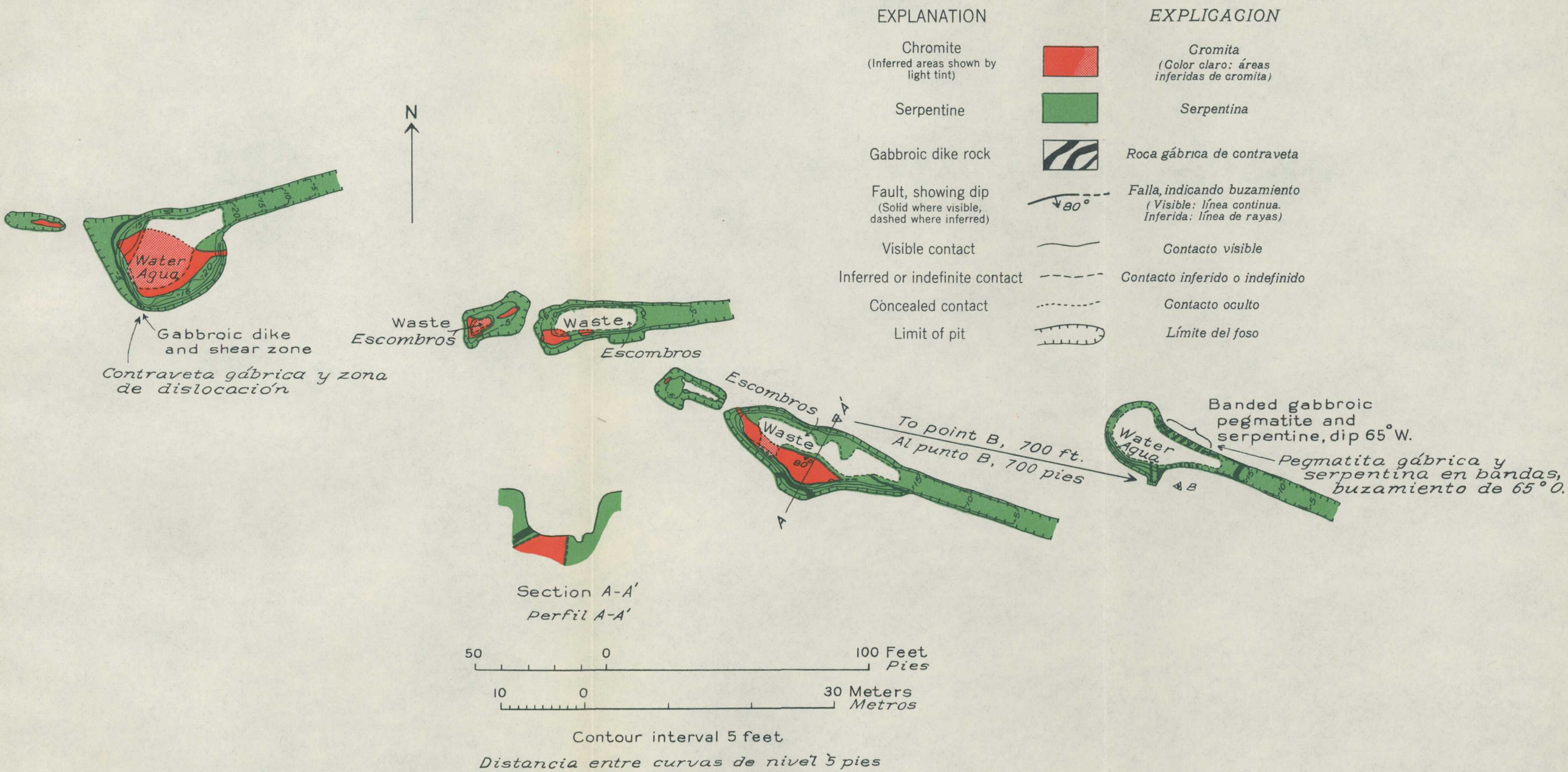
The amount of lode ore remaining seems to be rather small, but is sufficient to justify further exploration. Some of the pits reveal deep pockets of residual ore under a comparatively thin layer of float ore; though the tonnage in the cover may be small, the pockets might yield a large amount.

Guillermina mine (10).--The Guillermina mine lies about 2 kilometers southwest of El Cid mine, and like El Cid shows no topographic expression. The ore body consists of nodules and octahedra of chromite, or a mixture of both in a matrix consisting principally of troctolite. The deposit, as shown in plate 12, consists of two ore bodies having very irregular outlines. The southern sides of both ore bodies and the western end of the larger body are bounded by faults, and there is a strong probability that both were once parts of one larger mass.



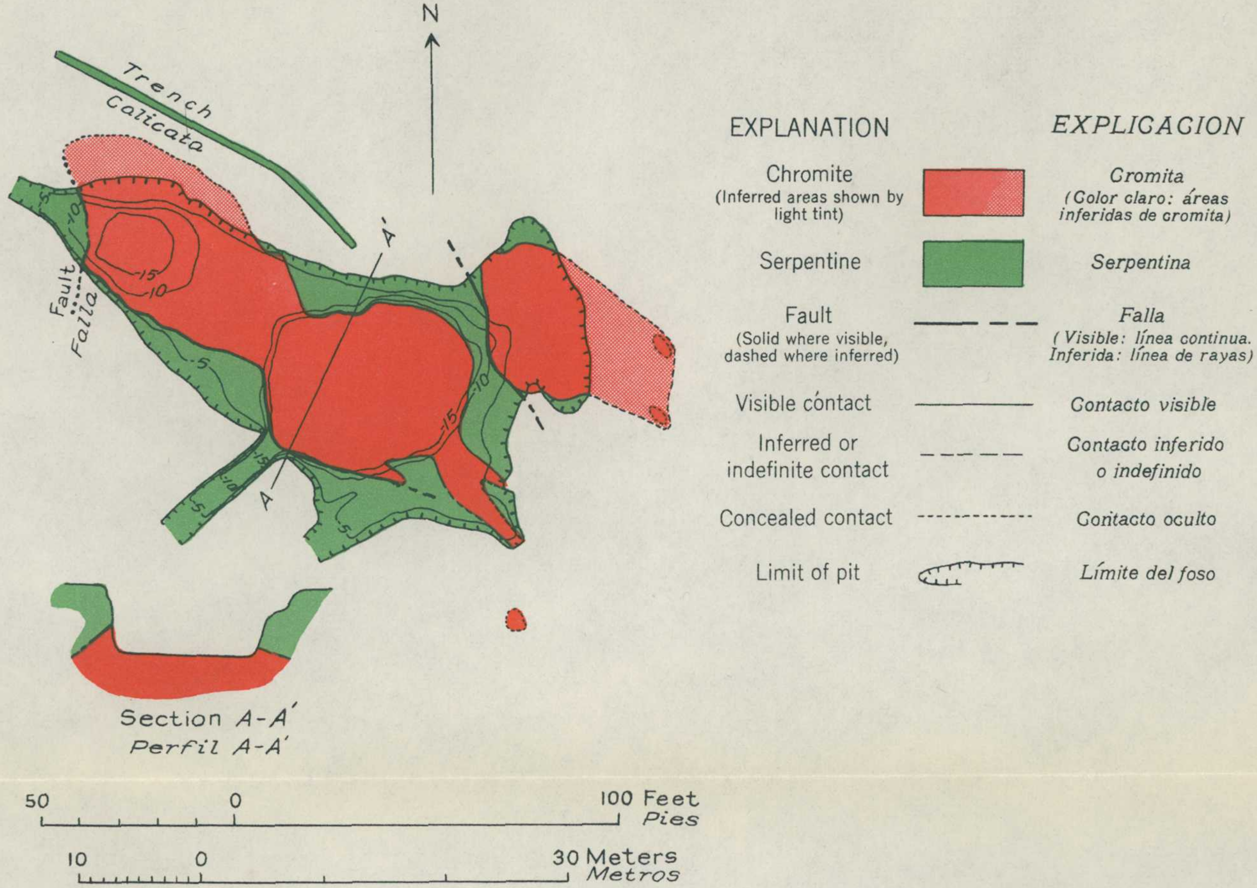
PLAN AND SECTIONS OF THE AVENTURA MINE, CAMAGÜEY

PLANO Y PERFILES DE LA MINA AVENTURA, CAMAGÜEY



PRINCIPAL WORKINGS AT EL CID MINE, CAMAGÜEY

EXPLOTACIONES PRINCIPALES DE LA MINA EL CID, CAMAGÜEY



Contour interval 5 feet

Datum assumed

Distancia entre las curvas de nivel 5 pies

Plano de referencia supuesto

PLAN AND SECTION OF THE GUILLERMINA MINE, CAMAGÜEY

PLANO Y PERFIL DE LA MINA GUILLERMINA, CAMAGÜEY

The mine yielded about 3,000 tons of ore before operations were suspended because of the low grade (20-30 percent Cr_2O_3) and high lime content of the ore. Analyses indicate that the Cr_2O_3 content of the chromite is the same as in other Camaguey ore, and that the ore would be suitable for milling (table 1).

Time in the field did not permit detailed examination of the deposit, and only the major relations can be outlined here. The relations of octahedra and nodules are shown in plates 3, B and 4, briefly discussed above (pp. 19-20). The country rock of the deposit is serpentinized dunite that grades outward into peridotite. The gangue in the border of the ore body consists of serpentinized dunite and a very small proportion of feldspar, whereas the gangue in the central part consists of troctolite containing approximately 20 percent of partly altered olivine. In the intermediate zone troctolite and dunite are distributed in splotches in the ore. The size and distribution of nodules and crystals seems unrelated to the composition of the gangue or to the distance from the edge of the ore body; in fact, some of the largest nodules occur at unfaulted igneous contacts. Planar structure indicated by parallel arrangement of flattened nodules is likewise unrelated to primary contacts, for in places it is cut off by them. Dikes of coarse-grained troctolite and fine-grained gabbro cut the chromite. The coarse troctolite contains a small amount of pyroxene, shows pronounced banding parallel to the walls, has poorly defined contacts, and shows the same degree of alteration as the matrix of the ore. The fine-grained gabbro dikes contain a large amount of pyroxene and very little olivine, have sharp contacts that cut across nodules, and show very little alteration. The troctolite dike is cut off by the hanging-wall fault of the main ore body, and its relation to the country rock is not known; the gabbro dikes continue out into the serpentinized country rock.

Jose mine (84).--The Jose mine is the easternmost chrome mine in the district. It is about 1¼ miles (2 km.) west of Central Lugareno, and ore is hauled about 4 miles (6.5 km.) over poor roads to Lugareno station on the Cuba Northern Railroad. The mine has produced about 2,000 tons of ore averaging 30-32 percent Cr_2O_3; the pure chromite contains slightly over 35 percent Cr_2O_3 (table 2).

The ore body is an irregular lens of massive ore containing feldspar in the gangue; the ore is similar to that in the Aventura mine. The lens is about 85 feet (26 m.) long, 20 feet (6.1 m.) in greatest exposed width, and has been mined in an open pit to a depth of about 45 feet (13.7 m.). The ore body trends about N. 45° E. and dips steeply southeastward. The ore is cut by numerous small faults and a few irregular gabbroic dikes that extend into the adjacent dunitic country rock. Although a large amount of ore remained, plans had been made to abandon the mine shortly after the writer's visit because of the dangerous condition of the pit walls, and excessive amounts of water.

La Caridad mine (74).--La Caridad mine, owned by the Juragua Mining Co., is 3.1 miles (5 km.) southwest of Minas, the station to which ore from the mine is delivered. This was the only chrome mine in Cuba in which power equipment was being used in extensive stripping operations in the spring of 1941. The mine produced about 8,500 tons of shipping ore from small lenses near the surface, and was believed to be worked out, when a large ore body was discovered by means of the torsion balance. In March 1941, the pit was about 500 feet (153 m.) long, 150 to 200 feet (46 to 61 m.) wide, and about 40 feet (12.2 m.) deep. Diamond-drill holes indicate that the chromite forms a nearly flat lying tabular body whose upper surface is about 70 feet below the surface of the ground. A 1½-cubic yard dragline scraper and a 1-cubic yard steam shovel were in use, and production of chromite was scheduled to begin early in the summer. Two very small lenses of chromite and several magnesite veins were visible in the walls of the pit. Pieces of chrome ore cut by gabbroic dikes were seen on the dump.

La Victoria mine (56).--La Victoria mine is about 3 miles (5 km.) northeast of Altagracia, and $1\frac{1}{4}$ miles (2 km.) from Victoria Switch, the loading point on the railroad. It is one of the larger mines in the district, with a production of several tens of thousands of tons to its credit. The workings, as shown in plate 13, consist of a large pit and a number of smaller ones strung out either way from it, along a series of chromite lenses. The total distance explored in this manner is about 850 feet (260 m.).

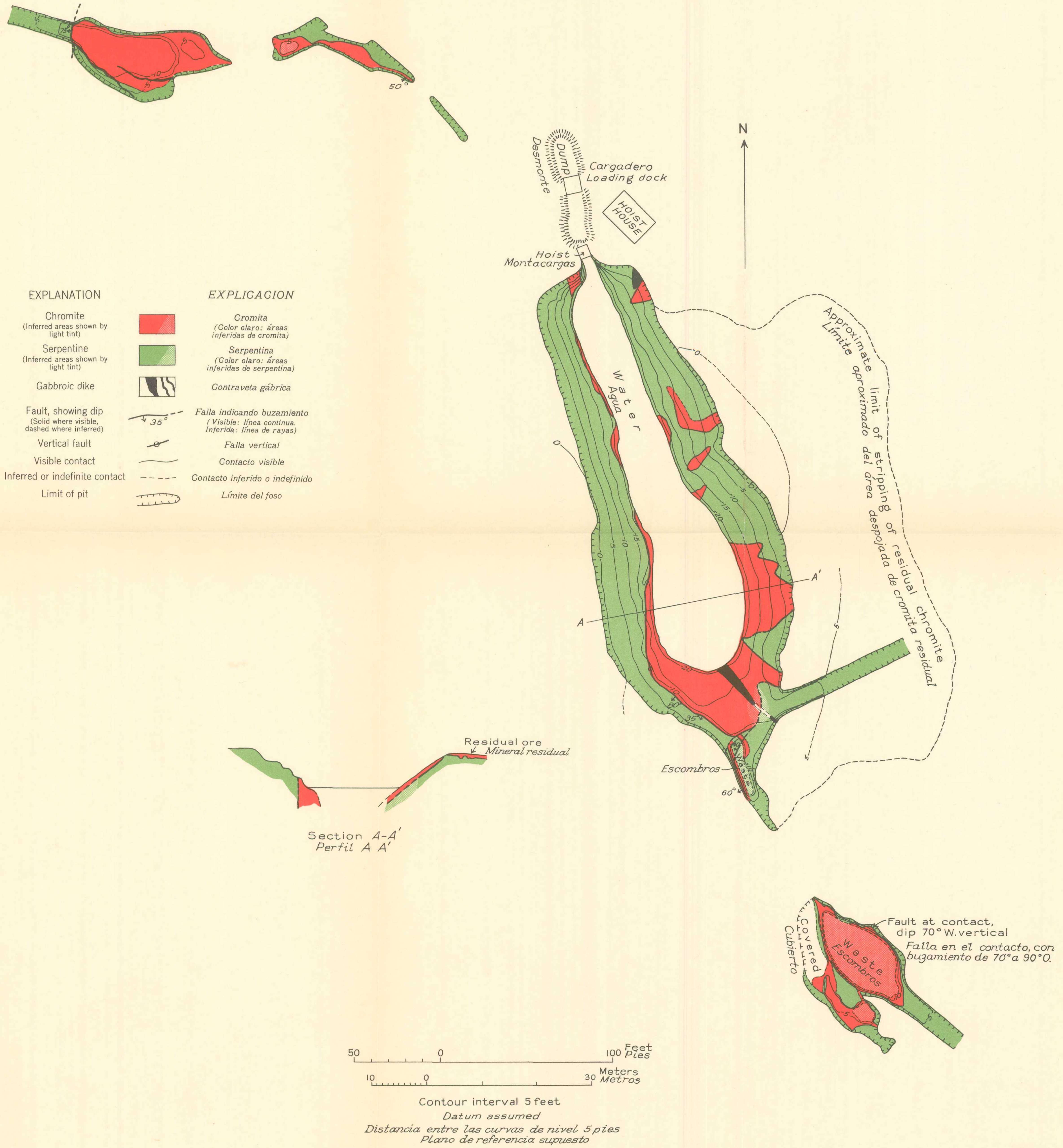
The ore visible in the main pit is chiefly massive, although high-grade disseminated material occupies the southeast end; high-grade disseminated ore is exposed in the smaller workings. The ore bodies are partly bounded by faults, and in places are badly sheared internally. The main ore body lies between two faults that intersect at the south end, and converge downward (sec. A-A'). The fault along the west side dips essentially vertically except near the southern end of the pit, where the dip is very irregular. As the eastern boundary fault dips 40° W. under the ore, most of the chrome exposures in the east side of the pit are only patches of a thin veneer, although some may be small lenses in the footwall of the fault.

The larger ore body in the southern pit is cut off on the northeast side by a well-defined nearly vertical fault, and on the southwest edge is cut off by a zone of shearing that dips steeply into the pit wall. The ore in the westernmost pit is bounded by igneous contacts except at the west side, where it is cut off by a fault dipping 75° W. The irregular mass in the intermediate opening consists essentially of two lenses that are connected by a highly sheared stringer, and which pinch eastward to a 12-inch (30 cm.) stringer. Serpentinized dunite forms the country rock. The distribution of gabbro dikes is indicated on the map, but it is impossible on a map of this scale to show the numerous small faults that cut and offset them.

The incline at the south end of the main pit gives an excellent profile of the bedrock surface and cross section of the residual ore (fig. 3). The residual ore averages about a foot in depth and has been stripped from an area of about half an acre (0.2 ha.).

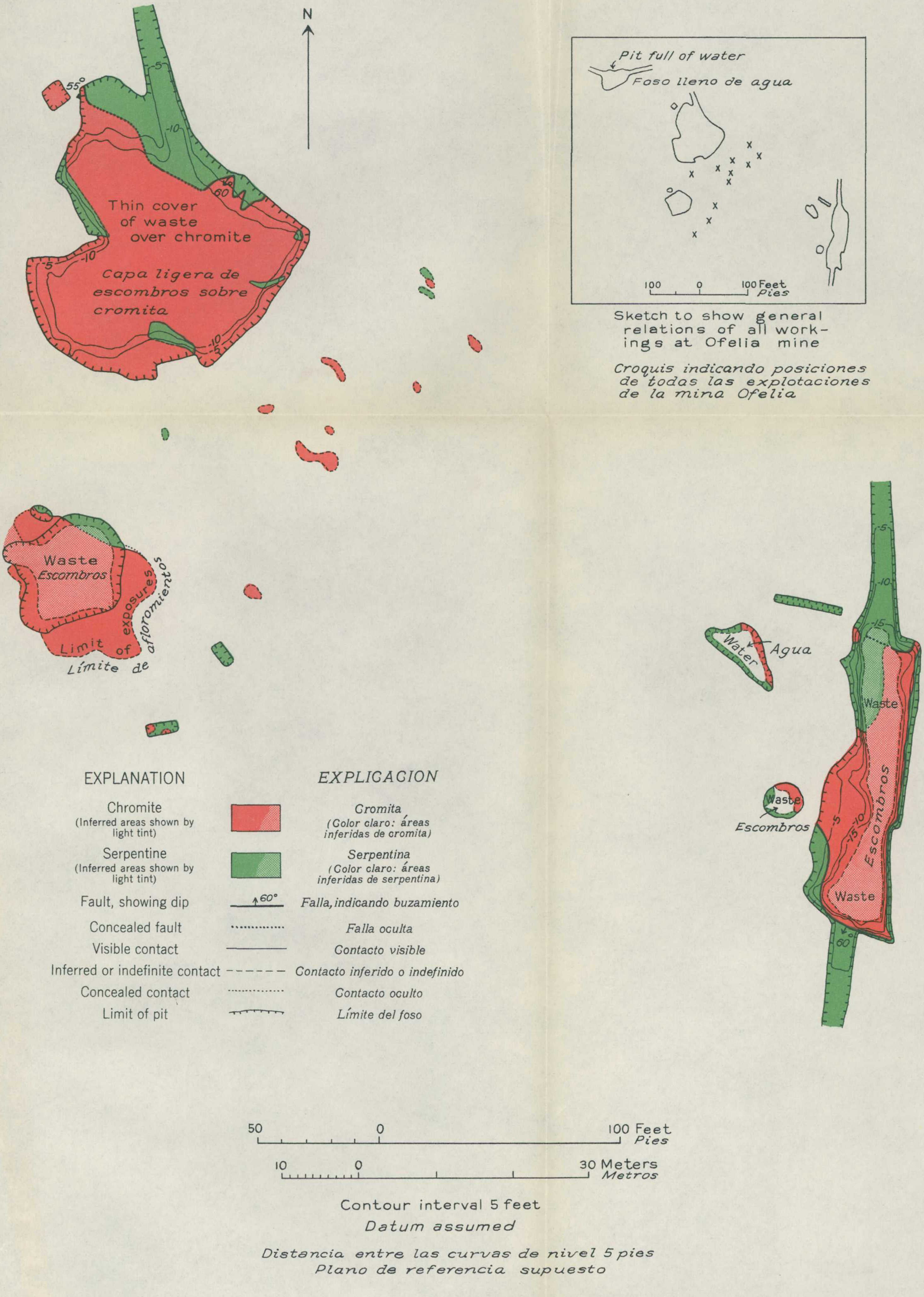
Ofelia mine (21).--The Ofelia mine is about 5 miles (8 km.) northwest of Cromo, the distance by road being somewhat greater. The denouncement covers at least three separate deposits distributed over an area of 4 to 5 acres (1.5 to 2 ha.) of flat grassland. Nearly 9,000 tons of ore was shipped from this mine before operations were suspended. Analyses indicate that the chromite contains 35 to 36 percent Cr_2O_3, so that the ore should be suitable for milling. Little ore could be seen in the small pit full of water (see pl. 14), and that ore body seems to have been mined out.

The entire floor and the walls along the south side of the large central pit are in disseminated ore that probably contains 60 to 80 percent chromite, or about 20 to 27 percent Cr_2O_3. The ore has a splotchy appearance due to uneven distribution of chromite, and in places shows good linear structure. The serpentine masses in the southeastern side of the pit are apparently inclusions of altered dunite in the ore, though the elongate mass may be a dike. The ore is cut off on the northeast by a well-defined fault that dips about 60° under the pit; the contact in the west side is a frozen igneous contact. The limits of the ore body are nowhere exposed in the south half of the pit, and the shallower pit to the south reveals ore that is identical in appearance and may be part of the same mass. The soil over the entire area in which chromite is exposed is very rich in



PLAN AND SECTION OF LA VICTORIA MINE, CAMAGÜEY

PLANO Y PERFIL DE LA MINA LA VICTORIA, CAMAGÜEY



ACCESSIBLE WORKINGS AT THE OFELIA MINE, CAMAGÜEY

EXPLOTACIONES ACCESIBLES DE LA MINA OFELIA, CAMAGÜEY chromite. The deposit probably contains a large tonnage of milling ore, and might yield more high-grade shipping ore.

The easternmost pit was opened on the edge of a tabular mass of chromite that dips gently eastward. The ore ranges from disseminated low-grade to massive high-grade. The eastern wall of the pit reveals 8 to 10 feet (2.4 to 3 m.) of chromite overlain by 5 to 10 feet (1.5 to 3 m.) of serpentinized dunite; the contact is very irregular, in part igneous and in part faulted. The ore is cut off on the south by an irregularly curved southward-dipping fault that crosses the southern end of the pit. Another southward-dipping fault forms the northern boundary of the ore body. The ore in the western wall of the pit is highly sheared and mixed with serpentine, and there are no exposures beyond the edge of the pits. This deposit would appear to be well suited for a small stripping operation.

Rafael mine (33).--The Rafael denouncement covers three main pits that were being worked in the spring of 1941, areas of float ore that were being mined, and two large abandoned openings. Only the three pits in operation at the time of the writer's visit are shown on the accompanying map (pl. 15). The mines are very close to the railroad siding at Cromo. Total production from the Rafael mine exceeds 70,000 tons of ore.

Pit No. 1 is nearly 50 feet (15.3 m.) deep, and consists of two parts. The shallow abandoned portion was occupied by a lens hat was elongated in a northwest direction and has been mined out. Small remnants of the northwest end of this body were left in the old incline. The larger lens consists of high-grade ore bounded by steeply dipping faults which are not shown because of th r complexity. The fault along the northeastern side dips ste ly into the wall, and it is doubtful if all the ore can be rec red from the present opening. The south end of the dep is cut off by irregular vertical slickensided surfaces, and northwest side is bounded by a poorly exposed fault dipping ' to 75° under the ore. The body as a whole probably plunges steeply eastward, and it showed little evidence of pinching out downward at the time of the writer's visit.

Pit No. 2, which is about 750 feet (228 m.) northeast of Pit No. 1, also was developed on two chromite bodies. The northern excavation was full of water, and the southern lens of high-grade ore had been nearly worked out in March 1941. Judging from the form of the pit, both ore bodies plunged steeply northwestward and pinched downward. The remnant of the southern lens dipped about 80° NW., under the steep wall of the pit. Although the southern and eastern borders of this lens were cut off by faults, the other contacts were affected little by faulting, and the northern end frays out into a number of low-grade lenses too small to mine. The visible part of the ore body in the northern half of this pit consists of milling-grade, disseminated ore. A fault dipping northward 50° or less forms the footwall of the northern ore body, and it is possible that the northern body represents the faulted upper portion of the southern body.

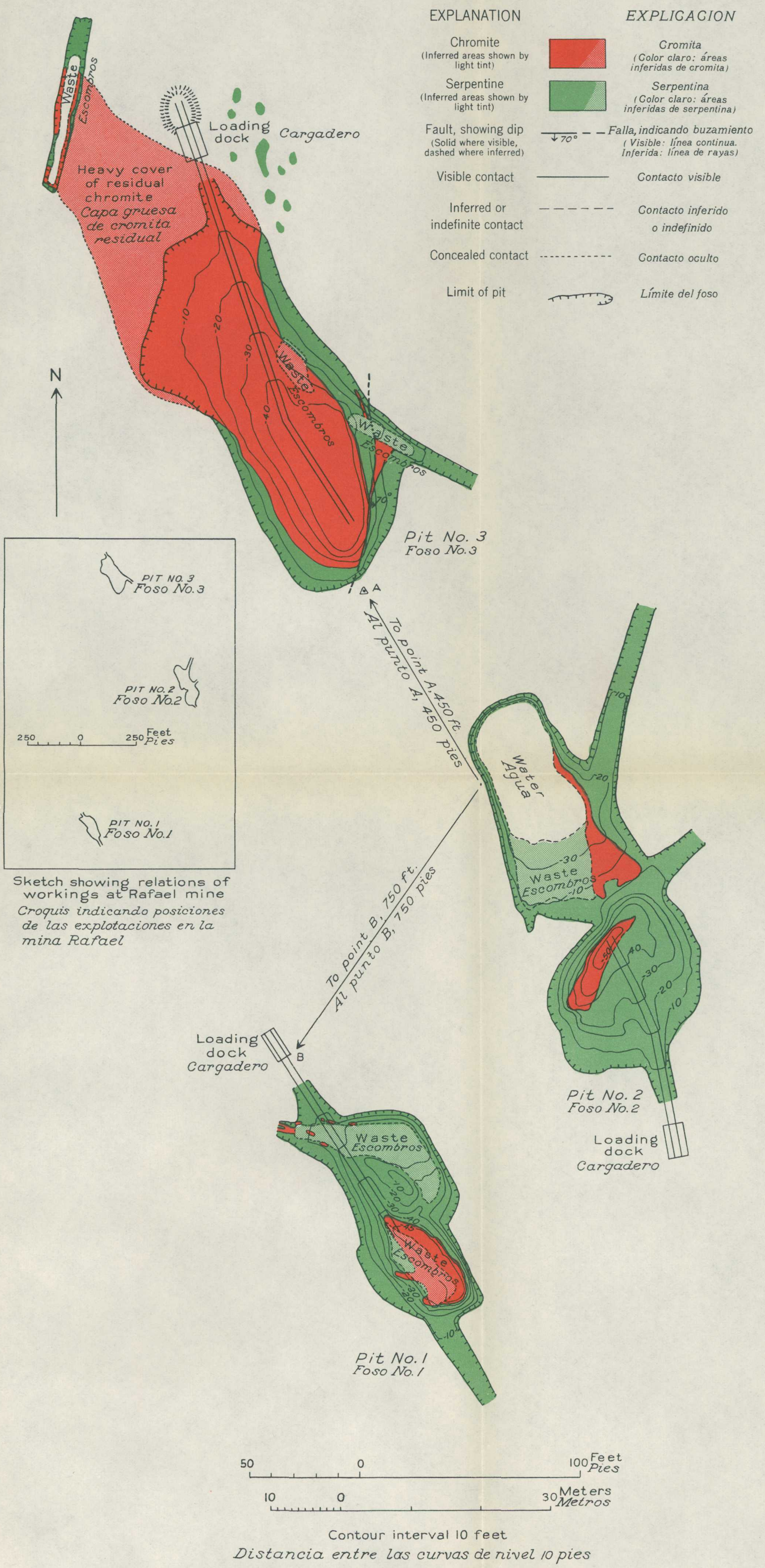
Pit No. 3 is excavated in the largest ore body now exposed on the Rafael denouncement. It is about 500 feet (153 m.) northwest of Pit No. 2. Most of the ore is low-grade disseminated chromite enclosing occasional horses of barren serpentine up to 10 feet (3 m.) across. The southeastern corner of the ore body is cut off by a north-south fault dipping 65°-80° E., under a small sliver of ore. The contact in the west side of the pit dips gently westward at an uncertain angle and is probably not faulted. The eastern contact is certainly igneous and well-defined; it is very irregular and stands nearly vertically. The extension of the ore body to the northwest is uncertain, because that area is covered by an unusually heavy blanket of float chromite, which in places is as much as 5 feet thick. The presence of disseminated ore in the trench to the northwest, however, is suggestive.

The Rafael denouncement has been worked for float chrome as well as lode. As mentioned above, the float is 4 to 5 feet (1.2 to 1.5 m.) thick in places. Analysis of a 4-foot channel sample from the ground surface to serpentine bed rock a few hundred feet northwest of the three pits described, showed 25.88 percent Cr_2O_3, or about 70 percent chromite in the sample, if the chromite itself contains 35 percent Cr_2O_3. The chromium-iron ratio is only slightly over 1 because of the amount of lateritic iron ore present.

Teide and Demasia Angelina Tercera mines (20).--The Teide denouncement contains many chrome deposits (see pl. 16), and the Demasia Angelina Tercera denouncement, which adjoins the Teide on the south, covers some deposits related to the Teide group. The denouncements may therefore be described most conveniently together. The principal workings are clustered around the summit of a broad hill that rises 50 to 100 feet (15 to 30 m.) above the surrounding terrain; a second group of workings extends around the northern base of the hill, about 1,000 feet (300 m.) to the north. The Teide was one of the first producing mines in the district, and yielded some 50,000 tons of ore up to the end of 1938. The workings are about 5½ miles (9 km.) northwest of Cromo.

The ore at the Teide mine is varied in texture and grain size. The massive ore shows few distinctive features or textures, and grades in normal manner into medium-grained disseminated ore. The large body of disseminated ore in the southern group of workings contains numerous small massive lenses with gradational borders, and grades outward irregularly into altered barren dunite. The dump from the largest pit in the northern group is largely composed of brecciated coarse chromite in troctolite. The chromite fragments range in size from about an inch (2.5 cm.) to a millimeter, the finer grains being embedded in the interstitial feldspar. Some of the blocks of ore reveal obscure dikes of banded gabbro or troctolite which look as if the dike material had been injected into a mushy mixture of chromite and troctolite. The chromite fragments show no orientation, and in a general way the ore resembles the type shown in plate 8, C, though with more complete fragmentation and greater dilution. The dump could be milled very readily, for the chromite in the ore is very hard, and weathering has reduced most of the feldspar to the consistency of hard chalk.

The two largest pits in the northern group, 50 by 200 feet (15 by 61 m.), and 40 by 80 feet (12 by 24 m.) respectively, and the two deepest pits in the southern group were partly full of water and revealed very little chromite, but chromite was exposed in almost every other opening. The large shallow pit, which is the most northerly pit in the southern group, revealed the most ore. The chromite in this pit is principally disseminated milling-grade ore mixed with a good deal of barren serpentine. The principal exposed ore body lies between two east-dipping north-south faults, and is overlain by serpentine. (See pl. 16, sec. A-A'.) The serpentine contact is a highly irregular, unfaulted igneous contact. Though the faults are obvious in the northern part of the pit, they could not be traced with assurance into the southern end, and it is not known whether the southeastern ore body is a faulted segment of the larger ore body or an independent one. Shallow drill holes show that the ore extends considerably beyond the limits of the pit. Another deposit of milling-grade ore is exposed in the southeastern group of workings shown on the large scale map (see pl. 16), where three pits are lined up along a probably continuous lens of ore some 150 feet (50 m.) long and of undetermined width. The easternmost pit of the southern group shown on the small scale sketch reveals a lens of high-grade ore 50 feet (15.2 m.) long and 12 to 15 feet (3 to 4 m.) wide, which trends N. 30° W., and dips 40° to 50° SW. between two faults. The trench north of



ACCESSIBLE WORKINGS AT THE RAFAEL MINE, CAMAGÜEY

EXPLOTACIONES ACCESIBLES DE LA MINA RAFAEL, CAMAGÜEY this pit follows a sheared chromite stringer 100 feet (30 m.) long, and from 1 foot (30 cm.) to 4 feet (1.2 m.) wide, lying en echelon with the larger lens. The large pits containing water are 40 to 50 feet deep, and are reported to contain good ore. The ore body in the pit at the edge of the Demasia Angelina Tercera denouncement was said to continue northward into the Teide ground.

Float ore covers a large part of the hill and has been mined from an area of about 2 acres (0.8 ha.). The number of chrome exposures and the size of some of the known deposits indicate that this area merits extensive subsurface exploration.

Western Oriente Province

Holguin district

The Holguin mining district in the past has been best known for its gold and copper mines. A few hundred tons of chrome ore were mined about 1918, and 450 tons containing about 32 percent Cr_2O_3 were shipped in the fall of 1940 by J. A. Silva. The chromite deposits are exposed in two parallel belts of serpentine trending N. 70°-80° E., between Holguin, Gibara, and Central Santa Lucia (pl. 17). The district is characterized by rolling topography with a relief of about 500 feet (152 m.). The serpentine belts form ridges, above which rise isolated knobs or mesas of massive white limestone that overlie the serpentine. The roads on the hills are rocky and passable most of the time, whereas those in the coastal plain to the north are impassable in wet weather. The ore shipped in 1940 was trucked to Gibara from the Bob and Junior, Angelita Silva, Clemencia, and Bad Luck denouncements.

The geologic structure of the Holguin district is dominated by a series of northeastward-trending folds, which in places have been faulted. The serpentine is exposed in the cores of anticlines, and the overlying manganese-bearing volcanics and associated limestones occupy synclines. The local trends are markedly at variance with the prevailing northwest trends along the northern coast of eastern Cuba.

The country rock of the chromite deposits comprises partly serpentinized peridotite and dunite. Most of it is blocky, with shearing mainly limited to definite zones. Foreign inclusions are so abundant in the serpentine on the Angelita Silva denouncement that their debris masks much of the serpentine (see p. 10).

Bob and Junior mine.--The workings on the Bob and Junior denouncement consist of a number of shallow cuts and trenches scattered along the southwest end and northern slope of the southern serpentine ridge. The largest pit on the end of the ridge is about 50 feet (15.2 m.) across and 25 feet (7.6 m.) deep. It yielded about 100 tons of nearly massive ore from a sheared lens that dipped about 70° W. in thoroughly serpentinized dunite. The two principal openings are on the north slope of the ridge, about 200 feet apart on a line running N. 40° E. The southwestern pit is about 65 feet (20 m.) long, 15 to 20 feet (4.5 to 6 m.) deep, and trends N. 20° E. The cut followed a line of high-grade lenses not over 3 feet (1 m.) in maximum width, which yielded about 75 tons of 36- to 37-percent ore. The northeastern pit is 20 feet (6 m.) long, 6 feet (2 m.) wide, and about 27 feet (8.3 m.) deep, and was excavated in following down a small high-grade lens.

Angelita Silva mine.--The workings on the Angelita Silva denouncement include a drift, a crosscut tunnel and a number of shallow cuts along the chrome-bearing zone. The drift, driven N. 75° E. into the east bank of a small creek near the west end of the denouncement, is about 300 feet long, including lateral branches and crosscuts. The chromite occurs as small high-grade lenses in low-grade disseminated ore and barren serpentine; the largest lens found was from 1 to 3 feet (30 cm. to 1 m.) wide, 5 feet (1.5 m.) high, about 30 feet long, and yielded about 50 tons of ore. A 35-foot (10.6 m.) raise to the surface connects with a surface pit about 50 feet (15 m.) across, in which a chromite zone 20 feet (6 m.) wide is exposed. The zone is vertical, and may contain 10 percent Cr_2O_3 in the form of irregular lenses and pockets of high-grade ore 6 to 18 inches (15 to 45 cm.) long. A 10-foot (3 m.) shaft east of the raise reveals good planar structure striking N. 15° E., or normal to the trend of the ore zone, and dipping vertically. The north end of the bands are cut off sharply by serpentinized dunite along an unfaulted igneous contact. East of the drift a number of shallow pits have been excavated on lenses of millimeter-grained low-grade disseminated ore ranging from 6 inches to 1½ feet (15 to 45 cm.) wide. In two of these pits the chromite is in direct contact with horses of schistose diorite. The crosscut tunnel had been driven about 330 feet (106 m.) S. 10° W. under the chromite zone from the north base of the ridge, about 750 feet (230 m.) east of the drift. At the time of the writer's visit, the tunnel penetrated about 10 feet (3 m.) of low-grade ore directly below and about 125 feet (38 m.) under a small surface exposure. It is reported to have cut about 8 feet (2.4 m.) of high-grade ore a little farther in. This tunnel indicates that the chromiferous zone is essentially vertical, and apparently may be prospected as a fairly regular tabular deposit. The chromite is probably similar in composition to that on the Clemencia denouncement, which contains 42 percent Cr_2O_3.

Clemencia mine.--The chrome ore on the Clemencia denouncement occurs in a well-defined zone similar to that on the Angelita Silva. This zone has been explored by surface workings scattered over a distance of about 1,650 feet (500 m.) along the northern slope of the serpentine ridge east of the Rio Gibara, in the vicinity of the limestone knob called El Encanto.

Two pits about 10 feet (3 m.) deep and two 25-foot (7.6 m.) shafts, 50 feet (15.2 m.) apart and connected by a tunnel date from Spanish times. Three open cuts southwest of the shafts indicate that the ore zone ranges from 3 to 20 feet (1 to 6.1 m.) in width through a length of about 750 feet (230 m.). The ore ranges from very fine grained, low-grade disseminated ore to nearly massive chromite which in places has been thoroughly crushed. Two crosscut tunnels were driven into the hillside about 50 and 100 feet (15.2 and 30.5 m.) respectively, below the outcrop. The upper tunnel cut good ore, but was caved; the lower tunnel, driven by hand without explosives, was stopped when it struck a large horse of diorite.

Chromite from the Clemencia mine contains about 42 percent Cr_2O_3, and has a Cr:Fe ratio of 2.6 (table 1). Neither of these deposits shows promise of yielding much high-grade ore, though some is to be expected. If systematic exploration shows reasonable continuity of milling-grade ore, the two mines together might support a medium-sized mill that would produce concentrates containing about 40 percent Cr_2O_3.

Bad Luck mine.--The Bad Luck denouncement extends across a large limestone mesa known as Gibara Saddle, and covers chrome exposures in two localities. The principal workings are on a serpentine ridge exposed in a reentrant eroded into the north side of the mesa. A series of irregular shallow pits and cuts expose chromite in a zone about 700 feet (215 m.) long and 60 feet (18 m.) wide, trending about N. 40° E., diagonally across the ridge. The high-grade lenses attain a maximum width of about 5 feet (1.5 m.), and have yielded about 200 tons of 25- to 26-percent ore. Most of the chromite is disseminated in a completely serpentinized dunite matrix. Some of the ore contains nodules up to a centimeter across, and octahedra of the type shown in plate 3, B. The pure chromite contains about 38.5 percent Cr_2O_3, and 12 percent Fe, with a Cr:Fe ratio of

2.2 (table 2). Though no minable high-grade ore is in sight, the deposit might yield a few thousand tons of milling ore that would produce a refractory-grade concentrate.

Low-grade disseminated ore containing 20 to 30 percent of chromite is exposed in a pit on the northwest slope below Gibara Saddle. The exposure is 25 feet (7.6 m.) long by 12 feet (3.6 m.) wide, and highly sheared. Two pits 150 feet (50 m.) farther down the slope reveal lenses of medium-grade ore 12 and 18 inches (30 and 45 cm.) wide, respectively.

Eastern Oriente Province

General geology and physiography

The eastern part of Oriente includes some of the wildest and most rugged terrain in Cuba. (See pl. 18.) Hayes, Vaughan, and Spencer summarized the physical geography of the region as follows:[18]

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

Hayes, Vaughan, and Spencer recognized the anticlinal nature of the mountains along the north coast, and the domical structure of the Sierra de Nipe. They inferred that

> All the mountains in the eastern part of Cuba have been carved from a high plateau, indications of which are seen in the level summits of El Unque near Baracoa, and of other flat-topped mountains which have been observed within the drainage of the Mayari and Sagua rivers. The broad flat summits of the Sierra Nipe are also doubtless a remnant of this old plateau.[19]

18/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., Report on a geological reconnaissance of Cuba: Civil Report of Brig. Gen. Leonard Wood, Military Governor of Cuba for 1901, p. 12 (pag. 11).
19/ Idem, p. 11 (pag. 10).

The northern mountain range seems to be made up of three domical folds that form the Sierra de Nipe, the Sierra del Cristal, and the Cuchillas de Toar, respectively. Of these domes the Sierra de Nipe is best defined, the Cuchillas de Toar the largest and least obvious. This structural pattern is revealed by the distribution and attitude of the Tertiary sedimentary cover, and by the form of the mountains.

The Tertiary sediments lying unconformably on the serpentine core wrap three-quarters of the way around the Sierra de Nipe and reach an altitude of nearly 900 feet on the north slope. Dips on the north side vary from a maximum of about 20° to nearly horizontal on the coastal plain north of Mayari. The sedimentary rocks extend up the valley of the Rio Mayari in a small embayment and wrap around the northern side of the Sierra del Cristal. Gently dipping limestones extend far inland south of Sagua de Tanamo, in an embayment between the Sierra del Cristal and the Cuchillas de Toar. Serpentine extends to the coast from the vicinity of Cananova nearly to the mouth of the Rio Toa, and the sedimentary cover is apparently absent from this area. Sedimentary rocks lying unconformably on the serpentine and dipping eastward away from it, occupy a belt 2 to 3 miles (3.2 to 4.8 km.) wide in the vicinity of Baracoa. These sediments wedge out northward along the coast somewhere between the Rio Toa and Navas Bay.

The profile of the Sierra de Nipe viewed from any quarter has the form of a broad arch, above which rises one prominent point, Mensura Peak. The summit plateau, when viewed from the air, is seen to fray out into sloping ridges instead of breaking off in a steep mountain front. The surrounding plains rise gently toward the mountain base, and the streams occupy valleys that gradually increase in depth mountainward. The Sierra thus has the aspect of a dome whose steep flanks have been eroded deeply. Erosion has been so great in the valley of the Rio

Mayari that the depth of the structural sag between the Sierra de Nipe and the Sierra del Cristal cannot be definitely ascertained.

The broad arc formed by the coastline between Moa and Baracoa reflects the domical form of the Cuchillas de Toar. From Moa to Canete, in the area which includes the Moa iron-ore fields, the laterite-covered serpentine surface rises southward from the shore on an unbroken 5° slope for several miles, nearly to the crest of the range. In the vicinity of Baracoa dissection has proceeded rapidly in the sedimentary cover, and the domical form is revealed principally by accordance of ridges. Laterite-covered flats are common on the stream divides southwest of Baracoa, and many of the ridges slope smoothly eastward across serpentine and sedimentary rocks alike.

The streams draining the Cuchillas de Toar occupy valleys that deepen rapidly headward into steep-walled gorges. The valley of the Rio Cayoguan, for instance, is about 600 feet (200 m.) deep at the Cayoguan mines, only 3.7 miles (6 km.) from the coast. As the stream gradients are steep and rainfall is very heavy, stream erosion is rapid. All the streams draining northward between Baracoa and Preston, and the tributaries of the Rio Cauto as well, have meandering courses, even in the gorges. Most of the valleys show rude radial drainage away from the centers of the principal domes, across both serpentine and sedimentary rocks alike. The mouths of the streams have been drowned and are marked by estuaries. Many of the estuaries are partly blocked by elevated coral reefs. Coastal terraces up to as much as 250 feet (76 m.) above sea level form conspicuous features of the coast line near Baracoa.[20] Baracoa is built on a terrace that is partly cut into Tertiary sediments, and partly formed by the surface of an elevated coral reef.

20/ Hayes, C. W., Vaughan, T. W., and Spencer, A. C., op. cit., p. 19 (pag. 19).

The northern range of mountains in eastern Oriente is believed to comprise three major domical folds whose present relief is the result of late Tertiary or early Quaternary uplift along axes of earlier Tertiary folding. The drowned river mouths and elevated coastal terraces are proof of crustal instability in recent geologic times. Although laterite is still forming on all but the steepest serpentine slopes, the thick iron-ore blanket is presumed to have been formed on a surface of low relief before the last period of uplift, because the smooth laterite-covered surfaces now are being rapidly destroyed by stream erosion. This old surface, which probably approached a peneplain in smoothness, bevelled the serpentine and folded Tertiary sedimentary rocks, and may have extended across all of eastern Oriente Province. Mensura Peak, in the Sierra de Nipe, and El Yunque de Baracoa probably represent erosional remnants, or monadnocks, on that surface. Taber has indicated that analogous deformed erosion surfaces in the Sierra Maestra are probably Pliocene.[21]

Transportation in the serpentine areas of eastern Oriente is easy in some parts and very difficult in other parts. The gentle laterite-covered slopes support open pine forests, known as pinales, in which a car can be driven almost anywhere. The higher parts of the Sierra de Nipe and the Moa district are covered by this type of forest. The dissected portions or cuchillas, in contrast, are characterized by steep-walled canyons in which 50° slopes are not unusual. The vegetation on these slopes consists of brush and hardwood, too small to be of commercial value for timber, and so thick that travelling or prospecting is a very slow, arduous process. Travel across the drainage lines is difficult because of the canyons to be crossed,

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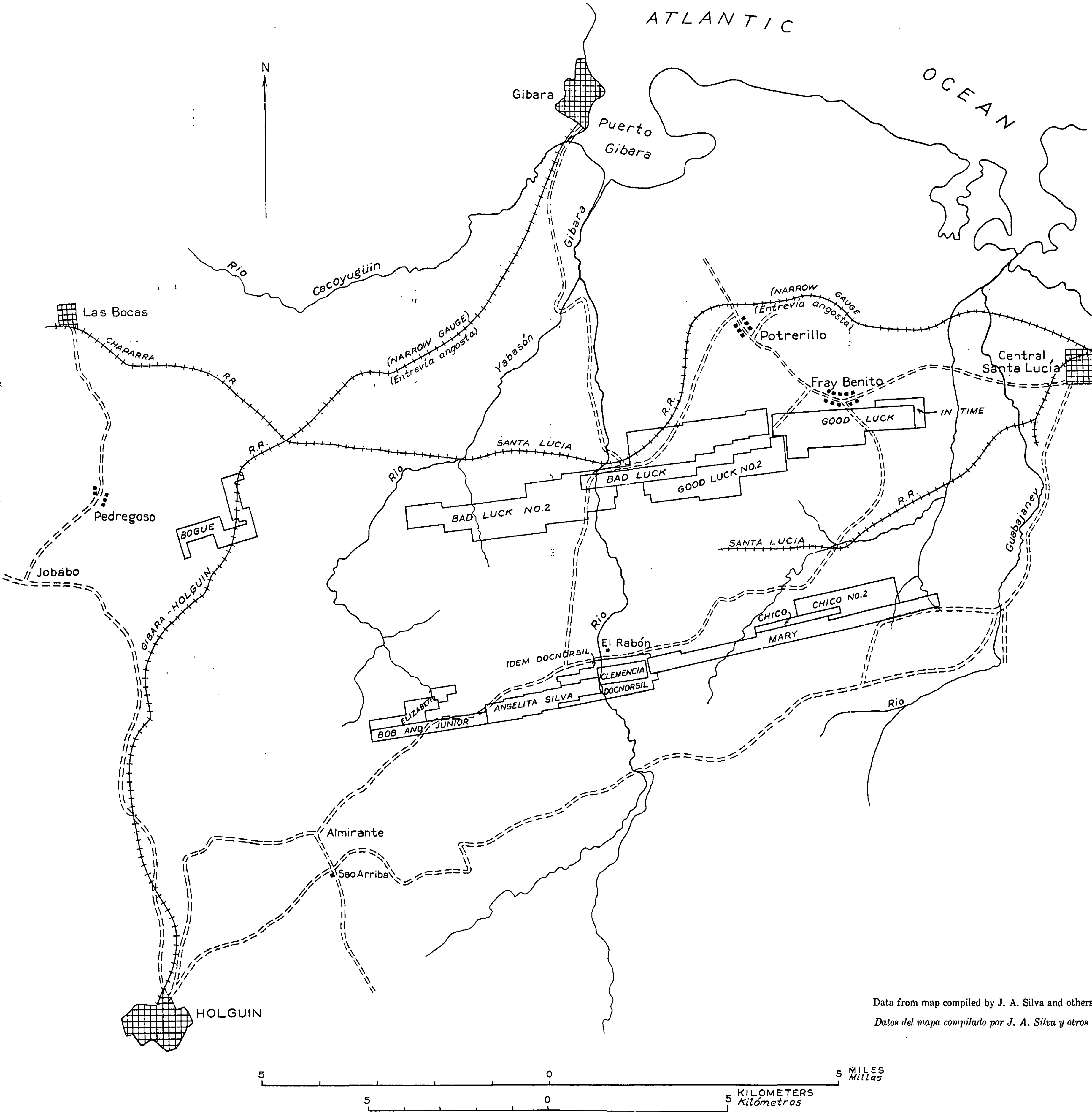
21/ Taber, Stephen, Sierra Maestra of Cuba, part of the northern rim of the Bartlett Trough: Geol. Soc. America Bull. 45, p. 596, 1934.



Data from map compiled by J. A. Silva and others
Datos del mapa compilado por J. A. Silva y otros

CHROMITE DENOUNCEMENTS AND PRINCIPAL TRANSPORTATION ROUTES IN THE VICINITY OF HOLGUIN, ORIENTE PROVINCE

DENUNCIOS DE CROMITA Y RUTAS PRINCIPALES DE TRANSPORTE EN LAS CERCANIAS DE HOLGUIN, PROVINCIA DE ORIENTE

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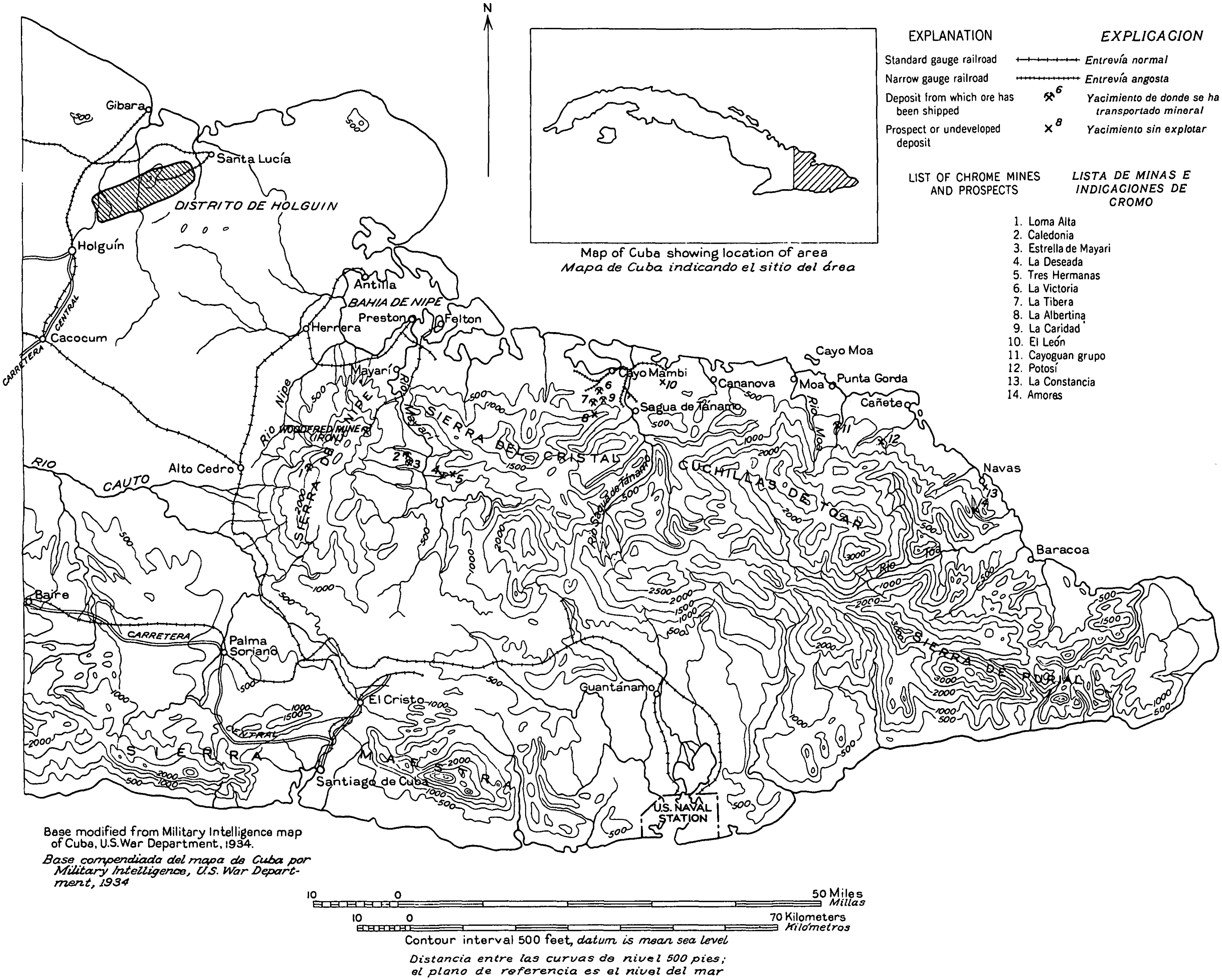

MAP OF THE EASTERN PART OF ORIENTE PROVINCE, SHOWING LOCATION OF THE PRINCIPAL CHROME DEPOSITS

MAPA DE LA PARTE ORIENTAL DE LA PROVINCIA DE ORIENTE, INDICANDO UBICACIONES DE LOS YACIMIENTOS PRINCIPALES DE CROMO and is almost impossible during rainy periods when the streams are in flood.

Mayari district

The Mayari chrome district comprises the Sierra de Nipe and the serpentine areas included in the drainage basin of the Rio Mayari. Ore mined on the summit upland can be hauled easily by truck to the Woodfred mine, and thence by rail to tidewater at Felton. Ore from the deposits on the southeast slope of the Sierra de Nipe at the present time must be hauled by pack mule to a poor road that climbs nearly a thousand feet (300 m.) up to the pinales.

Analyses indicate that the chromite in this district contains 55 to 58 percent of Cr_2O_3, and good concentrates or high-grade ore are therefore of metallurgical grade. (See tables 1 and 2.)

Loma Alta mine (1).--The Loma Alta mine, discovered in 1940, is about 8 miles (13 km.) southeast of Woodfred, at an altitude of some 2,000 feet (600 m.), near the northwest edge of the pinales. The deposit was revealed by heavy chrome float on a low rounded knoll, and its extent was not known at the time of the writer's visit, though some 200 tons of ore averaging about 45 percent Cr_2O_3 had been mined and shipped to Felton. The workings consisted of an open cut 100 feet (30 m.) long in the western side of the hill, wholly in ore. A 35-foot (10.7 m.) shaft had been sunk in ore at the east end of the cut, and a 20-foot (6.1 m.) shaft had been sunk in ore about 25 feet to the north. A number of small pits and shallow drill holes were scattered over the area of heaviest float in a rude circle 150 to 200 feet (46 to 61 m.) across.

The ore consists of medium-grained disseminated chromite, having a splotchy appearance due to small strung-out masses of high-grade ore a few inches to a foot long. The uppermost

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15 to 20 feet (4.6 to 6.1 m.) of ore is thoroughly weathered, and therefore richer than the ore at greater depth. The ore at the bottom of the shaft is in a matrix of serpentinized dunite and is excellent milling grade. Analysis of clean concentrate from this deposit shows that the chromite contains about 56.6 percent Cr_2O_3, and has a Cr:Fe ratio of 3.4 (table 2). The limited workings and drill holes indicated that the deposit might contain several thousand tons of good milling ore. A few hundred tons of float might be recovered from debris on the south slope of the hill.

Caledonia mine (2).--The Caledonia mine has produced almost 95,000 tons of chrome ore averaging between 40 and 45 percent Cr_2O_3. The mine is about 7 miles (11 km.) southeast of Woodfred, in a northern tributary of Arroyo del Pino. The ore was hoisted by a 6,000-foot (1,830 m.) tram line to the edge of the pinales, whence it was trucked to Woodfred. The tram line was dismantled when the mine was abandoned, and all other equipment was removed.

The mine consists of an open cut on the southwest bank of the arroyo, extending approximately 300 feet (90 m.) vertically from the bottom of the arroyo to the top of the ridge, and 400 to 500 feet (120 to 150 m.) along the ridge. The floor of the quarry is parallel to the slope of the hill and 25 to 50 feet (7.5 to 15 m.) lower; a round-bottomed irregular trench some 20 feet (6 m.) wide and 10 to 20 feet (3 to 6 m.) deeper than the rest of the cut extends about two-thirds of the way up the north end of the quarry. Scattered patches of chromite show that the quarry floor probably accurately reflects the form of the footwall of the ore body. Pure chromite from this mine carries almost 57 percent Cr_2O_3, and has a Cr:Fe ratio of about 3.4 (table 1). Massive, nodular, and disseminated ore are all present, with all gradations between the various types. As much as 15 feet (5 m.) of black massive ore is visible in the stopes, and this type of ore apparently formed the larger part of the ore body. Though small pockets of nodular ore occur within massive ore, most of the nodules are found near the contacts, where the massive ore grades into barren dunite either through a zone of disseminated ore, or through nodular ore in which the number of nodules decreases outward. Many of the nodules are elliptical and nearly an inch (2.5 cm.) long. The average grain size in the disseminated ore is from 1 to 3 millimeters. Banded structures were seen only at the south end of the deposit in some of the disseminated ore, parallel to the trend of the main ore body.

The wall rock and matrix of the ore is thoroughly serpentinized dunite showing comparatively little shearing. The dunite varies in thickness from 6 inches to about 3 feet, and grades abruptly into peridotite. The country rock, and dominant rock in this part of the Sierra de Nipe, is peridotite containing 10 to 30 percent of pyroxene or pseudomorphs after pyroxene. No feldspathic rocks were seen in place in the vicinity of the Caledonia mine, though their presence is indicated by a 12-inch (30 cm.) block of coarse-grained chromite-bearing norite found in the arroyo below the mine.

The ore body seems to have been a single tabular mass striking about N. 80° E., and dipping about 40° N., parallel to the canyon wall; the deeper portion of the quarry indicates a keel-like bulge near the north end. A thin envelope of dunite evidently completely surrounded the chromite mass. A few thousand tons of ore probably still remains in the bottom of the mine, below the level of the creek. The ore is at least 15 feet thick in places at water level, and it was said that very little had been stoped out. It seems reasonable to suppose that when the region is rendered more accessible, possibly by a road down the Rio Mayari, mining will be resumed, though not on the previous scale.

Estrella de Mayari mine (3).--The Estrella de Mayari mine is about 1 kilometer southeast of the Caledonia mine, at an altitude of about 800 feet (245 m.) above sea level, and 300 to 400 feet (100 to 120 m.) above Arroyo del Pino. Ore from the mine is packed by mules over a trail that rises 500 feet in 3,000

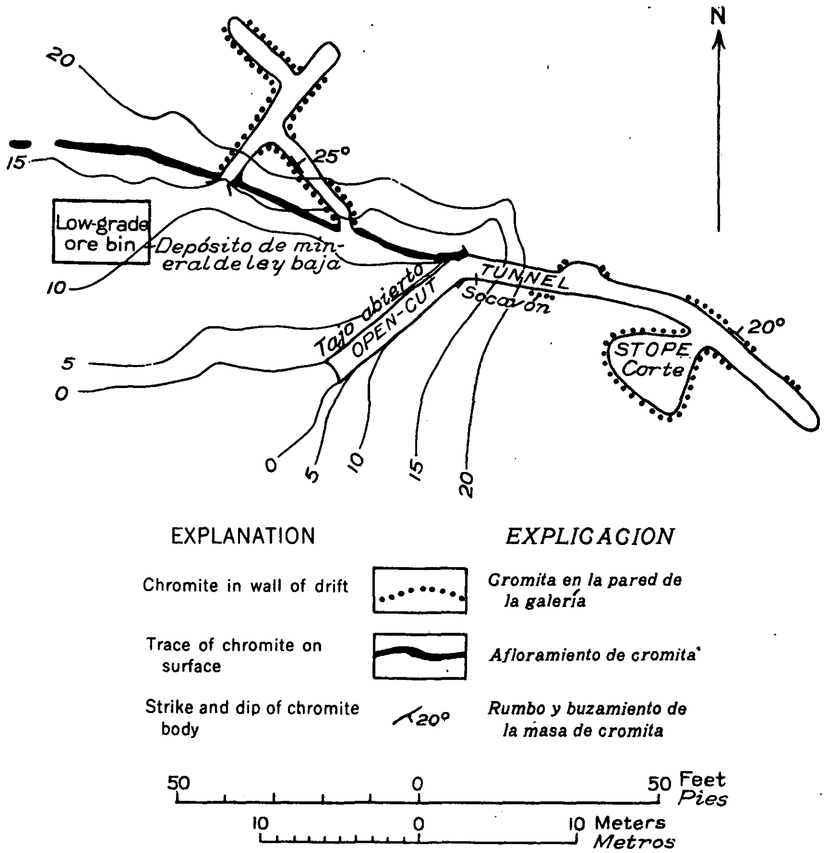


Figure 5.--Sketch map of underground workings at the Estrella de Mayari mine, Oriente.

feet (150 m. in 915 m.) to a road that climbs another 600 feet (183 m.) to the top of the Sierra de Nipe. About 60 tons of sacked ore piled at the end of the road in February 1941, has since been shipped.

The chromite is exposed in small lenses of massive and disseminated ore in a dunitic zone 500 to 600 feet (150 to 180 m.) long, trending N. 60° E. In the northern part of this zone most of the ore is in irregular low-grade pockets up to 6 feet (2 m.) across. The chrome in the southern part, which has been mined by two tunnels, forms a nearly continuous mass up to 6 feet (2 m.) thick, dipping 20° to 30° NE. (fig. 5). The ore has been intensely sheared, and in places is broken up into a series of lenses, the largest seen being about 10 feet (3 m.) long and 6 feet (2 m.) thick. The chromite in this part is massive, crumbles readily, and shows a distinct purple color. Analyses show that the chromite contains almost 57 percent Cr_2O_3 and has a Cr:Fe ratio of about 3.5 (table 2). Though the grade of the ore is excellent, the amount is probably very small.

Other chrome deposits known in the Mayari district include La Deseada and the Tres Hermanas, both on the west slope of the Sierra Cristal. These deposits are inaccessible and are said to be small. Prospectors were very active in the fall of 1941, and new discoveries of chromite were reported. The district seems promising as a source of limited quantities of high-grade metallurgical ore.

Sagua de Tanamo district

The known chrome deposits in the Sagua de Tanamo district lie in the foothills of the Sierra del Cristal, mostly within the drainage of the Rio Sagua de Tanamo. Narrow gauge tracks of the Tanamo Sugar Corporation serve the area, and ore is shipped via Cayo Mambi, the corporation's headquarters. Total reported production of the district is between 2,000 and 3,000 tons averaging 40 to 45 percent Cr_2O_3, shipped in 1939. The chrome deposits are exposed in rolling hills of serpentine rising 400 to 500 feet (120 to 150 m.) on both sides of the broad flood plain of the Rio Sagua. Roads could be built to the mines with comparative ease. The chromite probably varies greatly in tenor of Cr_2O_3 in various deposits. The analyses of pure concentrated chromite from La Victoria and La Tibera mines, shown in table 2, and analyses made by private interests in Cuba, indicate that the range is at least from 38 to 55½ percent Cr_2O_3, and may be considerably greater. Since several of the larger deposits in the district contain ore of milling grade, the Cr_2O_3 content of pure chromite from every minable deposit should be determined as a part of sampling.

La Victoria mine (6).--La Victoria denouncement includes two open cuts about 2,000 feet (600 m.) apart and 1 mile (1.6 km.) south of Rio Grande junction on the line of the sugar company. The western cut is about 1,500 feet (500 m.) from the nearest point on the railroad; a spur track formerly ran to the eastern cut. This mine was the largest in the district, having produced between 1,500 and 2,500 tons.

The eastern open cut is 130 feet (40 m.) long, heads S. 30° E. up a small gully, and has a face about 40 feet (12 m.) high. The ore body lay east-west across the end of the open cut, and was mined over a length of about 40 feet (12 m.) to a maximum depth of about 50 feet (15 m.). Very little ore was left in the face and west wall, but a vertical body of ore 10 feet (3 m.) wide, bounded on the north by a vertical fault and on the south by a well-defined gradational contact, was left in the southeast corner. This body was traced 45 feet (14 m.) southeastward on the surface, in which distance it had pinched to a width of 3 feet (1 m.) before it disappeared under surface debris. The ore is disseminated, varying from high- to low-grade, and showing well-developed linear structure dipping 60° N. As chromite from this deposit contains 55½ percent Cr_2O_3 (table 2), the ore should be of good milling grade.

The western open cut extends 125 feet (38 m.) S. 30° E. into a gentle hillside, is 20 to 30 feet (6 to 9 m.) wide, and

30 feet (9 m.) deep at the face. A 4- to 6-foot (1.2 to 2 m.) band of low- to high-grade ore exposed in the east wall dips about 30° NE. Irregular dikes of pegmatitic gabbro up to 18 inches (45 cm.) thick cut both ore and serpentinized dunite country rock.

La Tibera mine (7).--Two open cuts at an altitude of about 450 feet (140 m.), 2.3 miles (3.8 km.) south of Rio Grande junction 5 miles southwest of Cayo Mambi and somewhat less than 1.5 miles (2.5 km.) from the nearest point on the railroad, constitute La Tibera mine. The larger pit is about 40 by 50 feet (12 by 15 m.) in area and 12 to 15 feet (3.7 to 4.5 m.) deep. The ore consists of disseminated to massive chromite irregularly distributed in serpentinized dunite and cut by pegmatitic gabbro dikes. The visible ore was limited mainly to an area about 20 feet (6.1 m.) square in the floor of the pit, and appeared to form a flat-lying body. The south edge of the pit follows a fault striking N. 65° E., and dipping 60° N. As chromite from this deposit contains about 38 percent Cr_2O_3 (table 2), concentrates would be of refractory grade at best.

The smaller pit is about 100 feet southeast of the other, and is triangular in outline. It reveals a lens of massive ore about 4 feet (1.2 m.) thick that dips about 30° SW. against a fault striking N. 70° E. and dipping 70° NW. This small ore body probably contains less than 100 tons of ore.

La Albertina deposit (8).--The chrome deposits on the Albertina denouncement are 1.25 miles (2 km.) almost due south of La Tibera mine, on the north and east slopes of a steep hill about 250 feet (75 m.) high. The main exposures are near the top of the hill at an altitude of about 650 feet (200 m.); no work had been done on them. On the north slope, west of the trail, a pile of large chromite blocks about 10 feet (3 m.) across and 4 feet (1.2 m.) high apparently marked the location of a small lens of ore. East of the trail, on the easterly slope, chromite float was found along the hillside for about 80 feet (24 m.), apparently below a continuous lens trending northward, and ending at a small gully. Chromite float was scattered along the slope 100 feet (30 m.) farther north in a manner suggesting that it was derived from small lenses arranged en echelon. The discovery pit is near the foot of the hill, about 400 feet (120 m.) above sea level. It is a cut about 10 feet (3 m.) deep which reveals medium-grade disseminated ore in the footwall of an east-west fault dipping 45° N. The width of the ore body is about 15 feet (4.5 m.), the length is unknown.

Other deposits.--Many other deposits have been denounced in the Sagua de Tanamo district, but the limited time in the field precluded visiting them. Those described are believed to be representative of the district; some others may be larger, many are undoubtedly smaller. A large proportion of the ore is disseminated and would therefore require milling, and the grade of concentrates will vary in chromium content from one deposit to the next. The size of the deposits probably would not justify erection of numerous small mills, and the interests of the district might best be served by a centrally located custom mill supplied from all the mines in the area. With some such arrangement, the district might produce several thousand tons of concentrates and some high-grade lump ore.

Cayoguan mines

The Cayoguan chrome mines, known also as the Moa and Punta Gorda deposits, are on the Rio Cayoguan about 3 miles (5 km.) from the north coast of Oriente. The Cromita deposit was first worked in 1918 and 1919, when about 1,500 tons of ore was mined and hauled to Punta Gorda. Production began again in 1940, and some 8,500 tons of ore was shipped between September 1940 and June 1941.

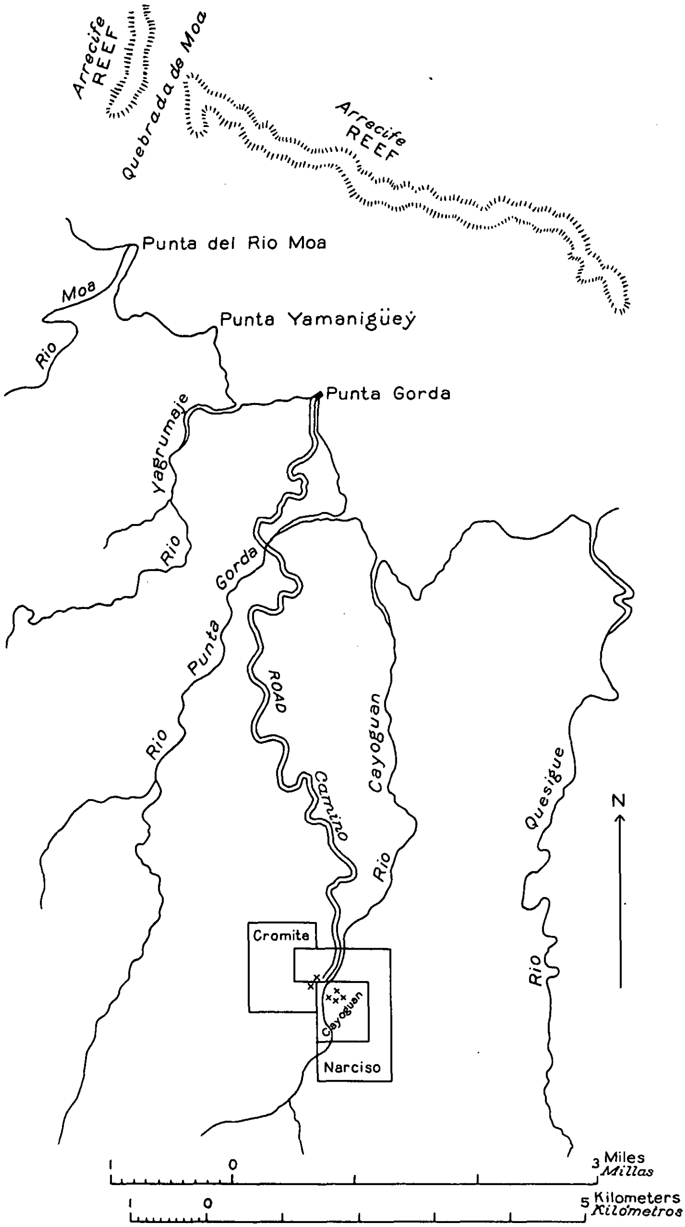


Figure 6.--Map showing Punta Gorda and Cayoguan chrome deposits.

The deposits on the Narciso and Cromita denouncements are in the northwest wall of the river valley; those on the Cayoguan denouncement are in the opposite valley wall, and on the edge of the upland (fig. 6). Since the valley is very narrow and rocky below the deposits, the ore is trucked over a 7½-mile (12 km.) road that climbs up to the old laterite-covered erosion surface, and traverses it to Punta Gorda. At Punta Gorda a dock 120 feet (36 m.) long accommodates lighters on which ore is stored for shipment. The anchorage is protected by a reef through which ships up to 4,000 tons cargo capacity can get within 1,000 feet (300 m.) of the dock.

The Narciso deposit was the only one being mined in February 1941, though ore body No. 1 on the Cayoguan denouncement was opened up later in the year. The main working level at the Narciso mine was about 320 feet above the river, and the height of the quarry face was about 110 feet (33.5 m.). Ore was broken from the main face on the upper level (see pl. 19), rolled to the lower level, and sorted there. The ore was then hauled 300 feet (91 m.) in wheelbarrows to the head of a log chute 470 feet (142 m.) long, through which the ore tumbled down to the loading gate.

The ore consists of massive coarse-grained chromite containing 38 to 39.5 percent Cr_2O_3, and having a Cr:Fe ratio of 2.6 to 2.8 (table 2); because of its high Al_2O_3 content, this ore is in great demand for refractories. The Narciso ore is hard and ships well; that from the Cayoguan is softer when weathered, but may be hard when fresh. An irregular network of gabbroic pegmatite dikes cuts the Narciso ore body. The corners of the chromite blocks are sharply angular, and the chromite contains very little interstitial feldspar. Pieces of brecciated chromite in gabbro found in the Rio Cayoguan may have come from ore bodies on the Cayoguan denouncement. The country rock of all the deposits is banded peridotite in which zones of olivine-rich gabbro are present. Gneissic gabbro is exposed along the road about half a mile from the Narciso mine, and banded gabbro with feldspar augen, identical in appearance with some troctolite (see pl. 2, A), is exposed within 10 feet (3 m.) of the north contact of ore body No. 2 on the Cayoguan denouncement. The trend of the banding is approximately parallel to the vertical contacts of the ore bodies.

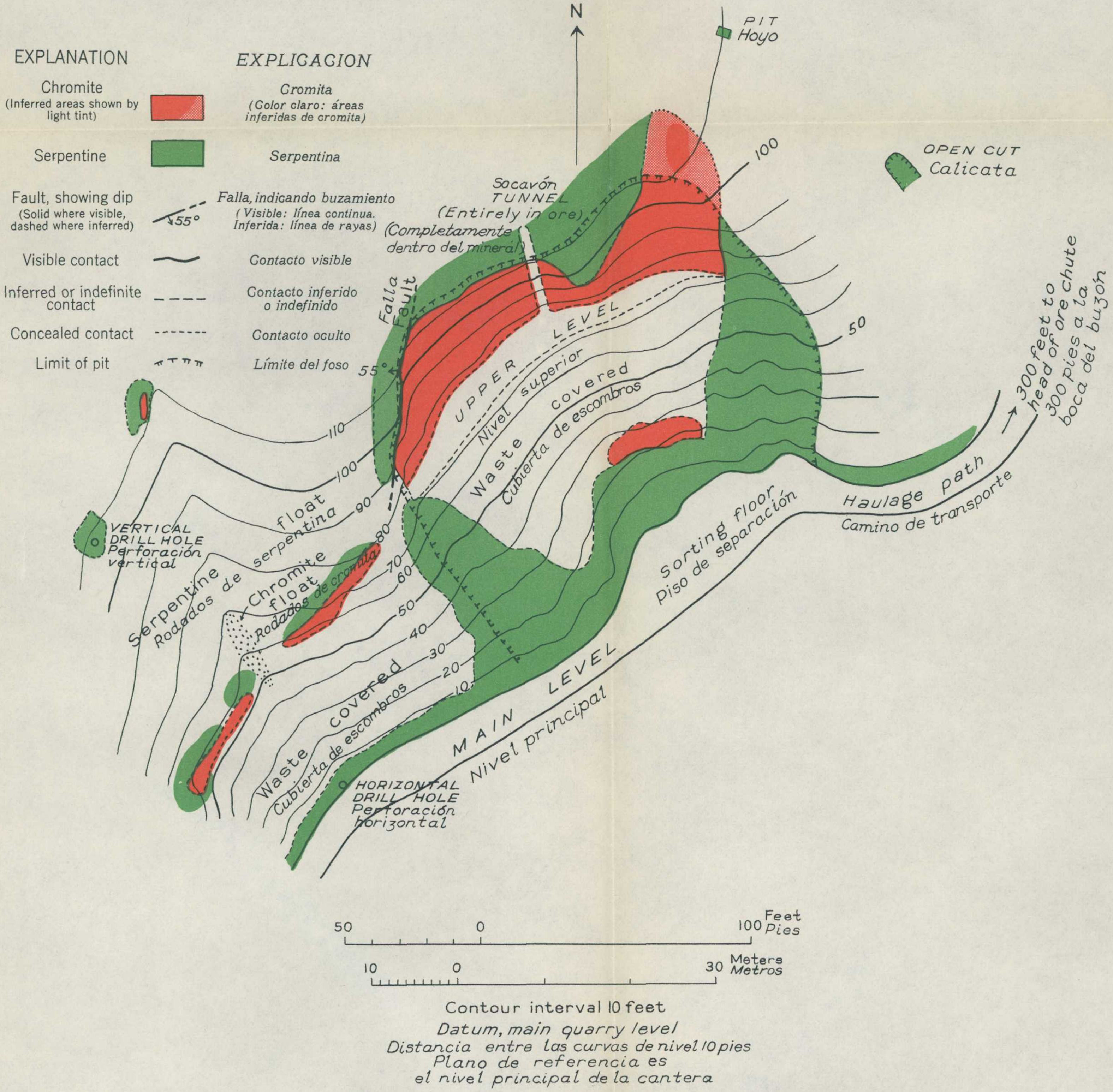
The exposures of chromite on the Narciso and Cromita denouncements are very close together (see pl. 19), and may be faulted segments of a single ore body. The east-west boundary line between the two denouncements lies just south of the southwest end of the upper level. The exposures yielded very little information regarding the dip of the ore bodies. The eastern limit of the ore was a vertical igneous contact. The western contact in the quarry face was a north-south fault dipping about 55° W., and might be a fracture offsetting the two ore bodies. The tunnel extending 30 feet (9.2 m.) into the face was in solid ore, showing that the upper contact dips into the hill at an angle less than 70°. The exposures on the Cromita are steep faces of high-grade ore from 6 to 15 feet (2 to 4.6 m.) high, covered at both top and bottom. Diamond drilling by the Chromium Mining & Smelting Corporation of Cuba is reported to have indicated the presence of large ore bodies on the Cromita denouncement.

About 150 feet above the road and 100 feet east of the ore chute, on the Narciso denouncement, there is a caved tunnel from which about 800 tons of ore was shipped. The ore was said to be in a vertical lens trending north, and extending at least 40 feet into the hill. Numerous boulders of chromite and a lens of massive ore about 4 feet (1.2 m.) wide were seen in a small creek about a kilometer north of the main workings.

The largest exposures on the Cayoguan denouncement, shown in plate 20, indicate three distinct ore bodies. Ore body No. 1

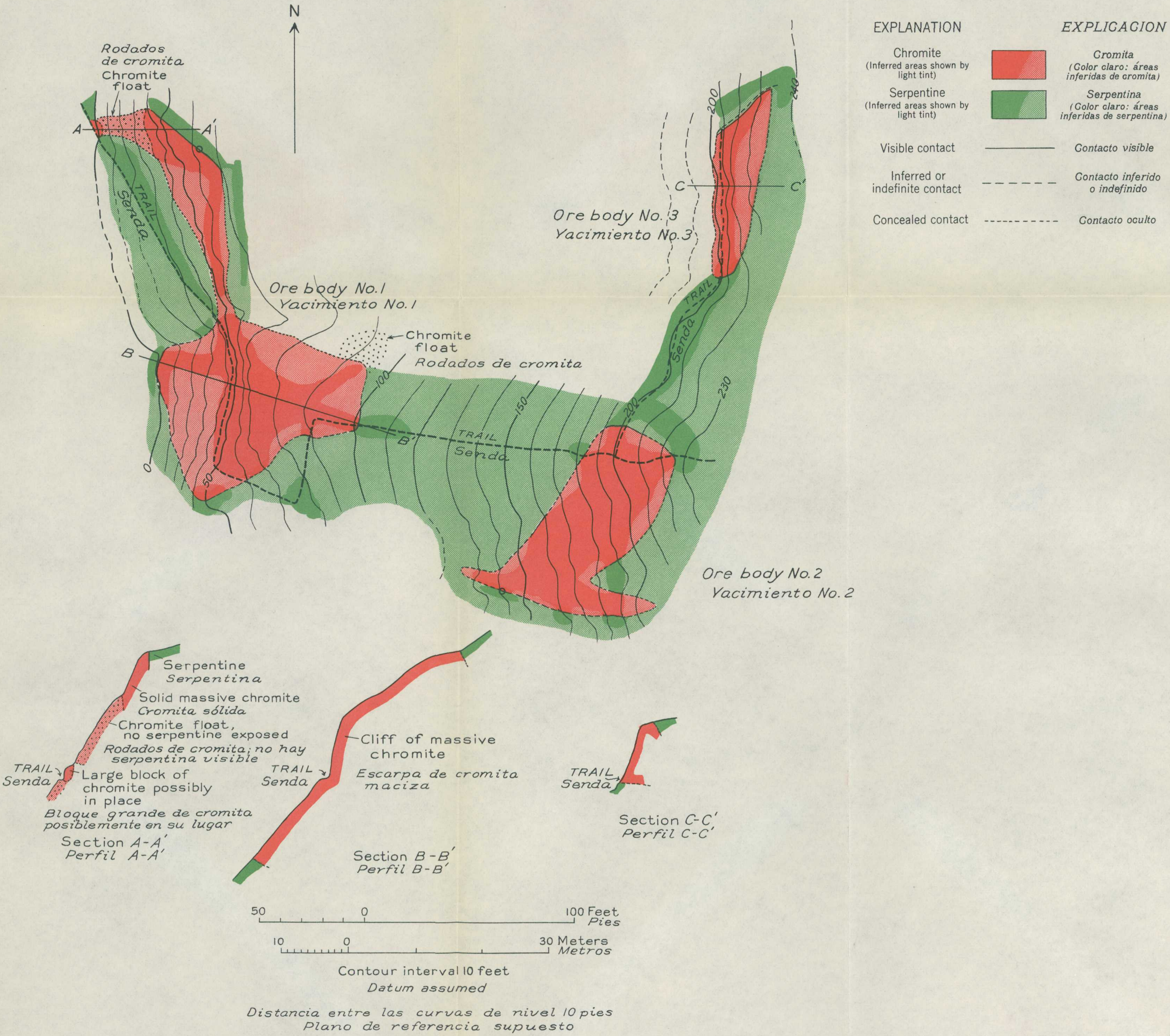
is about 300 feet above the river. The croppings were nearly continuous for a distance of about 175 feet (53 m.) along the slope; their average height was 8 to 10 feet (2.4 to 3 m.), the maximum was 30 feet (9.1 m.) in a vertical cliff. A vertical igneous contact trending N. 50° W. was well exposed for about 45 feet (14 m.) at the north end of the cropping; the other contacts were concealed or very poorly exposed. The southern contact of ore body No. 2 is a vertical igneous contact striking about N. 60° W., and the east-west extensions at the southern end of this ore body are bounded by nearly parallel vertical contacts. The northern contact seems to be essentially vertical where the trail to ore body No. 3 crosses it. The contact at the south end of ore body No. 3 is frozen against serpentinized dunite, and bends over on top of the chromite from a vertical dip to nearly horizontal. The steep part of the contact strikes northwest. Another body of massive chromite is indicated by an exposure about 20 feet (6 m.) square in the bed of a small creek 400 to 500 feet (120 to 150 m.) east of the top of ore body No. 2. Since the boundaries of the mass are not exposed, its size is not known. About 250 feet (75 m.) northeast of this exposure there is an old trench 20 feet (6 m.) long which reveals large blocks of chromite that cannot be far out of place.

The reserves of the Cayoguan group of deposits are undoubtedly large. If the deposits on the Cayoguan denouncement extend eastward into the hill as is suggested by the contact of ore body No. 3, the tonnage to be won by underground mining may be much greater. The exposures on the edge of the upland show that the chrome-bearing zone is much more extensive than is indicated by the map, and may contain bodies not exposed at the surface. These deposits are probably the most promising source of high-grade refractory chromite in Cuba and could be operated profitably in normal times.



PRINCIPAL WORKINGS ON THE NARCISO AND CROMITA DENOUNCEMENTS, ORIENTE

EXPLOTACIONES PRINCIPALES EN LOS DENUNCIOS NARCISO Y CROMITA, ORIENTE



PLAN AND SECTIONS OF THE PRINCIPAL CHROMITE EXPOSURES ON THE CAYOGUAN DENOUNCEMENT, ORIENTE

PLANO Y PERFILES DE LOS AFLORAMIENTOS PRINCIPALES DE CROMITA EN EL DENUNCIO CAYOGUAN, ORIENTE

Potosi deposit (12)

Burchard's description of the Potosi deposit leaves little to be added until the ore body is developed. The estimate of reserves given by Burchard,[22] namely, 10,000 to 20,000 tons, is probably conservative as the deposit is second only to the Cayoguan mines as a prospective source of high-grade refractory ore in Cuba. The Harbison-Walker Refractories Co., the owner of the Potosi and adjoining denouncements, was reported to be initiating a program of drilling here in the fall of 1941. The character of the ore and essential relations of the ore body to the surrounding rocks are very similar to those already described at the Cayoguan group. However, the chromite is slightly richer in Cr_2O_3 (39.9 percent) and considerably higher in iron (table 2). Gabbroic pegmatites cut the ore, and in places the gabbro has been injected into broken ore to produce the breccia textures shown in plate 7.

La Constancia deposit (13)

La Constancia deposit is about three-quarters of a mile (1.2 km.) due south of Navas Bay, on the north slope of the first hill. It was necessary to cut a trail to reach the deposit.

Two ore bodies were seen. One is an east-west-trending mass 4 to 5 feet (1.2 to 1.5 m.) thick and 35 feet (10.6 m.) long, exposed in a trench; the other is an irregular mass about 10 feet (3 m.) across revealed in a shallow cut 30 feet (9 m.) south of the east end of the trench. The ore consists of medium- to coarse-grained brecciated chromite in a matrix of olivine-rich gabbro, and is similar in appearance to that shown in plate 7, B. Most of the country rock is serpentinized dunite, though the southeast edge of the southeast ore body is cut off

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22/ Burchard, E. F., op. cit., p. 2544.

by gabbro pegmatite containing chromite fragments. Analyses of the ore quoted by Burchard 23/ indicate that the chromite contains about 40 percent Cr_2O_3. The limited surface exposures and the character of the ore have not encouraged further exploration.

Amores deposits (14)

The Amores deposits are about 9½ miles (15 km.) northwest of Baracoa in the valley of the Rio Baez. There are five principal deposits and a number of smaller ones ranging in altitude from about 500 feet (153 m.) to nearly 1,000 feet (305 m.) above sea level, and forming two main groups approximately 500 feet (153 m.) apart. The country is very rugged, with 50° slopes near the river. The Juragua Mining Co., the owner of the deposits, plans to haul the ore by truck about 8½ miles (14 km.) to Maravi Bay when the deposit is developed. In March 1941, the mine was served by a 4-mile (6.5 km.) trail from Navas Bay. The deposits had been partly explored by nearly 1,000 feet (305 m.) of tunnels and numerous pits and trenches.

The ore consists mostly of medium-grained disseminated chromite in a matrix of serpentinized dunite. Some of the deposits contain a good proportion of nearly massive ore, and nodular chrome was found in one deposit. Some of the deposits will yield lode ore of shipping grade, and all the float ore could be shipped. Analyses of samples from opposite ends of the largest deposit indicate that the chromite contains between 35 and 39 percent Cr_2O_3 and 11 or 12 percent Fe (table 2). Analyses made by the company indicate that most of the ore ranges in grade from about 20 to 30 percent, whereas the Cr_2O_3 in the chromite may range between 34 and 40 percent. It is apparent, therefore, that most of the ore will have to be milled.

The upper group of deposits includes two large and one small ore body situated on the crest of a narrow ridge. The larger

23/ Burchard, E. F., op. cit., p. 2543.

deposits are 40 by 85 feet (12 by 26 m.) and 50 by 150 feet (15 by 46 m.) respectively, and about 50 feet (15 m.) apart. Tunnels show that both deposits are thin and lie nearly flat; they may be remnants of a formerly continuous ore body.

Two of the deposits in the lower group are on the crest of a ridge between Arroyo Tibes, a tributary of the Rio Baez, and the river, 130 and 270 feet (40 and 82 m.) respectively above the river. The upper deposit is about 225 feet (68 m.) long, about 60 feet (18 m.) wide, and trends northeast. Tunnels indicate that the exposed portion is about 25 feet (7.5 m.) thick, and that the ore extends northward into the hill under a cover of serpentine. The northeast half of the exposed part of the ore body has been dropped 20 to 30 feet (6 to 9 m.) by an incipient landslide. The lower deposit is much smaller, and appears to be almost entirely of shipping-grade ore. Tunnels at the lower contact of the ore show that the deposit is at least 70 by 100 feet (21 by 30 m.) across, and possibly 30 feet (9 m.) in maximum thickness.

The largest deposit in the lower group lies about 200 feet (61 m.) northwest of the other two. It is an irregular tabular mass about 400 feet (122 m.) long, trending northeast and dipping irregularly northwest. The ore body is well exposed in a steep ridge between Arroyo Tibes and the river, crosses the arroyo bottom and disappears under the serpentine in the main ridge to the northeast. This deposit consists mainly of milling-grade ore, and contains a good deal of barren serpentine. Linear and planar structure are shown in some of the low-grade disseminated ore. The width of ore at the surface ranges from 25 to 100 feet (7.6 to 30.5 m.) measured along the slope, and the vertical range of croppings is slightly over 100 feet (30.5 m.) from the bed of the arroyo to the top of the ridge. Tunnels indicate that the ore extends down dip under the serpentine forming the ridge, and drill holes in the bed of the arroyo penetrated several feet of ore.

A series of seven small high-grade deposits have been found in the precipitous wall of the main river valley over a distance of 400 feet (122 m.) northwest from the southwest end of the main ore body. They are progressively lower toward the northwest and are rudely alined in a manner that suggests the presence of an ore-bearing zone that dips northwestward and includes the large deposit. By a slight reversal of dip the zone would include the two other flat-lying deposits in the lower group. Several other small deposits have been found in this vicinity on both sides of the Rio Baez, and prospecting was still going on at the time of the writer's visit.

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