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ALUMINOUS LATERITIC SOIL OF THE SIERRA DE BAHORUCO AREA DOMINICAN REPUBLIC, W. I.

By

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By Samuel S. Goldich and Harlan R. Bergquist

ABSTRACT

Aluminous lateritic soil in savannas on the southwestern slope of the Sierra de Bahoruco in Barahona Province constitutes the most important known reserve of aluminum ore in the Dominican Republic. Nine deposits aggregating 6 million long tons were mapped and sampled in the Aceitillar area approximately 18 miles northeast of Pedernales and from 4,000 to 5,000 feet above sea level. The deposits are accumulations in valleys in middle and upper Eocene limestone and range in size from 100,000 to 2,000,000 long tons. The reddish-brown, finely divided to concretionary, lateritic soil resembles ferruginous bauxite, and composite samples contain 46 to 49 percent of alumina (Al_2O_3); 19.4 to 20.6 percent of total iron as Fe_2O_3; and 1.6 to 5.2 percent of silica (SiO_2).

Lateritic soil, averaging 42 percent of Al_2O_3 and 10 percent of SiO_2, covers a terrace of middle or upper Oligocene limestone at Bucan Polo, approximately 1,250 feet above sea level and 9 miles northeast of Pedernales. A reserve of 2.5 to 5 million long tons of this material is inferred. Samples of lateritic soil from terraces along the trail from Pedernales north to El Fondo de Mella contain from 16 to 25 percent of silica.

The principal minerals of the lateritic soils are gibbsite, boehmite, hematite, and clay minerals. The concretionary soil at high altitude in the Aceitillar area is gibbsitic; the earthy soil on the Bucan Polo terrace at a lower altitude contains considerable boehmite.

Chemical analyses of samples of limestone bedrock from the Aceitillar area indicate that the Eocene limestone is relatively pure calcium carbonate and contains less than 0.1 percent of alumina (Al_2O_3). A large volume of this limestone would be required to produce the soil if this bedrock is the parent material. However, the lateritic constituents may have been derived from other sources, and the soil could be an inherited soil that has come to rest on the Eocene limestone. Detailed studies are necessary to determine the complete geologic section that was available for weathering.

A reconnaissance of the Dominican Republic did not reveal other areas that appear favorable for the occurrence of aluminous

lateritic soil. Additional exploration is recommended in the vicinity of the known deposits and in the regions to the northwest and on the northeastern slope of the Sierra de Bahoruco.

INTRODUCTION

Discovery of aluminous lateritic soil

The discovery, in 1942, that certain lateritic soils on the island of Jamaica contain up to 50 percent of alumina (Al_2O_3) and less than one percent of silica (SiO_2) and are therefore potential ores of aluminum, stimulated search for similar material in other islands of the West Indies. The discovery was made when Sir Alfred D'Costa, concerned over the lack of fertility of the red soil on his property northeast of Claremont in St. Ann Parish, sent samples to the Hope Agricultural Laboratory in Kingston where chemical analyses were made. The soil is finely divided, red, reddish-brown, and buff-colored material that resembles ordinary red earth or clay so closely that its actual alumina content had not been suspected. Once the alumina content of the red soil of Jamaica became known the probability of similar occurrences on other islands of the West Indies was apparent. In July 1943, aluminous lateritic soil similar to the Jamaican material was discovered in Haiti by geologists of the Reynolds Mining Corp., and shortly after, similar deposits were located by the Alcoa Mining Co. in the Sierra de Bahoruco in the southwestern part of the Dominican Republic.

Use of term.—The term "aluminous lateritic soil" is used in this report for surface material composed predominantly of the hydrous oxides of aluminum and oxides of iron, titanium, and manganese. The essential minerals are the bauxite minerals, gibbsite and boehmite, and the low-silica, aluminous lateritic soil might be called ferruginous bauxite. Through usage in the industry, however, this term has acquired a commercial significance, and for the present it seems advisable to use the term aluminous lateritic soil. The term soil is used for all the lateritic material from the surface to the limestone bedrock.

Scope and methods of investigation

The investigation of the occurrence of aluminous lateritic soil in the Dominican Republic was undertaken by the Geological Survey, United States Department of the Interior, in cooperation with the Department of Agriculture of the Dominican Republic as a part of the program of cooperation with American Republics sponsored by the United States Department of State, under the auspices of the Interdepartmental Committee on Scientific and Cultural Cooperation.

Field work was started on May 1, 1944, and completed on July 15, 1944. The available time was divided between exploration of deposits in the Sierra de Bahoruco and a reconnaissance of other parts of the Republic. Deposits of aluminous lateritic soil in the Sierra de Bahoruco were mapped and sampled to determine the reserves and the physical and chemical characteristics of the deposits, and to study the geologic factors involved in the origin of the soil. Mapping was done by Brunton compass and pace traverse. Auger hole sites, however, were located with a tape, and these locations served as control for the mapping of the individual savannas. Approximate surface elevations were determined with an altimeter, and supplementary determinations were made by hand level.

Double-spiral soil augers, $1\frac{1}{2}$ to 2 inches in diameter, were used in drilling the lateritic soil. Representative samples were tested on a portable differential thermal analysis unit designed by Dr. Sterling B. Hendricks of the U. S. Department of Agriculture. The principle of this apparatus and the basic parts have been described by Hendricks, Alexander and Nelson.1/ Two check samples were sent to the chemical laboratory of the Geological Survey in Washington, D. C., and the analyses returned by cablegram. These analyzed samples were used as standards, and by camparison with them the differential thermal analyses in the field permitted not only the identification of the principal minerals of the lateritic soil but also a close approximation of the grade.

Acknowledgments

The cooperation of the Dominican Government contributed materially to the success of the field investigation. Dr. Humberto Bogaert, Secretary of State for Agriculture of the Dominican Government, took an active interest in all phases of the work. Dr. Howard A. Meyerhoff, Mineral Adviser of the Dominican Government, conferred with the Geological Survey party on several occasions in Ciudad Trujillo and arranged for the field work. Mr. Miguel A. Cestero, agronomist in the Department of Agriculture, was assigned by Secretary Bogaert to work with the party and was of invaluable assistance in the prospecting. The personnel and equipment of the party were transported from Ciudad Trujillo to the field in a light truck supplied by the Dominican Government. Assistance received from many persons and the generous hospitality extended to the party accelerated the progress of the field investigation. Special thanks are due Captain Pluyer Trujillo in appreciation of his untiring efforts in looking after the needs of the party in Pedernales, both before and after trips into the Sierra de Bahoruco. Señor Alfredo Cross, government agent at Pedro Sánchez, and Señor Andres Sierra, alcalde at Los Rios, likewise were helpful in making arrangements in their respective areas.

A flight over the Sierra de Bahoruco in a plane of the Dominican Air Force was arranged by Secretary Bogaert. Major Roger Willock, U. S. Naval Attache, arranged for a flight over the Samaná Peninsula. Dr. W. S. McCann and Mr. Albert Copp of the Alcoa Mining Co. supplied valuable information on the occurrence of lateritic soil in Barahona Province. Useful information was provided by Mr. H. N. Hansard of Ciudad Trujillo, whose familiarity with the country and with weather conditions was of material assistance in planning the field excursions.

The Rock Analysis Laboratory and geologic laboratories in the Department of Geology at the University of Minnesota were made available to the Geological Survey by arrangements with Dr. F. F. Grout, Director of the Rock Analysis Laboratory, and Dr. G. A. Thiel, Chairman of the Department of Geology. This generous cooperation is greatly appreciated. Dr. J. W. Gruner of the University of Minnesota made X-ray analyses of a number of samples.

1/ Hendricks, S. B., Alexander, L. T., and Nelson, R. A., Minerals present in soil colloids: I. Descriptions and methods for identification; II. Estimation in some representative soils: Soil Sci., vol. 48, pp. 257-279, 1939.

GEOGRAPHIC FEATURES

Location and accessibility.—The Sierra de Bahoruco area, in Provincia de Barahona, lies in the southwestern part of the Dominican Republic (pl. 15). The Dominican Republic constitutes the eastern part of Hispaniola, which lies between Jamaica and Puerto Rico in the West Indies (fig. 7). The western part of the island is the Republic of Haiti. The aluminous lateritic soil deposits are part of a larger area that occurs as a belt across Jamaica, southern Haiti and southwestern Dominican Republic (fig. 7).

The Sierra de Bahoruco area is reached from the capital, Ciudad Trujillo (pl. 15), by highways which skirt the mountain range on the north and south. There is no road crossing the mountains, and travel is by mule trail. The principal trail crossing the range connects Pedernales on the coast with Duvergé on the Barahona highway to the north. The mountains are accessible either from Duvergé or from Pedernales. In the investigation in 1944 Pedernales served as a base for supplies.

The Aceitillar area, the most important of the lateritic soil areas explored, is situated along the Pedernales-Duvergé trail approximately 18 miles northeast of Pedernales. This area between the stations of Rancho Nuevo and Charco de la Paloma is southwest of the divide at an altitude of about 4,500 feet. The Bucan Polo area (La Estancia) is about 9 miles northeast of Pedernales and approximately 1,250 feet above sea level (pls. 16, 18). The trail from Pedernales to Bucan Polo has been widened, and a road could be built at a moderate expense. The 9 miles to Bucan Polo can be covered easily in 3 hours by loaded pack animals. Two hours are required to travel from Bucan Polo to Rancho Nuevo; there is a difference of 1,900 feet in elevation between these places in a distance, airline, of approximately 4 miles. An additional hour is required to reach the Aceitillar savannas in the lateritic soil district.

El Fondo de Mella is a locality about 10 miles north of Pedernales on the trail to a military post (Agua Nigra) in the Sierra de Bahoruco. This trail follows the international boundary and is shown approximately on the index maps (pls. 15, 16).

Climate and vegetation.—Meteorological data are lacking for the Sierra de Bahoruco. In the hot, dry coastal area adjacent to Pedernales the annual rainfall is 20 inches or less, and irrigation is necessary for gardens and crops. The rainfall increases with altitude in the mountains and frequently comes in torrential downpours of great violence. The annual precipitation in the mountains is 60 inches or more.[2] It comes in two wet or rainy seasons; in April and May, and in September to November. Because of the altitude the mean annual temperature is considerably lower than that of the coastal lowlands. Even during the hot months of June and July blankets are needed at night.

The savannas at altitudes above 3,000 feet are relatively flat valley areas, chiefly open parklike grassland. The larger savannas support a good stand of pine; trees 16 inches or more in diameter are common with an average spacing of approximately 30 feet. Seedlings and saplings are fairly numerous. There are a few bushes and scrubby plants, but bunch grass and a fern, locally known as "aceitillar," constitute the chief vegetation in addition to the pine. A few cattle and hogs find their way up to

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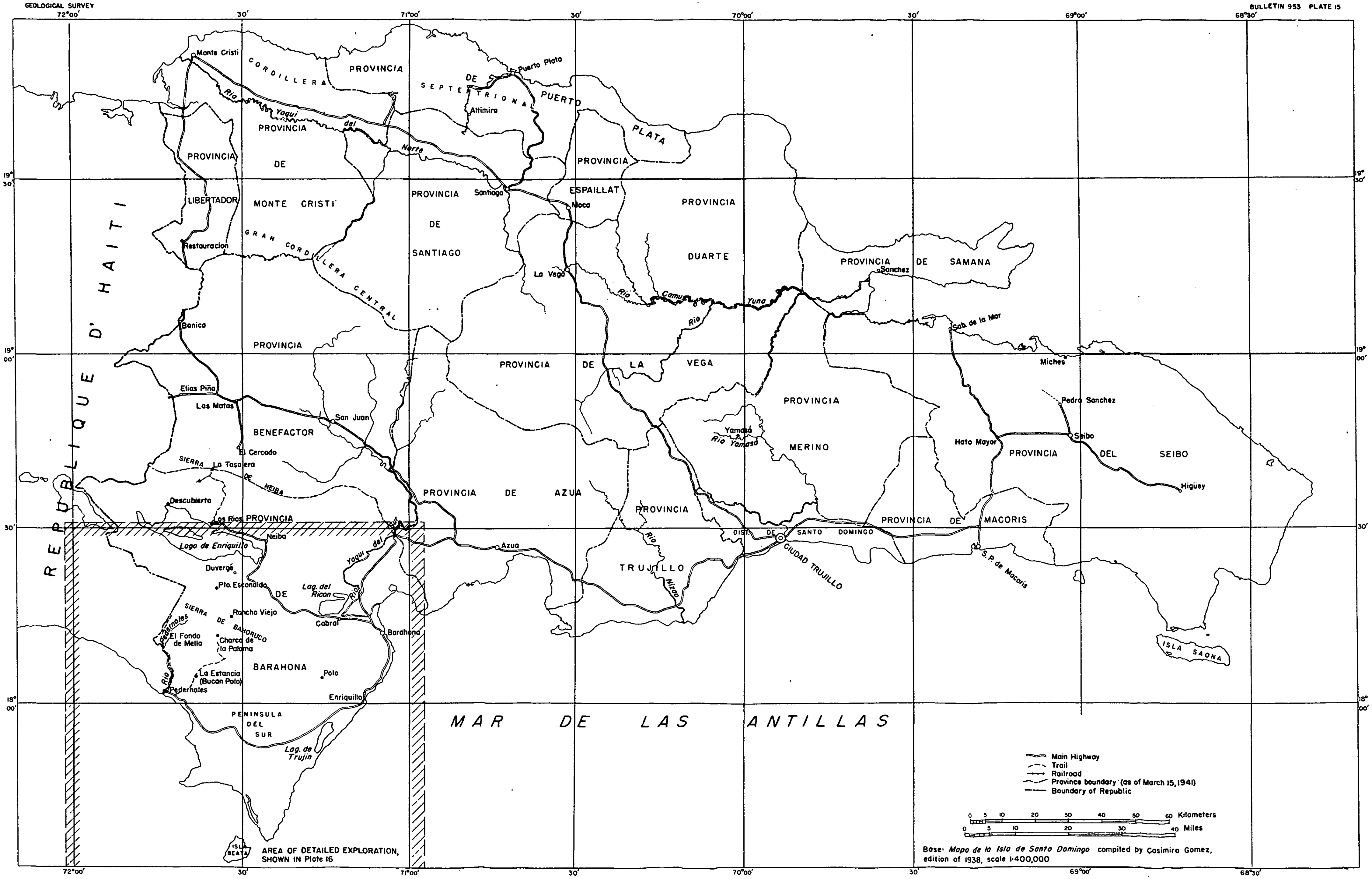
[2] Alpert, Leo, The areal distribution of mean annual rainfall over the island of Hispaniola: Monthly Weather Review, vol. 69, pp. 201-204, 1941.



Base: *Mapa de la Isla de Santo Domingo* compiled by Casimiro Gomez, edition of 1938, scale 1:400,000

INDEX MAP OF THE DOMINICAN REPUBLIC

the savannas. The scarcity of water and a lack of means of storing the rainfall have impeded and discouraged settlement in the mountains. Rancho Nuevo, Charco de la Paloma, and Rancho Viejo are shelters along the trail for the benefit of travelers crossing the range.

Bucan Polo is a settlement of a few families. In this area the terrace is heavily overgrown with trees and brush that make an almost impenetrable forest. Clearings have been made for pasture and crops. Coffee is grown along the trail to El Fondo de Mella, and small patches of corn and groves of bananas were seen from the trail. Tree cacti are abundant at lower elevations on the plain around Pedernales. Lignum vitae (guayucan) trees are fairly numerous along the trails north and northeast of Pedernales.

TOPOGRAPHY

General features.—The main topographic forms of the southwestern part of the Dominican Republic are controlled by the larger structural features of the island of Hispaniola. The Sierra de Bahoruco is an anticlinal range that is continued in the Montagne de la Selle in Haiti. The range attains altitudes of 5,000 to 6,000 feet above sea level in the Dominican Republic, rises to the northwest, and reaches its highest peak in Haiti in Mont la Selle with an elevation of 8,793 feet above sea level. North of the mountain range is a narrow depression 7 to 9 miles in width, Hoya de Enriquillo. Enriquillo basin is continued to the west in the Cul-de-Sac depression of Haiti. This valley at a late geologic date was a strait and only recently has been cut off from the sea. Lake Enriquillo is a remnant of the sea that has been gradually concentrated by evaporation until the surface of this body of salt water is now much below sea level. To the south of the Sierra de Bahoruco are the ridges and terraces of the Península del Sur from 1,000 to 2,000 feet above sea level.

Drainage.—The main ridge line and drainage of the Sierra de Bahoruco are shown in plate 16. Charco de la Paloma on the Pedernales-Duvergé trail is near the crest of the range. The main drainage is to the northeast and southwest on the flanks of the anticline, and to the southeast roughly is parallel to the strike of the mountain fold. This southeast drainage probably was initiated as a consequence of the plunge of the folded strata to the southeast. On the northwestern slope of the range large tributaries of the main streams follow the strike of the beds, and a trellis-type drainage pattern is being developed. Northwest of Rancho Viejo a deep canyon, Cañada Diablo, has been incised in the limestone. Similarly, tributaries of the streams on the southwestern slope of the Sierra de Bahoruco have developed roughly parallel to the strike of the limestone strata. As a result a series of valleys trending east or southeast have been developed on the flank of the mountain range.

Savannas.—Soil fills in the mountain valleys form savannas that are separated by rugged limestone ridges. The savannas of the explored area (pl. 17) are small, usually attenuated areas of lateritic soil in valleys that lie at successively lower elevations on the southwestern slope of the Sierra de Bahoruco. Nine savannas have been mapped, and for convenience and to avoid the ambiguity that arises from multiple names and different spellings, the savannas have been assigned numbers for reference (1-9, pl. 17). Sabana Canote (No. 9), the largest in the area, is in the northern part of the district and is approximately 5,000 feet above sea level. This savanna is roughly square in shape, measuring about 2,000 feet across and containing about 109 acres.

Several savannas, about 2 miles south of Sabana Canote are known locally as the Aceitillar savannas. They are from 4,000 to 5,000 feet above sea level. The main savanna (No. 2) of the group is roughly rectangular in shape, is 3,200 feet in length, and averages about 1,000 feet in width. This savanna has a surface area of about 83 acres. Other savannas range from 8 acres to 57 acres in size. The small savanna (No. 4) near the southern edge of the district is 4,150 feet above sea level or approximately 850 feet below the level of Sabana Canote.

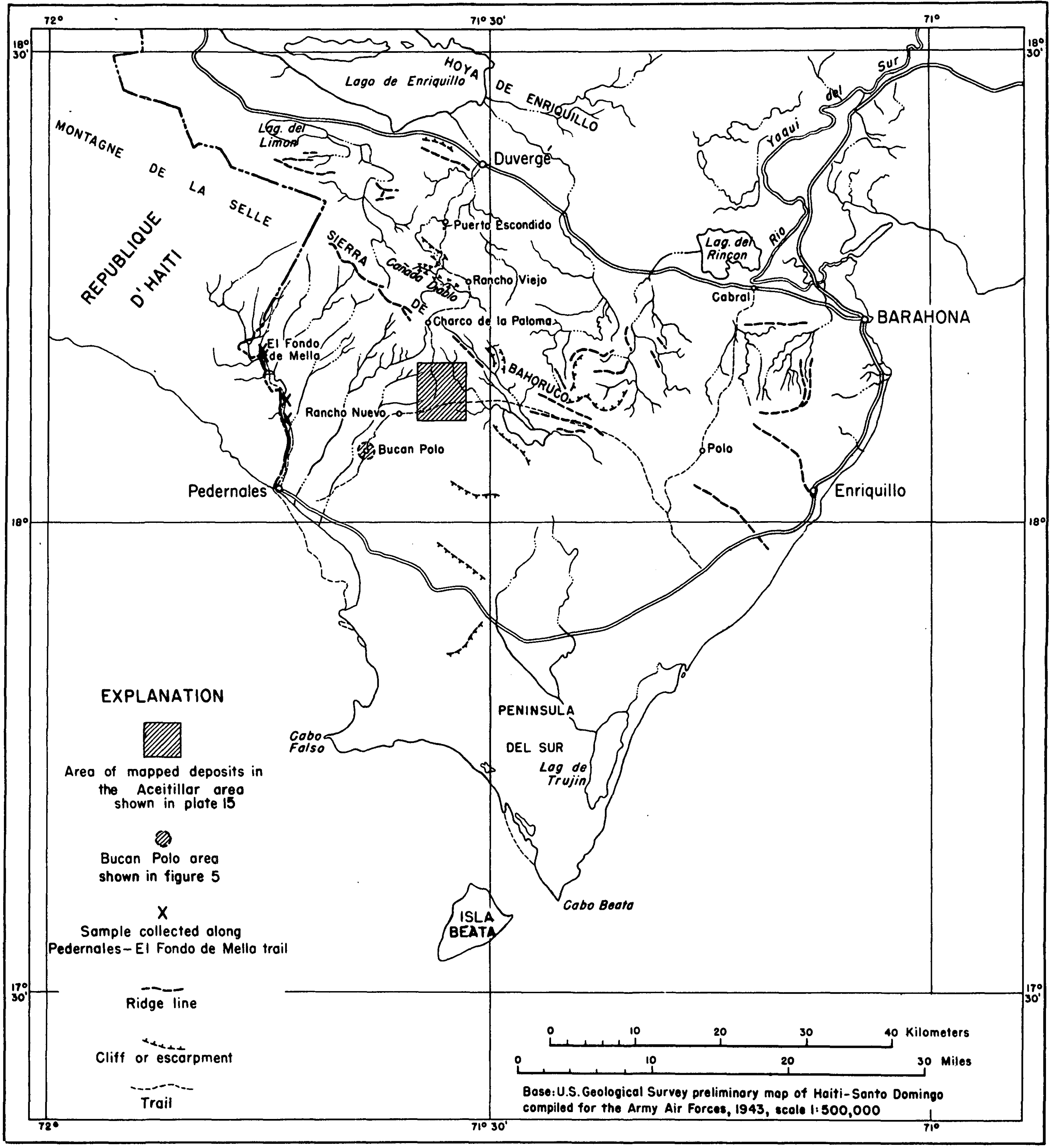
Sabana Canote is characterized by a relatively flat surface. Some of the other savannas are marked by prominent hills more or less centrally situated. Arroyos or quebradas are developing along the edges of the savannas. They are dry except during the intervals of very heavy rain. Knobs with crusts of hardened concretionary soil stand above the general surface level and indicate dissection of the savannas. This surface feature is well developed in savanna No. 2 (pl. 18). Sinks with vertical walls of soil clearly demonstrate that the hardened lateritic soil has collapsed because of the removal of underlying material through subterranean passages. Solution of limestone, along the margins of the savannas where runoff from the limestone ridges causes a concentration of water, probably has resulted in subsidence or lowering of the savanna surfaces, with the development of more or less centrally situated hills.

Terraces.—A number of terrace flats at different altitudes occur on the flanks of the Sierra de Bahoruco. The Bucan Polo terrace, approximately 1,250 feet above sea level is one of the more prominent of these terraces and was partly explored in the present investigation. The lateritic soil on the Bucan Polo terrace differs in composition and physical properties from that of the savannas at a higher altitude, and soil samples from terraces along the trail from Pedernales to El Fondo de Mella indicate a progressive decrease of the silica content of the lateritic soil with increasing altitude. These observations suggest that a study of the terraces and physiographic history would add to the knowledge of the origin and occurrence of the lateritic soils in the Sierra de Bahoruco region.

GEOLOGY

The Sierra de Bahoruco is composed principally of Eocene limestone flanked by Oligocene and Miocene sediments. The beds have been folded into a large anticline which trends northwest and appears to plunge to the southeast. The main structure is modified by smaller folds and by faults. The geology of the northern slope of the Sierra de Bahoruco along the trail from Duvergé to Rancho Viejo has been described briefly by Condit and Ross.3/ South of Duvergé past Puerto Escondido to Cañada Diablo in the vicinity of Rancho Viejo is a single series of sedimentary beds which is said to include several distinct parts, but there is no great stratigraphic break between them. These beds are probably of early Miocene or late Oligocene age and have an approximate thickness of 3,380 to 4,790 feet. They are chiefly limestone, some impure, with small amounts of tuffaceous claystone and conglomerate. Near the base of the series is a conglomerate composed of pebbles of foraminiferal limestone derived from the underlying, hard, semicrystalline Eocene limestone.

3/ Vaughan, T. W., Cooke, C. W., Condit, D. D., Ross, C. P., Woodring, W. P., and Calkins, F. C., A geological reconnaissance of the Dominican Republic: Dominican Republic Geol. Survey Mem., vol. 1, pp. 219-221, Washington, 1921.



Base: U.S. Geological Survey preliminary map of Haiti-Santo Domingo compiled for the Army Air Forces, 1943, scale 1:500,000

SKETCH MAP SHOWING AREAS PROSPECTED FOR ALUMINOUS LATERITIC SOIL

747156 O - 47 (Face p. 58)

According to Condit and Ross the rocks are folded into open anticlines and synclines. The average strike of the beds is N. 70° W. Between Duvergé and Cañada Diablo the dips are as high as 60°, but dips of 15° to 25° are more common. Near Cañada Diablo and Rancho Viejo the beds are bent sharply upward, and dips of 70° N. to vertical are common. Steep southerly dips of the basal beds near Rancho Viejo indicate that the beds are actually overturned.

The following notes on the limestone are based on observations and fossil determinations made of samples collected from the areas where the lateritic soil was drilled and mapped. Limestone is everywhere the bedrock of the aluminous lateritic soils.

Limestone

Aceitillar area

Description.—The limestone of the Aceitillar region is dense to finely crystalline, massive rock ranging from white to buff or pink. Weathered surfaces are dark gray and usually are irregularly pitted. Skeletal outlines of shells of gastropods and other fossil mollusks stand out on the weathered surfaces. Microfossils are present and are abundant in some specimens. The limestone is hard and generally breaks with an uneven or irregular surface. The finer-grained rock breaks with a more even to subconchoidal fracture. Veinlets of calcite and small vugs lined with calcite druses are prominent in most freshly broken surfaces. These surfaces may exhibit a mottled effect with the chalky white porous tests of Foraminifera and larger fossils contrasting with the dense gray to buff-colored limestone matrix.

In the mapped area (pl. 17) the limestone is massive; traces of the bedding planes have been obliterated by solution and recrystallization. Joint planes, however, are prominent, and the joint system appears to have influenced drainage and development of the valleys. A rubble of limestone covers most outcrops and hill slopes. South of Rancho Nuevo there are good exposures of bedded limestone along the trail approximately 2,000 feet above sea level. In these outcrops the strike of the beds is approximately N. 40° W., and the dip is 14° SW. A thickness of at least 2,000 feet (610 meters) is estimated for the limestone but no measurements were made. Localities from which collections of limestone for chemical analysis and for paleontological study were made are shown on plate 17.

Chemical composition.—A comparatively pure calcium carbonate composition is indicated by chemical analyses of two limestone samples from the district, as shown in table 4. Sample No. 5 was collected from an outcrop in the northwestern part of savanna No. 4, and sample No. 10 from the western end of savanna No. 1 (pl. 17). If the CaO is calculated as $CaCO_3$, these samples contain more than 99 percent of calcium carbonate. The alumina content of sample No. 5 is 0.03 percent; none was found in sample No. 10. The silica contents are small, 0.03 and 0.05 percent, respectively. Total iron as Fe_2O_3 is relatively more abundant, 0.05 and 0.13 percent. Ferrous iron was not determined, but a sample of limestone from Sabana Canote (No. 8), contains 0.01 percent of FeO. The density of a composite of the three samples was determined in a fused-silica pycnometer as 2.704 (25.6°/4°C). This value approaches the density for pure calcite (2.710). The relative purity of the samples is of special interest in considering the origin of the aluminous lateritic soil, and further reference will be made to this feature.

Table 4.—Chemical analyses of limestone samples from the Aceitillar area, Sierra de Bahoruco
[Norman Davidson, analyst]

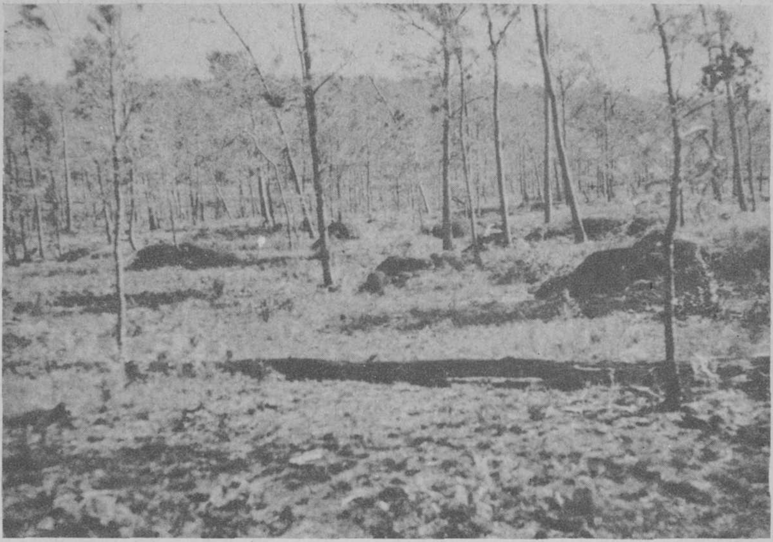
Constituent	5	8	10
CaO.................	55.65	-----	55.90
MgO.................	0.14	-----	0.04
SiO.................	0.03	-----	0.05
Al_2O_3................	0.03	-----	0.00
Fe_2O_3................	0.05	-----	0.13
P_2O_5................	0.01	0.01	0.01
TiO_2................	-----	0.00	-----
FeO.................	-----	0.01	-----
MnO.................	-----	0.00	-----

5. Outcrop northwest of auger hole No. 39 in northwestern part of savanna No. 4.
8. From western end of outcrop in Sabana Canote.
10. South of auger hole No. 1, near western end of savanna No. 1.

Age.—A tentative age of middle to upper Eocene is assigned to the limestone of the Aceitillar area on the basis of a preliminary examination of fossiliferous material made by Mrs. Esther R. Applin of the Geological Survey. Mrs. Applin prepared and examined thin sections of limestone samples from a number of localities, and the following conclusions are based on her observations.

Limestone samples from locality No. 7 near the northeast corner of Sabana Canote contain large specimens of *Dictyoconus codon* Woodring and many specimens of *Lepidocyclina* (*Pliolepidina*) *pustulosa* (H. Douvillé). The dense limestone collected south of savanna No. 5 shows many sections of miliolid Foraminifera. A polished surface of the rock shows numerous sections of *Borelis* cf. *matley* Vaughan and some specimens of *Borelis jamaicensis* Vaughan. Mrs. Applin suggests a middle Eocene age for the limestone from Sabana Canote and from savanna No. 5.

A different fauna characterizes the specimens collected from the savannas to the south and southwest, and this fauna is assigned to the upper Eocene. Hard, dense, cream-colored limestone from the eastern end of savanna No. 2 contains *Dictyoconus codon var*. nannoides (Woodring). A few sections of the same species and a section of *Eodictyoconus* sp. were found in a polished surface of limestone from savanna No. 4. Hard white limestone collected near Rancho Nuevo approximately 1 mile west of the mapped area has a large amount of microfossil material. Polished surfaces show many sections of several species of *Lepidocyclina*. The most common and characteristic form is tentatively referred to *Lepidocyclina* (*Pliolepidina*) *pustulosa* var. *tobleri* (H. Douvillé).



A. INDURATED SURFACE OF CONCRETIONARY LATERITIC SOIL (FOREGROUND) AND RESIDUAL KNOBS FORMED BY EROSION IN SAVANNA NO. 2

B. FLAT SURFACE IN SOUTHERN PART OF SAVANNA NO. 3 COVERED WITH "ACEITILLAR" FERN. WHITE LIMESTONE SHOWS IN BACKGROUND

Dr. T. Wayland Vaughan examined a few of the foraminiferal limestone specimens of the Aceitillar area. In the hard white limestone collected near Rancho Nuevo, he noted *Dictyoconus* sp., *Amphistegina* sp., and *Lepidocyclina* sp., the latter belonging in the same group as *L. sherwoodensis* Vaughan, a middle Eocene species of Jamaica. He assigns this limestone to the Eocene but states it is not certain whether it should be upper or middle Eocene.

In a limestone sample from locality No. 7 near the northeastern corner of Sabana Canote, Vaughn noted *Dictyoconus americanus* (Cushman), *Eodictyconus* sp., *Miscellanea* sp., and *Lepidocyclina* sp., and suggests a middle Eocene age for the rock. In a specimen of limestone from an inlier in the eastern part of Sabana Canote he identified *Dictyoconus americanus* (Cushman) and *Lituonella* ? sp. and considers the rock as middle Eocene.

Dr. Vaughan determined *Lituonella* sp., *Coskinolina* sp., and *Dictyoconus americanus* (Cushman) in a limestone specimen collected near the quebrada in the southwestern end of savanna No. 2 and suggests a middle Eocene horizon on the basis of *Coskinolina* and *Dictyoconus*.

A large low-spired gastropod, collected at locality No. 12 north of the intersection of the trails near the southwestern corner of the mapped area (pl. 17), was identified as *Velatis vokesi* by C. W. Cooke of the Geological Survey. This form was described by Cooke from the upper Eocene of Anse Lezard and St. Jean Bay, St. Bartholomew (Leeward Islands).

Bucan Polo area

Description.—White to pink, dense to finely granular limestone forms the bedrock of the Bucan Polo terrace. The general strike of the beds is northwest. Along the trail to Pedernales south of Bucan Polo are good exposures in which the limestone dips from 6° to 10° SW. These beds range from less than 1 inch to massive layers a foot or more thick. Solution along bedding planes and collapse of the limestone have produced breccia. Near the northern end of the Bucan Polo area a sample (1-a, fig. 5) of limestone breccia cemented by concretionary reddish-brown lateritic material was collected. Differential thermal analysis of the cementing material showed gibbsite and kaolinite. Large sinkholes have been developed in the limestone near Bucan Polo, and there are cavernous openings in the limestone cliffs along the trail to Pedernales.

Age.—Samples of the limestone were examined by Mrs. Applin who tentatively assigned the limestone to the middle or upper Oligocene. A dense pink-stained limestone sample (No. 1, fig. 5) collected near the southern end of the Bucan Polo area contains many sections and molds of *Amphistegina* cf. *lessoni* d'Orbigny and a few sections of underterminable *Operculinoides*. Samples of dense white and pink limestone collected about a quarter of a mile south along the trail to Pedernales show many sections of *Miogypsina* cf. *gunteri* Cole together with some sections of a *Camerina* similar to an unnamed species that has been reported from the middle Oligocene.

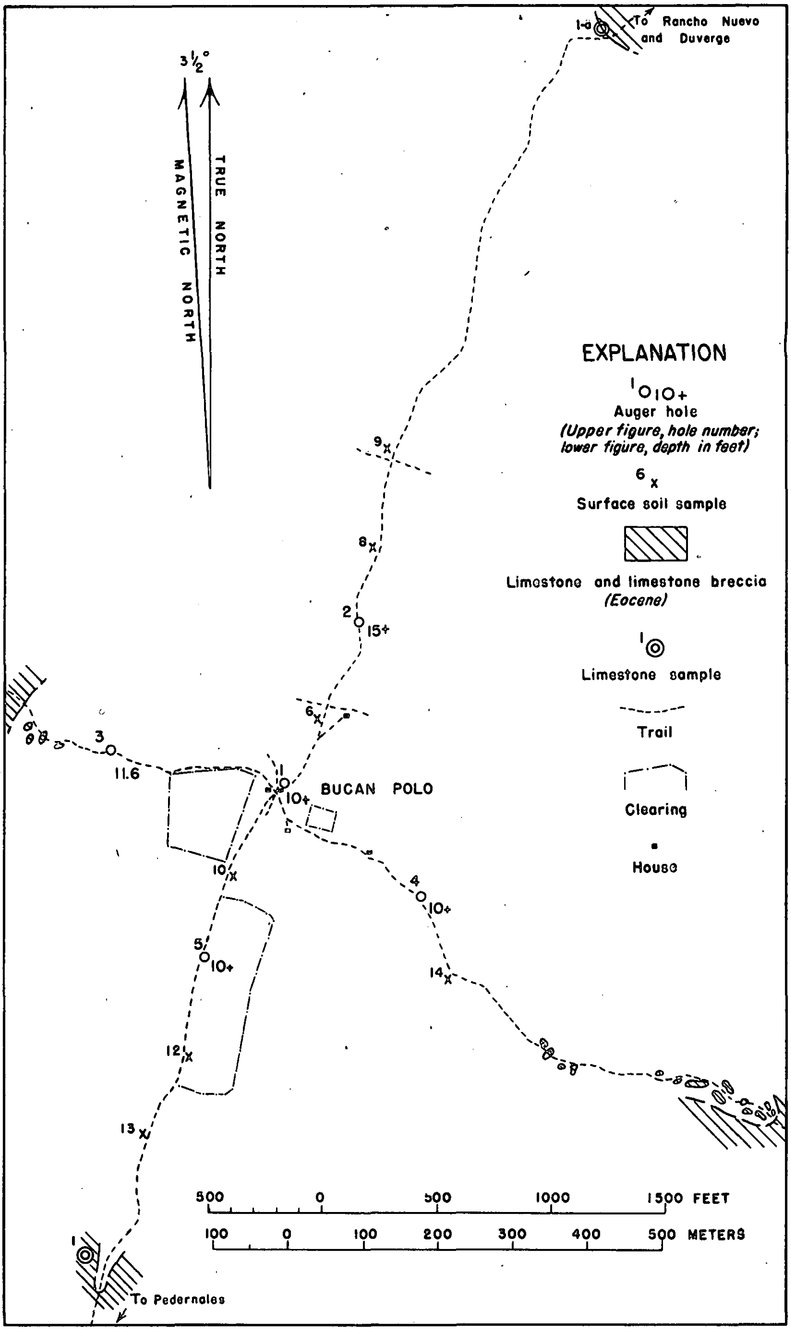


Figure 5.—Trail traverses in the Bucan Polo area showing location of auger holes and surface soil samples

DRILLING 30-FOOT AUGER HOLE (NO. 9) IN SAVANNA NO. 2

Aluminous lateritic soil

Two different types of lateritic soil were found in the Sierra de Bahoruco. The soil of the pine tree savannas in the limestone valleys of the high mountains, 4,000 to 5,000 feet above sea level, is reddish-brown concretionary lateritic material of low silica content. At lower elevations dark-brown friable lateritic soil, usually more siliceous than the red concretionary material, occurs on limestone terraces and flats. The first type of lateritic soil was investigated in the Aceitillar area (pl. 17). The second variety was explored in the Bucan Polo area (fig. 5) and along the trail leading north from Pedernales to El Fondo de Mella (pl. 16).

Exploration methods.—The lateritic soil deposits in the Aceitillar area were explored by mapping and drilling with hand augers in order to arrive at estimates of areas and thicknesses of the deposits for volumes and tonnages of reserves.

Nine savannas and certain irregular extensions of these savannas were mapped in the Aceitillar area (pl. 17). One or more auger holes (pl. 19) were drilled in the deposits, and in the two largest savannas (Nos. 2 and 9) an attempt was made to block out the deposits by drilling a number of auger holes spaced 400 feet apart. Other savannas in the regions adjacent to the savannas shown in the mapped area were visited, and surface samples were collected for testing. Sabana de los Garitos situated west of Sabana Canote and Sabana de los Pinalitos southeast of savanna No. 4 contain small deposits that were not explored with auger holes. These savannas as well as the deposits of the mapped Aceitillar area are briefly described in a later section.

Extensive areas of lateritic soil are found on terraces at lower altitudes. Only one of these areas, at Bucan Polo, was drilled. Five auger holes were bored in this deposit (fig. 5).

Isopach map.—The distribution of the lateritic soil in deposits of the Aceitillar area in which a member of auger holes were drilled is shown on the map, plate 17, by means of isopach lines which connect points of equal soil thickness. The isopach interval is 5 feet, and the areas of greatest soil thickness are shown by a number of isopach limes more or less concentrically disposed. The isopach lines for savanna No. 2 show that the southwestern part of the savanna is underlain by a greater thickness of lateritic soil than the northeastern part. The close spacing of the isopach lines on the south and west suggest that the accumulation was influenced by the drainage, which in this savanna is to the southwest. A similar spacing can be seen in the isopach lines drawn for savanna No. 9, and the drainage here is also to the west.

Aceitillar area

Description of soil.—The typical aluminous lateritic soil of the Sierra de Bahoruco savannas is reddish-brown finely divided material with small hard concretions, most of which are less than 2 millimeters in diameter. In a few places there are hard barren concretionary surfaces such as those of savanna No. 2. The soil is uniform throughout the vertical section except for the local surface crusts, and well-developed zones or horizons are lacking. The contact of the soil with the underlying massive limestone is sharp, but the bedrock surface is irregular.

The surfaces of the savannas generally are littered with concretions. The concretions or pellets occur throughout the soil, and no variation in abundance with depth was noted. In a sample from hole No. 5 near the southwestern end of savanna No. 2, concretions 1 millimeter or larger in diameter compose 13 percent by weight of the soil. However, this figure does not represent the absolute abundance of concretions in the soil because many are less than 1 millimeter in diameter. The concretions 1 to 2 millimeters in diameter are nearly spherical in shape and commonly have smooth polished surfaces. Larger concretions generally are less regular in shape. A flat concretion 6 millimeters in length was the largest recovered from hole No. 5.

Concretions measuring 1 to 2 centimeters in diameter were found both on the surface and in the auger hole samples. A variety of shapes, textures, and colors was noted. Some of the larger concretions of irregular shape are fine-grained, reddish-brown soil, hardened but earthy; others are black and vitreous. Concentric structures are characteristic of these concretions. Some have a black core encased by reddish-brown material, and others have a black outer zone enclosing reddish-brown soil. Some of the larger earthy concretions are composites and contain smaller concretions. A few spherical concretions, 1 centimeter or larger in diameter, are dense reddish-brown material with a high vitreous luster.

A few large concretionary cobbles of soil were found on the surface. They have a thin outer crust of dark reddish-brown color that contrasts sharply with the light yellowish-brown inner portions. Just within the crust are irregular and discontinuous black segregations of manganese dioxide. The individual small concretions in the earthy yellow matrix of the boulders are yellow brown to dark reddish brown. The relationships suggest that iron oxide was leached from the matrix and formed the outer crust. Manganese dioxide, likewise, moved outward and became concentrated in a less well defined outer zone.

Many of the concretions are strongly magnetic. Although some magnetite is present in the lateritic soil, the amount is insufficient to explain the strong magnetic susceptibility of the concretions on the basis of residual magnetite. This magnetic property appears to be a secondary and acquired characteristic and has been noted in pisolites from bauxite and laterite from other parts of the world.

Chemical composition.—The concretionary lateritic soil of the savannas is remarkably uniform in chemical composition. The analyses in table 5 are numbered to correspond with savanna numbers on plate 17. Deposits in which a number of auger holes were drilled are represented by composite samples prepared from the auger cuttings in proportion to the depths of the holes. Deposits No. 7 and No. 8 are represented by samples from single drill holes. Sabana de los Garitos is represented by an analysis of a surface sample collected by Mr. Cestero (table 5, No. 10).

Table 5.—Chemical analyses representing deposits of aluminous lateritic soil in the Aceitillar area, numbered to correspond with savanna numbers on plate 1.
[S. S. Goldich, analyst]

	1	2	3	4	5	6	7	8	9	10
SiO_2	3.73	1.72	2.43	1.55	2.01	2.25	2.09	2.95	5.17	0.99
TiO_2	2.71	2.62	2.69	2.50	2.70	2.75	2.60	2.64	2.66	2.71
Al_2O_3	47.16	48.18	48.37	48.53	48.28	47.70	47.70	47.81	46.25	46.18
P_2O_5	0.22	0.19	0.26	0.21	0.13	0.17	0.15	0.17	0.19	0.25
Fe_2O_3	20.58	20.18	19.75	19.43	19.52	20.25	20.48	19.73	20.61	18.17
MnO_2	0.42	0.42	0.56	0.44	0.20	0.21	0.13	0.15	0.37	0.20
MgO	---	---	---	---	---	---	---	---	0.12	---
CaO	---	---	---	---	---	---	---	---	0.02	---
H_2O-	1.53	0.74	0.89	0.74	0.73	0.79	0.84	0.77	1.21	1.75
Loss on ignition	23.65	25.85	25.34	26.55	26.23	25.81	26.00	25.69	23.43	29.60
	100.00	99.90	100.29	99.95	99.80	99.93	99.99	99.91	100.03	99.85
Density t°/4°		2.741	2.738						2.761	
Available Al_2O_3 1/	43.1	46.3	45.7	46.8	46.1	45.2	45.4	44.6	40.6	45.1

1/ Calculated available alumina = percent Al_2O_3 - (percent SiO_2 x 1.1)

The following ranges for the principal constituents were found in samples from auger holes representing the nine mapped deposits:

Constituent	Range in percentages
SiO_2	1.55- 5.17
TiO_2	2.50- 2.75
Al_2O_3	46.25-48.53
P_2O_5	0.13- 0.26
Fe_2O_3	19.43-20.61
MnO_2	0.13- 0.56
H_2O-(below 110°C.)	0.73- 1.53
Loss on ignition	23.43-26.55

Magnesia and lime are sparingly present in the soil. The total iron as Fe_2O_3 in the sample from Sabana de los Garitos is somewhat below average for the district. The relatively large loss on ignition (29.6 percent) probably is caused in part by organic matter in the surface soil. The small content of silica in this sample is of interest, because surface samples from deposits of aluminous lateritic soil in Haiti and in Jamaica usually contain more silica than the soil at depth.

An analysis of a sample (table 6, No. 11) representing hole No. 5 near the southwestern end of savanna No. 2 agrees closely with the analysis of the composite sample for the deposit as a whole (table 5, No. 2). Close agreement with these analyses also is shown in the analysis (table 6, No. 13) made by Mr. Grimaldi of a sample from hole No. 17 in the central part of the savanna. These data indicate that the soil in the deposit is fairly uniform in composition.

Concretions.—A representative portion of material from hole No. 5 was washed in a sieve, and the concretions 1 millimeter or greater in diameter were separated from the soil. Compared to the analysis of the soil as a whole, the concretions (table 6, No. 12) show a greater relative amount of Fe_2O_3, MnO_2, and P_2O_5. Percentages for Al_2O_3, TiO_2, and SiO_2 are smaller for the concretions than for the soil. An analysis of concretions scooped up from the surface of savanna No. 3 near auger hole No. 33 (table 6, No. 15) compared with the analysis of the composite sample for this deposit shows similar relationships, except that the relative amount of silica in the concretions is greater than in the soil of the deposit as a whole.

The concretions are believed to develop in place in the soil, and the differences in chemical composition are considered the result of a redistribution of the constituents subsequent to the accumulation of the soil. The concretions, therefore, are regarded as an "aging" phenomenon. Although time is a factor in this process, movements of ground water or soil moisture and the chemical and physical environment may be the controlling factors. Fineness of grain or particle size, pH of the ground water, and aeration of the soil probably influence the processes of concretion formation and the resulting chemical changes. The absolute changes that have taken place in the soil are difficult to measure, but the relative changes are shown in figure 6. In this plot, the ratio of the percentage for each constituent in the concretions to the percentage for the constituent in the soil as a whole, multiplied by 100 ($\frac{\text{concretions}}{\text{soil}} \times 100$), is shown. Thus, the concretions from the sample from hole No. 5 contain 96 percent of the silica content of the soil, 90 percent of the TiO_2, 93 percent of the Al_2O_3, and so forth. Points to the left of the 100 percent line indicate relative losses; to the right, relative gains. It is not known to what extent iron has migrated to nuclei which grew to form the concretions or how much alumina has moved out. Probably both changes took place. Similar changes are indicated in the development of the perdigónes (iron oxide pellets) in the Matanzas soil of Cuba. Analyses of the perdigónes and of the soil as a whole given by Bennett and Allison [4] have been

Table 6.—Chemical analyses of auger hole samples and of concretions, Aceitillar area. [Nos. 11, 12, and 15, S. S. Goldich, analyst; Nos. 13 and 14, F. S. Grimaldi, analyst]

Constituent	11	12	13	14	15
SiO_2	1.61	1.54	1.80	2.12	3.29
TiO_2	2.62	2.36	2.46	2.46	2.44
Al_2O_3	48.63	45.37	48.76	48.82	45.44
P_2O_5	0.20	0.22	---	---	0.31
Fe_2O_3	19.48	24.16	19.76	19.24	25.74
MnO_2	0.45	0.92	---	---	0.23
H_2O-	0.77	1.06	26.87	26.67	3.02
Loss on ignition	26.51	24.62	---	---	19.46
	100.27	100.25	99.65	99.31	99.93
Density t°/4°					2.853

11. Hole No. 5 (1-24.7 feet), savanna No. 2.
12. Concretions from hole No. 5.
13. Hole No. 17 (1-28 feet), savanna No. 2.
14. Hole No. 33 (1-20 feet), savanna No. 3.
15. Concretions on surface near hole No. 33.

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[4] Bennett, H. H., and Allison, R. V., The soils of Cuba: Table 6, p. 77, Tropical Plant Research Foundation, Washington, 1928.

reduced to ratios and plotted in figure 6. The changes indicated in the formation of the concretions from hole No. 5 are found in the perdigón development in the Matanzas soil, except that in the latter they are somewhat accentuated indicating that the processes have gone further.

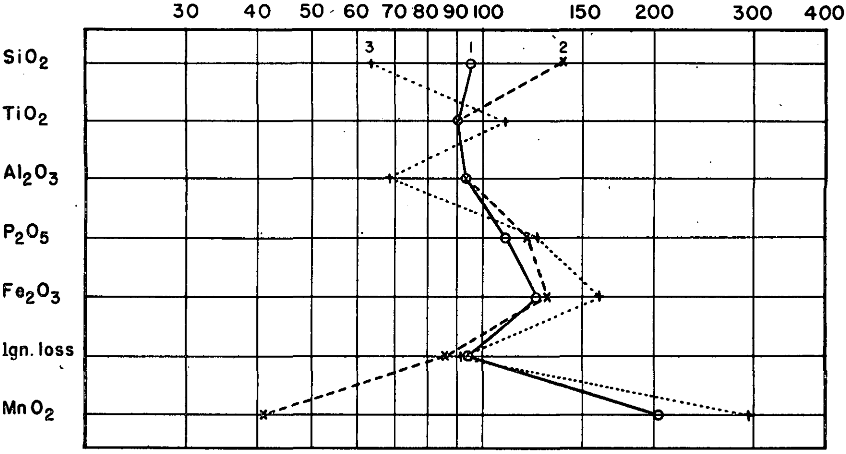

Figure 6.—Chemical changes in the development of concretions in soil. Ratios for the principal chemical constituents in the concretions to the same constituents in the soil as a whole ($\frac{\text{concretions}}{\text{soil}}$ x 100) are shown. (1) Concretions from auger hole No. 5, savanna No. 2; and (2) surface concretions from savanna No. 3, Sierra de Bahoruco; (3) perdigónes from Matanzas soil of Cuba.

In the surface concretions from savanna No. 3 silica shows a relative gain, and manganese dioxide a relative loss (fig. 7). These changes are comparable to changes noted in the surface material in aluminous lateritic soil deposits in Haiti. In the Haiti deposits the silica content of surface samples is frequently twice as great as the average silica content for the deposits. In the same soils manganese moved downward from the upper soil and is concentrated near the base of the deposit. The chemical composition of the surface concretions suggests that similar changes have taken place in the soil deposits of the Sierra de Bahoruco.

Mineralogical composition.—The principal mineral of the soil is gibbsite [$Al(OH)_3$]. Boehmite [$AlO(OH)$] and kaolinite [$Al_2Si_2O_5(OH)_4$] have been identified by X-ray and differential thermal analyses. Hematite (Fe_2O_3) is the chief iron ore mineral; goethite ($HFeO_2$) is subordinate. The theoretical compositions of these minerals in oxide form are shown on the following page.

Mineral	Composition	Percent			
		H_2O	Al_2O_3	Fe_2O_3	SiO_2
Gibbsite ..	$Al_2O_3.3H_2O$	34.6	65.4	---	---
Boehmite ..	$Al_2O_3.H_2O$	15.0	85.0	---	---
Kaolinite .	$Al_2O_3.2SiO_2.2H_2O$ ..	14.0	39.5	---	46.5
Hematite ..	Fe_2O_3	---	---	100.0	---
Goethite ..	$Fe_2O_3.H_2O$	10.1	---	89.9	---

Gibbsite-boehmite-kaolinite.—Differential thermal analyses indicate from 60 to 70 percent of gibbsite in the lateritic soil. Boehmite was identified on X-ray films, but this mineral is sparingly present. Differential thermal analysis of a soil sample from auger hole No. 5 gave 71 percent gibbsite and for the concretions separated from this sample, 63 percent. From the chemical analyses, contents of 72 and 67 percent of the gibbsite were calculated. Kaolinite, identified by X-ray films, can be estimated in most samples by differential thermal analyses and accounts for most of the silica in the soil. Approximately 10 percent of kaolinite is estimated for the Sabana Canote deposit. The average kaolinite content in other deposits is 5 percent or less. Ten percent of kaolinite is indicated in the light-colored sample from a depth of 9.6 feet in hole No. 46 of savanna No. 5. This sample contains 6.1 percent of silica or slightly more than average for the Sabana Canote deposit.

Hematite-goethite.—The anhydrous oxide of iron, hematite, is the principal iron mineral in the lateritic soil. Goethite is suggested by the brown rather than red color of some surface soil samples. The average hematite content of the lateritic soil is 20 percent.

Accessory minerals.—Quartz, zircon, and magnetite or ilmenite are found in residues obtained by washing portions of the lateritic soil to remove the fine material. Quartz is not abundant in the soil of the district as a whole, but angular grains approximately 0.1 millimeter in diameter were fairly common in a residue from Sabana Canote soil. Well-formed crystals of zircon and grains of magnetite or ilmenite occur in most residues. The smallest crystal of zircon measured 0.06 millimeter in length and 0.02 millimeter in width; the largest, 0.15 millimeter in length and 0.08 millimeter in width. Most of the crystals are approximately 0.10 millimeter in length and 0.03 millimeter in width. Similar accessory minerals have been found in samples of aluminous lateritic soil from Haiti and from Jamaica.

The mineral forms of manganese, phosphorus, and titanium in the soil have not been positively identified. The manganese dioxide in the soil probably is in the form of pyrolusite (MnO_2). Phosphorus may be combined as a phosphate of iron or aluminum, and titania probably is in a hydrated oxide.

Bucan Polo area

Description of soil.—The lateritic soil of the Bucan Polo terrace is dark reddish brown in a wet state and dark brown when dry. It is markedly loose and friable and does not contain concretions such as characterize the soil at higher altitude in the Aceitillar savannas. At the time of the field work in June and July, the soil contained very little moisture. The friable material would not adhere to the spiral auger bit, and recovery of the soil from the hole was a slow process unless water was added during the drilling. The location of the 5 auger holes and 14 surface soil samples is shown on figure 5, a sketch map of the trail traverses in the Bucan Polo area.

Chemical and mineralogical composition.—The alumina contents of composite samples representing the five auger holes range from 41 to 44.5 percent (table 7), and average 42.6 percent. Other constituents show the following ranges: SiO_2, 8.5 to 12.6 percent; TiO_2, 2.2 to 2.4 percent; P_2O_5, 1.3 to 2.4 percent; Fe_2O_3, 19.4 to 20.4 percent; MnO_2, 0.6 to 1.1 percent; H_2O- (moisture lost below 110° C.), 2.0 to 2.4 percent; and loss on ignition (above 110° C.), 16.7 to 20.2 percent.

Gibbsite and boehmite are the principal minerals and are admixed with about 20 percent of hematite and rather large amounts of a clay mineral which may be halloysite. If the silica is assumed to be combined in a clay mineral with a composition similar to that of halloysite ($Al_2O_3.2SiO_2.2H_2O$), the chemical analyses indicate a range of from 18 percent of clay mineral for sample No. 2 to 27 percent for sample No. 1. Estimates of the

Table 7.—Chemical analyses of soil samples from auger holes in the Bucan Polo area [S. S. Goldich, analyst]

Constituent	1	2	3	4	5	Average
SiO_2..................	12.6	8.5	9.8	10.9	12.5	10.7
TiO_2..................	2.2	2.4	2.4	2.4	2.2	2.3
Al_2O_3..................	41.3	44.5	43.5	42.7	41.0	42.6
P_2O_5..................	2.4	1.3	1.8	2.0	2.4	2.0
Fe_2O_3..................	19.4	19.7	20.4	19.5	20.3	19.9
MnO_2..................	1.0	0.6	0.8	0.9	1.1	0.8
H_2O-..................	2.5	2.0	2.1	2.4	2.4	2.3
Loss on ignition......	17.1	20.2	18.0	18.0	16.7	18.0
	98.5	99.2	98.8	98.8	98.6	98.6
Density t°/4°.........		2.786				
Available Al_2O_3 1/....	27.4	35.1	32.7	30.7	27.2	30.8

1/ Calculated available alumina = percent Al_2O_3 - (percent SiO_2 x 1.1).

gibbsite content of these samples from differential thermal analyses range from 19 percent for sample No. 1 to 40 percent for sample No. 2. From the percentage of gibbsite and the calculated contents of clay mineral the percentages of boehmite may be deduced. The approximate percentages of the hydrous aluminum oxides and of clay mineral in the auger-hole samples estimated from the differential thermal analyses and from the chemical analyses follow:

Mineral	Auger hole samples					Surface samples		
	1	2	3	4	5	9	13	14
Gibbsite.....	19	40	25	25	22	29	16	19
Boehmite.....	21	13	22	21	20	--	--	--
Clay mineral.	27	18	21	23	25	--	--	--

The two samples from the northern part of the Bucan Polo terrace, No. 2 and No. 9, contain a relatively large amount of gibbsite, 40 percent and 29 percent, respectively. The smallest gibbsite content, 16 percent, is estimated for surface sample No. 13, the most southerly of the samples. Samples from the other four auger holes contain nearly equal amounts of gibbsite and boehmite.

The washed residues of the soil contain small amounts of angular grains of quartz, crystals of zircon, and grains of magnetite or ilmenite.

Pedernales-El Fondo de Mella trail area

The lateritic soil on terraces along a trail which leads north from Pedernales to a military post at Agua Nigra in the Sierra de Bahoruco, resembles the soil of the Bucan Polo area. Soil on massive limestone was sampled at four places along the trail. Analyses of the samples (table 8) show a range of silica from 16.0 to 24.7 percent. The alumina content ranges from 32.2 to 36.5 percent, but these values are approximate as phosphorus was not determined. The high content of silica precludes consideration of these soils as a potential source of aluminum ore. However, the samples indicate a progressive decrease in the relative amount of silica with increasing altitude. The lowest silica contents (16.0 and 17.9 percent) were found in samples of soil at El Fondo de Mella, approximately 2,150 feet above sea level. Differential thermal analysis of sample No. 4 indicates about 10 percent of gibbsite, a somewhat larger amount of boehmite, and a clay mineral. Further exploration of this area at higher altitudes is recommended.

Table 8.—Chemical analyses of surface soil samples taken along the trail from Pedernales to El Fondo de Mella [S. S. Goldich, analyst]

Constituent	1	2	3	4
SiO_2	24.7	20.5	16.0	17.9
TiO_2	1.6	1.8	1.9	1.8
Al_2O_3	32.2	36.5	35.3	34.6
Fe_2O_3	14.3	16.1	15.9	15.5
MnO_2	0.9	0.7	0.7	1.1
H_2O-	4.8	4.1	4.6	4.6
Loss on ignition	18.4	17.3	22.9	22.1
	96.9	97.0	97.3	97.6

1. Reddish-brown soil on limestone terrace, 800 feet above sea level, approximately 5 miles north of Pedernales.
2. Reddish-brown soil with waxy luster on small flat, 1,350 feet above sea level, approximately 6.5 miles north of Pedernales.
3. Reddish-brown friable soil on massive limestone. Sample collected near trail in area locally known as El Fondo de Mella, approximately 2,150 feet above sea level and 10 miles north of Pedernales.
4. El Fondo de Mella, about 600 feet north of sample No. 3.

ORIGIN OF ALUMINOUS LATERITIC SOIL

Development of deposits

The deposits of aluminous lateritic soil of the Sierra de Bahoruco are surface accumulations. In the Aceitillar area, catchment basins for the soil were provided by the limestone valleys, and at lower altitudes, sites for soil accumulation were afforded by limestone terraces. There are some notable physical, chemical, and mineralogical differences between the high-level and low-level soils. Boehmite is rare in the concretionary lateritic soil at high altitude but is abundant in the friable earthy material on the terrace at Bucan Polo and in the samples taken along the trail from Pedernales to El Fondo de Mella. Silica is relatively more abundant in the Bucan Polo soil than in Aceitillar deposits and even more so in samples from the El Fondo de Mella area, in which it ranges from 16 to 25 percent.

These samples indicate a progressive decrease of silica content with increasing altitude. This difference is a fundamental difference between the soil of the high savannas and that of the lower flats and reflects the greater content of clay minerals in the soil at lower altitudes. In contrast with these differences between the soils, it is striking that the ratios of $Al_2O_3:Fe_2O_3:TiO_2$ for the analyzed soil samples from the three areas are similar. Averages for these ratios follow:

Area	$Al_2O_3:Fe_2O_3:TiO_2$	$Fe_2O_3:Al_2O_3$
Aceitillar............	67.9:28.3:3.8	0.42
Bucan Polo............	65.7:30.7:3.6	0.47
El Fondo de Mella.....	66.8:29.8:3.4	0.45

The similarity of these ratios suggests that the difference in the soils are those of processes or of stage of soil formation rather than differences of parent material.

The fact that the Aceitillar savannas are being dissected and eroded indicates that present conditions in this area are different from those under which the soil accumulated. The deposits may antedate the Recent uplifts indicated by the raised terraces along the coast of Hispaniola. They may even date back to the Pliocene, for the soil rests on limestone that was folded in late Miocene or Pliocene time when the Sierra de Bahoruco was uplifted.

Relationship of soil to limestone

The low-silica aluminous lateritic soil deposits of the Aceitillar area are similar to deposits of lateritic soil on the Southern Peninsula of Haiti and on the island of Jamaica. Not only are these soils alike in chemical composition but they also occur on similar fine-grained, white to light-yellow or buff-colored Tertiary limestone composed almost wholly of calcium carbonate and ranging from lower Eocene to Oligocene and possibly Miocene age (fig. 7). This belt of Tertiary limestone afforded plateau and mountain conditions that locally were favorable for the accumulation of the lateritic soil. The close relationship of soil to the limestone might suggest that the source material was contained in the limestone beds, and that as the limestone was removed in solution, the lateritic constituents accumulated as insoluble residues in sites favorable for their preservation.

Analyses of limestone.—Chemical analyses (table 4) of samples of the limestone bedrock from the Aceitillar area show very small contents of alumina. Analyses of limestone samples from localities of low-silica aluminous lateritic soil in Haiti show a similar composition. The percentage ranges for the principal constituents in five analyses follow:

Constituent	Percent
CaO	55.60-55.90
MgO	0.04- 0.36
SiO_2	0.01- 0.05
Al_2O_3	0.00- 0.07
Fe_2O_3	0.02- 0.13

Averages are SiO_2, 0.03 percent; Al_2O_3, 0.04 percent; and Fe_2O_3, 0.07 percent. The average P_2O_5 content is 0.01 percent. Titania (TiO_2) could not be detected in the samples by ordinary chemical methods. The titania content of a composite of three limestone samples from the Aceitillar area was found to be 0.0002 percent by spectrographic analysis (table 9). Titania was not found in a composite of six samples of fresh limestone from the Southern Peninsula of Haiti. Of the other consitutents reported in the spectrographic analyses of the lateritic soil, only Cr_2O_3, V_2O_5, NiO, MnO, and SrO are in sufficiently large amounts to be determined in the limestone samples. With the exception of strontia these constituents are present in larger amounts in the soil than in the limestone, and ratios of the percentages for these constituents in the soil compared to that of the limestone range from 3 to 10,000.

The alumina content of the limestone sample from savanna No. 4 is 0.03 percent (table 4) or about average for the analyzed samples. Large volumes of limestone of this composition would be required to yield the known deposits. To produce the 3 million long tons of alumina estimated in the soil of the mapped deposits of the Aceitillar area, 10 billion tons of limestone would be required. This is a concretion ratio of about 1,500 tons of limestone per ton of soil, assuming all the alumina is saved. Lateral as well as downward movements probably were involved in the accumulation of the soil, and a thickness of several thousand feet of limestone may be an adequate source for the materials, although the alumina content of the analyzed samples is small. However, the analyzed samples may not fully

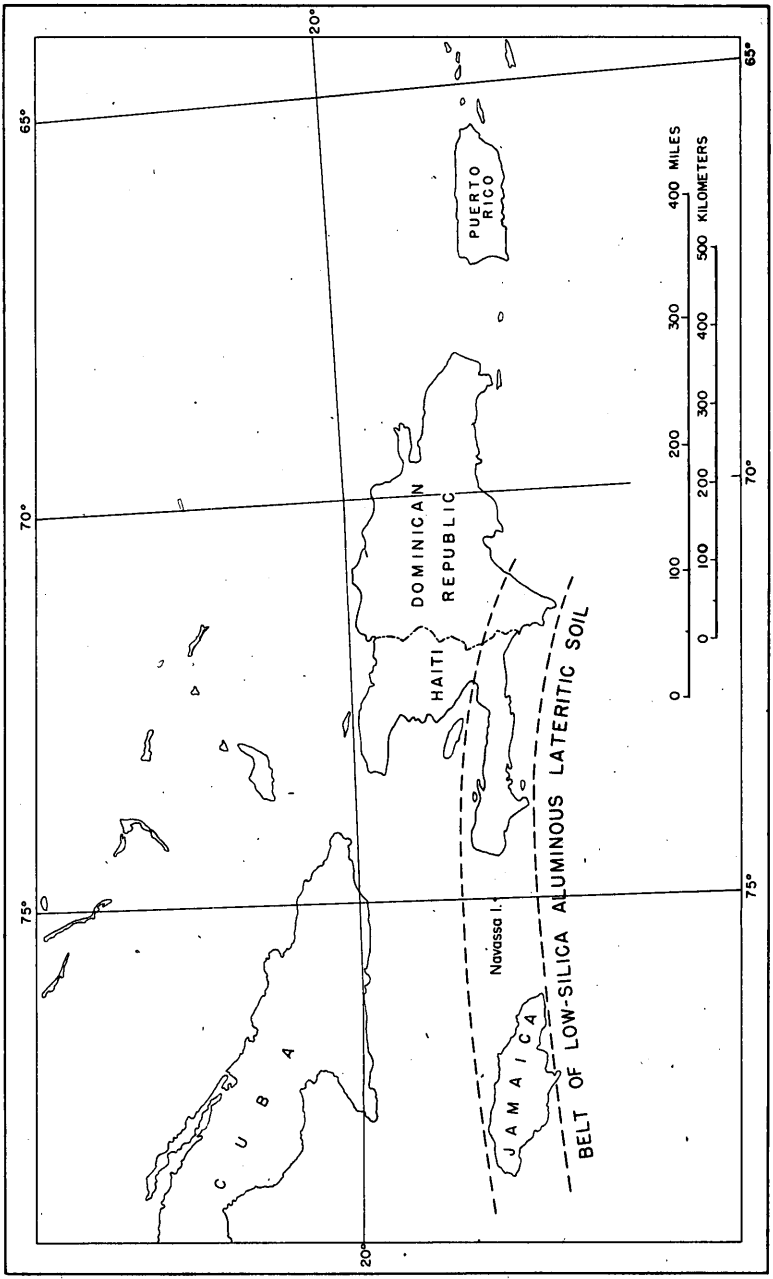

Figure 7.—Belt of low-silica aluminous lateritic soil deposits on limestone of Eocene and Oligocene age in the Caribbean region.

represent the geologic section subjected to weathering. The lateritic soils may represent the residue of beds of somewhat different composition than the comparatively pure calcium carbonate bedrock on which they have come to rest, and thus, the lateritic materials may represent an inherited rather than a derived soil.

Table 9.—Spectrographic analyses for minor elements in limestone and lateritic soil from the Aceitillar area and from the Southern Peninsula of Haiti. [Esther W. Claffy and K. J. Murata, analysts]

Constituent [1]	1	2	3	4
TiO_2	0.0002	2.0	NF.	3.0
ZrO_2	NF. [2]	0.04	NF.	0.04
Cr_2O_3	0.004	0.1 [3]	0.004	0.08
V_2O_5	0.006	0.02	0.003	0.05
NiO	0.0003	0.009	NF.	0.007
MnO	0.0005	0.5	0.001	0.5
SrO	0.006	0.0005	0.006	0.0005
BaO	NF.	0.0005	NF.	0.0006
La_2O_3	NF.	0.01	NF.	0.03
Y_2O_3	NF.	0.008	NF.	0.03
Yb_2O_3	NF.	0.0005	NF.	0.002
BeO	NF.	0.0006	NF.	0.0008
Ga_2O_3	NF.	0.001	NF.	0.001
CoO	NF.	0.005	NF.	0.005

1. Composite of fresh limestone samples from localities Nos. 1, 2, and 5 in the Aceitillar area of the Sierra de Bahoruco.
2. Lateritic soil composite sample from deposit of savanna No. 2, Aceitillar area.
3. Composite of six samples of fresh limestone from the Southern Peninsula of Haiti.
4. Lateritic soil from the Southern Peninsula of Haiti.

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[1] Looked for but not found: W, Mo, Sn, In, Ge, Zn, Cd, Pb, Bi, Cu, Ag, Au, Pt, Re, Cb, Ta. Tl, As, and Sb looked for, but ignition of lateritic soil samples before analysis would remove any As, Sb, and Tl present.

[2] Not found; the element may be present in amounts below the limit of sensitivity of the method.

[3] Chemical analysis by Norman Davidson, 0.095 percent Cr_2O_3.

Inferred composition of parent material.—Although the available data are inadequate to determine whether the immediate source of the lateritic constituents is the limestone bedrock of the deposits or other materials, the probable composition of this source material can be inferred from the composition of the soil. As pointed out the ratios of Al_2O_3:Fe_2O_3:TiO_2 in samples of the lateritic soil from the three areas sampled in the Sierra de Bahoruco are fairly constant. Low-silica aluminous lateritic soils from Haiti and Jamaica exhibit similar ratios. These ratios are like those for igneous rocks of andesitic composition and suggest that igneous material of this composition may be the source of the lateritic constituents. Volcanic ash and other pyroclastic materials of andesitic to basaltic composition are widespread in many of the Tertiary formations of the Caribbean region. Material of this composition is readily susceptible to lateritization. The crystals of zircon, magnetite-ilmenite, and grains of quartz, many of which have the crystal terminations and the sharp uniform extinction between crossed nicols that are characteristic of volcanic rocks, may represent the relict minerals of such igneous material. Furthermore, the spectrographic data (table 9) show the minor constituents in the lateritic soil in amounts that would be expected from an igneous source material of intermediate composition.

DESCRIPTION OF LATERITIC SOIL DEPOSITS

Aceitillar area

Savanna No. 1.—Savanna No. 1 is 2,700 feet east of the Pedernales-Duvergé trail (pl. 17). The irregular outline of the savanna is controlled by the joint system of the massive limestone. The surface elevation near the western end is approximately 4,065 feet above sea level. The valley floor is flat and regular except for the quebrada in the northwestern part. The quebrada drains to the north joining the main drainage line that flows westward. The west wall of the quebrada is limestone. The east bank exposes the concretionary lateritic soil to a depth of 10 feet.

Three auger holes were drilled in this savanna. None was bottomed on limestone, and depths of 24 feet for hole No. 1 and of 20 feet for holes No. 2 and No. 3 indicate an appreciable thickness of soil. Although the surface area is small, it is estimated that the pocket contains 200,000 cubic yards (153,000 cubic meters) of soil, assuming an average thickness of 15 feet.

Savanna No. 2.—Savanna No. 2 is the largest of the Aceitillar group. This deposit is 2,000 feet east of savanna No. 1. The two deposits are connected by a narrow valley with nearly vertical walls of limestone, which rise 40 to 50 feet above the trail. This savanna is roughly rectangular in outline and is 3,200 feet in length in a northeast-southwest direction. Near its northeastern end the savanna measures 500 feet in width, but this dimension increases to 1,200 feet to the southwest.

The approximate surface elevation of the northeastern part of the savanna is 4,250 feet above sea level or 200 feet above the level of savanna No. 1. The first impression obtained on entering the savanna from the west is that of a long narrow flat valley bordered by limestone ridges. However, there are a number of surface irregularities. Near the center of the savanna, barren outcrops of indurated, reddish-brown, concretionary lateritic soil are conspicuous. These barren surfaces and a number of small knobs form a level which is as much as 10 feet above the surface of other parts of the savanna. A quebrada borders the savanna on the northeast and runs along the southern edge, draining the area to the southwest. The quebrada is 12 to 15 feet deep and 20 to 30 feet wide. Small gullies or draws are developing on the savanna. Near the southwestern end of the valley two small circular sinkholes about 15 feet in diameter have been formed by collapse of the lateritic soil due to removal of material through subterranean drainage. In drill hole No. 6 near one of the sinkholes a cavity was struck at a depth of 12 feet and the auger fell to a depth of 14.5 feet.

Twenty three auger holes spaced on a grid marked by stakes 400 feet apart were drilled in this area. The hardened concretionary lateritic soil presented some special drilling problems, and it was only through the generous cooperation of the Alcoa Mining Co. that this drilling program was completed. Because of the time consumed in drilling at depths greater than 20 feet, a number of holes in the central part of the savanna were not bottomed. These holes were abandoned in soil at depths ranging from 20 to 30 feet. The average thickness of the lateritic soil is estimated to be about 16 feet, and a minimum of 2,000,000 cubic yards (1,529,000 cubic meters) of soil is indicated.

Savanna No. 3.—Northeast of savanna No. 2 is a smaller savanna which is 2,400 feet in length and 700 feet in maximum width. The surface elevation at auger hole No. 33, located on a small hill near the center of the deposit, is 4,300 feet above sea level or 50 feet higher than the eastern part of savanna No. 1. Seven auger holes were drilled in the deposit. The master hole controlling the drilling pattern is hole No. 33, drilled to a depth of 24 feet without encountering limestone. Four holes were drilled on 600-foot radii from hole No. 33. These were bottomed on limestone at depths ranging from 8 to 19.5 feet. Hard, dry, concretionary soil was encountered in hole No. 38, which is 800 feet south and slightly west of hole No. 37. Drilling of this hole was exceptionally slow, and it was abandoned at a depth of 4 feet.

The northeastern limit of the deposit was set arbitrarily in the constricted part of the savanna 600 feet northeast of hole No. 36. Savanna No. 3, including the small extension to the south, contains about 42 acres. The volume of soil in this deposit is estimated to be 600,000 cubic yards (459,000 cubic meters).

Northeast extension, 3A.—The irregular area northeast of savanna No. 3 was not drilled. The total area is about 22 acres but there is a large outcrop of limestone just north of the trail. Northeast of this limestone area is a hill of lateritic soil which is 4,415 feet above sea level. The western and southwestern slopes of this hill are covered by abundant limestone boulders. An estimate of 100,000 cubic yards (76,000 cubic meters) for a soil area of 13 acres is based on an assumed average soil thickness of 5 feet.

Savanna No. 4.—A small savanna (No. 4) is situated approximately 1 mile southeast of savanna No. 3. The intervening country along the trail between the two savannas is characterized by ridge and valley topography of a rugged and monotonous nature. The central part of savanna No. 4 is a hill of fairly symmetrical shape. The surface elevation at hole No. 41 on this hill was determined with the aneroid as 4,170 feet above sea level. The relative elevations of the collars of the other drill holes were determined with a hand level. All the holes were drilled to the limestone bedrock. The area of savanna No. 4 is 20 acres, and approximately 200,000 cubic yards (153,000 cubic meters) of soil is contained in the deposit.

Savanna No. 5.—Savanna No. 5, approximately 1,200 feet east of the northeast extension of savanna No. 3, is 1,700 feet in length in an east-west direction. The surface area is 22 acres. A northwest-southeast trend in the shape of the savanna and the extension of the narrow tongue of soil to the southeast suggest an alinement of this savanna with deposits to the northwest, Nos. 6 and 6A. Auger hole No. 46 is near the northern edge of a hill in the south-central part of the savanna. The surface elevation at this point is about 4,490 feet above sea level or 190 feet above the level of the collar of drill hole No. 33 in savanna No. 3, 5,400 feet to the west. Surface elevations at other drill-hole locations in savanna No. 5 were determined with a hand level. In drill hole No. 46 a peculiar "slick" material of much lighter red color than is typical of the soil of the district was encountered at a depth of 9.6 feet. This material was difficult to drill with the soil auger, and the hole was abandoned. Four additional auger holes were drilled to limestone bedrock. The deepest hole No. 44, in the western part of the area, penetrated 23 feet of soil. With the exception of the light-colored material found in hole No. 46, the samples from the auger holes showed typical reddish-brown concretionary soil closely resembling the material in the savannas to the west. This deposit is estimated to contain 250,000 cubic yards (191,000 cubic meters) of lateritic material.

Savanna No. 6.—Savanna No. 6 is 800 feet northwest of No. 5. The southern tip of the savanna is 400 feet north of the trail, but the savanna is not visible from the trail because of intervening limestone hills. Savanna No. 6 is 2,000 feet in length in a north-south direction and as much as 1,500 feet in width. Three auger holes were drilled in the area. Hole No. 49 was drilled to 20 feet without striking limestone. This hole was located near the northern end of a hill of soil in the central part of the savanna. In auger hole No. 50, located 600 feet to the southeast of hole No. 49, limestone was found at a depth of 15.7 feet. The surface elevation at this point was determined with the aneroid to be 4,465 feet above sea level. Approximately 250 feet east of this point is a small sink formed by collapse of the soil into a solution cavity in the underlying limestone. Hole No. 51 southwest of hole No. 50 and approximately 740 feet due south of hole No. 49 was drilled to limestone bedrock at a depth of 9.5 feet. Forty four acres are contained in this savanna which in areal extent is larger than savanna No. 3. The deposit is estimated to contain 500,000 cubic yards (382,000 cubic meters) of soil.

Northwest extension, 6A.—Northwest of savanna No. 6 and following the alinement of savannas No. 5 and No. 6 is a smaller deposit that is roughly rectangular in outline. This savanna is 1,500 feet in length and ranges from 450 to 800 feet in width. A large roughly circular outcrop of limestone in the center of the savanna occupies nearly half the area. An estimate of 100,000 cubic yards (76,000 cubic meters) of soil in this deposit is based on an assumed average thickness of 5 feet.

Savanna No. 7.—Savanna No. 7 with a surface area of 12 acres is 900 feet north of savanna No. 6. A single hole, No. 52, was drilled near the center, and limestone was encountered at a depth of 15 feet. A preliminary estimate of 140,000 cubic yards (107,000 cubic meters) is made on an assumed average depth of 7.5 feet.

Savanna No. 8.—Northeast of savanna No. 7 a gorge, 150 to 200 feet deep and 175 feet or more wide, has been cut in the limestone. Just across this gorge and north of savanna No. 7 is a larger savanna (No. 8) with a surface area of 21 acres. This deposit is being dissected by gullies that drain into the gorge. The hilly surface is covered by a heavy stand of pine. A single auger hole (No. 53) was drilled to obtain a sample for chemical analysis. Because of the slow progress made in drilling the indurated concretionary soil and the lack of time, this hole was abandoned in soil at a depth of 9 feet. A preliminary estimate of 200,000 cubic yards (153,000 cubic meters) of soil is made for the deposit.

Savanna No. 9 (Sabana Canote).—Sabana Canote is the largest savanna in the Aceitillar area. Situated in the northern part of the mapped area, this savanna is approximately 2 miles north of the main Aceitillar savanna, No. 2. The Pedernales-Duvergé trail crosses the savanna in a north-south direction. About one hour is required to travel the distance from Canote to the the trail intersection in the southwest corner of the district. The trail leading south to savanna No. 3 is less traveled and is rough and rocky. The savanna is a relatively flat and regular surface approximately 5,015 feet above sea level, or 750 feet above the level of savannas No. 2 and No. 3. Near the eastern end of the area of a large outcrop of massive limestone rises a few feet above the soil level. Tongues of soil, filling irregular narrow valleys on the southern and western sides of the savanna, give it an irregular outline. The main body is roughly a square area 2,000 feet across.

Auger holes spaced 400 feet apart were drilled along lines at right angles across the savanna (pl. 17). None of the holes was drilled deeper than 20 feet, and a number of auger holes in the central and western parts of the area were abandoned in soil. The spacing of the isopach lines on plate 17 shows increasing thickness of soil from east to west in the deposit. The soil area of the savanna is 106 acres, and a minimum estimate of 1,900,000 cubic yards (1,453,000 cubic meters) of soil is based on measurements made on the isopach map. A probable maximum estimate is 2,500,000 cubic yards (1,912,000 cubic meters).

Sabana de los Garitos.—Sabana de los Garitos is west of Sabana Canote, and according to Mr. Cestero can be reached in about 45 minutes from Sabana Canote. The savanna is approximately 1,200 feet long in an east-west direction, and is about 700 feet wide near the eastern end. Mr. Cestero estimated that the area is half the size of savanna No. 3. A hill of reddish-brown concretionary soil near the eastern end of the savanna rises 25 to 30 feet above the general level. Five surface samples were collected by Mr. Cestero; auger holes were not drilled. If the estimated area of 20 acres is indicative of the size of the deposit, a reserve on the order of 200,000 cubic yards (153,000 cubic meters) of soil can be inferred.

Other savannas.—A number of small savannas are southeast of the mapped area within a radius of 3 miles of savanna No. 4. The largest of the savannas visited is Sabana de los Pinalitos which is about 1,000 feet in length and 400 feet in width. A differential thermal analysis of a surface sample indicates a composition similar to that of the soils of the Aceitillar savannas. No estimates of tonnage were made for these small savannas.

Bucan Polo deposit

The Bucan Polo deposit of lateritic soil covers a terrace at an altitude of 1,250 feet, 9 miles northeast of Pedernales on the trail to Duvergé. Because of the heavy forest cover on the Bucan Polo terrace, exploration was restricted to the trails. The Pedernales-Duvergé trail crosses the area in a direction roughly N. 20° E., and was mapped by a Brunton compass and pace traverse (fig. 5). Along this trail the soil area is 5,600 feet in length. A northwest-southeast trail crossing the main trail also was mapped. Along this trail the soil area is 3,600 feet in width.

North of this trail there are at least two additional trails on the terrace that are roughly at right angles with the Pedernales-Duvergé trail. These trails were not mapped, but a brief reconnaissance of the terrace showed the soil area to be extensive. An average width of 2,000 feet is assumed, giving approximately 200 acres for the total area. The surface is relatively flat, but some large sinkholes have been developed in the limestone.

Five auger holes were drilled in the area and surface samples were collected at points along the trail (fig. 5). Only auger hole No. 2 near the western edge of the area was bottomed, striking limestone at a depth of 11.6 feet. Auger holes Nos. 1, 4, and 5 were abandoned at 10 feet in soil, and hole No. 2, in the northern part of the area, was abandoned in soil at a depth of 15 feet. Assuming an average thickness of 10 feet, 2,500,000 cubic yards (1,912,000 cubic meters) of soil is estimated in the Bucan Polo deposit.

RECONNAISSANCE IN OTHER PARTS OF THE DOMINICAN REPUBLIC

A short reconnaissance of the Dominican Republic showed no regions except the Sierra de Bahoruco in which conditions appear to be favorable for the occurrence of aluminous lateritic soil in potentially commercial deposits. A preliminary geologic map, by C. P. Ross and D. J. Varnes of the Geological Survey, prepared in connection with a reconnaissance for strategic minerals made in 1941, was useful in this phase of the investigation. Limitations of time made it necessary to restrict the exploration to the more readily accessible parts of the Republic, and only a casual examination of these areas was made. A reconnaissance of the western part of the Samaná Peninsula was made by airplane. Three trips on the principal highways were made by automobile, and a number of side trips were made by mule or on foot. The routes traveled are shown in plate 16.

Aerial reconnaissance.—As seen from the air, the western part of the Samaná Peninsula is characterized by rugged topography which is unfavorable for the occurrence of large deposits of aluminous lateritic soil. Reddish-brown soil occurs on limestone, but exploration on the ground does not appear to be warranted. A red soil cover marks the hilly region southeast of Yamasá and south of Rio Yamasá, approximately 19 miles north of Ciudad Trujillo. As this part of the Republic has not been mapped geologically, there is no indication of the composition of the soil.

Sierra de Neiba.—Exploration in the Sierra de Neiba was limited to the trail from Los Rios to La Tasajera (pl. 16) situated on the divide approximately 5,700 feet above sea level. This is a region of typical rain forest. Yellowish-brown soil occurs on massive limestone which is weathered to pinnacles that protrude through the thin soil on the southern slope of the range. On the crest of the mountain, the massive medium-grained limestone forms a narrow flat ridge. An auger hole at La Tasajera was drilled to chalky limestone at a depth of 13.5 feet. A second hole drilled on the ridge about 3 miles west of La Tasajera penetrated 6.5 feet of soil. Samples from these holes are light-yellow to brown silty clay in which abundant grains of quartz can be seen with a hand lens. A surface sample collected south of the divide at the junction of the Los Rios trail with the trail to Descubierta was analyzed by Goldich with the following results:

Constituent	Percent
SiO_2	33.1
TiO_2	1.9
Al_2O_3	22.6
Fe_2O_3	18.6
MnO_2	0.1
H_2O-	7.6
Loss on ignition	13.3

The analyses indicate that the clay at La Tasajera is of no commercial value.

Pedro Sánchez area.—Reddish-brown soil on the upland region northwest of Pedro Sánchez (pl. 16) is a thin mantel derived from basaltic igneous rocks of Cretaceous age. Similar reddish-brown soil was examined in roadcuts along the highway from Ciudad Trujillo to Santiago. The basaltic rock is weathered to a depth of several feet, but the residual materials contain a large proportion of partially decomposed rock fragments.

Northern provinces.—Areas of Eocene and Oligocene limestone mapped by Ross and Varnes in the northern part of the Republic were visited in Puerto Plata and Santiago Provinces (pl. 16). These areas afford small possibilities for commercial deposits of aluminous lateritic soil. Residual clay occurs on igneous rocks in Liberator Province. Deep weathering of quartz diorite is found north of Restauración, but the product of this weathering, as indicated by differential thermal analyses, is kaolin.

RESERVES AND PROSPECTS

Aceitillar area

Tonnage.—A volume of 6,000,000 cubic yards of aluminous lateritic soil is estimated for the savannas that have mapped in the Aceitillar area. A summary of the volumes estimated for the individual deposits is given in table 10.

The grain density of the air-dried samples representing savannas No. 2 and No. 3 is 2.74. A cubic foot of solid material of this density would weight 170 pounds. The soil in place, however, has a relatively high porosity and contains some moisture. Tests made of blocks of aluminous lateritic soil from deposits in Haiti indicate a porosity of 40 to 50 percent. Unlike the Sierra de Bahoruco soil this material is not concretionary and probably is less compacted. If, for purposes of conservation estimates, a porosity of 50 percent is assumed for the Sierra de Bahoruco soil, a cubic foot of the concretionary material in place would weigh 85 pounds calculated on a dried basis. A volume of 26 cubic feet in place would be equivalent to one long ton (2,240 pounds) of dry soil. For preliminary estimates of tonnage, a factor of 27 cubic feet per long ton has been adapted; the volume figures in table 10 may be read directly as tonnage figures in long tons place calculated on a dried basis. The volume figures are regarded as minimum values; hence, a reserve of over 6,000,000 long tons in place calculated on a dried basis is indicated for the deposits.

Table 10.—Surface area and volume of soil in mapped deposits of the Aceitillar area

Deposit No.	Soil area		Volume	
	Acres	Hectares	Cubic yards[1]	Cubic Meters
1	8	3.4	200,000	153,000
2	83	33.6	2,000,000	1,529,000
3	55	22.1	700,000	535,000
4	19	7.6	200,000	153,000
5	22	8.8	250,000	191,000
6	57	23.2	600,000	459,000
7	12	4.7	140,000	107,000
8	21	8.4	200,000	153,000
9	106	43.0	1,900,000	1,453,000
Total	383	154.8	6,190,000	4,732,000

[1] Volume figures in cubic yards may be read directly as tonnage figures in long tons (2,240 pounds) of soil in place calculated on a dried basis allowing 27 cubic feet of soil per long ton.

Grade.—Of the 6,000,000 tons of indicated reserves, 4,000,000 tons probably will average better than 46 percent of Al_2O_3 and less than 3 percent of SiO_2. The iron content, as Fe_2O_3, of this material is approximately 20 percent. This high content of iron is an undesirable feature, and it is reported that in the Bayer process difficulties are encountered in removing the iron oxide by filtration because of the fineness of grain size. If this difficulty is overcome the soil would be suitable for use in the production of metallic aluminum and can be classed as a high-iron or ferruginous bauxite.

Experience in Bayer process plants in Arkansas has shown that silica in bauxites results in a loss of alumina approximately equivalent to 1.1 times the silica content. Using this factor, the percentages of alumina available (available alumina) to the Bayer process have been calculated from the chemical analyses, table 5. A range from 46.8 percent of available alumina for deposit No. 4 in the southern part of the mapped area to 40.6 percent for Sabana Canote in the northern part is indicated. The large deposit, No. 2 of the Aceitillar group, has an available alumina content of 46.3 percent. A weighted average for all the deposits is 44.2 percent. If the Sabana Canote deposit is omitted, an average of 45.8 percent for available alumina is obtained. Although ore containing 44 percent of available alumina will not bring the price of higher-grade bauxite, it appears likely that there will be a market for this material if the cost of mining and transportation can be kept low enough to insure a fair margin of profit. In composition, the aluminous lateritic soil compares favorably with deposits of similar character in Jamaica and in Haiti and these deposits are now being studied by different companies with the view of utilizing them as aluminum ore.

Bucan Polo area

In comparison with the deposits of the Aceitillar area, the lateritic soil of the Bucan Polo area is inferior in alumina content. The available alumina contents of the analyzed samples range from 27.2 to 35.1 percent, averaging 30.8 percent. The reserves of this low-grade material, however, are large. A minimum of 2,500,000 long tons is estimated for the Bucan Polo area, and a total of 5,000,000 tons is regarded as probable. Closer drilling of the area with chemical analyses of interval samples is recommended to test the variations in composition of the soil indicated from south to north within the area and with depth in the deposit.

PROSPECTS FOR THE SIERRA DE BAHORUCO REGION

Further prospecting in the Sierra de Bahoruco is recommended. Closer drilling of the mapped deposits to determine tonnage is desirable. Likewise mapping and drilling of deposits such as Sabana de los Garitos west of Sabana Canote and Sabana de los Pinalitos southeast of the mapped area would indicate how much can be added to the estimated reserves. Several large savannas near the crest of the Sierra de Bahoruco were seen in an airplane flight over the mountains. These savannas should be investigated. Prospecting, likewise, should be undertaken on the northeastern slope of the range. It is possible that further field investigations in these areas will add an amount equal to or greater than the indicated reserves in the known deposits. An even larger amount of material of the grade of the Bucan Polo deposit can be anticipated.