Geology of South-central Oriente, Cuba

By G. EDWARD LEWIS *and* JOHN A. STRACZEK

Geologic Investigations in the American Republics

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By G. Edward Lewis and John A. Straczek

ABSTRACT

The south-central Oriente area covers about 3,000 square kilometers in Cuba's easternmost province, Oriente, and is the chief source of manganese ore in Cuba with a recorded production of approximately 782,750 long tons of concentrates and crude ore during the years 1942–1945.

Rocks in the area and their ages in ascending order are: pre-Tertiary igneous rocks, the Habana(?) formation of late Cretaceous age, the Cobre formation of latest Cretaceous(?), Paleocene(?), early and middle Eocene age, the San Luis formation of middle to late Eocene age, Tertiary igneous rocks, Oligocene rocks, the La Cruz formation of middle Miocene age, and Quaternary alluvium.

The Habana(?) formation unconformably overlies a complex of ultramafic rocks, and includes volcanic rocks, undifferentiated intrusive rocks, and clastic and minor limy rocks. The thickness is estimated to reach at least 500 meters, the uppermost 200 meters being represented by the Picote conglomerate member. Fossils from the Habana(?) formation are of late Senonian age.

The Cobre formation unconformably overlies the Habana(?) and older rocks. It is made up chiefly of great thicknesses of water-laid pyroclastic rocks. Lava flows and limestones are intercalated in and subordinate to the pyroclastic rocks. Lava flows are most numerous in the lower part of the Cobre; limestones, in the upper part. Limy tuffs are common, and most of the limestone is tuffaceous. The Charco Redondo limestone member of the Cobre formation is the uppermost, thickest and most extensive limestone of the Cobre. The Cuabitas limestone lentil of the lower part of the Cobre is of subordinate importance. The greatest thickness of the Cobre rocks exposed in south-central Oriente is estimated to be about 4,000 meters in the Sierra Maestra where the base of the formation is not exposed; a total thickness between 4,500 and 6,000 meters has been assumed. The Charco Redondo limestone member, including some interbedded tuff, reaches a greatest thickness of about 100 meters in the Nipe Highlands of the mapped area. Although the age of the lowest part of the Cobre formation is not definitely known, fossils from the lower part may be as old as latest Cretaceous(?) or Paleocene(?); those from the upper part, including the Charco Redondo limestone member, are of middle Eocene age.

The San Luis formation in most places overlies the Cobre formation with a gradational, seemingly conformable contact; where observed by us, the change is

abrupt in a few places, and the contact unconformable in one. Limy shale, mudstone, siltstone, and sandstone, tuffaceous sandstone, sandstone, conglomerate, marl and limestone make up the San Luis rocks, the clastic components setting them apart from the rocks of the Cobre formation. The Camarones conglomerate member is a thick lens in the upper part of the formation. The greatest thickness of the whole formation in the mapped area is estimated to be between 1,000 and 1,500 meters; the Camarones conglomerate member has a greatest exposed thickness of 475 meters in an area where the top of the formation is eroded away, but this is not in the area where the formation is estimated to be thickest. Fossils from the lower part of the San Luis formation are of middle Eocene age; those from the upper part, including the Camarones conglomerate member, are of late Eocene age.

Marl and limestone of an unnamed formation overlie the San Luis with seeming conformity in the northern part of the mapped area, but the top of this formation is not exposed so no estimate was made of its thickness. Fossils from these rocks are of Oligocene age.

The La Cruz formation is represented only immediately northeast of Santiago Bay in the mapped area, where lower La Cruz argillaceous limestone with basal sandstone and conglomerate rest with marked angular unconformity on Cobre rocks. The top of the formation is not preserved here. The La Cruz fossils are of middle Miocene age.

Undifferentiated Quaternary alluvium is widely developed in some parts of the main river valleys of south-central Oriente.

Partly or wholly serpentinized peridotite is the chief rock of the Sierra de Nipe ultramafic complex, which has dunite and pyroxenite as minor constituents. These ultramafic rocks antedate the Habana(?) formation whose clastic components include fragments of the ultramafic rocks. The Habana(?) formation is intruded by small stocks of weathered and intensely altered fine-grained dacitic or quartz dioritic rocks that are thought to be pre-Tertiary in age.

The Sierra Maestra batholiths are dioritic bodies that intrude the rocks of the south slopes of the Turquino and Gran Piedra Ranges. In the mapped area, they intrude only Cobre rocks. The mineral composition of the batholiths suggests that they may represent a part of the magmatic reservoir from which some of the volcanic rocks of the Cobre formation were derived, and the batholiths are thought to be of Eocene age, at least in part. Erosion seems to have exposed the batholithic rocks in San Luis time, to judge from constituents of the Camarones conglomerate.

Intrusive dacites, andesites, diorites, and basalts of Tertiary age occur chiefly as small stocks in the Santiago Basin and the nearby Sierra Maestra, but subordinately as a small number of widespread dikes in the northern foothills of the Sierra Maestra and in the Cauto Valley. Most of these rocks intrude the volcanic rocks of the Cobre formation, but a few dikes and one stock intrude the San Luis formation.

The main structural features of south-central Oriente generally trend west to west-northwest, as does the Sierra Maestra in this area. However, there are exceptions to this general trend, particularly in the northward-trending structures of the Sierra de Nipe and Mayarí Valley. The chief structural provinces from north to south are the broadly anticlinal Nipe-Cristal Highlands, the synclinal Cauto-Guantánamo Lowlands, and the complexly homoclinal, north-dipping Sierra Maestra Highlands. The few major folds and faults within these broad structural provinces apparently are chiefly phenomena associated with compression rather than tension. Such major features are commonest in the Santiago Basin and that part of the Sierra Maestra flanking it in a northerly direction. Two times of major deformation established the main structural trends of south-

central Oriente, the first in latest Cretaceous or earliest Tertiary time, and the second between late Eocene and middle Miocene time when the present south coast and the Sierra Maestra seem to have been localized where now found.

The manganese deposits of south-central Oriente are divided into eight types based primarily on occurrence and lithologic association, and secondarily on the nature of the manganese minerals and the presence or absence of jasper. So far as is known, all are syngenetic. By far the most important economic type is bedded oxide in tuff, associated with jasper. The largest ore bodies are in the upper 30 meters of the Cobre formation.

Prospecting is most likely to be successful if carried out by drilling through at least 150 meters of San Luis rocks that overlie the Cobre manganiferous rocks along the southern edge of the Cauto-Guantánamo Lowlands north of the known large low-grade ore bodies.

INTRODUCTION

PREVIOUS INVESTIGATIONS

From October 1940 to October 1945, the Geological Survey, U. S. Department of the Interior, cooperated with the Dirección de Montes, Minas, y Aguas of the Ministerio de Agricultura of Cuba, in a study of the manganese districts of Oriente, under a project sponsored by the U. S. Department of State.

Interim reports on the results of these studies and résumés of previous work were published by Park (1942) and by Park and Cox (1944). At this time (1949) J. A. Straczek and F. S. Simons are preparing a general report on the manganese deposits of Cuba, with emphasis on those of Oriente.

Regional geologic mapping was needed to integrate the detailed and other studies of discrete areas around mines and prospects. In response to this need, W. P. Woodring and S. N. Daviess undertook a program of field work intermediate in nature between detailed mapping and reconnaissance in the Guisa-Los Negros area of Oriente from December 1942 to April 1943, and later published their results (1944).

SCOPE AND METHODS USED FOR PRESENT REPORT

Field work of the same character as that done by Woodring and Daviess, to extend this type of investigation further eastward, was carried out by J. A. Straczek, F. S. Simons, and G. E. Lewis from December 1944 to January 1945; by Straczek and Lewis from February to May 1945; and by Straczek from June to September 1945. The present report gives the results of their work.

The areal coverage is uneven. Some areas where many mines were studied, such as the area from Boniato northeastward to the San Ricardo and Consuelo mines, are discussed in detail. Other areas, particularly in the north-northwestern part of south-central Oriente, were studied only along wide-spaced traverses.

Because there was no suitable planimetric or topographic base map, and because a short field season did not permit construction of a proper base, we plotted all our geologic observations directly on aerial photographs first made available through the cooperation of the U. S. Navy, and later through that of the U. S. Army Air Force. This geologic information and other details from mine maps prepared by the Geological Survey, together with information about hydrology, communications, and settlements of the area identified on the aerial photographs, were transferred by vertical sketchmaster to a base on which the position of Blanca Battery Observation Spot, latitude 20°00′16.5″ N., longitude 75°50′23.6″ W. (according to U. S. H. O. Chart No. 1856), in Santiago, and surveys of the alignments of the several standard-gage railroads of the area were plotted as the only available semblance of control. This reconnaissance base map was compiled at a scale of 1:30,000; although its accuracy is essentially that of an uncontrolled aerial photo mosaic, we know of no other map with comparable topographic, hydrologic, and communications information. It has been reduced to a scale of 1:50,000 in the base for our geologic map and the associated structure sections (pls. 19, 20), and to a scale of 1:100,000 in the base for the shaded relief map prepared by Messrs. Hal Shelton and G. W. Harbert for this publication (pl. 21).

ACKNOWLEDGMENTS

We gratefully acknowledge the kind help and hospitality of those mining establishments, sugar and other plantations, and individuals who placed their facilities at our disposal, particularly the Cuban Mining Co., Esperancita, Guanabá, Manacas, and Valle de Manganeso mines; Central Miranda, Central Unión, and Central América; and Messrs. Manuel Muñoz, Francisco Vidal, Elmer Kobler, and Frank Trotter. The Cuban Government and its aforenamed agencies, together with their cognizant officials, extended every possible courtesy to us; we are particularly indebted to Sres. Ingos. Antonio Calvache, Jesús de Albear, and Jorge Brodermann for their interest and willing cooperation. The American Embassy at Havana and the American Consulate at Santiago gave us all possible assistance. The Santiago office of the U. S. Commercial Co. Agency and manager J. B. Hand personally gave us their unstinting help at all times. W. D. Johnston, Jr. and J. Van N. Dorr, II, of the Geological Survey supervised the planning and execution of the project. Messrs. C. F. Park, Jr., F. S. Simons, W. P. Woodring, P. W. Guild, T. P. Thayer, D. F. Hewett, and M. W. Cox of the Geological Survey, and T. W. Vaughan of the National Museum favored us with their knowledge of the geology of the area.

Sr. de Albear accompanied us on several field trips in order to familiarize himself with the rock units and their stratigraphic relations. Closely cooperating with us in Cuba and the United States, he has studied the large foraminiferal microfauna collected from the several sedimentary rock units, and has identified this microfauna. In these studies he had much kind help from T. W. Vaughan, P. J. Bermúdez, and the late J. A. Cushman and Dorothy K. Palmer. Sr. de Albear's determinations published herewith are of a preliminary nature; he is working on a detailed study of the stratigraphic micropaleontology of south-central Oriente.

The ostracodes were identified by Prof. F. M. Swain; the corals, by Prof. J. W. Wells; and the other larger fossils by Mr. J. B. Reeside, Jr. Prof. Stephen Taber generously permitted the use of his photographs for illustrations.

GEOGRAPHY

REGIONAL SETTING

Oriente, the easternmost and largest province of Cuba, is set apart from the rest of the island by its physical geography, the direct reflection of its geologic structure. The chief physiographic divisions are peculiar to the province, except for the anticlinal northern highlands of Oriente, which are the only eastward structural extension of the rest of Cuba. The present report covers an area of Oriente in which these chief divisions are, from the northern mountain system to the Caribbean Sea: the broad anticlinal Nipe-Cristal Highlands, the broad synclinal Cauto-Guantánamo Lowlands, the broad homoclinal Sierra Maestra Highlands, and the very narrow discontinuous South Coast Lowlands. Hayes, Vaughan and Spencer (1901, p. 10–12, 26–28) probably were the first of several writers who have recognized and stressed these broad geographic and geologic features, although Ansted (1856, p. 145) made known the rudiments of the area's structure and stratigraphy nearly half a century before.

LOCATION AND ACCESSIBILITY

This report deals with an area of about 3,000 square kilometers in south-central Oriente which reaches some 50 kilometers from the head of Santiago Bay in the south to the Sierra de Nipe in the north, and about 80 kilometers eastward from the Río Contramaestre in the adjoining Guisa-Los Negros area (Woodring and Daviess, 1944) to the Río Jarahueca and the Río Baconao (see location map, fig. 20).

The Central Highway (Carretera Central), a modern paved road, links Santiago de Cuba with Contramaestre at the western edge of the area. The only other paved road runs north from Santiago de Cuba to Boniato, where one fork leads to San Luis and another to

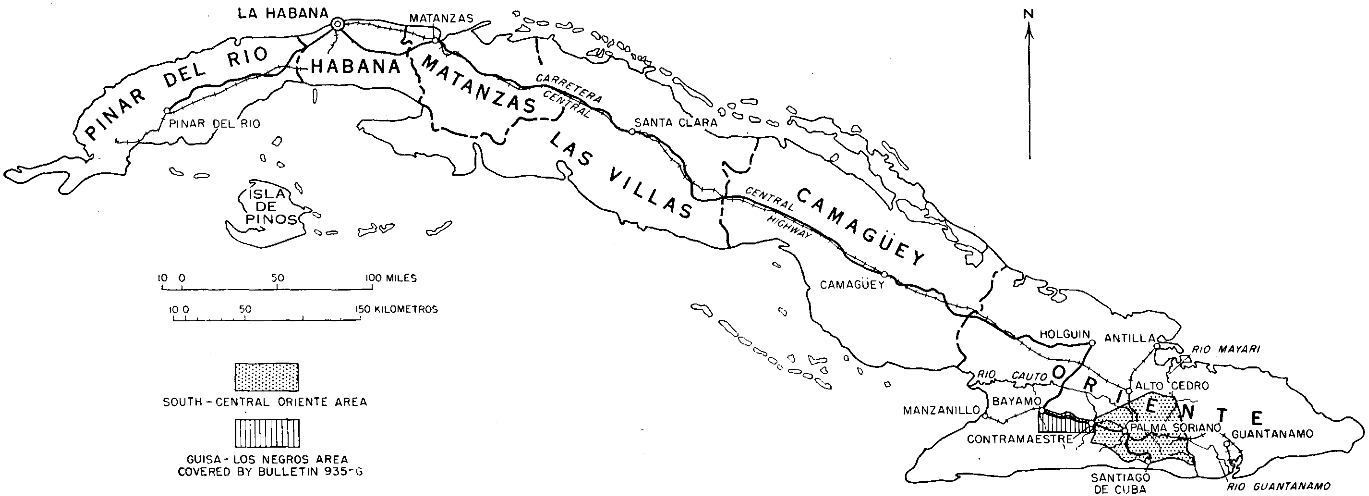

Figure 20.—Map showing location of south-central Oriente area with relation to the Guisa-Los Negros area.

Alto Songo. The Central Highway crosses the Sierra Maestra through the Paso del Maniel and the Puerto de Moya; the San Luis road crosses at Boniato Ridge; the Alto Songo road, through the Dos Bocas Valley. The other roads are of dirt and are mostly impassable to motor vehicles during the rainy season from May to November, when most places shown on the map can be reached only by horse trails.

The Cuba Railroad, Consolidated Railroads of Cuba (Ferrocarril de Cuba, Ferrocarriles Consolidados de Cuba), runs from Santiago de Cuba across the Sierra Maestra through the Dos Bocas Valley and Barbacoa Pass (Paso de Barbacoa) to San Luis junction; one branch links San Luis and Contramaestre; another, San Luis and Alto Cedro by way of the northwest corner of the area. The Guantanamo and Western Railroad, Consolidated Railroads of Cuba (Ferrocarril Guantánamo y Occidente, Ferrocarriles Consolidados de Cuba), runs eastward from San Luis to Guantánamo and beyond. Spur lines connect the Santiago-San Luis line with the Quinto and Ponupo mines. Sugar plantations in the area, chiefly in the Cauto and Guaninicum Valleys, have standard- and narrow-gage railroads.

Santiago de Cuba, a major port, is the only large city in the area; the population is more than 115,000. Palma Soriano has a population of more than 15,000; San Luis, nearly 10,000. Palmarito, El Cobre, Dos Caminos, La Maya, Alto Songo, El Cristo, Boniato, Cuabitas, and El Caney are small towns. Other places shown on the maps are sugar centrals, villages, plantations, and country stores.

PHYSIOGRAPHIC DIVISIONS

Nearly half a century ago Hayes, Vaughan and Spencer (1901, p. 29) wrote:

> A general description of the physiographic features of the island has been given, but with the exception of occasional hints, no discussion of that most important phase of the geologic history, called geomorphology, will be undertaken. In the present imperfect state of our knowledge of the stratigraphy and areal geology of the island, and because of the lack of accurate topographic maps, it would be hazardous in the extreme * * * to write the history * * * [it] is the climax of the general geologic history, and requires a detailed knowledge of nearly all phases of the geology before it can be deciphered.

Taber's reconnaissance reports (1931, 1934) included geomorphic information, as did Keijzer's (1945). We have not attempted geomorphic studies, but include some observations, chiefly to show the broad problems which should be studied. There still is no accurate topographic map, so a shaded relief map on the reduced photogrammetric base has been prepared to show the topographic setting (pl. 22). Even so, the 1901 remarks are equally cogent today to discourage an attempt at geomorphic studies without a good topographic base map.

SOUTH COAST LOWLANDS

In and around Santiago de Cuba, Hayes, Vaughan and Spencer (1901, p. 19) recognized "the remnants of a level coastal plain, now deeply dissected, [whose] altitude is about 400 feet" and below which there is a succession of coastal terraces and benches. Taber (1931, p. 552–554; 1934, p. 603–608) and Keijzer (1945, p. 143) added much to our knowledge of this one of several narrow and discontinuous lowlands on the south coast. It was cut into the Sierra Maestra-Caymán Ridge scarp which rises from the Caymán Trough.[1]

Santiago Basin.—Only the northern part of this lowland (fig. 21) appears in the area mapped. The Santiago Bay Lowland flanks the bay shore; beyond and to the northeast is the El Caney Lowland, in the drainage basins of the Río Guamá and the lower Río San Juan.

SIERRA MAESTRA HIGHLANDS

The Sierra Maestra mountain system, cheek by jowl with the Caribbean Sea, is the highest and longest in all Cuba. The highest summit, Pico Turquino, is 2,005 meters (6,578 feet) above sea level and towers 9,243 meters (30,324 feet) over the nearby Oriente Deep of the Caymán Trough. The east-west length of the system is about 250 kilometers between Cape Cruz and Guantánamo Bay; the greatest north-south width is about 30 kilometers south of Bayamo. This grand relief feature is the eastern, dry-land extension of the Caymán Ridge.

Taber (1931, and especially 1934) proposed definite names for specific parts of the Sierra Maestra and other nearby physiographic divisions. We have modified and enlarged Taber's usage.

Turquino Range.—That part of the Sierra Maestra which lies west of Santiago Bay and the Cuabitas-El Cristo Corridor is the Turquino Range (figs. 21–23, 40, 43); several sections of this range are within the area mapped by us. The El Gato Massif in the southwest corner of the area has steep slopes of much-dissected volcanic rocks that are covered with a tangled growth of forest and brush. Loma del Gato peak and its flanking slopes cannot fitly be called a range, ridge, or mountain, but conforms best to the definition of a massif: "a part of a range which appears, from the position of the depressions by which it is more or less isolated, to form an independent whole".[2] The Guaninao Piedmont lies between the Cauto Lowlands and the El Gato Massif, and between the Río Cauto and Río Contramaestre; it is a piedmont section of hills and valleys dissected out of volcanic rocks. The Boniato Piedmont, between Boniato Ridge and

[1] For bathymetric terminology, see Hess, H. H., Bathymetric chart of the Caribbean Sea, Hydrog. Office Miscel. 9062.

[2] Century Dictionary and Encyclopedia, New York, 1911.

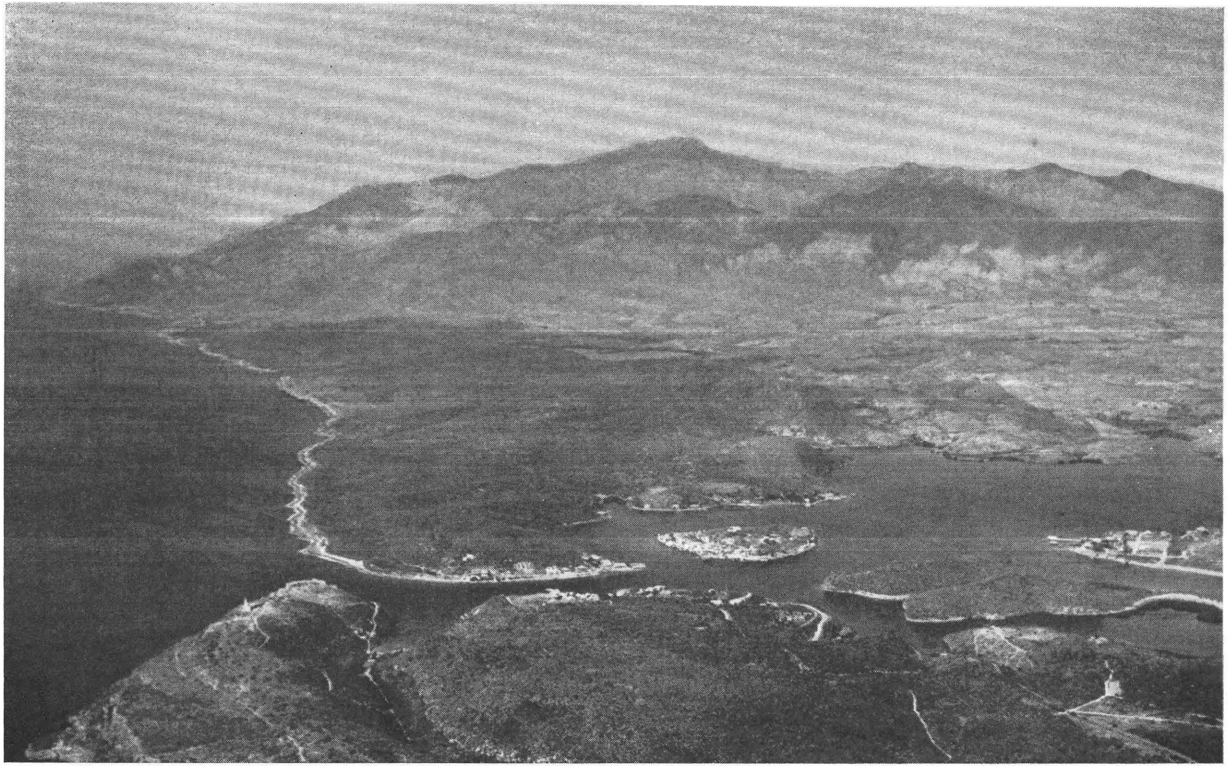

FIGURE 21.—View westward across the south end of Santiago Basin along the Caribbean coast. The entrance to Santiago Bay is in the foreground; Turquino Range of the Sierra Maestra is in the distance. Photograph by U. S. Navy.

the Cauto Lowlands (fig. 28), has been dissected out of volcanic rocks covered by limestones of gentle dip, and extends from the Río Cauto to the Río Guaninicum. The easternmost part of the Turquino Range is Boniato Ridge (figs. 22, 40). The Valley and Ridge section (fig. 23) is a striking group of features with trellis tributaries adjusted to the structure but with main streams superposed across the east-northeast structural trend of the country. The ridge summits seem to record an old erosion surface; they may be remnants of the same raised and deeply dissected old coastal plain that are seen in the highest summit

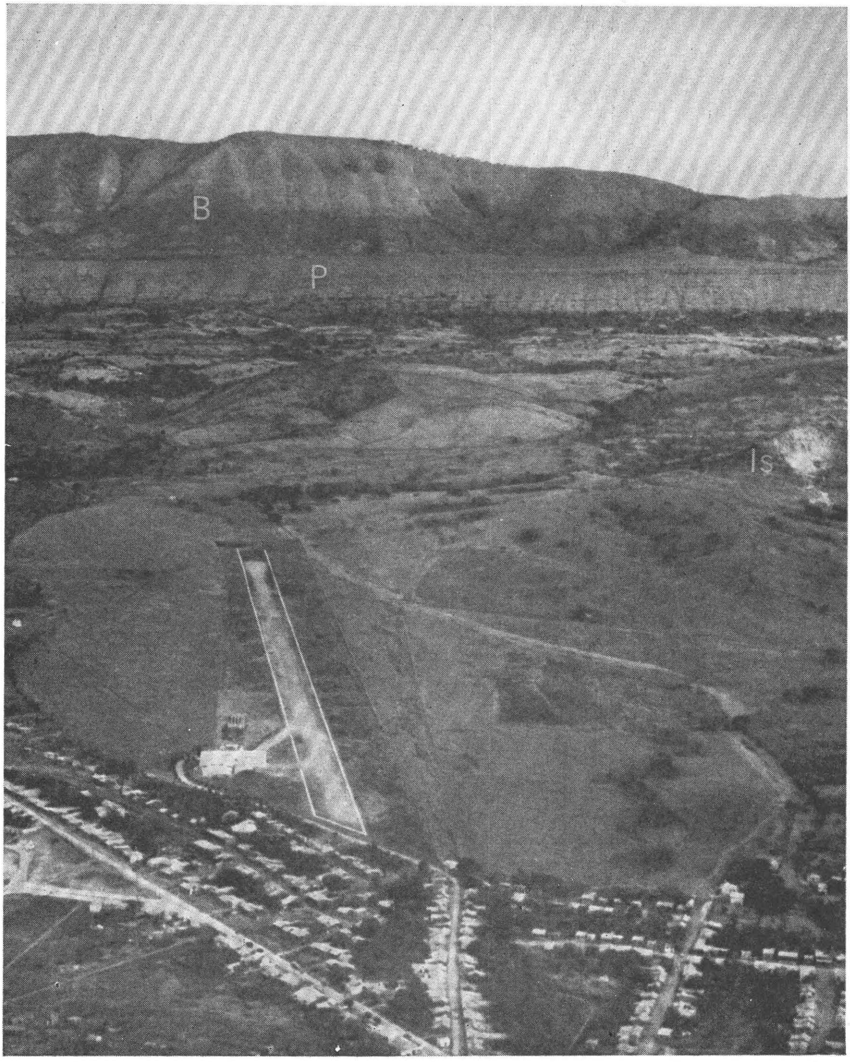

FIGURE 22.—View northward across the Santiago Bay Lowland to Pelado Ridge, *P*, and Boniato Ridge, *B*. Note the quarry in Cuabitas limestone lentil of the Cobre formation at extreme right, *ls*. Photograph by U. S. Navy.

FIGURE 23.—Stereopair showing parts of northern Santiago Bay Lowland and the Valley and Ridge section of the Turquino Range. Note quarries in Cuabitas limestone lentil of Cobre formation, *ls*, and small basalt stock, *b*. Photograph by U. S. Navy.

levels within the Santiago Basin. One notable exception is Pelado Ridge (figs. 22, 43), a hogback controlled by a fault. The trend of this ridge is more easterly, and oblique to that of the other ridges of this section.

Cuabitas-El Cristo Corridor.—The Dos Bocas Valley is the main topographic feature which separates the Turquino Range from the

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Gran Piedra Range for some 5 kilometers between Cuabitas and Barbacoa Pass (fig. 24) on the southern outskirts of El Cristo. Together, these two sections make up the Cuabitas-El Cristo Corridor through the Sierra Maestra between the Santiago Basin and the Cauto Valley. The railroad north from Santiago uses Barbacoa Pass, a short and narrow gap, but the Santiago-San Luis-Alto Songo road bypasses this gap to the west.

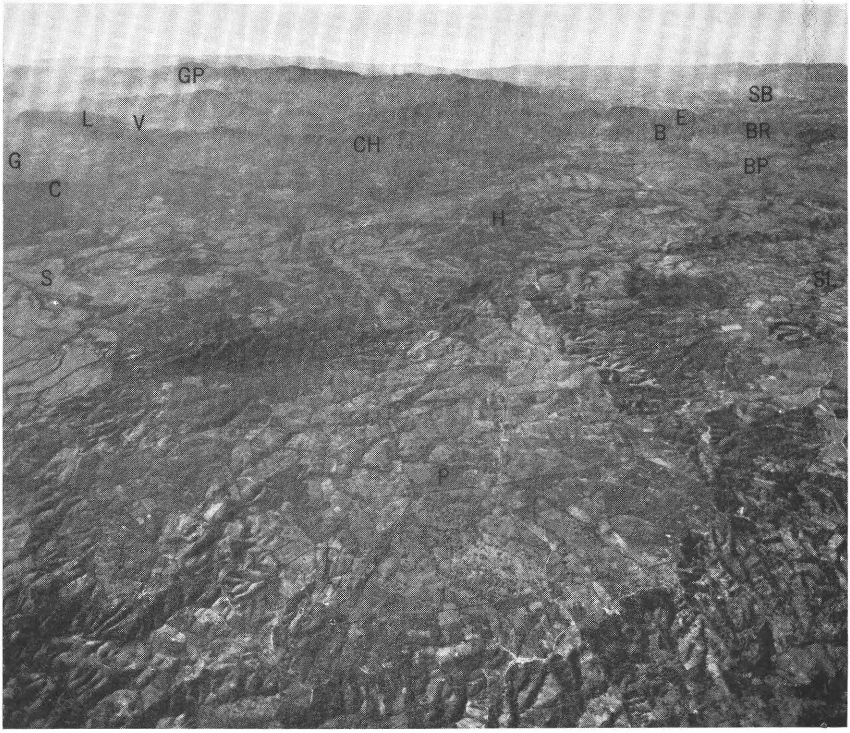

FIGURE 24.—View southward across La Prueba Plateau, *P*, to Gran Piedra Range of Sierra Maestra and Santiago Basin, *SB*. Sabanilla Lowland, *S*; Cuatro Caminos Hills, *C*; Headwaters Hills, *H*; Boniato Piedmont, *BP*; and San Luis Lowland, *SL*, in middle distance. La Galleta Lowland, *G*; Loreto Mesa, *L*; Emilia Valley, *V*; Camarones Heights, *CH*; La Gran Piedra peak, *GP*; Barbacoa Pass, *B*; Boniato Ridge, *BR*; and Escandel Hills, *E*, in far distance. Photograph by U. S. Air Force.

Gran Piedra Range.—A great, angular crag at the summit of the highest peak, La Gran Piedra ("the great stone"), gives its name to this range (figs. 24, 25) which reaches from the Cuabitas-El Cristo Corridor to Guantánamo Bay. The wedge-shaped westernmost extension of this range, the Escandel Hills, lies en échelon between Boniato Ridge and the Gran Piedra Massif, with the point of the "wedge" between the Dos Bocas Valley and the Santiago Basin. The northern slopes of the Gran Piedra Massif are within the southeastern corner of the present area. Baconao Ridge is a striking hogback just north of this massif; its scarp faces south and its dip slope

FIGURE 25.—Stereopair showing parts of Baconao Ridge, *B;* Emilia Valley *V;* and Loreto Mesa, *L,* Gran Piedra Range. Photograph by U. S. Navy.

slants down to the north. Several entrenched meanders of the upper Río Baconao have been superposed across the crest of this hogback. Immediately north of Baconao Ridge is Emilia Valley, the lower part of which includes successive northern loops of the superposed meanders of the Río Baconao, whose trellis tributary, the Arroyo San Juan, flows down the upper Emilia Valley. Headwaters of the Arroyo San Juan, Río Guaninicum, Río Ponupo, and Río Barrancas (the last two join to form the Río Guantánamo) have their sources on Camarones Heights, a mountain mass of dissected thick, coarse sandstones and conglomerates (figs. 24, 36). These same rocks underlie Loreto Mesa to the east-southeast, a remnant of an old erosion surface of very low relief that is now surrounded by sheer cliffs. This mesa lies just north of and rises about 300 meters above the lower Emilia Valley; its top accords more or less with those of Camarones Heights and Baconao Ridge. These summit levels may record the same erosion surface whose relics are seen further north in the Nipe Highlands, and probably this is the erosion surface from which the Río Baconao and other streams have been superposed across the geologic structure. The Limones Mountains lie outside the mapped area, between the Río Baconao and the Guantánamo Basin.

CAUTO-GUANTÁNAMO LOWLANDS

The Cauto-Guantánamo Lowlands stretch from the Gulf of Guacanayabo some 250 kilometers east-southeast to Guantánamo Bay and the Caribbean coast. That part of these lowlands less than 200 meters above sea level reaches its greatest width of over 100 kilometers in the extreme west, and its least width of about 10 kilometers in the low uplands around Alto Songo at the divide between the two river systems.

Cauto Valley.—The river system of the Río Cauto is the largest in Cuba, and the western end of the Cauto Valley is wider than any part of the western two-thirds of the island of Cuba. The Cauto Plain (name proposed by Woodring and Daviess, 1944, p. 360) is a section of the Cauto Valley physiographic province. Part of the Cauto Plain lies in the northwestern portion of the present area (fig. 26). Morcate Ridge, a long, low cuesta (fig. 38) whose dip slope is on the north, runs west-southwest from the Sierra de Nipe to the Río Contramaestre and beyond, marking the southern limit of the Cauto Plain. Woodring and Daviess (1944, p. 360) named and described the Mafo Lowland of the upper Contramaestre valley, another section of the Cauto Valley physiographic providence. The divide between the Río Cauto and its tributary, the Río Contramaestre, forms the crest of the low, rolling Aguacate Hills, which separate the Mafo Lowland from the Palma Lowland (fig. 28). The Soriano Hills rise to another low, rolling divide just east of Palma Soriano between the Río Yarayabo and the Río Grande; they separate the Palma Lowland from the San Luis Lowland of the lower Guaninicum valley (figs. 24, 26). Across the Río Cauto to the north, the Miranda Lowland (fig. 26) lies between the San Nicolás Hills and the Marginal Hogbacks of the Nipe Highlands.

Divide Uplands.—Low hills around Alto Songo form the Divide Uplands (fig. 24) between the west-flowing headwaters of the Río Guaninicum and the east-flowing tributaries of the Río Guantánamo. The dissected divide itself forms the Headwaters Hills between Camarones Heights and the tablelands south of the Sierra de Nipe.

East of the divide are the Cuatro Caminos Hills between the valleys of the Río Majagua and the upper Río Guantánamo.

Guantánamo Valley.—A small part of the Guantánamo Valley (fig. 24) is in the area of the present report, including the La Galleta Lowland drained by the headwaters of the Río Majagua, and to the north, the Sabanilla Lowland, which lies athwart the upper Río Guantánamo.

NIPE-CRISTAL HIGHLANDS

The northern highlands of Oriente are represented in this report by the Sierra de Nipe, the Sierra del Cristal, and the uplands which flank

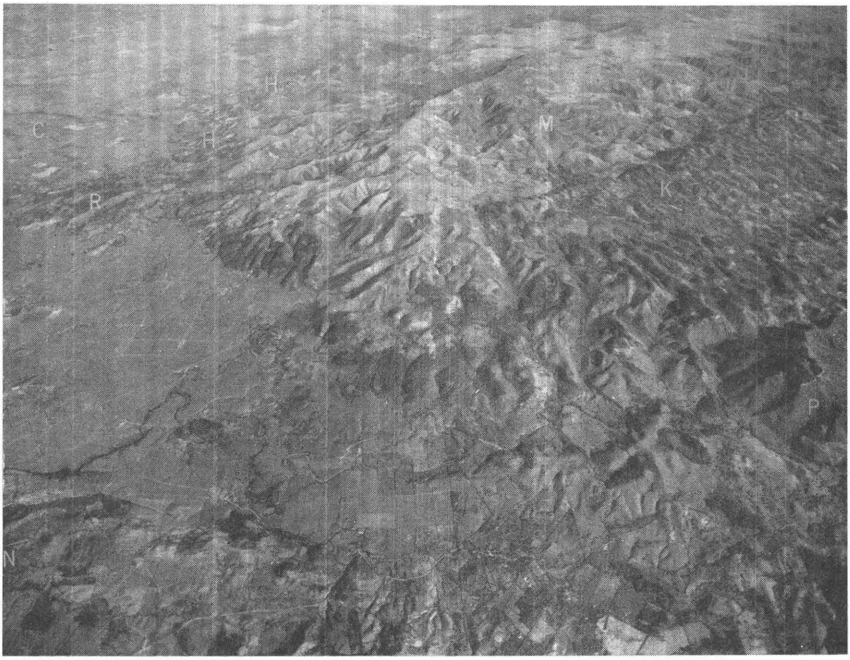

FIGURE 26.—View northward across Nipe Highlands and Cauto Lowlands. San Nicolás Hills, *N*; Miranda Lowland, *L*; and Monte Picote, *P*, in foreground. Cayo del Rey Hills, *R*; and Pedernal Karstland, *K*, in middle distance; note west and north rims of Pedernal Karstland where faults have been located on map (pl. 19). Cauto Plain, *C*; Marginal Hogbacks, *H*; and Central Massif, *M*, of Sierra de Nipe in far distance. Photograph by U. S. Air Force.

these two mountainous tracts to the south. The two sierras are separated by the superposed Río Jarahueca and Río Mayarí, which flow through a steep-sided gorge. Nowhere do these highlands reach heights half so great as that of Pico Turquino, the chief of the Sierra Maestra peaks.

Sierra de Nipe.—Two domical uplifts, the Sierra de Nipe (fig. 26) and the Sierra del Cristal, are elliptical mountain masses which together really form a single curvilinear range as pointed out by Hayes, Vaughan, and Spencer (1901, p. 11): the long axis of the Sierra de Nipe on the west continues eastward into that of the Sierra del Cristal (see

Thayer and Guild, 1947, fig. 1). This range is divided by a structural sag as well as by the Mayarí Valley into the two component sierras. The Central Massif of the Sierra de Nipe, bevelled by striking erosion surfaces, was first described by Hayes, Vaughan, and Spencer (1901, p. 11, 28), and more recently by Keijzer (1945, p. 62) and by Thayer and Guild (1947, p. 928–929). Rugged Marginal Hogbacks of arched-up limestone separate the Central Massif from the Cauto Lowland and Cayo del Rey Hills on the west and southwest. The Cayo del Rey Hills are foothills of softer rocks that project southwestward beyond the harder rocks of the Marginal Hogbacks into the Cauto Lowland. No other sections of the Sierra de Nipe were mapped.

Fringing Uplands.—Broad highland tracts to the south of the Sierra de Nipe proper are tablelands, more or less deeply dissected in different sections of these uplands, in which headwater erosion has formed several walled-in basins, one of which has interior drainage. The Río Piloto, whose stream course is adjusted to the structure, separates the Central Massif from the broad plateau of the Pedernal Karstland to the south (figs. 26, 44). Much forest growth and scrub combine with the limestone crags and cliffs to make this a rough and rugged section. The canyons of the Río Caoba and Arroyo Jocurito divide the Pedernal Karstland from the more dissected Florida Blanca Plateau to the southeast. Here, the upland surface still shows some isolated limestone buttes although in most places, such as the neighborhood of La Caoba, the overlying limestones have quite weathered away, leaving a bare upland surface of older pyroclastic rocks, with a mantle of Terra Rossa in places as a relic of the former limestone cover. The tops of these tablelands may accord with the main erosion surface of the Central Massif (Thayer and Guild, 1947, p. 928–929). The Río Sumidero, a tributary of the Río Jarahueca, has dissected the pitlike Sumidero Basin in the southeastern Florida Blanca Plateau: they get their names from El Sumidero (the drain) at the basin's northeast corner where the river flows out through an underground channel in the limestone cliff. A steep, knifelike ridge separates the Sumidero Basin from the Villafaña Basin to the southwest. The Nuevo Mundo Karstland lies west and south of the two basins; the greatest development of thickly forested, karst-surfaced plateau is at the northwest where the Nuevo Mundo Karstland projects into the broad La Burra Basin drained by the Río Jagua headwaters. The Río Joturo valley and the Río Jutinicú headwaters separate the Nuevo Mundo Karstland from the rolling uplands of the La Prueba Plateau to the east (fig. 24). These uplands, with Loreto Mesa, may represent remnants of the same erosion surface seen in the Sierra de Nipe. The deeply dissected San Nicolás Hills reach westward from the Nuevo Mundo Karstland almost to the Río Cauto, between the Río Guaninicum and the Río Jagua.

Mayarí Valley.—The canyon of the Río Mayarí separates the Sierra de Nipe from the Sierra del Cristal. The lower part of this canyon and all the lower Mayarí Valley are north of the south-central Oriente area. Above the mouth of the Río Jarahueca, however, the Río Mayarí is a much less impressive stream than the former; seemingly, the choice of names was an accident of early exploration. The Río Jarahueca is the main stream above this junction, and the course of the Jarahueca Valley prolonged downstream is the same as that of the lower Río Mayarí. The Jarahueca-Mayarí Canyon lies within the south-north main valley that separates the Nipe Highlands from the Cristal Highlands whose westernmost margin alone is represented in the area studied and mapped. These meandering streams have had their courses superposed across the axis of the Nipe-Cristal Highlands in a deep, relatively narrow, steep-walled canyon.

SEDIMENTARY ROCKS

GEOLOGIC NAMES

Hayes, Vaughan and Spencer (1901) proposed no names for the rock units described and mapped in the present report. Vaughan (1918, p. 276) was the first to describe and name a rock unit, the La Cruz marl (La Cruz formation of present report), in this area. Taber, in his original study (1931), discussed another unit, the "Cobre series", to which he assigned an age range from Cretaceous or older at the base to late Eocene near the top (1931, p. 537–541). In his more detailed subsequent study, and without commenting on his "Cobre series" described only three years before, Taber named and described the "Vinent formation (Cretaceous?) * * * Cobre formation (Eocene) * * * [and] San Luis formation * * * The fauna of the San Luis formation is similar to that of the upper part of the Cobre and indicates a late Eocene age". He (Taber, 1934, p. 575–588) also discussed the La Cruz marl of the Santiago area, and several other rock units outside the area of the present report.

N. H. Darton (1926) previously had named and described the rock units of the Guantánamo Basin, to the east of the area described in the present report, after a geologic reconnaissance early in 1916. He had collected small lots of fossils which were studied and described by Cushman (1919, 1920), Jackson (1922), and Vaughan (1924). Darton named the Guaso limestone, thought to be Eocene, and probably upper Eocene. The overlying soft sandy shale with intercalated sandstone and limestone he named the Guantánamo shale and described it as follows (1926, p. 328):

> This shale outcrops extensively throughout the basin * * * Apparently it extends far northwest * * * and westward, for I noted it along the railroad to San Luis, and to Jiguaní where the underlying limestone comes up.

He thought it to be Oligocene, or very low Miocene, and in this formation he included the coarse "conglomerate of Boquerón and Caimanera * * * that appears to be in the midst of the formation."

Finally he named the "Maquay formation" (which he thought to be Oligocene or lower Miocene), a "succession of sandstones and limestones overlying the Guantánamo shale." There can be little doubt that this spelling is an oversight, and that the name of this formation should be spelled Maquey. Darton (1926, p. 324) says in a footnote that the word "Maquay" is a "name derived from shells and not from the maguey plant." We believe that, in all probability, "Maquay" is either a lapsus calami or the result of confusion of Spanish phonetics and Cuban zoology: painstaking inquiry has unearthed no such word as "maquay", and no "shells" of Oriente bear this or a similar name. However, the anomuran decapod crustacean, *Cenobita clypeatus*, a hermit crab that lives in a cast-off gastropod shell and is a land crab rather than an aquatic crab, is known locally as the "macao de la tierra" or "maquey". The Sierra del Maquey, from which the formation name was taken, probably gets its name from these crabs rather than from the shells used as portable living quarters (Castellanos, 1944, p. 107). Darton recognized that "the oldest formation in the region consists of schists and other crystalline rocks" which he did not study and to which he gave no name (1926, p. 324, 326–332).

Late in 1915, O. E. Meinzer made a geologic reconnaissance of the region around Guantánamo Bay and eastward along the coast for some 50 kilometers. He collected fossils which were studied and described by Cooke (1919), Cushman (1919, 1920), and Vaughan (1924, 1926). The results of Meinzer's work, published seven years after Darton's publication dealing with the same general area, include a geologic map of the U. S. Naval Reservation at Guantánamo Bay, a report on fossils by T. W. Vaughan, and a brief sketch of the geology that neither refers to Darton's earlier publication and its rock unit names, nor gives new names for the rock units described by Meinzer (1933, p. 248, 250–252):

1. A basal complex of metamorphic and igneous rocks of unknown age. 2. Tilted beds of conglomerate, limestone, shale, and impure sandy and marly materials, several thousand feet in aggregate thickness (chiefly Oligocene; Eocene at bottom and possibly as young as Pliocene at top). 3. Probably all Pleistocene. 4. Recent; possibly in part Pleistocene.

Both publications are excellent reconnaissance reports, and it is puzzling to find that neither writer refers to the other's work.

For the Guisa—Los Negros area, Woodring and Daviess used the designation "Cobre volcanics", named the Charco Redondo limestone as a separate formation (considering both units together to be equivalent to the Cobre formation described by Taber), and recognized the San Luis formation of Taber (1944, p. 363–379).

Taber thought that the San Luis formation he described might be equivalent to the Guaso limestone described by Darton, but, in discussing the Guantánamo shale, decided against the possibility that this last formation might be equivalent to the San Luis formation. Taber (1934, p. 586) says:

> Darton thought that the Guantánamo shale extended westward to San Luis and Jiguani, but the San Luis formation, although similar in appearance, is definitely late Eocene, whereas the Guantánamo shale is mainly Oligocene.

Woodring and Daviess (1944, pl. 68) mapped the San Luis formation and underlying Charco Redondo limestone near Jiguaní but did not record the possibility that the Guaso limestone of Darton and their Charco Redondo limestone on the one hand, and the Guantánamo shale (or possibly Guaso limestone plus Guantánamo shale) of Darton and the San Luis formation described by Taber on the other hand, might be equivalents, with Darton's names having priority.

At this point, it is well to digress in order to make several pertinent observations. Hill (1899, p. 78) named a "Cobre formation" in Jamaica, about 200 kilometers distant from the nearest outcrops of the Cobre formation in Cuba which was named and described more than a quarter of a century later by Taber. There are also two San Luis formations in the Caribbean area: that in Cuba, described by Taber, and that in Venezuela, attributed by Liddle (1928, p. 251) six years earlier to Hodson and Weaver. There seems to be no general agreement as to determination of validity of identical names in different countries, however near to each other they may be.

Keijzer records large faunas of Foraminifera from the Guaso limestone and Guantánamo shale of Darton, and from the San Luis formation described by Taber. As noted in our discussion of the age of the San Luis formation, Keijzer's studies (1945, p. 88–92) led him to conclude that late Eocene

> is most probably the age of all samples from the San Luis formation * * * The association * * * in the Guaso limestone * * * which underlies the certainly Upper Eocene Guantánamo shale * * * is strongly suggestive of Middle Eocene * * * The same association was found * * * in the Cobre formation, which underlies the Upper Eocene San Luis formation * * * The corals * * * cannot be regarded as distinctive for Eocene or Oligocene.

Had this information been available to Taber, in the light of his remarks about the Guantánamo shale, he would presumably have used Darton's name, Guantánamo, rather than a new name, San Luis, in his description of the formation which rests conformably on the Cobre; perhaps he would have substituted formation for shale.

Strangely enough, Keijzer (1945, p. 84–85), who eliminated the supposed age discrepancy between the Guantánamo shale described by Darton and the San Luis formation of Taber, takes the other alternative:

> The present investigation * * * has shown the Eocene age of the whole of the Guantánamo shale, and both formations have been united as San Luis formation. Though the name of Guantánamo shale has priority, it has been dropped in favour of that of San Luis formation, as the name [shale] is not characteristic for the formation as a whole.

Keijzer also discusses the Maquey ("Maquay") formation of the Guantánamo Basin, from which the only previously reported fossils were three species of echinoids (Darton, 1926, p. 332). Keijzer lists over 100 species of Foraminifera which were collected from these rocks and identified, and concludes that the fauna indicates a range "between Lower Oligocene at the base and Middle Oligocene and perhaps Upper Oligocene or even Miocene" in the higher parts (1945, p. 92–97). Keijzer (1945, p. 50–51) named and described the "Oligomiocene Nipe series * * * covering most of the Nipe Basin" some distance northwest of Guantánamo Basin, but did not consider the possibility that his "Nipe series", or at least the lower part of it, might be equivalent to the Maquey formation. The Oligocene rocks described in the present report have not been referred to any named unit; further mapping may show that they are equivalent, in whole or in part, to the Maquey formation.

The area mapped by us does not extend far enough eastward to reach the area studied by Darton, and there is no certainty as to the equivalence of rock units or their contained faunas in the two areas, so we have used the following names, in ascending stratigraphic sequence: the Upper Cretaceous Habana(?) formation (Palmer, 1934, p. 128) with the Picote conglomerate member; the Upper Cretaceous(?) to Eocene Cobre formation, with the Peluda volcanic member, the Cuabitas limestone lentil and the Charco Redondo limestone member; the Eocene San Luis formation, with the Camarones conglomerate member; Oligocene rocks; the Miocene La Cruz formation; and Quaternary alluvium.

However, future mapping in the intervening area may show that, with respect to the stratigraphic sequence listed above, the names which eventually should be adopted are: Habana(?) formation; Cobre formation, with the Guaso limestone member at the top of this formation or at the base of the next higher formation; Guantánamo formation, with distinct Camarones conglomerate and "conglomerate of Boquerón and Caimanera" members, or with both of these considered as a single Boquerón conglomerate member; Maquey formation; La Cruz marl; and younger rock units which will have to be named later.

Such a procedure would automatically eliminate the possible confusion with other uses of the name San Luis formation. Taber's name "Cobre" is well-established, and there are no accepted precedents or rules to suggest that it should be discarded because another formation bears the same name in a nearby country. The case of the San Luis formation is different, because the Guantánamo shale described by Darton is a name even better established than San Luis or Cobre in addition to having 8 years of priority. Maquey is a well-established name, and Keijzer's name "Oligomiocene Nipe series" is reasonably sure to be split into more than one formation when future and more detailed work is done. In short, we believe that Darton's names applied to rock units in the Guantánamo Basin in 1926 have priority and eventually can be shown to be applicable to the adjoining area mapped by us.

HABANA(?) FORMATION (UPPER CRETACEOUS)

The Habana formation (named Havana shales by J. W. Lewis, 1932, p. 539, with an obscure reference to De Golyer, 1918) occurs in all the provinces of Cuba according to Palmer (1945, p. 12), who described this upper Cretaceous rock unit (1934, p. 128) as "a series of shales, marls, chalks, loosely consolidated gravels, conglomerates, and calcareous sandstones" in the Habana city area. We are not sure that discontinuous outcrops, separated by breaks of 50 to 100 kilometers along a linear extent of more than 1,000 kilometers from Pinar del Río to Oriente, with different sequences of sedimentary rocks but with similar faunas, can be referred to the same formation. The alternative of adding a query (?) is preferable to that of coining a new name or describing an unnamed rock unit while there is a possibility of identity.

Keijzer has identified "volcanic rocks, tuff-sandstones, sandstones, conglomerates, limestones (sometimes tuffaceous) and marls" in northern Oriente as the Habana formation, and has discussed the problems of age and correlation (1945, p. 18, 20–24, 151–155).

The oldest stratified rocks mapped in this report are exposed in the Fringing Uplands south of the Sierra de Nipe. They crop out in the bottom of the Sumidero Basin, and a similar, but possibly somewhat younger, mapped sequence crops out in the bottom of La Burra Basin.

Rocks which resemble the Habana(?) formation of the Sumidero and La Burra Basins crop out in two localities east of the present area. We observed a similar occurrence 5 to 10 kilometers northeast of Seboruco and about 8 kilometers east of the Sumidero Basin, on the road to Mayarí Arriba, as did Keijzer (1945, p. 76, 79). M. W. Cox (oral communication) found comparable outcrops in El Infierno Basin, about 6 kilometers east of Seboruco. It is also possible that correlation might be established between the Habana(?) formation and the rocks observed by Hayes, Vaughan and Spencer in the Mayarí Arriba Basin (1901, p. 28, 100).

The stratigraphic and age relations between the Habana(?) formation and the Vinent formation of the southern Sierra Maestra (Taber, 1934, p. 575–576) are not known. Neither has been recognized in any area where the other is known to crop out and the known faunas have nothing in common zoologically. The only fossils reported from the Vinent formation were identified by T. W. Vaughan (in Taber, 1934, p. 576) as "corals belonging to the genus *Leptophyllia*(?), a species of which is found in the Cretaceous of Jamaica, and sponges that are Mesozoic and probably Cretaceous in age." Keijzer attached great significance to a single specimen of stream gravel from a river bed in the Guantánamo Basin northeast of the Gran Piedra Range. The specimen is a fragment of conglomerate whose matrix contains large Foraminifera of late Cretaceous age, and pebbles thought by Keijzer to be derived from the Vinent formation and from the batholithic rocks which intrude the Vinent formation. According to Keijzer (1945, p. 105–106), this specimen proves that the Vinent formation was deposited before late Cretaceous time, that the post-Vinent batholithic rocks were intruded before late Cretaceous time, and that there must be an Upper Cretaceous formation, undiscovered to date, which unconformably overlies both the Vinent formation and the batholithic intrusives. If such a hitherto undiscovered formation does exist in fact, it may be equivalent to the Habana(?) formation mapped by us in the Sumidero and La Burra Basins. The Vinent formation is so poorly known that direct and meaningful comparisons are impossible: it may be equivalent to one or more of the pre-Habana Cretaceous formations listed by Palmer (1945, p. 7–11) or it may be equivalent to the Habana(?) formation of the Sumidero and La Burra Basins. We do not know, and do not believe that further speculation would be of value.

HABANA(?) FORMATION OF THE SUMIDERO BASIN

CHARACTER AND DISTRIBUTION

The gently warped Cobre formation unconformably overlies the much-folded Habana(?) formation of sandstones, conglomerates, limestones, marls, and volcanic rocks. The Río Sumidero and its affluents have eroded away the cover of the Cobre and have exposed the Habana(?) rocks across the bottom of the basin, which is 3 kilometers wide.

More than 200 meters of Habana(?) stratified rocks are present, but the unexposed base, the folded structure, the lack of recognizable and traceable individual beds, and the cover of soil and vegetation precluded measurement of accurate sections. The sedimentary rocks, chiefly coarse-grained, poorly sorted clastics that are yellowish to reddish brown on weathered surfaces, are mainly sandstones and conglomerates with minor interbedded sandy shales. Limy, highly fossiliferous sandstones and conglomerates with minor interbedded impure dark-gray fossiliferous limestones crop out on the northwest side of the basin, but the rocks exposed elsewhere in the basin appear to be noncalcareous and nonfossiliferous. Conglomeratic sedimentary rocks crop out along all the north and east sides of the basin. They generally range from poorly bedded to massive rocks whose attitudes and relation to the fossiliferous rocks in the northwestern part of the basin are uncertain. Well-bedded sandstones and sandy shales, in beds which range from 5 to 30 centimeters in thickness, crop out in places near the fault along the southeast side of the basin. These rocks may be primary tuffs in part, but appear to be mainly sedimentary rocks which are in part reworked tuffs.

The components of the sedimentary rocks are chiefly subrounded to well-rounded grains and pebbles of dark, fine-grained volcanic rocks, together with lesser amounts of coarser-grained diabasic and dioritic rocks, and minor amounts of serpentine. Pebbles in the conglomerates are as large as a few centimeters in diameter, but average less than 25 millimeters. Pebbles and grains in the fossiliferous rocks at locality 248 are similar to those elsewhere in the basin; specimens of the conglomeratic rocks from this locality show well-rounded pebbles of aphanitic to holocrystalline, often porphyritic, volcanic rocks, pebbles of light- to dark-green serpentine, and a few pebbles of medium-grained diorite or gabbro. The pebbles average less than 2 millimeters in diameter but are as large as 10 millimeters. Thin sections show that the smaller grains, those less than 1 millimeter in diameter, consist largely of subangular quartz, rounded volcanic rock fragments, plagioclase (andesine), and fragments of pyroxene, biotite, chlorite, zeolite, and celadonite(?). Clay minerals of the montmorillonite group are present, especially in the less limy portions of the rocks. Fine-grained brown to gray indurated shales near the northern contact of the stock at the northeast part of the basin are seen, in thin section, to be tuffaceous shales which contain angular grains of albite, subangular quartz, and scattered silicified Foraminifera in a matrix of a montmorillonite-group clay mineral and calcite. These rocks are interbedded with sandstones and conglomerates, and show a contact-metamorphic aureole around the small dacite stock, with which porphyritic dikes are associated.

FOSSILS

Fossils were found only in the northwestern part of the Sumidero Basin, where the dark-colored limestones, in places just south of the Río Sumidero and in its immediate vicinity, consist of a closely-packed mass of pelecypod and gastropod shells, corals, a few other larger fossils, ostracodes, and poorly-preserved Foraminifera, the last indeterminable according to L. G. Henbest and J. F. de Albear. Interbedded sandstones and conglomerates which crop out along the Río Sumidero contain coaly partings with plant debris which is indeterminable, according to R. W. Brown.

The ostracodes were studied by F. M. Swain; the corals, by J. W. Wells; the remaining larger fossils by J. B. Reeside, Jr. Determinations of the fossils are summarized in the following table.

Fauna of the Habana(?) formation, Sumidero basin

	Localities		
	248	249	250
Algae, undetermined	×	------	------
Corals:			
Desmophyllum n. sp	×	------	------
Periseris n. sp	×	------	------
Trochocyathus sp. cf. *T. matleyi* Wells	------	------	×
Bryozoan of *Membranipora* group	×	------	------
Pelecypods:			
Striarca n. sp	×	×	------
Aguileria n. sp	×	------	------
Ostrea cf. *O. incurva* Nilsson	×	------	×
sp	------	×	------
Exogyra sp., juvenile	×	------	------
"*Septifer*" *acutus* Trechmann	×	------	------
Cardium (*Trachycardium*?) sp	×	------	×
Linearia? cf. *L. carolinensis* Conrad	×	------	------
Venerid?, undetermined fragment	×	------	------
Corbula? sp	×	------	------
Gastropods:			
Nerita sp. 1	×	------	------
sp. 2	×	------	------
sp. 3	×	------	------
Polynices n. sp	------	×	------
sp	×	------	------
Turritella n. sp. aff. *T. potosiana* Böse	×	------	×
sp	------	------	×
Delphinula? sp	------	------	×
Cerithium aff. *C. cardenasense* Böse	×	------	------
Actaeonella (*Volvulina*) aff. *A. laevis* Sowerby	×	×	------
(*Volvulina*) n. sp	------	×	------
Gastropod, undetermined	×	------	------
Lepadid barnacle plate	×	------	------
Ostracodes:			
Cytherella sp	×	------	------
Paracypris sp	×	------	------
Bairdia cf. *B. comanchensis* Alexander	×	------	------
Cythereis sp. aff. *C. tridenta* Israelsky	×	------	------

AGE OF FORMATION

Mr. Wells (written communication) assigns a late Cretaceous age to the three genera of corals from localities 248 and 250 in the Sumidero Basin, with these comments:

> *Desmophyllum* is a genus not previously known earlier than Oligocene in the Americas. *Periseris* is a genus not previously recorded above the Lower Cretaceous in the Americas. *Trochocyathus matleyi* occurs in the Blue Mountain series, Maestrichtian, Jamaica.

Mr. Swain (written communication) has determined the ostracodes from locality 248 to be of Cretaceous age, and adds the following observations:

The Cuban examples of *Cythereis* are similar to Israelsky's species from the Upper Cretaceous (Marlbrook and Arkadelphia) of Arkansas in general outline and in the presence of three median-longitudinal ridges on the valve surfaces. Differing from *C. tridentata,* the dorsal ridge on the Cuban examples extends farther posteriorly, and its ventral slope bears a row of pits; the broadly rounded anterior margin is finely spinose.

Cythereis subovata Alexander and *C. sandidgei* Alexander from the Lower Cretaceous Grayson formation are similar to the Cuban forms in that three ridges are more or less developed on the surface, but the shape is somewhat different, the anterior marginal rim is lower and less angulated, and the surface is finely pitted in both species from the Grayson.

The Cuban material is of Cretaceous rather than younger aspect, although I am not able to say with certainty whether it is Upper or Lower Cretaceous. The *Cythereis* suggests Upper Cretaceous, but related forms occur in the Comanche. The *Bairdia* probably ought not to carry much weight in age determination, but it is very much like Alexander's *B. comanchensis* (upper Denton and lower Weno, northern Texas).

Mr. Reeside has referred the pelecypods and gastropods from localities 248, 249, and 250 in the Sumidero Basin to the latter part of late Cretaceous time, with the following comments:

Locality 249 may be higher than localities 248 and 250; locality 250 may be a little higher than locality 248. The three lots constituting this collection have enough in common to indicate that they belong to one fauna. Although some of the commoner Mesozoic types that might be expected, such as the ammonites the rudistids, and such genera as *Inoceramus, Trigonia, Roudairia,* and *Nerinea* are not present, it seems beyond question that the material is of later Upper Cretaceous age. I have little basis for closer placement, but the relatives of the species observed have been considered elsewhere to be as old as Campanian.

It is possible that some of the Habana(?) formation of the Sumidero Basin is younger than that part of the formation represented by localities 248, 249, and 250, but we believe that these localities represent the upper part of the formation and assign a late Senonian age to them, in view of the fossil evidence. Some of the rocks of this formation outside the northwest part of the basin may well be older than Campanian.

HABANA(?) FORMATION OF LA BURRA BASIN

CHARACTER AND DISTRIBUTION

La Burra Basin, 8 kilometers wide, is about 7 kilometers west of the Sumidero Basin; structural and stratigraphic relations are similar in the two areas. Tilted rocks of the Habana(?) formation crop out across the floor of the La Burra Basin, on the slopes of Monte Picote below the Cobre cap rock, and on the bounding slopes around most of the basin, where the gently warped Cobre formation overlies the Habana(?) rocks unconformably.

As in the Sumidero Basin, measurement of accurate sections was impossible; sandstones, shales, conglomerates, limestones, and tuffs with a total thickness of at least 500 meters crop out in the Habana(?)

formation of La Burra Basin, and the base of the formation is not exposed. The clastic rocks are in part limy. The sandstone grains and conglomerate pebbles are generally well-rounded and are composed of dioritic to gabbroic igneous rocks, reworked pyroclastic rocks and serpentine. In general, the rocks are deeply weathered and range in color from yellowish to reddish brown; their brown color is in sharp contrast to the overlying white, green, and gray Cobre rocks. The Habana(?) rocks, especially near the center of the basin, are intruded and metamorphosed by stocks of dacitic and fine-grained quartz dioritic rocks.

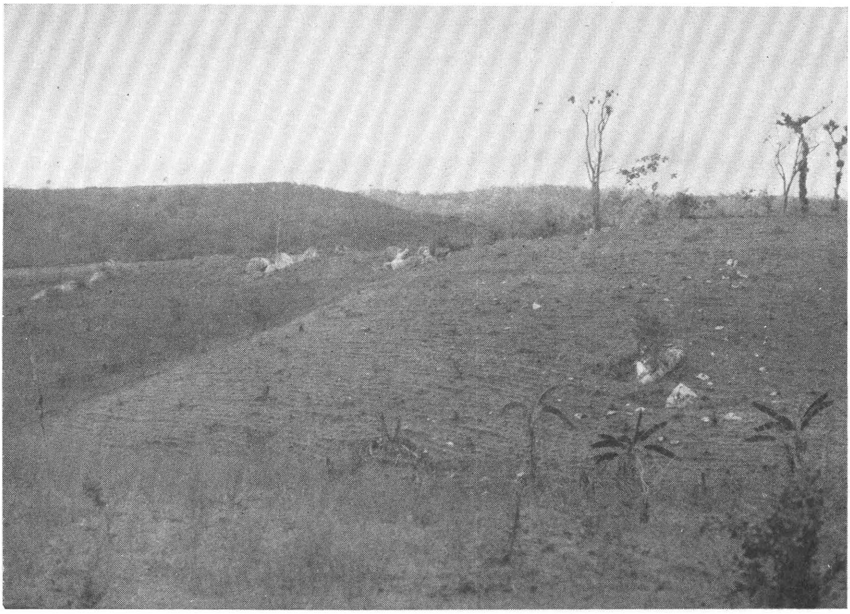

FIGURE 27.—Reef limestone occuring as small lenses in the Habana (?) formation, weathering out on grassy slopes underlain by clastic rocks. La Burra Basin, locality 245.

Throughout the basin, conglomerates and conglomeratic sandstones contain pebbles generally less than 25 millimeters in diameter. However, the upper part of the Habana(?) formation in the western part of the basin consists chiefly of a coarse conglomerate, which has been mapped separately as the Picote conglomerate member. Lenses of fossiliferous limestone, ranging from massive to brecciated and from white to gray, in the Habana(?) formation crop out in the western half of the basin where they are interbedded with limy conglomeratic sandstones, conglomerates, and shales that also are fossiliferous. The limestone lenses (fig. 27) are as much as 3 meters thick, and some of them are traceable for 100 meters or more. They contain corals, Foraminifera, and many rudistid fragments; the overlying and underlying limy sedimentary rocks in places contain Foraminifera and mollusks.

A fossiliferous sandstone crops out along the road on the northeast bank of the Río Jagua at locality 244, 800 meters west of Sabana la Burra. It is a brownish- to whitish-gray, poorly sorted, massive rock that contains subrounded pebbles as much as 5 millimeters in diameter. Most of the pebbles are composed of yellowish to dark-green serpentine, but many are made up of fine-grained volcanic rocks. Thin sections show grains of a serpentine mineral, turbid albite, and a very little quartz. The grains are set in a matrix of clay and calcite.

Some of the interbedded conglomerates, tuffaceous sandstones, and shales in the eastern part of La Burra Basin have coaly partings similar to those in the Sumidero Basin. One lens of pyritic lignite, about 20 centimeters in greatest thickness and 2 meters long, crops out on the bank of the Río Jagua north of the Esperancita mine. This section of rocks appears to be noncalcareous and is lithologically similar to the noncalcareous clastics of the Sumidero Basin. Coarse-grained sandstone near the lignite outcrop contains carbonized plant remains. Thin sections show subangular andesine and analcite grains, and rock fragments, in a fine-grained clay matrix.

Between the Río Jagua and the Esperancita mine, weathered, poorly bedded brown sandstones with interbedded shales crop out along the road. These sandstones are composed of subrounded grains of rock fragments, plagioclase, augite, opaque minerals, and a few subangular grains of quartz, in a matrix of clay minerals, probably of the montmorillonite group. The interbedded shales are similar in composition but contain more clay, in which irregular patches of secondary quartz and silicified Foraminifera are scattered.

Primary, but slightly reworked, water-laid tuffs crop out in the northwest part of La Burra Basin. This sequence of pyroclastics underlies the massive conglomerate which forms the upper part of the Habana(?) formation in this area; the pyroclastic rocks evidently overlie and interfinger with the fossiliferous rocks to the south. The tuffs are weathered to yellow and brown, and are poorly sorted, poorly bedded rocks. Thin sections of one specimen, collected near the Sabana la Burra road junction, show a silicified and chloritized tuff that contains fragments of altered and devitrified glass, angular fragments of fresh feldspar, augite, and a little quartz.

PICOTE CONGLOMERATE MEMBER

The upper part of the Habana(?) formation in northwestern La Burra Basin is so highly conglomeratic as to constitute a mappable member. The name is taken from the section exposed on the slopes of Monte Picote below the Cobre cap rock (fig. 26); here the Picote conglomerate member has no perceptible bedding, but is a massive, poorly sorted aggregate more than 200 meters thick. The pebbles, cobbles and boulders are mostly of fine- to medium-grained gabbros and fine-grained diorites, with subordinate serpentine and volcanic rocks; their diameters average about 20 centimeters, but a few large boulders are more than 1 meter in greatest diameter.

From Monte Picote northward, the fragments are chiefly subangular to angular, but a few are rounded; angular and subangular fragments decrease and rounded fragments increase in number southward from Monte Picote. Between 4 and 5 kilometers south of Monte Picote, the coarse clastics grade very rapidly southward into finer clastics, so that the stratigraphic equivalent of the Picote conglomerate member cannot be distinguished from the underlying Habana(?) rocks in this part of the basin. An overprint on the map (pl. 19) shows the southernmost outcrops which are clearly distinguishable, and beyond which this member could not be mapped without more detailed work, if at all. The fossiliferous, limy, fine conglomerates and sandstones into which the Picote conglomerate member grades southward are brown weathered rocks which consist of well-rounded pebbles and grains of volcanic rocks and serpentine. Under the microscope, rounded grains of green hornblende, epidote, turbid albite or orthoclase, and some quartz are seen. Lenses of gray-weathering white limestone occur in the basal part of the Picote member near the southern limit of the mapped outcrops of this member. These limestones are like those in the Habana(?) formation elsewhere in the basin, and contain coral and rudistid fragments.

The coarse Picote conglomerate member was identified and mapped northward and northwestward beyond La Burra Basin as far as the Central Massif of the Sierra de Nipe, 8 kilometers north of Monte Picote. The conglomerate in this area rests unconformably on the rocks of the ultramafic complex, and is overlain unconformably by the pyroclastic rocks or massive limestone of the Cobre formation. Where the Charco Redondo limestone member of the Cobre formation rests directly on the conglomerate, well-rounded boulders of diorite or gabbro, as much as 50 centimeters in diameter, are scattered through the basal part of the limestone, and the upper few meters of the conglomerate contain a matrix of brown, impure limestone.

A sample of coarse constituents was collected from about 5 meters below the base of the Charco Redondo limestone member on the west slope of Monte Picote. Here the fragments are subangular to rounded, and average less than 20 centimeters in diameter, although some are as much as 60 centimeters in diameter. More than 90 percent of the pebbles and cobbles consist of fine- to medium-grained, equigranular dioritic and gabbroic rocks; the balance consists of well-rounded pebbles of serpentinized peridotite generally less than 5 centimeters in diameter, with a few pebbles of fine-grained volcanic rocks. Three of four specimens of the dioritic and gabbroic rocks studied under the microscope are altered diorite, and one an altered olivine gabbro. The chief minerals in the diorites are plagioclase (calcic andesine), much of it altered to kaolin, and green hornblende which probably replaced pyroxene. A small amount of chlorite replaces hornblende, and one specimen shows patches and veinlets of carbonate. One specimen of fine-grained diorite has a mosaic texture, with anhedral plagioclase and hornblende; another has a diabasic texture. The gabbro specimen contains euhedral to subhedral kaolinized plagioclase as large as 3 millimeters in length, augite, and green hornblende that replaces the pyroxene. A little chlorite is secondary after hornblende, and scattered patches of antigorite(?) probably indicate original olivine.

The origin of the Picote conglomerate member is uncertain but the constituent rocks seemingly came from the north. This member possibly may be a fanglomerate deposited south of the Central Massif along the shore of a Senonian sea into whose deposits it grades southward. A landslide or mudflow deposit, or a marine breccia, would be alternative but not convincing explanations. The progressively greater rounding of the fragments, their progressively smaller size, and their gradation southward into more normal and finer marine clastics would seem to preclude landslide or mudflow origins. Their fanglomeratic texture, the absence of bedding, and the lack of marine organic remains (other than the fragmental ones in the limestone lenses at the base in the south) point to a continental rather than to a marine origin. The carbonaceous material in the immediately underlying sandstones of the Habana(?) indicates that, just prior to Picote sedimentation, continental deposition may have taken place.

FOSSILS

The limy rocks of the Habana(?) formation in the western part of La Burra Basin locally contain many fossils. Pelecypods and gastropods are the most abundant megafossils and are associated with a few cephalopods, coral and echinoid fragments, ostracodes and Foraminifera. The few plant remains collected were indeterminable, according to R. W. Brown. The Foraminifera were studied by J. F. de Albear; the corals, by J. W. Wells; and the remainder of the collections, by J. B. Reeside, Jr. Their identifications of the fossils are summarized in the following table:

Fauna of the Habana (?) formation, La Burra basin

	Localities				
	243	244	245	246	247
Foraminifera:					
Operculina bermudezi Palmer				cf.	
Miscellanea dickersoni (Palmer)	×		cf.	cf.	×
vermunti (Thiadens)				cf.	
Pseudorbitoides israelskii Vaughan and Cole	cf.		cf.		
sp	×				×
Vaughanina cubensis Palmer	cf.		×		×
Lepidorbitoides sp				×	×
(Asterorbis) hasanensis Palmer				cf.	
rooki Vaughan and Cole					×
Orbitoides sp			×	×	
Unidentified		×			
Coral, *Leptoria* n. sp	×				
Echinoid fragment, possibly *Hemiaster*		×			
Mollusks:					
"*Arca*" sp		×			
Inoceramus (*Actinoceramus*) sp., aff. *I. fibrosa* (Meek and Hayden)		×			
Ostrea sp		×			
Pecten sp		×			
Synclonema sp		×			
Pseudamusium? sp		×			
Tenea? cf. *T. parilis* Conrad		×			
Turritella sp		×			
Cypraea? sp		×			
Pachydiscus cf. *P. colligatus* (Binckhorst)		×			
Baculites sp		×			
Ammonite, indeterminable		×			
Ostracodes, unidentified		×			

Keijzer (1945, p. 71) collected and identified the following Foraminifera from locality K234 in western La Burra Basin: *Vaughanina cubensis* Palmer, *Sulcoperculina dickersoni* (Palmer), *Omphalocyclus macropora* (Lamarck), and *Lepidorbitoides* sp. He did not distinguish the rocks that we have described as the Habana(?) formation from the overlying Cobre formation.

AGE OF FORMATION

Mr. de Albear (written communication) has determined the age of the fauna of larger Foraminifera from the Habana(?) formation of La Burra Basin to be Maestrichtian; the assemblage is characteristic of the typical Habana formation of western Cuba. Keijzer (1945, p. 71) considers the Foraminifera collected and identified by him as "clearly proving the Upper Cretaceous age (locality K234)."

Mr. J. W. Wells (written communication) assigns a late Cretaceous age to the coral identified by him, and adds this comment: "Genus unknown previously in Americas. Badly preserved".

Several specimens collected by W. P. Woodring in 1942 and one collected by D. W. Rockwell, of the Cuban Mining Co., were added to the fossils collected by us from the Habana(?) formation of La Burra Basin; the entire collection of macrofossils, except for one coral cited above, was identified as of late Cretaceous age by J. B. Reeside, Jr., (written communication) who states:

I do not find anything in common between this lot and the Sumidero Basin Cretaceous lots. The general preservation is not as good and the facies is obviously different. *Pachydiscus* cf. *P. colligatus* is referred tentatively to upper Senonian. The form I have called *Inoceramus* (*Actinoceramus*) makes me suspect that the deposit may be as late as Maestrichtian.

The Picote conglomerate member naturally is inferred to be slightly younger than the underlying Habana(?) rocks of localities 243–247 inclusive (and also the Keijzer locality K234), but some of the Habana(?) rocks of eastern La Burra Basin may well be older than those of the western part, to which we assign a late Senonian age in view of the fossil evidence.

COBRE FORMATION (UPPER CRETACEOUS? PALEOCENE? AND EOCENE)

The Cobre formation is the most important stratigraphic unit in the south-central Oriente area: it is the most widespread, it is several times thicker than any other, and it has the greatest economic importance. The type locality presumably is in the neighborhood of El Cobre, a town in the Sierra Maestra about 14 kilometers west by north of Santiago de Cuba. The "Cobre series" was named and described by Taber (1931, p. 537–541), who later (1934, p. 576–581) named and described the Cobre formation; seemingly, both names refer to the same rock unit. Woodring and Daviess (1944, p. 363–374) used two formational names, Cobre volcanics and Charco Redondo limestone, to describe the rocks included in the Cobre formation of Taber. We have followed Taber in the use of the name Cobre formation, and have treated the Charco Redondo limestone as an important member of the Cobre formation.

The San Luis formation overlies the Cobre formation conformably throughout all but a very small part of the area described here. The Cobre formation overlies the Habana(?) formation and older rocks with angular unconformity in the Nipe-Cristal Highlands, but the base of the Cobre formation was not observed elsewhere. The relation between the Vinent and Cobre formations is not known, but both seem to be intruded by the Sierra Maestra batholithic rocks.

The Cobre formation comprises volcanic rocks, chiefly waterlaid pyroclastic deposits, which are interbedded with subordinate sedimentary rocks. The estimated greatest thickness of the formation in the mapped area is about 4,000 meters in the Sierra Maestra Highlands, where its base is not exposed. Northward, in the Nipe-Cristal Highlands, the base is exposed but the formation overlaps the older rocks and is thinner, and the limestones are a more important part of the sequence. Taber (1934, p. 577) estimated that, in the El Cobre-Santiago neighborhood, the total thickness is "over 4,500 meters, and possibly as much as 6,000 meters."

Limestones in the Cobre formation, particularly the Charco Redondo limestone member, are more resistant to erosion than the pyroclastic rocks of the Cobre, and the rocks of the Habana(?) and San Luis formations (fig. 28). Crags of the Charco Redondo limestone member tower above valleys and lowlands of less resistant rocks in areas of considerable relief such as the Nuevo Mundo Karstland, the Marginal Hogbacks of the Sierra de Nipe, or Baconao Ridge. Limestone-topped hills in areas of low relief, such as the Aguacate Hills or the Boniato Piedmont of the Sierra Maestra, generally are more rugged and steep than adjoining areas of less resistant rocks. Drainage patterns developed on the volcanic rocks of the Cobre are much finer than those on the Charco Redondo limestone member, but not so fine as those on the Habana(?) formation.

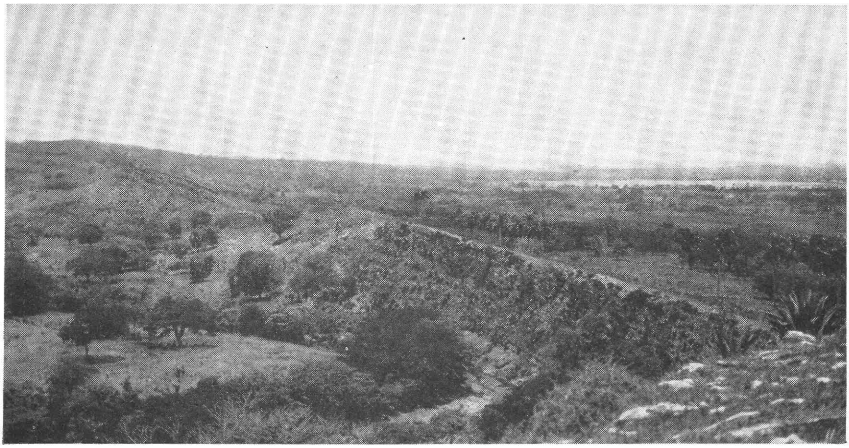

FIGURE 28.—Hogback at west end of the monocline of Boniato Piedmont cut by the superposed Río Yarayabo. Charco Redondo limestone member of Cobre formation crops out on dip slope and upper two-thirds of the scarp; pyroclastic rocks of the Cobre formation, at base of the scarp. San Luis rocks and Quaternary alluvium floor Palma Lowland beyond dip slope.

CHARACTER AND DISTRIBUTION

Fine-textured pyroclastic rocks generally are commonest in the upper part of the Cobre formation; coarse-textured pyroclastic rocks and lava flows, in the lower part. These volcanic rocks are chiefly andesitic, but their composition ranges from basaltic to dacitic; in areas not examined by us, Taber (1934, p. 577–579) found rhyolitic rocks as well Pyroclastic rocks grade or change abruptly from well-sorted to poorly sorted; pure tuffs, to limy tuffs or tuffaceous limestones (fig. 29). Limy sediments are a lesser component of the formation; their relative importance ranges from a little in the lowest part of the formation to a preponderance in the uppermost part.

BEDDED VOLCANIC ROCKS

The pyroclastic rocks of the Cobre formation are classified in two general groups: agglomerates and tuffs. Such a classification was followed by Park (1942), Park and Cox (1944), and by Woodring and

Daviess (1944), but both Taber (1931, 1934) and Keijzer (1945) describe the pyroclastic rocks of the Cobre formation as volcanic breccias and tuffs. Inasmuch as the bulk of the coarse pyroclastic rocks of the Cobre formation consists essentially of rounded to subrounded ejecta, we prefer the use of the term agglomerate rather than breccia. A detailed classification following that proposed by Wentworth and Williams (1932, p. 19–53) would of necessity require much more intensive mapping and study of the pyroclastic rocks of the Cobre formation than has been attempted, in order that the mode

FIGURE 29.—Gradational contact between thick-bedded Charco Redondo limestone member on hilltop and underlying thin-bedded tuff of Cobre formation with subordinate limestones underlain in turn by massive nonlimy pyroclastics in foreground, along Central Highway just south of locality 87.

of origin of individual beds might be worked out. In this report, a pyroclastic rock which consists of rounded, subrounded, and angular ejecta greater than 32 millimeters in diameter in a matrix of tuff is called an agglomerate; one composed of ejecta less than 32 millimeters in diameter is called a tuff.

AGGLOMERATES

Agglomerates occur throughout the Cobre formation in beds which range from a few meters to 300 meters or more in thickness, but the thickest and best developments of agglomerate are in the lower and middle part of the formation. Some agglomerates appear to be intrusive, but most commonly they are interbedded with and grade into tuffs (see fig. 30); in places, the agglomerates are interbedded with lava flows. Some agglomerates are interbedded with limestones.

The agglomeratic rocks generally are massive and consist of rounded to angular fragments of lava, tuff, and limestone set in a matrix of altered tuff. The fragments of tuff and limestone usually are present in minor amounts, but some agglomerates consist almost entirely of rounded, generally elongate blocks of tuff as much as 2 meters in greatest diameter, in a matrix of tuff.

Agglomerates crop out over wide areas throughout the Sierra Maestra, and are found in the Nipe-Cristal Highlands also. A section at least 550 meters thick, between the mouth of the Río Negro and the Chévere mine, is predominantly agglomerate. To the west these

FIGURE 30.—Well-bedded tuff and interbedded massive agglomerate of Cobre formation along Carretera Central 1 km east of Puerto de Moya. Small, high-angle transverse faults are filled with white alteration products.

rocks interfinger with and grade into tuff, much of which is limy. To the east they extend at least as far as the Sigua area, where Park and Cox mapped a massive agglomerate more than 186 meters thick. In the Santiago Basin, agglomerates and tuffs are interbedded, but in general the fine pyroclastic rocks predominate. However, the proportion of agglomerate to tuff increases westward, and the agglomerates predominate in the western part of this area.

Agglomerates crop out at the foot of Pelado Ridge. The rocks on the south slopes of the Escandel Hills and Boniato Ridge are composed of much agglomerate interbedded with limy tuffs. Westward along the south slope of Boniato Ridge the proportion of agglomerate to tuff increases, and agglomerates predominate in the western part north of El Cobre, where more than 300 meters of massive agglomerate, with some interbedded massive tuff and minor beds of limy sedimentary rocks in the upper part, were measured. Massive agglomerate, which contains rounded boulders of porphyritic lava as large as 1 meter in diameter set in a matrix of tuff, is conspicuous throughout an area of about 8 square kilometers atop Boniato Ridge north of El Cobre. The agglomerate is interbedded with tuff and limestone in places. Near the center of the area, a part of the agglomerate has a lava matrix, and a lava flow in this part of the section is exposed at the area's east edge. To the south and southwest, on the Río Domingo and Río Yarayabo, agglomerate over 100 meters thick is associated with lava flows near the top of the Cobre formation; on the Río Grande, this same agglomerate directly underlies the Charco Redondo limestone member in places. East and west of the area bounded by the Río Domingo and Río Yarayabo, the agglomerate grades into rocks that consist principally of tuff.

In the Arroyo Ermitaño, south of El Cobre, massive agglomerates in the lower part of the Cobre formation interfinger with flow rocks. In the Sierra Maestra west of El Cobre, sections consisting principally of agglomerates are usually less than 300 meters thick and are confined largely to the lower part of the Cobre formation. Here, massive agglomerates, which contain boulders of andesite as large as 60 centimeters in diameter, crop out in the Río Cauto, Río Grande, and in the surrounding high hills.

Agglomerate is exposed in several of the mine areas in the Divide Uplands between the Río Guaninicum and Río Cauto. Agglomerate crops out at the Sultana mine in the Ponupo district and in poor exposures in the northern part of El Aura dome.

In the Nipe-Cristal Highlands, extensive outcrops of agglomerate are exposed in the areas underlain by Cobre rocks. About 300 meters of massive agglomerate interbedded with some tuff crop out in the drainage basins of Bruñi, Joturito, and Martinica Arroyos, where this rock contains boulders of porphyritic basalt as much as 1 meter in diameter. Much agglomerate is exposed also in the San Nicolás Hills east and northeast of the La Llave mine.

The agglomerates of the Cobre formation that were studied range in composition from basaltic to dacitic, but are largely basaltic or andesitic. The coarse fragments of lava in the agglomerates range in color from gray, or greenish- or reddish-gray, to nearly black. These fragments most commonly are porphyritic with a dense, fine-grained groundmass, but some are even grained, and many are vesicular or amygdaloidal. Most of the coarse ejecta are subrounded but they do not have the shape and structure of typical volcanic bombs; none appears to have a fine-grained glassy selvage. In hand specimens, the coarse ejecta of the agglomerates are comparatively fresh rocks, in distinct contrast to the tuff of the matrix, which invariably is much more highly altered and usually is lighter in color than the coarse fragments. Plagioclase phenocrysts can be recognized in some of the fragments. In some amygdaloidal rocks, zeolite, calcite, and bright bluish-green celadonite (?) fill the vesicles. The tuff matrix of the agglomerates is made up of fragments that have a considerable size range. These fragments consist for the most part of lava, more or less altered glass, and, in places where matrix alteration is intense, white, green, or tan clay minerals. The matrix also contains broken crystals of fresh feldspar, pyroxene, and, more rarely, quartz.

Suites of coarse fragmental material were collected from twelve localities whose stratigraphic position ranges from the lower part of the Cobre formation to the top. As many as five specimens were collected at localities where the individual coarse constituents appeared to have a considerable range in color, texture, and composition; only one or two specimens were collected at localities where the fragments showed few megascopic differences. The suites were studied megascopically and in thin section. In general, little difference exists between the individual coarse fragments collected from any one agglomerate, but some agglomerates have fragments which differ in composition and range from dacite to basalt.

Hand specimens of ejecta from an agglomerate 2.5 kilometers east-northeast of El Caney, 2,000 to 3,000 meters stratigraphically below the top of the Cobre and near the level of the Cuabitas limestone lentil, are made up of purplish-brown and gray porphyritic lava which contains plagioclase phenocrysts in an aphanitic groundmass. A thin section of one specimen shows euhedral to subhedral calcic albite or sodic oligoclase and a small amount of augite and anhedral quartz in a fine-grained holocrystalline groundmass of laths of plagioclase, augite, and accessory magnetite which is partly oxidized to hematite. Considerable penninite is scattered through the groundmass and replaces augite. The rock evidently is an altered dacite, as potash feldspar was not recognized although it may be present in the groundmass. Two other specimens of different ejecta have essentially the same composition, but quartz was not recognized definitely and plagioclase microlites and microphenocrysts of the groundmass appear to be more calcic than the larger grains of this mineral.

About 1.5 kilometers east of Boniato, an agglomerate bed intercalated in tuffs, some of which are limy, contains ejecta that show the widest apparent range of composition of any of the specimen suites examined. This agglomerate bed is several hundred meters higher stratigraphically than the agglomerate 2.5 kilometers east-northeast of El Caney. One specimen is a gray, dense, aphanitic rock, either an andesite or a dacite; a thin section shows phenocrysts of calcic andesine in a fine-grained groundmass which contains anhedral plagioclase and quartz(?), chlorite, and disseminated magnetite. Another specimen is a purplish-tan porphyritic rock that contains plagioclase phenocrysts in an aphanitic groundmass. A thin section shows phenocrysts of andesine in a groundmass of devitrified glass which contains microlites of feldspar and much finely disseminated red iron oxide. The third fragment that was examined is a dark-gray porphyritic basalt, which in thin section shows phenocrysts of calcic labradorite largely replaced by a zeolite, and a small amount of augite partly replaced by chlorite. The groundmass apparently is a devitrified glass which contains microlites of plagioclase, augite, and finely disseminated hematite.

Along the railroad 1.5 kilometers south of El Cristo an agglomerate is interbedded with tuffs about 600 meters stratigraphically below the top of the Cobre formation. The coarse fragments are very uniform in megascopic character; they are composed of gray, dense, fine-grained lava, and thin sections show zoned, euhedral calcic andesine and minor augite in a finer grained matrix of plagioclase laths and irregular anhedral masses, part of which may be quartz and a zeolite. Calcite and a zeolite replace some of the larger grains of plagioclase. Finely disseminated euhedral magnetite is accessory. The rock fragments appear to be altered andesite, but may be altered dacite.

An agglomerate crops out atop Boniato Ridge 4 kilometers northeast of El Cobre about 1,200 meters stratigraphically below the top of the Cobre formation. Two specimens of lava fragments from this agglomerate were determined in thin section as dacite or porphyritic andesite which contains augite, a small amount of anhedral quartz, and zoned plagioclase phenocrysts, which range in composition from albite to labradorite. A little hypersthene is also present, and chlorite replaces part of the augite. The groundmass is a devitrified glass, which contains microlites of feldspar, quartz(?), needles of apatite, and palagonite. Magnetite is accessory, and the rock also contains a little disseminated hematite.

Several specimens of ejecta were collected 2 kilometers northwest of El Cobre, about 1,500 meters below the top of the Cobre formation. One specimen is a brownish-gray porphyritic basalt breccia, which in a thin section shows labradorite, a little augite and chlorite in a holocrystalline groundmass of plagioclase laths, augite, and magnetite; zeolite fills 1-millimeter vesicles. Another fragment is a similar rock, but the plagioclase is albite; zeolite veins the rock, and amygdules are of celadonite (?) and chlorite. The rock apparently is an albitized basalt or andesite.

Another agglomerate underlies a flow rock 1.8 kilometers north-northwest of El Cobre on a tributary of the Río Domingo and is about 150 meters stratigraphically below the top of the Cobre formation. The coarse fragments are dark-gray to grayish-black basalt which contains cumulophyric phenocrysts of plagioclase, whose composition ranges from calcic labradorite to bytownite, and minor augite; a few anhedral masses of a reddish-brown mineral were identified tentatively as bowlingite. The groundmass contains plagioclase, augite, and glass in which a few small amygdules of zeolite are scattered.

An agglomerate in the northern part of El Aura dome is dacitic. The fragments of lava that compose this rock are porphyritic, gray, and highly vesicular. A thin section shows euhedral to subhedral andesine phenocrysts, augite, and anhedral quartz in a glassy groundmass which contains plagioclase laths and disseminated euhedral magnetite. Some of the vesicles contain a little chlorite.

The coarse fragments of the agglomerates in the Fringing Uplands south of the Sierra de Nipe are chiefly basalt but also include mafic andesite. Three specimen suites were collected from the Florida Blanca Plateau: on the Arroyo Joturito 1.5 kilometers south of its confluence with the Río Caoba, from a point 4.5 kilometers east by north of Nuevo Mundo, and from a third locality about 300 meters south of the Amelia mine in the Guanabá district. The tuff matrix of the agglomerate is pale apple green and is made up of fragments of hard gray to red lava, fragments of a dense, fine-grained material that appears to be an altered glass, and grains of clear, fresh plagioclase. The microscope shows the tuff to be made up chiefly of pale-brown montmorillonite, zeolite, and celadonite (?), together with angular grains of calcic andesine. The specimens from the first and second localities represent a part of the section at least 100 meters below the base of the Charco Redondo limestone member, but the third locality is less than 30 meters below the base of the Charco Redondo limestone member and probably not more than 150 meters below the top of the Cobre formation. The Arroyo Joturito specimens are porphyritic basalt and andesite, and contain phenocrysts of plagioclase, which ranges in composition from calcic andesine to sodic labradorite, small amounts of augite, and minor chlorite in a matrix of altered and devitrified glass. Zeolite partly replaces plagioclase in nearly all of the specimens. The coarse constituents of the agglomerate near Nuevo Mundo are also basalt and andesite similar in texture and composition to the Arroyo Joturito specimens; those of the agglomerate near the Amelia mine consist of greenish-gray to brown basalt which is commonly porphyritic. Euhedral to subhedral plagioclase, whose composition ranges from labradorite to bytownite, and augite are the principal primary minerals seen in thin section. Chlorite replaces augite, and in one specimen was the dominant mineral. Secondary minerals also include zeolite, iddingsite (evidently pseudomorph after olivine), and celadonite, most of which fills microvesicles. The groundmass is normally glassy and contains palagonite and microphenocrysts and microlites of plagioclase, but in one specimen it is holocrystalline. Magnetite is the accessory mineral.

Specimens were collected from the agglomerate that crops out in the San Nicolás Hills near La Llave mine, about 2.5 kilometers north of Manganeso. The coarse constituents are both andesite and basalt, but are largely basaltic. The basalt fragments are gray to greenish-black, and in thin section are seen to be similar in composition but highly altered: labradorite and augite are the principal primary minerals that can be recognized but in most of the specimens the plagioclase is more or less completely replaced by zeolite and calcite, and the augite by chlorite. Iddingsite was identified in one specimen. The rocks are holocrystalline, but the fine-grained matrix commonly is replaced in part by the secondary minerals, including celadonite(?). One specimen that was examined is andesite, a purplish-gray breccia of angular to rounded fragments, 13 millimeters in largest dimension, in a matrix of lava. The matrix and fragments contain phenocrysts of andesine and minor chlorite, probably after augite, in a fine-grained but holocrystalline groundmass of plagioclase and chlorite.

LAVA FLOWS

Lava flows ranging in composition from dacitic or rhyolitic to basaltic are sparsely distributed through the middle and upper part of the Cobre but are common in the lower part of the Cobre, especially in El Gato Massif. Most of the lava flows in the middle and upper part of the Cobre are shown on the areal map, but flows in the lower part of the Cobre have not been mapped, except for two outcrops in the Santiago Basin which are only tentatively designated as flows. Instead, the areas underlain by rocks that are chiefly flows, but which include intercalated pyroclastic and sedimentary rocks and probably fine-grained intrusive rocks, have been separated on the map from those areas where few flows are known to occur (see map, pl. 19). The general distribution of flow rocks in the lower part of the Cobre is indicated on the areal map by the overprint which shows only the approximate boundaries. Accurate mapping of these rocks was not attempted as it would have involved spending more time than was available considering the complexity of interfingering of pyroclastic and sedimentary rocks and the difficulty (because of poor exposures) of distinguishing massive flow rocks from possible intrusive rocks.

The greatest thickness of lavas in the lower part of the Cobre is along the upper north flank, the top, and south flank of El Gato Massif, extending from the head of the Arroyo Ermitaño westward to a point south of Solís, a total distance of about 15 kilometers. The approximate upper limit of this lava complex is traceable from a point 1 kilometer south of El Cobre, through a point 1 kilometer south of Hóngolosongo, and a point about 4.5 kilometers south of Solís.

The section of lavas extends southward beyond the area mapped to the dioritic batholith that intrudes these rocks, and has a total outcrop width ranging from about 3 kilometers on the east to 4.5 kilometers on the west. It is estimated that this section has a thickness of not less than 2,500 meters and it may be as much as 3,500 meters. The upper third or more consists of individual flows or groups of flows intercalated with pyroclastic rocks, tuffaceous sandstones, and lenses of fossiliferous limestone that contain a lower Eocene fauna. In places flows are subordinate to the fragmental rocks. The lower two-thirds, on the other hand, contains little pyroclastic material, and limestones or other sedimentary rocks seem to be absent.

Individual flows in the upper part of the section of lavas of the lower Cobre in El Gato Massif pinch out in several places in the area south of Hóngolosongo and the Uraguá dome. Many flows appear to be continuous for only a few kilometers. It is probable, therefore, that the upper limit of the lavas of the lower Cobre does not occupy the same stratigraphic position throughout the area but ranges through a zone perhaps several hundred meters thick. Because of the lack of well-defined marker beds that are traceable over the whole area it is not possible to determine accurately the stratigraphic range covered by the upper limit of the lava complex. If, however, the tuffaceous sandstone near locality 72, 1.5 kilometers southwest of El Cobre, is the same as that near locality 61, southwest of the Uraguá dome, then the top of this complex at these two places occupies a similar stratigraphic position about 2,000 meters below the top of the Cobre.

The western extension of the lava complex in the lower part of the Cobre has not been traced beyond the point south of Solís. The top of the zone probably passes a short distance to the south of the Río Grande, south of the Manacas dome, but as this area was not examined, the character of the rocks there is not known. Further to the west, however, the lavas of the lower Cobre evidently interfinger and grade into pyroclastic rocks and shale, for the latter rocks predominate in the upper Río Mogote drainage basin in the Guisa-Los Negros district, where Straczek made a short reconnaissance southward across the divide of the Sierra Maestra. Eastward, the lava flows of the lower part of the Cobre in El Gato Massif finger out into agglomerates, tuffs, and minor limestone beds that occupy the Santiago Basin. Two possible flows have been mapped in the Basin: one, 4 kilometers north of Santiago de Cuba, has an outcrop length of about 2,500 meters and a maximum width of about 75 meters; the other, andesite that shows perfectly developed columnar jointing, is 5 kilometers northwest of Santiago de Cuba and has an outcrop about 1,900 meters long and as much as 60 meters wide. Though these rocks are tentatively classified as flows they were not adequately studied and they may well be sills. The only other flow of the lower Cobre that was found in the Santiago Basin is an amygdaloidal basalt, several meters thick, that in places underlies the Cuabitas limestone lentil west of Cuabitas.

Very few flows were found in the lower part of the Cobre along the north flank of the Gran Piedra Massif but some of the rocks exposed on the south flank are reported by Taber (1934, p. 578–579) to be rhyolitic lavas or intrusive rocks, with andesitic rocks higher above. Minor flows of andesitic lavas are intercalated in agglomerates in the Sigua district (Park and Cox, 1944, p. 353).

Lava flows in the middle and upper part of the Cobre are few in number; they commonly occur as single flows intercalated in pyroclastic rocks and range in thickness from 1 or 2 meters to more than 30 meters. Some of the flows are traceable for as much as 3 kilometers but most have an outcrop length of a few hundred meters or less. A basalt flow, at least 20 meters thick, crops out on the Río Indio, 1.3 kilometers above its junction with the Río Baconao. The flow, which shows pillow structure, was not mapped. Near the base of Boniato Ridge, on the trail 8 kilometers northwest of Santiago de Cuba, there is an andesitic flow breccia 3 meters thick intercalated in tuff; this flow was too small to show on the map. A dacite flow and flow breccia ranging in thickness from a few meters to more than 30 meters forms conspicuous outcrops as much as 3 kilometers in length on both sides of the Río Domingo valley, 12 kilometers north of El Cobre; this lava flow is intercalated in massive tuffs and agglomerates. Further east toward the Central Highway, there are bold outcrops of massive volcanic rocks that were not mapped but which may represent the continuation of the same flow as they appear to be at the same stratigraphic position. They may, however, represent a different flow or even an intrusive rock. At least one basalt flow a few meters thick is exposed in a small area on the Río Yarayabo 9 kilometers north-northeast of El Cobre, but it is not mapped and its extent is not known. At Cruce de los Baños, near the confluence of the Río File and Río Contramaestre, an altered basalt flow at least 5 meters thick crops out over an area of more than one square kilometer.

Only one flow, a dacite flow a few meters thick, was recognized in the hills south of the Sierra de Nipe. At the top of the Cobre, 5 kilometers southeast of Palmarito, this flow has an outcrop length of about 1.5 kilometers, is intercalated in tuffs, and in part is unconformably overlain by a bed of limestone.

The lavas of the Cobre are fine-grained to aphanitic, but more commonly are porphyritic rocks that show a striking similarity to the fine-grained Tertiary intrusive rocks in range of mineralogic composition and type of alteration, insofar as microscopic studies, unsupported by chemical analysis, show. The flow rocks are generally much finer in grain and exhibit structures such as flow layering, flow brecciation, and vesicular or amygdaloidal structures seldom seen in the intrusive rocks. In general the flows of different composition are hard to distinguish in the field. The mafic types, including basalts and andesites, are commonly dark gray or brown, or greenish gray, but if altered are light gray and resemble the dacitic rocks that range in color from light gray to purplish gray or tan. Even under the microscope the different rock types are not easily distinguished. The identifiable minerals represent as little as 20 percent of the volume of some rocks and the classification of such rocks into the three groups, dacites, andesites, and basalts, is necessarily tentative.

The dacites are probably the most common flow rocks in the Cobre. As shown by microscopic studies these rocks are characterized by plagioclase phenocrysts ranging in composition from sodic oligoclase to andesine, in a groundmass of altered or devitrified glass containing microphenocrysts of plagioclase and quartz. Some of the specimens contain a small amount of augite, in part altered to chlorite, and one specimen contains biotite. Potassic feldspars were not identified in any of the rocks studied but may be present in the fine-grained groundmass of some specimens. The dacite group may therefore include rocks of rhyolitic composition.

Flows of dacitic composition occur throughout the Cobre. In the lower part of the Cobre, specimens were collected in the area south of El Cobre, and south of the Uraguá dome. About 4 kilometers south-southwest of El Cobre (0.3 kilometer south of locality 71) a dacite flow 5 meters thick shows conspicuous flow layering, columnar jointing, and sparse phenocrysts of altered plagioclase (as much as 2 millimeters in diameter) set in an aphanitic groundmass. The rock is light greenish gray on fresh fracture. The flow structure is characterized by layers and streaks showing slight differences in color and texture. In thin section the plagioclase phenocrysts were determined to be sodic andesine slightly altered to kaolinite and veined by calcite. The groundmass consists of euhedral to anhedral plagioclase, anhedral quartz, and accessory magnetite, in a matrix of devitrified glass. A little celadonite(?) seems to replace the glass and to fill sparse, scattered microvesicles. On the headwaters of the Rió Nima Nima, south of the above locality, lava flows occur in massive agglomerates and seem to be chiefly dacitic, but they were not studied.

The studies of thin sections indicate that the flow rocks of the lower Cobre in the area southwest of the Uraguá dome are principally dacitic. Many of the rocks show distinct flow layering and some are amygdaloidal, but those at the south edge of the area are massive rocks that probably include intrusives as well as flows. The rocks contain sparse phenocrysts of plagioclase, largely replaced by calcite, and quartz in a cryptocrystalline groundmass containing microphenocrysts of quartz. In one thin section, part of the quartz is distinctly secondary as it veins the rock and occurs in greatest amount in association with calcite. Quartz also replaces phenocrysts of feldspar. In a section of another specimen fine layering is due to alternation of irregular layers containing many microphenocrysts of quartz with layers of devitrified glass containing dustlike red iron oxide. The latter specimen contains sparse aggregates of chlorite that presumably are secondary after augite.

The extrusive complex of the Manacas district consists of one or more dacitic plugs with related flow rocks and flow breccias that are overlain unconformably by later pyroclastic rocks of the Cobre formation. In hand specimens the recognizable minerals include plagioclase phenocrysts, in grains as large as 5 millimeters in diameter, and phenocrysts of quartz as much as 5 millimeters in diameter. The phenocrysts are set in an aphanitic background. The microscope reveals a remarkable similarity in texture and mineralogic composition between the different rock specimens collected from the dacites. The plagioclase phenocrysts generally are not zoned and have the composition of calcic albite or sodic oligoclase. Laths of plagioclase in the groundmass which are as much as 0.3 millimeter long, appear to be a little more calcic than the plagioclase phenocrysts but have a mean index less than that of quartz, which is present in the groundmass as anhedral grains with a maximum diameter of 0.2 millimeter. Potash feldspar was not recognized with certainty but it may be present in the finer grained portions of the groundmass. The grains of feldspar and quartz are set in a still finer matrix of palagonite and devitrified glass. Pyroxenes or amphiboles were not recognized but the small amount of chlorite present in some of the specimens may be a product of alteration of mafic minerals. Magnetite is an accessory mineral. Alteration products include iron oxide and a white clay mineral.

A thin section from the dacite flow in the Río Domingo area contains sparse phenocrysts of plagioclase and augite as much as 2 millimeters in diameter, sparse green biotite, and disseminated euhedral magnetite, in a groundmass of devitrified glass, plagioclase laths, quartz, and biotite(?). Chlorite replaces part of the phenocrysts of augite, and much chlorite, irregularly disseminated, replaces the groundmass constituents. A little blue-green celadonite(?) fills microvesicles and replaces the glassy components of the groundmass. A section of fine-grained breccia from this same flow is similar and contains scattered angular fragments of glassy lava. Much disseminated, dustlike red iron oxide gives the rock a reddish-brown color.

The dacite flow in the San Nicolás area is porphyritic and amygdaloidal. One thin section contains phenocrysts of andesine, in part replaced by calcite, and grains of quartz with a maximum diameter of 0.1 millimeter. The groundmass contains plagioclase laths and small irregular masses of chlorite(?) in a cryptocrystalline or glassy matrix.

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Another contains sparse phenocrysts of augite in a groundmass that has a trachytic texture.

Andesitic flows are next in abundance to the dacites and are mineralogically similar but contain a greater proportion of mafic minerals and contain no visible primary quartz. In the normal andesite the plagioclase ranges in composition from oligoclase to calcic andesine, but in certain altered flow rocks the plagioclase is albite. Andesite flows were found only in the Santiago Basin and in the El Gato Massif. In the latter area the flows south and southwest of El Cobre, in the upper part of the lava complex of the lower Cobre, were found to be mainly andesitic. A thin section of a specimen from a flow about 2 kilometers southwest of El Cobre consists predominantly of fresh plagioclase (oligoclase) and augite. The rock is holocrystalline and even grained, with an average grain size of about 0.1 millimeter. Plagioclase laths show distinct flow alignment. A small part of the augite is replaced by pale-green chlorite and by lesser amounts of celadonite(?). Much euhedral magnetite is disseminated in the rock.

Thin sections of some of the rocks in the same area contain phenocrysts and microphenocrysts of albite but little or no augite. They appear to be secondarily altered flows of andesite or basalt, in which the plagioclase has been albitized and the original augite altered to chlorite. In this section, one specimen collected from a point 0.5 kilometer south of locality 72 shows albite phenocrysts 1 millimeter in diameter, in part replaced by zeolite and by calcite, in a groundmass of euhedral to anhedral plagioclase, chlorite, and accessory magnetite. The rock is cut by veinlets of calcite, and bluish-green celadonite(?) fills scattered microvesicles. Another specimen of an altered andesite or basalt flow rock collected from an outcrop 0.2 kilometer north of locality 73 is similar to the flow rock described above. A thin section shows albite phenocrysts with a maximum diameter of 1.5 millimeter in a groundmass of devitrified glass containing lathlike feldspar, irregular to rounded masses of chlorite, and much dustlike red iron oxide.

In the Santiago Basin, a specimen collected from the west extension of the flow(?) 5 kilometers northwest of Santiago de Cuba is an andesite. The rock is porphyritic and amygdaloidal, and a thin section contains phenocrysts of andesine, 1.5 millimeters in diameter, sparse augite and green hornblende. The plagioclase phenocrysts are largely replaced by zeolite, and the mafic minerals by chlorite. Part of the chlorite occurs as individual masses, as large as 1 millimeter in diameter, that appear to be pseudomorphic after both augite and hornblende, judging from the form of the aggregates of this mineral. The groundmass is holocrystalline and is made up of the same minerals that comprise the phenocrysts, but the plagioclase is fresher and a considerable part of the augite is also fresh. Early- to late-formed magnetite, in euhedral to anhedral grains about 0.05 millimeter in diameter, is scattered through the groundmass. Sparsely distributed amygdules as much as 2 millimeters in diameter are composed of chlorite, celadonite(?), and zeolite.

The only other andesite from the Santiago Basin that was studied in thin section is the flow breccia that crops out at the base of Boniato Ridge, 8 kilometers northwest of Santiago de Cuba. The rock is composed of angular fragments as much as several centimeters in diameter; all the fragments seem to be cognate and to be similar to the groundmass, which is made up of weakly zoned andesine and sparse augite in a matrix of devitrified glass. The groundmass is in part replaced by nontronite(?), calcite, and zeolite. Euhedral dustlike magnetite is accessory. A few rounded to angular grains of quartz, probably accidental fragments, are scattered through the groundmass.

The basaltic flow rocks are similar to the andesites but contain a more calcic plagioclase, more abundant mafic minerals and less glass. None of the rocks of this group appears to be olivine bearing; all could well be considered basaltic andesites rather than basalts.

In the lower part of the Cobre a basalt flow (or sill?) southwest of El Cobre has a maximum thickness of about 30 meters and was traced for nearly 3 kilometers along the outcrop. The rock is strikingly porphyritic; it contains numerous euhedral plagioclase phenocrysts as large as 1 centimeter in diameter in a very fine grained groundmass. A thin section shows the plagioclase phenocrysts to be unusually calcic (An 75–80) and many were found to be glomerophyric aggregates. The groundmass contains plagioclase laths, less calcic than the phenocrysts, augite, in part altered to chlorite, and much dustlike euhedral magnetite, in a cryptocrystalline to glassy matrix.

In the Santiago Basin the basalt flow that overlies the Cuabitas limestone lentil is a dark reddish-brown, highly amygdaloidal rock. A thin section shows amygdules, some more than 8 millimeters long, composed mainly of calcite with some earlier formed zeolite, including analcite. Two irregularly rounded amygdules in the thin section consist of very fine-grained, microfossiliferous limestone; evidently limy mud infiltrated some of the vesicles after solidification of the basalt. Plagioclase phenocrysts are numerous in the rock but are almost entirely replaced by zeolite, and many of the phenocrysts are cut by veinlets of a yellowish to reddish-brown, nonpleochroic mineral of low to medium birefringence, which seems to be an alteration product of the opaque to translucent, brown, glassy groundmass. The unidentified mineral, which may be palagonite, also veins the zeolite.

Thin sections of the basalt flows on the Río Yarayabo consist of euhedral to subhedral plagioclase phenocrysts (labradorite) and augite in a fine-grained groundmass containing plagioclase laths, augite, and accessory magnetite. A small amount of chlorite replaces the groundmass constituents.

The flow at Cruce de los Baños is an albitic rock similar to the rocks described as altered andesites, but it contains a larger amount of mafic minerals; therefore it is described as an altered basalt. A thin section shows subhedral to anhedral albite as much as 2 millimeters in diameter and chlorite to be the chief constituents. Augite is present in small amount and euhedral dustlike magnetite is accessory. All of the albite is slightly altered to kaolinite(?), giving this mineral a turbid appearance; many of the albite phenocrysts and microphenocrysts contain minute inclusions of chlorite, and still smaller blebs of quartz(?). Most of the chlorite of the rock appears to be secondary after augite. A little zeolite, in small irregular masses, is scattered through the rock.

Lava breccias of two distinct types can be recognized in the Cobre. The normal flow breccias, already mentioned in the foregoing, consist of angular fragments of cognate lava, together with minor amounts of accessory and accidental fragments, set in a matrix of lava. This type of breccia occurs most frequently in the thin parts or at the ends of a thick lava flow, and grades into normal massive lava whose composition is similar to that of the fragments as well as the matrix lava of the breccia. It seems clear that the breccia was formed by the breaking up of solidified crusts of a flow and the resulting fragments mixed in molten lava (Tyrrell, 1931, p. 66). The mechanism is not strictly comparable to the method of formation of aa structures for the flow breccias of the Cobre formation show no evidence that they were formed of lava that was highly charged with gas during solidification. Scoriaceous or highly vesicular structures are uncommon or absent and the fragments do not have the rough shapes common to those in aa lava (Jaggar, 1947, p. 141).

The second type of lava breccia is a strikingly different rock that consists of numerous rounded to subrounded blocks of red, reddish-gray, or greenish-gray, dense lava, in a matrix of dense gray lava. Such "breccias" are known to occur in the lower part of the Cobre and Vinent(?) rocks in many places throughout the Sierra Maestra, but the only known occurrence of this kind of rock in the area mapped is that found 4.5 kilometers north-northeast of El Cobre, on Boniato Ridge. Here, an ovoid mass about 200 meters in diameter is underlain by the "breccia"; the mass appears to be intrusive into the surrounding agglomerates and tuff, and may occupy a volcanic vent. The boulders of the "breccia" make up 50 percent or more of the volume of the rock and range in size from a few centimeters to more than 30 centimeters. Surprisingly few of the boulders are less than 5 centimeters in diameter, most of them being 10 to 15 centimeters in diameter. The boulders are not vesicular and do not have a fine-grained or glassy selvage. Except for variations in color the lava of the boulders and of the matrix are similar in texture, generally non-porphyritic. This similarity perhaps reflects the fact that the fragments and matrix lava are essentially identical in composition; these fragments and the matrix lava probably are andesitic to basaltic, but the rock was not studied in thin section. If the nearby basaltic flows and the surrounding predominantly basaltic pyroclastic rocks are genetically related to the lava "breccia," then the "breccia" itself may be basaltic.

TUFFS

Tuffs are extensively exposed throughout the entire area underlain by the Cobre formation. They are massive to well-bedded, partly limy rocks which have the same range in composition as their coarser grained equivalents, the agglomerates; like the agglomerates, they are mainly andesitic to basaltic. On weathered surfaces the rocks are brown or gray, but on freshly exposed or unweathered surfaces are green, gray, light brown, pink or red, and sometimes nearly white. The components are extremely variable in grain size and the rocks generally are poorly sorted. Fine-grained tuffs alternate with or grade into coarse-grained rocks that contain angular to subangular lava fragments; most fragments are less than 32 millimeters in diameter, although widely scattered blocks as large as 6 meters in diameter were seen. Limestone and tuff fragments occur in the tuffs, but most of the fragmental components are lava, glass or grains of quartz, broken crystals of feldspar, and pyroxene. The tuffs are invariably altered, and alteration is intense near many of the manganese deposits. The finer grained and glassy constituents of the tuffs appear to have been altered more readily than the coarser fragments. A seemingly remarkable but common occurrence is the presence of recognizably fresh, glassy-white broken crystals of feldspar in an intensely altered tuff, whose principal constituents are green, white, or pink clay minerals of the montmorillonite group.

Lithic tuffs are exposed at some places such as the Quinto mine, where beds of lithic tuff up to 1.5 meters thick contain subangular fragments of somewhat altered, fine-grained, often porphyritic lava as large as 2 centimeters in diameter, in a matrix of rock fragments, clay minerals, and manganese oxides. Less commonly, crystal tuffs alternate with other types of tuff: at the San Luis mine, a crystal tuff partly replaced by manganese oxides consists dominantly of angular grains of feldspar and quartz about 3 millimeters in diameter; similar rocks are found near the top of the Cobre formation at the El Aura dome, and in El Cristo, Ponupo, and Jutinicú mine districts.

Throughout the Cobre formation much of the tuff is limy, but limy tuffs are most common in the upper half of the formation; many tuffs, seemingly noncalcareous on casual inspection, are found to be limy and even fossiliferous when examined closely. The limy tuffs nearly always are well-bedded, with individual beds from a few centimeters to one meter thick; some limy tuffs are flaggy, and in places they are crossbedded.

In the Sigua district a bed of limy tuff 150 meters thick is interbedded with agglomerate and well exposed in the mine area, with more limy tuff exposed to the south. Much of the 600-meter section of rock which forms the upper slopes of the main ridge of the Escandel Hills consists of limy tuff, all of which is at least 600 meters stratigraphically below the top of the Cobre formation. Much limy tuff crops out on Pelado Ridge. Limy tuff makes up a large part of the 750 meters of rock exposed on the middle and upper south slope of Boniato Ridge north of Santiago, but to the west these rocks grade into coarser and less calcareous pyroclastic rocks. A zone more than 200 meters thick, which contains much limy tuff, crops out on the ridge between Ramón de Guaninao and El Sur; south of Ramón de Guaninao, this zone is about 900 meters stratigraphically below the top of the Cobre formation. Limy tuffs are also conspicuous north of Ramón de Guaninao in the uppermost 300 meters of the Cobre formation.

Limy tuffs are not so common in the hills south of the Sierra de Nipe. However, in La Gloria mine district and in the San Nicolás Hills, much of the upper part of the Cobre formation consists of limy tuffs which interfinger with individual limestone beds of the Charco Redondo limestone member, and some limy tuffs are found in the steep south slopes of Florida Blanca plateau.

Tuffaceous sandstone is not common in the Cobre formation, although some of the rocks mapped as tuff have undergone some reworking and could be regarded as sandstones. Tuffaceous sandstone differs from tuff in having a higher degree of rounding of component grains and, usually, better sorting. A brown, well-sorted tuffaceous sandstone, in part limy, is exposed on the hill 1.6 kilometers south of El Cobre, a similar sandstone, which may have the same stratigraphic position, crops out on the crest of the Uraguá Hills 12 kilometers west of El Cobre. Under the microscope this sandstone is seen to be made up of subrounded grains of turbid albite, zeolite, and opaque minerals in a matrix of clay; no pyroxene or amphibole was recognized. Tuffaceous sandstone is interbedded with tuff and agglomerate in the valley of the Río Viajaca 3.2 kilometers south of Mafo.

Tuffaceous siltstones crop out in only a few localities; they are usually limy and commonly form steep slopes or cliffs. Part of a 150-meter section of rock along the road on the steep hill north of Ramón de Guaninao, and some of the rocks on the ridge between Ramón de Guaninao and El Sur are tuffaceous siltstones.

Tuffaceous shale beds as much as 5 meters thick and interbedded with tuffs of the Cobre crop out 1.6 kilometers north-northwest of El Caney.

Near El Caney a massive, highly altered tuff intercalated in poorly bedded pyroclastic rocks of the lower part of the Cobre forms a lenticular outcrop more than 4.5 kilometers long and 300 meters wide. The north contact of the rock extends through the north edge of the town. About 3 kilometers to the west of El Caney the massive tuff appears to wedge out, but to the east it interfingers and grades into massive agglomerate. The rock is whitish gray and shows numerous 2- to 5-millimeter, rounded to angular or irregular masses of a white clay mineral set in a matrix of soft greenish- to reddish-gray altered material. The pseudoporphyritic texture and the massive character combine to give the tuff the appearance of an intrusive rock; its pyroclastic nature, however, is evident, for in places boulders of amygdaloidal lava are scattered through the mass. Under the microscope the fragmental character of the rock is even more apparent. One thin section shows angular fragments of plagioclase, An 60–70, which are almost entirely altered to a montmorillonite clay mineral and zeolite. The altered plagioclase is set in a matrix of green chlorite, zeolite, and recrystallized, fossiliferous limestone. Another section from a point about 1.5 kilometers west of El Caney, in the area where the tuff contains scattered boulders of lava as much as 20 centimeters in diameter, shows plagioclase grains, ranging in composition from calcic albite to calcic oligoclase, which are largely replaced by zeolite and by a white montmorillonite clay mineral. The few recognizable fragments of augite that are present are in part altered to chlorite. Subhedral to anhedral later magnetite cuts across the grains of augite and plagioclase. The boulders of andesite in the tuff were also studied under the microscope. The main constituents were found to be subhedral plagioclase, An 35, in part altered to zeolite, and augite. The groundmass is devitrified glass in which microlites of feldspar and augite(?) can be seen.

Tuffs identical in appearance and evidently mineralogically similar to the massive, altered "porphyritic" crystal tuffs described above occur also at the heads of the Arroyo Ermitaño and Río Nima Nima, but the relative stratigraphic positions are obscure. The disconnected blocks of reef limestone at locality 71 are imbedded in such a tuff and a similar rock crops out 250 meters to the south.

Specimens of tuffs of the Cobre formation have been collected from several other localities, most of them from mine areas where these rocks were studied in connection with investigations of the manganese deposits. However, no systematic attempt has been made to obtain representative samples throughout the area underlain by pyroclastic rocks of the Cobre formation. The studies indicate that the composition and mineralogic character of the tuffs is similar to that of the coarse constituents of the agglomerates.

Specimens of tuffs were obtained from a point 1.6 kilometers south of El Cristo where these rocks are interbedded with agglomerate. The tuffs here contain angular fragments of dark aphanitic lava as large as 10 millimeters in diameter in a matrix of fragments that range from a few millimeters in diameter in the coarser textured tuff to less than 1 millimeter in the finer grained beds. Thin sections show angular fragments of glassy, generally porphyritic lava, angular plagioclase, shards of altered glass, and a small amount of angular augite and green hornblende. A few fragments of fine-grained, cryptocrystalline quartz are scattered through one of the sections studied. Chlorite replaces part of the tuff, and some appears to be pseudomorphic after grains of augite. The rock and mineral grains are set in a matrix of zeolite and some of the rocks and mineral fragments partly replaced by zeolite. Calcite veins the rock.

A red, fine-grained tuff from the manganiferous horizon of the Sigua area shows in thin section a few unreplaced grains of feldspar in a groundmass of zeolite and a montmorillonite clay in which are scattered dustlike grains of red iron oxide. The feldspar seems to be plagioclase but its composition was not determined. At the Rosita prospect, south of the Quinto mine area, tuff from the manganese bed is largely replaced by manganese oxides. Under the microscope only angular grains of lava and grains of albite can be recognized.

The felsic tuff that overlies the manganese-bearing beds in El Cristo, Ponupo and Jutinicú districts consists chiefly of angular fragments of calcic andesine and quartz set in a matrix of zeolite and a white montmorillonite clay mineral, as seen under the microscope. Rock fragments, augite, green hornblende, and later chlorite are present in minor amounts in the light-colored facies but are abundant in the darker colored facies. Some specimens show much calcite, most of which is interstitial. Locally, this calcite was later cut and replaced by zeolite and montmorillonite clay mineral, but some calcite veins the rock and must have been formed last of all. The light-colored facies of this tuff contains the following proportions of minerals: quartz, 20–30 percent; andesine, 40–60 percent; the rest, matrix of calcite, zeolite, and a white montmorillonite clay mineral.

Tuffs in and immediately below the manganiferous beds in these mine areas are well-bedded, water-laid, basaltic to andesitic rocks that commonly are distinctly limy and contain marine fossils. The larger fragments, those more than 2 or 3 millimeters in diameter, consist of fine-grained, commonly porphyritic, gray to reddish-gray or brown lava but the smaller grains are mainly broken fragments of minerals or shards of altered glass. In thin section the minerals are seen to be calcic andesine and labradorite, augite, sparse green hornblende, sparse biotite and apatite, and magnetite. The originally glassy components of the tuffs are largely replaced by zeolite and later white, pink, or green montmorillonite clay minerals, and in the most intensely altered rocks in or near the manganiferous beds, clay minerals replace plagioclase in part and almost completely replace zeolites and the mafic minerals.

Tuffs around Mogote San Nicolás, near La Llave mine area, are dacitic to basaltic. The two types of tuffs are interbedded and are difficult to distinguish in the field, although quartz may be recognized in some of the dacitic tuffs. Thin sections show the basaltic tuffs to be made up of shards of fresh to partially devitrified glass (which are in part replaced by zeolite and later yellowish-green nontronite), angular grains of fresh labradorite, augite, and rock fragments. Small amounts of interstitial, recrystallized fossiliferous limestone are present in some of the sections. The dacitic tuffs are similar in composition but contain angular quartz grains and sparse green hornblende in addition to the minerals recognized in the basaltic tuffs, and the plagioclase, some grains of which are weakly zoned, ranges in composition from sodic oligoclase to andesine. The pale- to bright-green color of the rocks of this area is due to nontronite. Beds in and adjacent to the manganese deposits contain larger amounts of montmorillonite clay minerals, which include white to pink varieties in addition to the green nontronite.

Some of the tuffs around Pinar Redondo and in the area north of La Burra Basin consist of a whitish-gray to greenish-gray ash that in many places appears to rest directly on serpentine or on the Picote conglomerate member. This ash is evidently basaltic in composition, inasmuch as it contains glass shards, most of which are remarkably fresh; fragments of microporphyritic glassy lava; angular grains of calcic labradorite; augite; and a small amount of quartz, green hornblende, and olivine(?). The olivine(?) is altered to iddingsite. Much nontronite veins and replaces the rock, particularly the glassy components, and a little celadonite(?) fills cavities in the fragments of glass.

From the brief studies that have been made of the volcanic rocks of the Cobre formation it appears that there is no general or consistent variation in lateral or vertical distribution of the different compositional types of flow and pyroclastic rocks, although more detailed studies may reveal systematic variations not now apparent. Dacitic, andesitic, and basaltic flow and pyroclastic rocks are distributed throughout the Cobre formation, and only in local areas does one compositional type appear to be dominant. In the San Nicolás area, for example, dacitic pyroclastic rocks appear to be more widespread than do the basaltic types. Even such generalizations are open to considerable doubt as differences may be more apparent than real because of the relatively small number of pyroclastic rocks that have been studied under the microscope.

PELUDA VOLCANIC MEMBER

The volcanic and sedimentary rocks that are exposed in three small areas in the southwestern part of the La Burra Basin are herein named the Peluda volcanic member, after the locality of La Peluda. The Peluda volcanic member is tentatively considered to be a member of the Cobre formation. It forms a distinct mappable unit separated from younger Cobre rocks by an unconformity.

The best development of the Peluda volcanic member is around La Peluda, where the rocks underlie an area of about 4 square kilometers. Isolated outcrops are exposed on the Río Jagua, 1.5 kilometers west-northwest of Sabana la Burra, and southwest of La Peluda, where a narrow arcuate belt of these rocks borders the southward projection of the La Burra Basin. These rocks have not been recognized elsewhere, but rocks of the same age may be present in such areas as in the Río Joturito valley, in the Sumidero Basin, and possibly also in the southern Santiago Basin and Sierra Maestra.

The total thickness of the Peluda volcanic member is not determinable for the rocks are overlain unconformably or disconformably by, and are overlapped by, volcanic rocks and interbedded limestone of the Cobre. The maximum exposed thickness is about 600 meters. The Peluda rocks in turn unconformably overlie interbedded conglomerates, sandstones, and shales equivalent to the Picote member of the Habana(?) formation. Toward the north edge of the La Burra Basin, the Peluda volcanic member thins and pinches out between the converging surfaces of unconformity.

The area underlain by the Peluda volcanic member is one of low, gentle relief; some of the low ridges and hills are formed by resistant beds but the rocks show less relief than the surrounding Cobre rocks. In contrast to the underlying Habana(?) rocks the Peluda rocks are not deeply weathered, but they are highly altered.

The Peluda volcanic member consists of andesitic to basaltic pyroclastic rocks, minor lava flows, and minor interbedded lenses of limestone. Over 90 percent of the rocks are greenish gray to green, massive to poorly bedded, highly altered tuffs that are in part limy, especially near the beds of limestone, and are made up of angular ejecta commonly less than one centimeter in diameter. Many of the fragments are composed of dense, gray, reddish-gray, or green, soft claylike material that appears to be altered glassy lava, although the rocks also contain grains of fresh feldspar. The scarcity of fresh fragments of lava in much of the tuff of the Peluda is in distinct contrast to the overlying younger tuffs of the Cobre which, even where intensely altered, contain many relatively unaltered fragments of lava.

Agglomerates have been found only in the southern part of La Peluda area, where they are associated with lava flows. They are massive rocks composed of crudely rounded ejecta of fresh, dark-gray, highly vesicular lava as much as 20 centimeters in diameter, and lie in a matrix of light brownish-gray altered tuff.

The only flow rocks observed in the Peluda volcanic member are those associated with the agglomerates. An area of about 1 square kilometer is underlain by at least two lava flows, each a few meters thick, that are intercalated in tuffs and agglomerates and are traceable to irregular dikes. The flow rocks are dark gray, highly vesicular, very glassy, and exhibit well-developed flow structures. The rocks are similar to the coarse constituents of the surrounding agglomerates. The intrusive rocks are also similar but show fewer and smaller vesicles; in places they are well exposed and show a contact selvage of black fresh glass as much as 10 centimeters wide.

Microscopic study reveals that the Peluda rocks are andesitic to basaltic in composition. The tuffs consist largely of a pale-brown montmorillonite clay mineral which is in part replaced by later blue-green celadonite(?), to which the rocks owe their greenish color. Zeolite and celadonite(?) fill cavities in the clay. Most of the cavities in the tuff fragments are less than half a millimeter in diameter and are well rounded; they appear to be vesicles that were filled during the process of alteration of the fragments. Presumably the mafic minerals, if they were present originally, have been replaced by later minerals, as none were seen in the rocks, but fragments of plagioclase (sodic labradorite) are a common minor constituent.

Specimens of lava were also collected and studied under the microscope. One specimen of greenish-gray, glassy rock, which shows numerous vesicles elongated parallel to the conspicuous flow layering, was collected from a point about 200 meters from the nearest exposed source of intrusive rock. The rock shows sparse unzoned plagioclase phenocrysts (calcic andesine), as much as 0.5 millimeter in length, set in a trachytic groundmass of devitrified glass and palagonite with numerous laths of plagioclase. Numerous crystals of magnetite, the largest 0.1 millimeter in diameter, are scattered through the groundmass. Some of the vesicles in the rock are a centimeter in length and are partly lined with celadonite(?) and later zeolite that encrusts the celadonite(?). Many microvesicles are completely filled with palagonite, celadonite(?) and quartz, or celadonite(?) and zeolite. Specimens collected from the intrusive masses are similar in composition but the plagioclase phenocrysts are a little more calcic (sodic labradorite), and rare augite phenocrysts were recognized. The flow and related intrusive rocks appear therefore to be basaltic andesites or basalts.

Grayish-white, fine-grained limestone, commonly a breccia containing angular fragments of limestone and volcanic debris but massive in places, occurs in the pyroclastic rocks as lenticular beds with a maximum length of 1.5 kilometers and a maximum thickness of 12 meters. The limestones are more resistant to weathering than the enclosing tuffs and commonly stand out as conspicuous ledges and blocks. Seven lenses are shown on the map, and others, not shown, are known to occur not only in La Peluda area but in the other areas underlain by Peluda rocks. One limestone lens that is not shown lies a few meters stratigraphically above the flows of the Peluda. Corals, fragments of rudistids, and poorly preserved Foraminifera have been found in the limestone breccias and also in the massive facies of the limestone.

The bulk of the pyroclastic rocks of the Peluda appears to be water laid, or to have been laid down on a land surface only slightly above sea level, judging by the presence throughout the sequence of beds of limy tuffs and associated limestone breccias and limestones that are believed to be shallow-water deposits. The flows have a local source as they are traceable into intrusive rocks; moreover the associated massive agglomerates indicate the close proximity of a vent that could well have been the source of the Peluda rocks. Source vents for the Cobre rocks younger than the Peluda are believed to lie east and west of the Peluda area. It seems probable, therefore, that the unconformity between the Peluda and overlying younger volcanic rocks represents a hiatus between different sequences of volcanic rocks, each having a different source, such as would be expected in an oceanic volcanic area having numerous active vents. Local tilting and beveling of deposited debris would be likely to occur in such an area.

Logically, then, the Peluda volcanic member should be considered part of the Cobre formation, but correlation of the Peluda rocks with Cobre rocks is uncertain in view of the faunal evidence which does not demonstrate conclusively that the Cobre formation includes rocks of comparable age. Keijzer, who first studied the Peluda rocks, considered them to be of Danian and Montian age because he found the calcareous alga *Terquemella,* a genus found in Danian and Montian beds in western Europe, in them (locality K228), and correlated the Peluda rocks with calcareous pyroclastic rocks of the Cobre southeast of Palmarito where he found the same alga (localities V331 and

V332, Keijzer, p. 68–72, 1946). It is possible that the rocks in the Palmarito area are not equivalents of the Peluda, because rudistids, which are commonly considered by geologists to have died out at the end of the Maestrictian, have not been found in the limestone beds there, and because the bulk of the pyroclastic rocks there evidently is dacitic, whereas the Peluda rocks appear to be mainly andesitic to basaltic. Moreover the rocks differ in type and intensity of alteration. If, however, the calcareous algae in the Peluda area came from the upper part of the exposed section of rocks above the rudistid-bearing reef limestones, as appears to be the case, then this section may well be equivalent to the oldest rocks in the Palmarito area. If this be true, then the unconformity over the Peluda rocks is either absent in the Palmarito area, and is therefore a local feature in the Peluda area, or it is to be correlated with the unconformity near Manganeso in middle Eocene rocks of the Cobre in the Palmarito area.

LIMESTONES

The upper 2,500 meters of the Cobre formation contains an appreciable amount of limestone, much of which is highly tuffaceous. The limestones and tuffs of the Cobre commonly are interbedded and grade laterally and vertically into each other (see fig. 29), but in places the vertical change from tuff to limestone is abrupt. The limestones of the Cobre formation are lenticular and their outcrops range in size from a few meters in length and several centimeters in greatest thickness to important rock units many kilometers in length and as much as 150 meters thick. The Charco Redondo limestone member, at the top of the Cobre formation, is the most important of these lenticular limestones. We have named the only other limestone lentil of areal importance stratigraphically lower in the formation; a few of the others were mapped and are locally noteworthy.

Thin-bedded limestones of the Cobre formation are dense, flaggy, and more tuffaceous than the thick beds, which are massive, open-textured, and usually contain algal and foraminiferal remains. Some of the massive limestones are partly or wholly crystalline in places. Tuffaceous material is an important constituent in some places, and occurs as fine to coarse grains scattered through the limestone, or less commonly as fragments. A few of the limestones have a basal conglomerate of angular to rounded tuff and limestone fragments. On the south flank of the Sierra de Nipe this type of conglomerate in the Charco Redondo limestone member also contains fragments of igneous rocks. In some places the limestones of the Cobre formation contain intraformational conglomerate.

Limestone outcrops are widespread throughout the exposures of the Cobre in the area mapped. In the Sierra Maestra, the limestone outcrops are concentrated on the lower northern slopes in a belt 80 kilometers long between the Río Contramaestre in the western part of the area and the Río Baconao in the eastern part. These limestones are interbedded with tuff and some agglomerate across as much as 15 kilometers of outcrop from north to south between Palma Soriano and the upper Río Cañas. In the Cauto-Guantánamo Lowlands, the upper limestones of the Cobre formation crop out in very restricted domical areas such as the Santa Cruz, El Aura, Ponupo-Mucaral, and Cuatro Caminos domes and the small dome 1 kilometer northeast of Central Algodonal, where the overlying San Luis formation has been eroded away. Limestone outcrops of the Cobre formation are very extensive in the Nipe-Cristal Highlands south of the Central Massif.

A dark-brownish, massive, tuffaceous limestone about 1,800 meters stratigraphically below the top of the Cobre formation crops out about 13 kilometers south of Mafo; it was traced eastward to the Río Contramaestre, across the river, and then southward along the east bank for 1 kilometer.

Another limestone, about 12.5 kilometers south of Mafo and about 1,900 meters stratigraphically below the top of the Cobre formation, was traced northeastward (locality 58) for 1.5 kilometers along the west bank of the Río Contramaestre. Possibly the same bed, a gray, highly tuffaceous limestone about 1.5 meters thick, crops out on the east bank of the Río Contramaestre and was traced for 3 kilometers southeastward (locality 59) along the north side of the Río Rico valley.

An impure, highly tuffaceous, gray limestone is exposed for 4 kilometers around the north flank of the Manacas dome. It ranges from massive limestone breccia 5 meters thick in the southeastern part of the outcrop through dense, fine-grained, thin-bedded, impure limestone near the Río Caney, to more than 20 meters of interbedded tuffaceous limestone and limy tuff west of the Guadalupe mine. Limy tuffs with minor thin-bedded tuffaceous limestones near El Sur may have the same stratigraphic position, about 2,000 meters below the top of the Cobre formation. West of the Guadalupe mine, the interbedded limestone and tuff sequence is separated from the Manacas dacite porphyry by some tens of meters of tuff, but these pyroclastic rocks thin eastward, and the massive breccia facies lies directly upon the dacite porphyry (locality 60). The breccia fragments are white fossiliferous limestone cemented by fine-grained gray limestone, and part of the breccia is highly recrystallized.

Thin-bedded, very impure limestone 3 to 5 meters thick crops out on both sides of the Río Caney 1.5 kilometers northeast of the Manacas dome; it overlies 15 meters of very limy tuff.

Near Hóngolosongo, and just west of the Río Cañas, several zones of impure limestone interbedded with tuff and tuffaceous clastic rock were mapped (localities 61–66). One of the outcrops, a very impure, partly conglomeratic, brown limestone from 1 to 10 meters thick, was traced for 4 kilometers. The other limestone zones are conglomeratic in part, and range from 1 to more than 15 meters in thickness, and from gray to brown in color.

The Uraguá dome is in part capped by and almost completely flanked by a sequence of interbedded and interfingering limestones and tuffs (localities 68–70). The limestones are in part gray to white, fossiliferous, cavernous rocks, and in part darker, tuffaceous limestones; the tuffs are somewhat limy. One section (localities 69–70) about 100 meters thick consists of tuffs interbedded with four limestone beds, whose thickness is from 4 to 20 meters; this 100-meter sequence is intercalated in tuff and agglomerate.

Outcrops of impure limestone interbedded with limy tuff were also mapped (locality 67) between the Hóngolosongo area and the Uraguá dome, and are separated from these two areas by observed and inferred faults; this intervening section may therefore repeat part of one or parts of both of the adjoining sections.

Isolated outcrops of two limy zones were observed in the lower part of the Cobre formation from 3 to 4 kilometers south-southwest of El Cobre (localities 71–72). Of these, the lower (locality 71), estimated to be about 2,500 meters below the top of the formation, is a bed of apparently intraformational limestone breccia at least 8 meters thick, intercalated between agglomerates. The higher (locality 72) is a zone of interbedded limy tuffs, limy shales, and impure, highly tuffaceous limestones.

A zone of very impure foraminiferal limestone interbedded with tuff crops out 3.5 kilometers east-northeast of El Cobre (locality 111). Discontinuous outcrops of reef limestone as much as 8 meters thick 5½ kilometers east-northeast of El Cobre (locality 112) and a similar limestone which crops out at the foot of Pelado Ridge (locality 114) occupy approximately the same stratigraphic position, slightly higher than locality 71, and several hundred meters higher than the Cuabitas limestone lentil.

All of the limestones discussed in the foregoing paragraphs occur in the lower part of the Cobre formation, and are estimated to be from 1,800 to 2,500 meters below the top of the formation. Sierra Maestra batholithic rocks were observed in contact with volcanic rocks of the lower part of the Cobre formation 3 kilometers southwest of locality 61, and 1.5 kilometers south-southwest of locality 71. The highest batholithic rocks, stratigraphically, at locality 71 are estimated to be about 4,000 meters below the top of the Cobre formation and about 1,500 meters below the dated limestone breccia at locality 71.

CUABITAS LIMESTONE LENTIL

A 15-meter thick limestone, here named the Cuabitas limestone lentil of the Cobre formation, crops out in a quarry in the northern outskirts of the town of Cuabitas (locality 120), from which the name was derived. Outcrops of limestone and limestone breccia in the same stratigraphic position along the strike for 4 kilometers to the southwest of the Cuabitas quarry (localities 118 and 119) and 5 kilometers to the east (localities 121 and 122) indicate an extensive lentil estimated to be at least 2,000 and possibly as much as 3,000 meters below the top of the Cobre formation (pl. 19). The Cuabitas limestone lentil is intercalated in a volcanic sequence of pyroclastic rocks, tuffaceous shales, and amygdaloidal lava.

In the outcrops of Cobre in the Fringing Uplands south of the Sierra de Nipe, Keijzer (1945, p. 72, localities V331–V332) found "partly silicified limestones" intercalated in tuffs about 3.5 kilometers east-northeast of Palmarito; these limestones may possibly be the stratigraphic equivalents of the Cuabitas limestone lentil, to judge from meager and questionable faunal evidence. Other possible, but improbable, equivalents are the limestones and limestone breccias observed by us at localities 235–241, and by Keijzer (1945, p. 69) at locality K228 from 0.5 to 2 kilometers southwest of La Peluda. These limestones are associated with tuffs, tuffaceous clastics, and lava, all stratigraphically lower than the recognized Cobre rocks.

Several dozen limestones that were mapped are intermediate in stratigraphic position between the lower limestones of the Cobre formation and the Charco Redondo limestone member at the top. These intermediate limestones of the Cobre are from 200 to 1,500 meters below the top of the formation, and are most conspicuous in Boniato Ridge and the Boniato Piedmont of the Sierra Maestra Highlands, and in the San Nicolás Hills of the Nipe-Cristal Highlands. Most of these limestones do not warrant specific mention; commonly they are flaggy and tuffaceous, and are interbedded with and grade into limy tuffs.

A few do merit individual description: For 7 kilometers from west to east (localities 75, 113), a foraminiferal limestone 1 to 6 meters thick crops out in a zone of tuffaceous limestone, limy tuff, and tuff at or near the top of Boniato Ridge at its western end, 2 kilometers north of El Cobre.

At the María and El Tesoro prospects 5 kilometers northwest of El Cobre, a foraminiferal limestone 1 to 3 meters thick crops out in gray to green well-bedded tuff. The limestone is conglomeratic, and contains fragments of limestone and volcanic rocks. It was traced for 3.5 kilometers northeastward (localities 77–78). Somewhat lower stratigraphically is a limestone that crops out at the Piedra Pisada prospect 5 kilometers north of El Cobre (locality 79), where the massive limestone is whitish-gray to gray in color. To the northeast the limestone is largely replaced by jasper and was traced for 2.5 kilometers (locality 81).

The limestone at the Boston manganese mine (locality 138), 3.6 kilometers east-southeast of El Cristo, is not impressive as it is only 30 centimeters to a few meters thick. But it has especial historical interest because this mine was the first to be worked for manganese in Oriente, beginning about 1887 according to Hayes, Vaughan, and Spencer (1901, p. 62). This was one of the first localities in Oriente

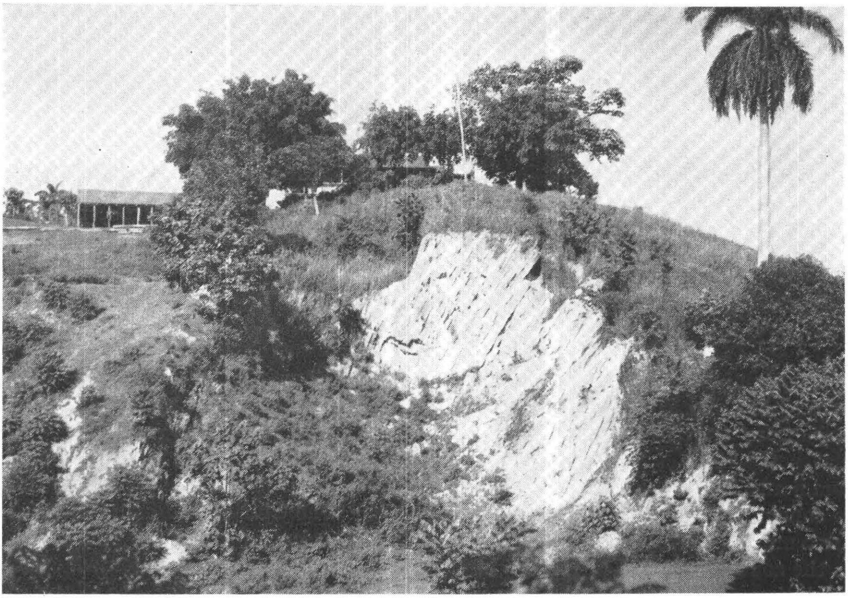

FIGURE 31.—Overturned, south-dipping Charco Redondo limestone exposed in quarry just south of El Cristo and west of Boniato-Alto Songo highway. Contact with San Luis formation is along right wall of quarry; contact with Cobre pyroclastic rocks of the formation is along west quarry wall and overgrown with vegetation.

where Eocene rocks were identified. The limestone is a densely packed mass of orbitoid Foraminifera (*Discocyclina crassa,* the characteristic species of the middle Eocene of Oriente, whose type locality is here) in a matrix of tuffaceous limestone speckled green by celadonite(?). The thin limestone overlies an ore-bearing zone of jasper and is overlain by tuff.

Mogote San Nicolás, 3 kilometers southeast of Palmarito (locality 230), is capped by a remnant of gray-white, massive, cavernous limestone 600 meters long and about 25 meters thick, similar to massive limestone of the Charco Redondo member. The limestone cap rock, formerly more extensive, may once have been continuous with the limestone whose outcrop 1 kilometer southeast of Palmarito (locality 229) was traced for 2 kilometers on the west flank of the dome, or with one or more of the other limestones of the Cobre which crop out around the flanks of the dome. These limestones may represent tongues of the main body of the Charco Redondo limestone or may be stratigraphically equivalent lenses. However, they lie below the intraformational unconformity at Manganeso and therefore cannot be correlated definitely with the Charco Redondo limestone member.

CHARCO REDONDO LIMESTONE MEMBER

The widespread limestone beds and zones of lenticular limestones in the uppermost part of the Cobre formation are herein correlated with the Charco Redondo limestone named by Woodring and Daviess from the type locality at the Charco Redondo mine in the Guisa-Los Negros area, and are considered, as a unit, to be a member of the Cobre formation. Because of the great thickness and broad expanse of outcrop of limestone at the top of the Cobre formation as described by Taber, and because of its association with important manganese deposits, Woodring and Daviess (1944, p. 367–368) described the Charco Redondo as a formation distinct from the rest of the Cobre in the Guisa-Los Negros area.

> The dominantly volcanic rocks to which the name Cobre volcanics is here applied are overlain by limestone that, though included by Taber in his Cobre formation, constitute a well-defined, economically important unit * * * In places the contact is gradational through a zone of calcareous tuff, but more commonly it is marked by an abrupt change from tuff to limestone, or from tuff to conglomerate with a calcareous matrix * * * The Charco Redondo limestone has a maximum thickness of about 150 meters in the central part of the area * * * in the south-central part, the top of the formation is not now represented. The formation thins westward, eastward, and northward. West of the Bayamo River * * * the upper part grades into thin-bedded limestone and marl mapped with the overlying San Luis formation, and the lower part probably grades into the volcanics of the Cobre * * * Toward the east the lower part of the Charco Redondo limestone is interpreted as fingering into Cobre volcanics.

Taber defined the overlying San Luis formation as differing "from the Cobre formation in being composed mainly of sedimentary, rather than pyroclastic, rocks" (1934, p. 384). Woodring and Daviess described and mapped rocks southwest of Mafo, at the eastern edge of the Guisa-Los Negros area, as overlying the Charco Redondo limestone member, and assigned these rocks to the San Luis formation (1944, p. 375):

> The lower part of the formation—that underlying a zone of limestone shown on the geologic map—consists principally of tuff and calcareous tuff * * * This unit of volcanic rocks has a maximum thickness of about 300 meters, but it thins rapidly westward * * * In the Mafo Lowland strata overlying the mapped limestone zone include thin beds of * * * tuff and marly tuff, as well as * * * tuffaceous sandstone.

This would suggest that this "tuff and calcareous tuff" and the overlying "mapped limestone zone" belong to the Cobre rather than to the San Luis formation, and finger or grade laterally into the Charco Redondo rocks to the west. We therefore traced the "mapped limestone zone", 5 to 10 meters thick, from the Sorpresa mine area to its westernmost outcrop as mapped by Woodring and Daviess. The outcrop continues 5.4 kilometers further westward to the Baire-Charco Redondo road, 1.5 kilometers southwest of Baire, where it passes into a zone, 10 meters thick, of interbedded tuff and limestone which directly overlies the massive Charco Redondo limestone mapped by Woodring and Daviess. This zone of interbedded tuff and limestone may be equivalent to a similar zone at the top of the Charco Redondo limestone in the type locality. Although seeming continuity was thus suggested between the "limestone zone" mapped by Woodring and Daviess and the main body of the Charco Redondo limestone, no field evidence was found either by Woodring and Daviess or by us to show such interfingering or gradation between the "tuff and calcareous tuff" and the underlying massive Charco Redondo limestone southwest of Mafo.

However, we did trace the "tuff and calcareous tuff" across the Río Contramaestre and along the strike into typical, mainly pyroclastic rocks of the Cobre which crop out continuously to the eastern edge of the area. The "mapped limestone zone" was also traced across the Río Contramaestre and eastward along the strike to the Río Baconao and beyond; it is 10 to 30 meters thick except for two gaps adjacent to which the "mapped limestone zone" thins to knife edges. One of these gaps, 1.8 kilometers long, is 4 kilometers west of Caney del Sitio; the other is just east of the Quinto mine area, and is 4 kilometers long. In these two gaps, the San Luis rocks directly overlie the pyroclastic rocks of the Cobre with no Charco Redondo limestone member present. The massive limestone in the Loma La Gloria dome of the Guisa-Los Negros district, and the interbedded tuff and limestone in the Los Negros Valley are downfaulted against pyroclastic rocks of the Cobre, and do not continue east of this fault or across the Río Contramaestre.

The stratigraphic sequence from older to younger rocks everywhere across the 80-kilometer stretch eastward from 0.5 kilometer south of Mafo to the Río Baconao is: typical pyroclastic rocks of the Cobre overlain almost everywhere by lenticular bodies of limestone and zones of limestone interbedded with pyroclastic rock, similar to the nonmassive Charco Redondo limestone of the Guisa-Los Negros area. These lenticular limy bodies and the underlying pyroclastic rocks between their knife edges are both overlain by typical rocks of the San Luis formation (fig. 28). The lenticular limy bodies commonly grade into the overlying San Luis rocks and the underlying pyroclastic rocks of the Cobre. Because of the nature of the foregoing rock units and the relations between them, they are here described for the Sierra Maestra Highlands, from older to younger rocks, as the Cobre formation, including the Charco Redondo limestone member of the Cobre formation, and the San Luis formation. The same procedure is followed in text and map as regards the prominent limestone at the top of the Cobre formation and below the San Luis formation in the southwestern Nipe-Cristal Highlands between the Río Cauto and the Río Jarahueca and Río Mayarí.

Taber's descriptions (1931, p. 537–538; 1934, p. 577–578, 580, 584) give a good idea of the character and distribution of the volcanic rocks and limestones of the Cobre and their relation to each other in the eastern Turquino Range:

> The most abundant and widely distributed rocks are * * * volcanic clastics * * * In addition to being well stratified, * * * except where coarsest, * * * these rocks are interbedded with limestones, and in places grade into them * * * The tuffs * * * are commonly calcareous and show all gradations into * * * limestone * * * In the series as a whole, lava flows probably constitute less than five per cent of the rocks * * * In the area immediately west of Santiago limestones constitute perhaps three per cent of the lower part of the formation, but in the upper part the proportion increases to as much as twenty per cent * * * The San Luis formation rests unconformably on the Cobre.

The Charco Redondo limestone member is here treated as one of those limestones of the Cobre which "constitute***as much as twenty per cent" of the upper part of the Cobre formation; other mapped limestone lenses within this part, where not known or inferred to be continuous with the Charco Redondo limestone member, are not identified with it or given other individual names.

The widest outcrops of the Charco Redondo limestone member in the Sierra Maestra Highlands are in the Boniato Piedmont between the Río Bellaco and Río Yarayabo. Near the Río Yarayabo 10 kilometers west-southwest of San Luis, the lower 15 meters of the Charco Redondo limestone member is dense, even bedded, and weathers to a whitish-gray color; the upper part is limestone with minor interbedded shaly limestone. The lower part grades downward into limy tuffs of the Cobre; the upper part grades upward into the San Luis formation (fig. 28). Along the Río Grande 4 kilometers east of the Río Yarayabo, there is an abrupt contact between the well-bedded, white to gray Charco Redondo limestone member and the underlying agglomerate of the Cobre, which contains subrounded to angular ejecta as large as 15 centimeters in diameter. Grayish-white, bedded limestone 9 to 12 meters thick overlies a zone, 12 meters thick, of interbedded tuffaceous limestone and limy tuff in the outcrops that are mapped as the Charco Redondo limestone member 8 kilometers north of Boniato. These beds grade downward into limy tuff of the Cobre, and upward into brown limy shale of the San Luis formation.

On the backslope of Boniato Ridge 3 kilometers north of Boniato, the bedded, impure Charco Redondo limestone member is 20 to 30 meters thick, and is underlain by coarse tuff of the Cobre. The Charco Redondo limestone member crops out at the eastern end of Boniato Ridge southwest of El Cristo and has a greatest thickness of 35 meters. Here, a zone of massive, grayish-white limestone is interbedded with fine-grained, flaggy, whitish-gray limestone, and overlies a basal brown, tuffaceous limestone. The relation to the underlying Cobre rocks ranges from a sharp contact with tuff to a gradation downward through limy tuff to green tuff. Limy shale, sandstone, and marl of the San Luis overlie the Charco Redondo limestone member here. In the Quinto mine area, the Charco Redondo limestone member is lenticular, thin bedded and flaggy. It ranges from a knife edge to 11 meters thick, and grades upward into limy shale of the San Luis, but the contact with the underlying tuff of the Cobre is abrupt.

Bedded Charco Redondo limestone member that weathers grayish white crops out for at least 15 kilometers along the strike in Baconao Ridge, and forms the back slope of this long hogback. At one place where the Río Baconao is superposed across the ridge (locality 211, fig. 25), the bedded limestone is about 60 meters thick, and grades downward through bedded tuffaceous limestone and 3 meters of basal limy tuff to a sharp contact with the underlying agglomerate of the Cobre.

The Charco Redondo limestone member is exposed in the Santa Cruz, Ponupo-Mucaral, Cuatro Caminos, and El Aura domes of the Cauto-Guantánamo Lowlands. At the small Santa Cruz dome, bedded limestone 12 meters thick overlies green tuff and tuffaceous limestone of the Cobre formation, and is overlain by limy shale of the San Luis. Lenticular limestones at the Ponupo-Mucaral domes range from a knife edge to more than 9 meters thick; sharp contacts separate the massive lower parts of these lenses from the underlying tuff of the Cobre formation, but the thin-bedded upper parts grade upward into limy shale of the San Luis. Similar relations exist in the southern part of El Aura dome, where lenses of the Charco Redondo limestone member range from a knife edge to 15 meters thick. The Charco Redondo limestone member was not seen at the Jutinicú dome, where the San Luis formation rests directly on tuff and limy tuff of the Cobre.

Massive Charco Redondo limestone member, like that in the type region, is best developed in the Nuevo Mundo Karstland of the Fringing Uplands south of the Sierra de Nipe. In the area of the Valle de Manganeso mine, 6 kilometers east-northeast of Nuevo Mundo, the massive, cavernous, grayish-white limestone is about 50 meters thick, overlies tuff and agglomerate of the Cobre formation at a very sharp contact, and represents only the lower part of the member;

the upper part, a flaggy and thin-bedded facies preserved in nearby areas, has been eroded away, and the original maximum thickness is not known. The Charco Redondo limestone member is 24 meters thick in the area of the Esperancita mine, 4.5 kilometers west-northwest of Nuevo Mundo. Here again, the top of the member has been eroded away, and although the uppermost few meters are well-bedded, most of the limestone is massive, cavernous, grayish-white rock separated from the underlying tuff of the Cobre formation by a sharp contact.

The Charco Redondo limestone member in the area of the Corinto mine, 2.4 kilometers east of El Iris in the eastern Florida Blanca Plateau, is 45 meters thick; the lower 10 to 15 meters is massive limestone in sharp contact with the underlying tuff of the Cobre formation, but the upper part is thin-bedded, and grades upward into limy shale of the San Luis.

North and southeast of Manguitos in the eastern San Nicolás Hills, the pyroclastic rocks of the Cobre formation finger into and are interbedded with the Charco Redondo limestone member so intimately that the relations of these rock units had to be shown diagrammatically on the map. The following sequence from the top downward shows the nature of the uppermost part of the Cobre formation 2 kilometers north-northwest of Manguitos:

Section north-northwest of Manguitos

	Meters
Eroded ground surface:	
San Luis formation:	
Shale, limy.	
Limestone, shaly; thin-bedded	2
Cobre formation:	
Tuff, limy, green; conformable, graded contact with San Luis formation	43
Charco Redondo limestone member, massive, grayish-white, cavernous, fossiliferous	3
Tuff	26
Charco Redondo limestone member, bedded, impure, tuffaceous	5
Tuff	6
Charco Redondo limestone member, massive, gray, cavernous	6
Tuff.	

Interbedded tuff makes up at least 50 percent of the rocks mapped as Charco Redondo limestone member in the La Gloria district 5 kilometers north of Manguitos. A massive limestone bed 10 meters thick overlies pyroclastic rocks of the Cobre formation with sharp contact at the Jesús Segundo mine; the basal part of this bed is a limestone matrix that contains boulders of diorite and gabbro with a greatest diameter of 50 centimeters. As much as 70 meters of interbedded tuff and limestones 0.5 and 3 meters thick are estimated to intervene between the basal part of the member, at the Jesús Segundo mine, and the uppermost 20 meters, in the Polaris and La Gloria mine areas; the proportion of limestone is greater in this uppermost zone, which grades upward into the San Luis formation.

Bedded limestone predominates in the upper part of the exposures of the Charco Redondo in the Pedernal Karstland and Marginal Hogbacks, but the lower part is massive and cavernous; this cavernous, massive facies is best exposed around the flanks of the Central Massif of the Sierra de Nipe.

Areas where the Charco Redondo limestone member is thick and massive show the various stages of erosion in soluble rocks: That part of the Nuevo Mundo Karstland just south of Nuevo Mundo is in the initial stage; the clastic-bearing San Luis formation overlies and protects the Charco Redondo limestone member, and surface streams drain the area. The Pedernal Karstland and the rest of the Nuevo Mundo Karstland are mostly in the young and mature stages, with typical features of both stages irregularly distributed; some tracts have funnel sinks and some surface streams; other tracts have underground streams, steep-sided solution valleys, and caves (figs. 26, 44). The southern Florida Blanca Plateau is the best example of the stage of old age with residual features; Terra Rossa several meters thick mantles the plateau surface between craggy, butte-like limestone remnants. In detail, solution carves the surface of the massive limestone into bizarre pits and pinnacles known locally as diente de perro (dogtooth); scanty residual clays in the pits support the heaviest forest of the region. The rugged karstland topography, the jagged diente de perro, the dense forest, and the tangled, thorny undergrowth combine to make the terrain almost impassable where it is not cleared, burnt over, or penetrated by trails.

ROCKS OF UNDETERMINED STRATIGRAPHIC POSITION

At locality 212 on the Siboney road about 5 kilometers east of Santiago Bay, dense gray fossiliferous limestone is intercalated in nearly horizontal altered andesitic flow rocks. The limestone contains abundant shell fragments and pieces of pentagonal crinoid stem ossicles, but no diagnostic fossils were found at this locality. These outcrops are surrounded by Quaternary alluvium and by rocks of the La Cruz formation; their subsurface continuity and identity with known formations are therefore uncertain. It is suggested that these rocks of undetermined stratigraphic position may be referable to the lower part of the Cobre formation, but it is possible that they are a part of the Vinent formation or of some other formation not described to date.

FOSSILS

FORAMINIFERA

The larger Foraminifera are the commonest fossils found in the Cobre rocks. Woodring and Daviess (1944, p. 366, 372) found larger Foraminifera at 23 localities in the Charco Redondo limestone member, and at 7 localities in the Cobre formation below the Charco Redondo limestone member. We collected them at 76 localities of the Cobre, distributed stratigraphically as follows: lower limy beds, 21 localities; middle limy beds, 36 localities; Charco Redondo limestone member, 19 localities. Mr. de Albear's identifications are listed in table 1. He identified 16 genera which comprise 41 species in the Cobre fauna; 12 genera were found at 5 or more localities. *Discocyclina* is the commonest genus: specimens of it were found at 68 localities; specimens of the most abundant species, *Discocyclina* (*Discocyclina*) *crassa* (Cushman), were found at 27 localities. Woodring and Daviess did not find *Lepidocyclina* below the Charco Redondo limestone, but judged that it might be found in the underlying part of the Cobre after further collecting (1944, p. 366): we found *Lepidocyclina* (*Polylepidina*) at 2 localities, and a specimen referred to this genus at a third locality, in the middle limy beds. Further collections in the Cobre may well revise our present conclusions, but, insofar as can be judged from known collections at this time, the Cobre fauna in the south-central Oriente area is distributed stratigraphically as in table 1.

The lower limy beds have a less abundant fauna than the middle limy beds and the Charco Redondo limestone member, with about half as many genera and only a quarter as many species. The new unnamed species of *Discocyclina* (*Discocyclina*) is confined to the lower limy beds in the Turquino Range, except for a single questionable specimen that was found low in the middle limy beds but may have been redeposited.

The collection of Foraminifera from the Peluda volcanic member was studied by Mrs. Palmer, and her determinations are included in the table.

The following compilation of Foraminifera found and identified by Keijzer (1945, p. 69–73, 110–111) is given because his information on larger Foraminifera is supplementary to ours, and because he cites four assemblages of smaller Foraminifera which yield additional stratigraphic information.

ALGAE

The fossils ranking next in abundance in the Cobre rocks to the Foraminifera are calcareous algae. Calcareous algae are of frequent occurrence throughout the limy beds of the entire formation, and are the commonest fossils of the lowermost limestones and limy beds. The calcareous algae collected by us were not identified, with the single exception of a Dasycladacean included with the coral identifications made by Mr. Wells (p. 240). Paleontologic and stratigraphic research on the algal flora of the Cobre should yield very worthwhile results. Keijzer attached considerable significance to the calcareous algae which he and his colleagues collected. The results of his research (1945, p. 175–184) are abridged in the following table:

Algae (and coral) of the Cobre formation

[Identifications of genera and species and determination of ages by Keijzer (1945) with his locality numbers. Stratigraphic names are those used in the present report.]

	Tuff of Peluda volcanic member	Cuabitas limestone member	Lower limy beds		
	Danian-Montian				Paleocene or lower Eocene
	K228	W345	V331	V332	W339
Dasycladaceae					
Brookella belgica Morellet	----------	----------	----------	×	----------
Terquemella sp. II Keijzer	×	×	×	×	×
Solenoporaceae					
Parachaetetes asvapatii Pia	----------	×	×	×	----------
Corallinaceae					
Mesophyllum sp	----------	×	----------	----------	----------
Indeterminate "Lithothamnidae"	----------	----------	×	----------	----------
Indeterminate meandroid coral	----------	----------	×	----------	----------

Additional Foraminifera of the Cobre

[Determinations of genera, species, and ages by Keijzer (1945), with his locality numbers. Stratigraphic names are those used in present report.]

	Tuff of Peluda volcanic member	Lower limy beds					Middle limy beds
	Danian and Montian	Paleocene (?) or lower Eocene			Lower Eocene		Middle Eocene
	K228	W339	T1058	T1059	V335	V336	T1064
Dictyoconus americanus (Cushman)							?
Vaughanina cubensis Palmer	?						
Amphistegina lopeztrigoi Palmer							×
Helicostegina sp							×
Discocyclina small sp		×			×		
(*Discocyclina*) sp							×
(*Asterocyclina*) *monticellensis* Cushman and Ponton							×
sp				×			×
Pseudophragmina (*Proporcyclina*) *flintensis* (Cushman)							?
Ammobaculites sp							?
Spiroplectammina excolata (Cushman)						?	
Textularia subglabra Cushman			?				
sp							×
Gaudryina sp							×
Pseudoclavulina amorpha (Cushman)						×	
Dorothia retusa						×	
Karreriella chapapotensis (Cole)							×
Massilina sp							?
Nodosaria sp							?
Cristellaria sp						×	
Spiroplectoides sp						?	
Angulogerina sp							×
Bolivina sp							×
Bolivinoides velascoensis (Cushman)						×	
Gyroidina sp						×	
Pulvinulinella culter mexicana (Cole)							?
velascoensis (Cushman)						?	
Globigerina eocaenica Terquem							×
small sp			×	×			
Hantkenina sp							×
Globorotalia aragonensis Nuttall			×				
crassaformis (Galloway and Wissler)						×	
crassata (Cushman)			×				
velascoensis Cushman						×	
Anomalina sp							×
Planulina sp							×

CORALS

Corals are less common than algae, but are found more frequently than any other animal macrofossils. Taber (1931, p. 540) reported the collection of several species of corals from the La Gloria quarry about 4 kilometers northeast of El Cobre; two genera, *Stephanocoenia* and *Cyathophora*, were identified by T. W. Vaughan. We visited a quarry about 4 kilometers northeast of El Cobre, and were told by local residents that it was the only La Gloria quarry known to them in that neighborhood; we were unable to find any additional coral specimens, and the only limestones found were blocks in the pyroclastic rocks of the Cobre formation which crop out at the quarry. Taber's specimens may have come from similar limestone blocks at this place or it is possible that his locality was a different one which we were unable to locate.

Corals occur in limestones throughout the entire formation, but they are least common in the middle limy beds and in the Charco Redondo limestone member. Both calcareous algae and corals are hard to get out of the matrix, and only rarely do they weather free; the corals are poorly preserved as a rule. Mr. John W. Wells identified the corals and made such age determinations or inferences as were possible. His results are quoted in the following table:

Coral (and alga) of the Cobre formation

[Identifications of genera and species, determinations of age, and comments by John W. Wells]

	Stratigraphic distribution and localities								Remarks
	Cuabitas limestone lentil					Lower limy beds	Middle limy beds	Charco Redondo limestone member	
	118	119	120	121	122	112	132	227	
Middle Eocene:									
Stylophora sp. cf. S. sp. A. Wells, 1934						×			From the middle Eocene (Richmond formation) of Jamaica.
Astrocoenia n. sp						×			
trechmanni Wells							×		Occurs in middle Eocene of Barbados.
Indeterminate meandroid faviid coral						×			
Indeterminate solitary coral								×	
Danian or Montain:									
Cladocora n. sp. aff. *C. jamaicensis* Vaughan	×	×	×		×				From the Upper Cretaceous of Jamaica.
Actinacis sp. cf. *A. barretti* Wells	×		×						From the middle Eocene (Yellow limestone) of Jamaica.
Montastrea n. sp. 1	×								May be allied to *M. edwardsensis* Wells. From the Lower Cretaceous of Texas; apparently the same species as at locality 236 in the tuff of the Peluda volcanic member.
Coral indet				×					
Dasycladacean alga				×					

OTHER LARGER FOSSILS

Fossils of the Charco Redondo limestone member, apparently terebratulacean brachiopods, were found associated with echinoid remains at locality 234, but could not be freed from the matrix or identified. Echinoid spines and test fragments were found at several other localities, but could not be identified. Woodring and Daviess (1944, p. 365, 373–374) list several mollusks among their fossils of the Cobre (including Charco Redondo) collected in the Guisa—Los Negros area: *Pseudomiltha*? cf. *P. haitensis* Woodring and Mansfield, *Corbis* cf. *C. claibornensis* Dall, small pelecypods, *Mitreola*? cf. M. *labratula* (Lamarck), *Terebralia*? sp., an ampullinid(?), and a *Campanile*-like nerineid of undetermined genus. Taber found one crab claw which was believed by M. J. Rathbun to be a new species of the genus *Lobonotus* (Taber, 1931, p. 540). Shark teeth are found occasionally in the manganese mines, and are present in several fossil collections from the Cobre formation. We found shark vertebrae associated with teeth at the Quinto mine, and collected shark teeth from other mine areas. J. W. Gidley identified shark teeth collected by Burchard (1920, p. 88) from the Charco Redondo area, as follows: "*Lamna* cf. *L. elegans* . . . *Isurus hastalis*, or very near this species * * * *Carcharodon auricularis*(?)". Mr. de Albear made field identifications of rudistids from localities 235, 240, and 241.

AGE OF COBRE FORMATION

Opinions of age based on Foraminifera.—Hayes, Vaughan, and Spencer (1901, p. 22) assigned an Eocene age to the Cobre rocks:

> The only rocks that we know to be positively of Eocene age in the Island occur * * * not far from the city of Santiago, where they are associated with manganese ores. This information is furnished us by Mr. Wm. H. Dall, who determined some fossils collected by Mr. Clarence King. Associated with the manganese ores in this province are foraminiferal limestones * * * which appear to be of Eocene age.

Later publications also assigned an Eocene age to the Cobre rocks, and this viewpoint was not modified or restricted until Taber described and named the "Cobre series" (1931, p. 537–541). He cited Cushman's (1919, p. 29) determination of an Eocene age, but went on to say (1931, p. 541) that

> the age of the different rocks within this series is somewhat uncertain. The beds at the base of the series are apparently Cretaceous or older, and near the top they are Upper Eocene.

Three years later, however, Taber (1934, p. 576, 580–581) redescribed these same rocks as the "Cobre formation (Eocene)" without reference to his original nomenclature and age assignment:

> The foraminifera found in the lowest levels of the formation, near Santiago, were not identifiable * * * A fauna was found * * * near the junction of the

Arroyo Rico and the Rio Contramaestra * * * Henbest identified *Camerina*, Nullipores (*Lithothamnium*?), *Discocyclina cubensis* (Cushman), and *Dictyoconus* sp. * * * forms that are typical of the Eocene in Cuba. Orbitoidal Foraminifera, probably *Discocyclina*, and other Eocene fossils were collected by D. F. Hewett * * * and identified by T. W. Vaughan and W. C. Mansfield * * * Several species of *Orthophragmina* (*Discocyclina*) have been identified by Cushman in limestones from * * * the manganese mines near Cristo.

Within the last few years there has been renewed interest in the age of the Cobre formation. Woodring (in Cooke, Gardner and Woodring, 1943, p. 1716 and chart 12) considers the Cobre formation to be upper Eocene. Woodring and Daviess, whose collections were restricted to the upper part of the formation, have this to say (1944, p. 366, 374):

Discocyclina crassa is the most abundant fossil from the Cobre volcanics * * * widespread and locally abundant in the Charco Redondo * * * has been found in formations assigned to the upper Eocene in Jamaica, Haiti, and Trinidad * * * *Discocyclina asterisca* * * * is thought to be characteristic of upper Eocene strata in Trinidad and Venezuela * * * *Lepidocyclina pustulosa* has been found in formations assigned to the upper Eocene in Jamaica, Mexico, Panama, Curaçao, Venezuela, and Trinidad.

Keijzer, whose collections represented the lower part of the formation as well as the upper part, assigned a much longer age range to the Cobre formation (1945, p. 70–74, 108–112, 212):

Cobre formation (Upper Cretaceous—Middle Eocene) * * * In the Palmarito subregion * * * a doubtful fragment of *Vaughanina cubensis* * * * was found * * * at Locality K228 * * * The species * * * may be regarded as an index fossil for the Habana formation, where it is of frequent occurrence, together with other species of larger foraminifera indicating a Maestrichtian or older age. But it is still present in * * * the Danian-Montian * * * Locality K228 * * * may be Paleocene * * * Between Puerto de Moya and Santiago * * * south of the fault scarps of * * * Boniato and * * * Pelado ranges * * * we found at localities W339 * * * T1059 * * * T1058 * * * W345 * * * foraminifera and algae [which suggest] a low horizon and may very well be Danian-Montian * * * From the smaller foraminifera at locality T1058, *Textularia subglabra* was originally described from the Tamesí (Velasco) shale of Mexico (Danian), while the abundance of *Globorotalia crassata* and *G. aragonensis* suggests a middle or lower Eocene age. The small Globigerinidae of locality T1059 * * * resemble *Globigerina triloculoides* Plummer, a Midway form, also known from elsewhere in the Paleocene * * * The upper parts of the formation contain a rather uniform assemblage * * * The fauna is indicative for Eocene. Upper Eocene as well as middle Eocene forms are present * * * This, together with the abundance of *Amphistegina lopeztrigoi* Palmer, makes a middle Eocene age the most probable.

Our collections of Cobre Foraminifera were studied mainly by J. F. de Albear, and in part by Dorothy K. Palmer. Mrs. Palmer studied two small lots from localities 238 and 240 that come from the Peluda volcanic member, which are not certainly referable either to the Cobre formation or to the Habana(?) formation but may represent the lowermost Cobre rocks in the Nipe-Cristal Highlands. She states (written communication) that these assemblages

> have been provisionally determined as Upper Cretaceous in age. These samples yielded rather poorly preserved specimens of *Lepidorbitoides?*, *Sulcoperculina vermunti* (Thiadens), and *Vaughanina?*. These forms are characteristic of the upper member of the Habana formation of western Cuba and the same genera have been reported in the Lawson limestone of the subsurface section in Florida.

It is not certain that all three forms were present in both lots. Mrs. Palmer's identifications referred to localities 238 and 240, and also to localities 246 and 247 which are in the Habana(?) formation of the Sabana La Burra area, without discriminating among the four as to content. Mr. de Albear's studies of the larger Foraminifera lead him to assign the following ages to the several parts of the Cobre formation (table 1): lower limy beds, early Eocene; middle limy beds, middle Eocene; Charco Redondo limestone member, middle Eocene, necessarily younger than the underlying middle limy beds but with no determinable faunal age difference. According to Mr. de Albear (oral communication), D. K. Palmer and P. J. Bermúdez concur with him in his opinion as to the above age determinations.

Opinion of age based on calcareous algae.—According to Keijzer (1945, p. 177),

> only a few forms indicate relations with territories outside the West Indian region. All of these originate from the transition beds from the Cretaceous to the Eocene. *Broekella belgica* Morellet is known from the Montian of Belgium and the Eastern Alps * * * *Parachaetetes asvapatii* Pia is also known from the Danian of India, while *Terquemella* sp. II shows much resemblance with *T. lenticularis* from the ?Lower Eocene of the same region. It seems not improbable, that with additional material, more relations with the Cretaceous-Eocene transition beds of India could be established.

The algal evidence would seem to be suggestive rather than conclusive; Mr. Wells noted a Dasycladacean alga associated with the coral fauna of the Cuabitas limestone lentil in our collections that was determined by him as of Danian-Montian age.

Opinions of age based on corals.—Taber (1931, p. 540) collected a few corals at the La Gloria quarry about 4 kilometers northeast of El Cobre, and quotes T. W. Vaughan's report on them as follows:

> Four, perhaps five, species are represented, and these seem to belong to four different genera. One of the genera is *Stephanocoenia*, and another seems to be *Cyathophora*. The presence of *Cyathophora* indicates a Mesozoic age, not younger than middle Cretaceous and perhaps somewhere in the Jurassic.

As noted in the section on fossils of the Cobre, there is a possibility that these specimens came from limestone blocks (pre-Cobre) in agglomerate of the Cobre; however, it is possible that the oldest Cobre rocks may be of latest Cretaceous age. The corals collected by us were studied by John W. Wells; those from the Cuabitas limestone lentil of the lower part of the Cobre were determined as Danian or Montian in age. All the others, including those from the lower limy beds, were determined as middle Eocene in age (p. 240).

Opinions of age based on other larger fossils.—No age determinations have been adduced from fossil brachiopods or echinoids. Woodring and Daviess state (1944, p. 374), as regards the mollusks they collected, that

> *Pseudomilthia haitensis* * * * occurs in the middle Eocene Plaisance limestone of Haiti * * * The unidentified *Campanile*-like nerineid * * * is a representative of a Mesozoic family not found heretofore in the Eocene.

Mitreola labratula (Lamarck) occurs in the middle Eocene of the Paris Basin. Of the genus *Lobonotus*, to which a fossil crab claw collected by Taber is believed to belong, M. J. Rathbun says (in Taber, 1931, p. 540):

> The only described species of the genus are *L. mexicanus* mihi from the upper Eocene of Lower California, and *L. sculptus* A. Milne Edwards from the Oligocene of Haiti.

J. W. Gidley, reporting on the fossil shark teeth from the Charco Redondo area (in Burchard, 1920, p. 88), states that "these teeth seem to be of Cretaceous or Tertiary, probably Eocene age."

Conclusions.—After weighing the foregoing evidence, we conclude that the Cobre formation as recognized probably ranges in age from Paleocene(?) to middle Eocene inclusive, although some of the lowermost Cobre rocks may be of late Cretaceous age. To the Cuabitas limestone lentil and its northern equivalents we assign a Paleocene(?) or early Eocene age; to the lower limy beds above the top of the Cuabitas limestone lentil, an early Eocene age; to the middle limy beds and the Charco Redondo limestone member, a middle Eocene age. Apparently the Peluda volcanic member may be as old as Maestrichtian or as young as Montian. The upper limit of middle Eocene is based chiefly on Mr. de Albear's interpretations; other authorities consider this part of the Cobre and its correlatives to be of late Eocene age.

INFERRED ORIGIN AND CONDITIONS OF DEPOSITION OF COBRE ROCKS

The presence, throughout most of the Cobre formation, of beds of limestone, calcareous tuffs, and siltstones, all bearing marine fossils, strongly suggests that the bulk of the volcanic rocks were laid down under submarine conditions. The fact that most of the fossiliferous rocks bear a shallow-water type of fauna, the fact that many lenses of limestone are sedimentary breccias or are conglomeratic, and that some limestones, and more commonly tuffs, are crossbedded indicates that the rocks were laid down in relatively shallow water. The occurrence in these rocks of dasycladacean algae is consistent with the interpretation of a shallow-water environment. Modern dasycladaceae are most abundant at depths of less than 3 to 5 meters, and rarely range below 30 meters. The maximum known depth from which they have been reported is 70 meters (Lemoine, 1940). Deeper water conditions are suggested, but not necessarily indicated, by the fine-grained, thin-bedded siliceous and calcareous rocks of the Cobre, many of which bear a pelagic fauna (see Crickmay and others, 1941, p. 80–102). Distribution of lava flows and coarse, massive pyroclastic rocks indicates that the major centers of volcanism were in the southern part of the mapped area, in the Sierra Maestra, or farther to the south in the now-foundered land off the present south coast of Oriente, but there were several vent areas, probably minor centers, in the northern part. The Cobre rocks apparently were deposited on a shallow submarine platform or a trough between an inferred land mass to the south and the serpentine protaxis region to the north. Sinking of the sea bottom seems to have kept pace with sedimentation and deposition of volcanic and other rocks.

At least one center of volcanism is indicated in the Gran Piedra Massif, and one in the El Gato Massif, not far off the main axis of these parts of the Sierra Maestra. A volcanic center is recognized on the northern flank of the Gran Piedra Massif, on the upper Río Indio, and another on Boniato Ridge, 4.5 kilometers north-northeast of El Cobre. North of the Sierra Maestra area, the San Nicolás Hills, the southern part of La Burra Basin south of La Peluda, and the lower Bruñi valley appear to mark volcanic centers. Each of these centers is marked by thick deposits of massive and poorly bedded coarse agglomerates and tuffs, that grade into and are interbedded with well-bedded, finer grained pyroclastic and sedimentary rocks. Some of the centers are marked by lava flows, which issued either from the same vents as the pyroclastic rocks or came from flanking fissures.

Other volcanic centers are probably present throughout the area mapped but their recognition is much less certain than the centers cited above. A center may be present in El Aura dome, for example, and still another in the Jutinicú dome.

Deposition of Cobre sediments seems to have taken place in an environment generally favorable to lime-secreting marine life and to limestone deposition. However, great amounts of fresh pyroclastic material repeatedly poured into the Cobre sea with the result that pyroclastic sedimentation quite or partly outstripped limestone sedimentation most of the time, and may have inhibited life occasionally.

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Limy sediments, usually tuffaceous, probably accumulated as lenses whenever and wherever the supply of fresh or reworked pyroclastic material was lessened or stopped; this process was most prevalent towards the end of Cobre time, when there seems to have been a tapering off of the volcanic activity which finally ended with the onset of San Luis time. The climactic deposition of limy sediments, with no admixture of clastics derived from the erosion of older formations, marked the closing phase of Cobre sedimentation. An inflow of such clastics marked the beginning of San Luis sedimentation.

SAN LUIS FORMATION (EOCENE)

The San Luis formation is next in importance to the Cobre formation among the stratified rock units of the south-central Oriente area. Its outcrops are widespread in the Cauto-Guantánamo Lowlands and in the immediately adjacent low hills and uplands on the north flank of the Sierra Maestra Highlands and the south and west flanks of the Sierra de Nipe. The width of outcrop ranges from as little as 200 meters, east of Cayo del Rey, to nearly 30 kilometers, west of San Luis. The formation is not of economic importance insofar as mineral production is concerned, but the rich sugar plantations in the area mapped are cultivated, for the most part, on tracts underlain by the San Luis formation. The type locality presumably is in the neighborhood of the town of San Luis, about 17 kilometers north of Santiago Bay. Taber (1934, p. 584–585) named and briefly described the San Luis formation, which "consists chiefly of thin-bedded limestones and shales, tuffaceous sandstones * * * and conglomerates * * * it differs from the Cobre formation in being composed mainly of sedimentary, rather than pyroclastic, rocks."

Oligocene limy rocks overlie the San Luis formation conformably, although with a clear change in lithology, in the northwestern part of the south-central Oriente area along the base of Morcate Ridge, and in one small part of the Mayarí Valley just north of the Río Caoba, but were not found in the southern part of the area. At the southern limit of outcrop the San Luis formation generally overlies the Charco Redondo limestone member of the Cobre with apparent conformity, but basal conglomerate of the San Luis unconformably overlies pyroclastic rock of the Cobre 3.5 kilometers southeast of Aguacate. Commonly the transition is gradual, with some interfingering and intergrading, but the change is abrupt in the Baconao Ridge—Emilia Valley sections. A gradational conformable contact with the underlying rocks is also characteristic throughout the Fringing Uplands.

The greatest thickness of the San Luis formation is hard to calculate because of the lack of uniformity in degree and direction of dip across broad areas of outcrop, for example, the area 29 kilometers wide and underlain by San Luis rocks between El Cobre and Cayo del Rey. The greatest thickness may be as much as 1,500 meters. In the Cauto Valley, it is estimated to be between 700 and 1,000 meters at the longitude of Contramaestre. The San Luis formation is only from 50 to 100 meters thick about 4 kilometers east of Cayo del Rey, and about 1 kilometer west-northwest of the mouth of the Río Caoba; in these two localities, presumably only the uppermost part of the formation rests on the older rocks.

The limy and finer clastic facies of the San Luis formation generally crop out in broad lowlands or low, rolling uplands, such as the Cauto Valley (fig. 32) and La Prueba Plateau; the more resistant limestone and thin conglomerate zones tend to form strike ridges of low relief. The thicker conglomerates crop out in rugged highlands such as Camarones Heights and Loreto Mesa (figs. 24, 25, 36).

CHARACTER AND DISTRIBUTION

The lithologic features of the San Luis formation are extremely diverse. It is made up of limy shale, mudstone, siltstone, tuffaceous sandstone, sandstone, conglomerate, marl, and thin zones of platy, thin-bedded limestone, with some massive limestone. Perhaps the chief of all the rock types included in this formation is well-bedded limy sandstone, with limy, silty shale bulking second. The limy, coarse- to fine-grained sandstones are gray on a fresh surface, but yellowish brown on a weathered surface. The finer clastic rocks contain more silty and fine sandy material than clayey material. None of the sandstones is highly indurated; the hardest and most resistant sandstones have a limy cement, as contrasted to the commoner, softer rocks whose chief cementing constituent is clay and whose calcareous constituent consists mainly of microfossils. The coarse-grained sandstones are thick bedded, poorly sorted, and commonly show crossbedding. The fine- and medium-grained sandstones are well sorted and generally well bedded in strata from 3 to 30 centimeters thick (fig. 32).

Hand specimens of the sandstones are composed mainly of grains of brown, gray, or greenish-gray fine-grained igneous rock fragments, feldspar, zeolites, and quartz. Grains less than 0.5 millimeter in diameter are angular and consist in large part of a single mineral, but larger grains are irregularly rounded and consist chiefly of rock. The few samples of sandstone of the San Luis that were examined under the microscope are made up mainly of angular grains of very turbid plagioclase, zeolites, and quartz, in addition to the rock grains. Magnetite is present, and detrital grains of blue-green celadonite (or glauconite), green hornblende, and augite are minor but common constituents. A pale-brown to greenish-brown montmorillonite mineral and lime are the cementing constituents.

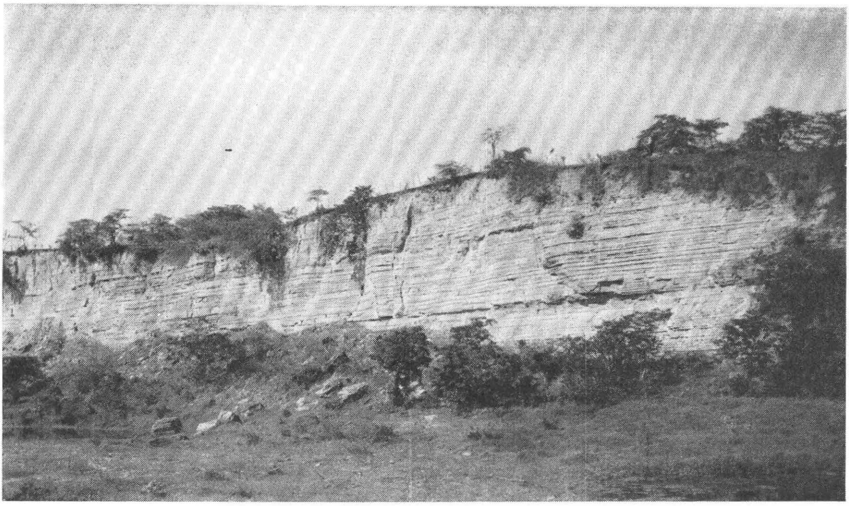

FIGURE 32.—Thin-bedded sandstone and shaly sandstone of San Luis formation in bluffs along southwest bank of Río Cauto at locality 93.

Shales of the San Luis formation are limy and fossiliferous, generally silty and somewhat sandy, and range in color from brown to gray: commonly, they are interbedded with, and finger and grade into sandstones. They are generally well bedded in strata from 1 to 10 centimeters thick; thinly laminated, fissile shales are not common. In a few places, there are massive mudstones a few meters thick. Most of the fine clastic components of the San Luis rocks consist of fragments of the size of silt and fine sand. For example, the reddish-brown, unweathered, limy, sandy shale that overlies pyroclastic rocks of the Cobre in the Quinto and Ponupo mine areas contains only an estimated 20 to 30 percent of clay-size components, if the upper limit of clay particles is assumed to be 4μ, the limit used by Twenhofel (1932, p. 240–241). Fine-grained sandstone is distributed irregularly throughout this shale in lenses as much as a few centimeters long and a few millimeters thick; sand-size grains are disseminated in the silt-clay matrix. Under the microscope, this shale is seen to consist of plagioclase, green hornblende, and magnetite, in grains as large as 0.1 millimeter in diameter, in addition to the limy constituent (mainly Foraminifera), a pale greenish-brown clay mineral, and disseminated red iron oxide dust.

The widespread but irregularly distributed, poorly sorted conglomerates and associated coarse, clean sandstones supply the most important evidence which bears on the source and conditions of deposition of the San Luis sediments. In the southeastern part of the area mapped, it was possible to distinguish a conspicuous rock unit which is described below as the Camarones conglomerate member of the San Luis formation. Outside the mapped limits of this member, most of the conglomerates occur as lenticular beds as much as several meters thick, which can be followed along the strike for distances from a few tens of meters to several hundred meters in most cases, but some evidently extend for several kilometers. These conglomerate lenses occur in poorly sorted, commonly crossbedded, coarse-grained sandstones interbedded with well-sorted, finer grained sandstones and shales (fig. 33).

Although the conglomerates of the San Luis formation are widespread, they represent only a small part of the total volume of rocks of the formation in the area mapped, even when the thick Camarones member is included. They are lithologically similar rocks composed of well-rounded pebbles, cobbles, and boulders, chiefly of hard, dense, fine-grained, dark-colored volcanic rocks, with minor whitish-gray quartz-rich granitic rocks, dense whitish-gray siliceous and tuffaceous limestone, and, more rarely, gray limestone, chert and siliceous shale. The larger components lie in a matrix of clean, generally very coarse sand composed of rock and mineral grains and cemented by a small amount of clayey material or by lime. The visible but poorly developed bedding of the coarser conglomerates, the well-developed bedding of the pebble conglomerates and the matrix of clean sand are characteristic. In general, there are few large cobbles and boulders in the conglomerates other than the Camarones member, and the rocks are fairly well sorted in all the finer conglomeratic facies.

The lower 75 to 150 meters of the San Luis formation along the southern limit of outcrop consist chiefly of interbedded limy shale and platy limestone; the limestone beds generally are from 2 to 15 centimeters thick. In places, sandstone and conglomerate are interbedded

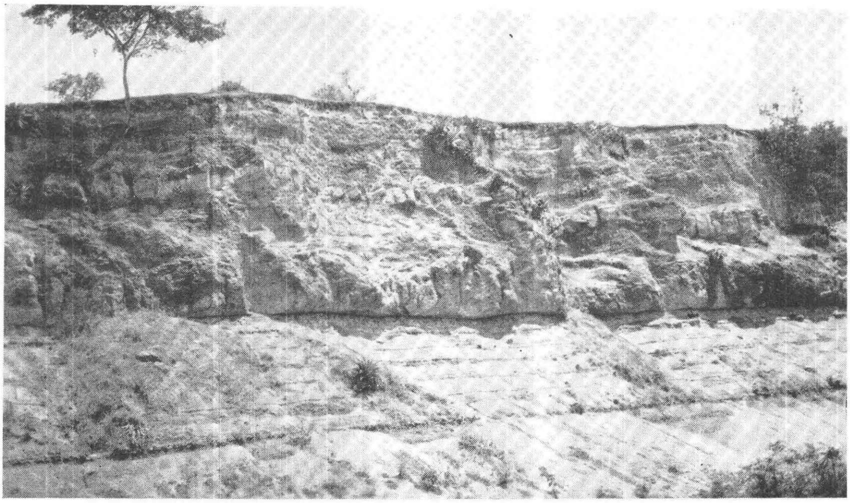

FIGURE 33.—Conglomerate and sandstone overlying thin-bedded shale in San Luis formation outcrops on the north bank of Río Yarayabo, 0.5 kilometer east of locality 90.

with the finer sedimentary rocks, and some of the limestone beds are conglomeratic. The conglomerates range from thin stringers to beds and zones several meters thick.

About 5.5 kilometers west of Mafo, at locality 37, the Charco Redondo limestone member grades up into limy shale of the San Luis, which is overlain by interbedded limy shale, platy limestone, and sandstone. Higher in the section, a bioherm limestone intercalated in sandstone crops out along the Río Naibo north of locality 37, and thin limestone beds intercalated in interbedded sandstone and shale were seen at locality 38.

Limy shale and marl of the San Luis formation grade downward into Charco Redondo limestone about 1 kilometer southwest of Mafo. The lowermost San Luis rocks between locality 32 and the Río Contramaestre are interbedded platy limestone and limy shale which also grade into the Charco Redondo limestone. At locality 34 (fig. 34) 2.4 kilometers downstream and higher in the section, the following sequence was recorded on the west bank of the Río Contramaestre:

	Meters
Top of river bank.	
Sandstone	2.5
Local disconformity.	
Conglomerate, coarse	3
Sandstone and fine-grained conglomerate with some coarse conglomerate lenses	3–5
Conglomerate, coarse, with cobbles as large as 15 centimeters	1
Local disconformity.	
Mudstone, limy	6
River level.	

Subangular blocks of coarse sandstone, some more than 2 meters long and as much as 1 meter thick, are contained in a lens of conglomerate exposed along the west bank of the Río Contramaestre south of the railroad bridge at Contramaestre, near locality 34 (fig. 35). The conglomerate is intercalated in and disconformably overlies coarse sandstone which is similar to the blocks in the conglomerate, and the sandstone near the conglomerate lens also contains similar blocks of sandstone. The north side of the conglomerate lens forms a steep, irregular contact with the nearly flat-lying sandstone, and evidently is one side of a channel cut into the sandstone.

The lower San Luis formation is made up chiefly of interbedded limy shale and platy limestone for about 13 kilometers along the strike from the Río Contramaestre to locality 52, where these beds finger eastward into a zone where they are interbedded with conglomerate and conglomeratic limestone about 100 to 150 meters above the base of the formation. Southeastward from locality 52 this conglomeratic zone thickens downward; its base occupies a

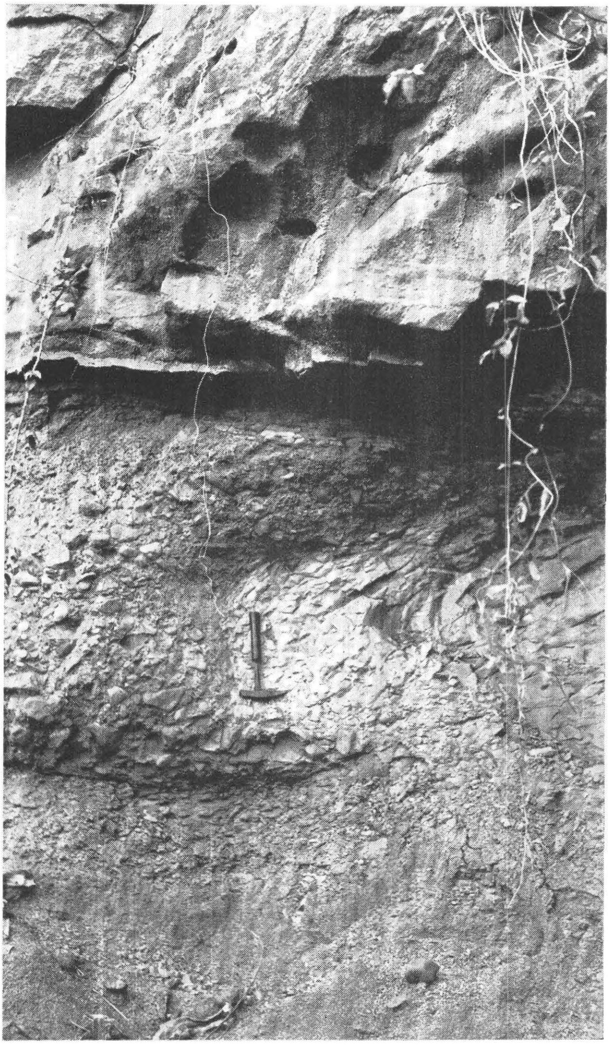

FIGURE 34.—Conglomerate-filled channel in shale, overlain by sandstone, in outcrop of San Luis formation on west bank of Río Contramaestre at locality 34.

progressively lower and lower stratigraphic position as far as a point 3.5 kilometers southeast of Aguacate, where conglomerate at the base of the San Luis formation lies disconformably on pyroclastic rocks of the Cobre formation. Evidently the Charco Redondo limestone member fingers out or was eroded away here before deposition of the conglomerate, which is made up of well-rounded volcanic rock cobbles and boulders as much as 30 centimeters in diameter. Eastward beyond this point, the base of the conglomeratic zone occupies a progressively higher and higher stratigraphic position as far as the neighborhood of Caney del Sitio, where Quaternary alluvium covers

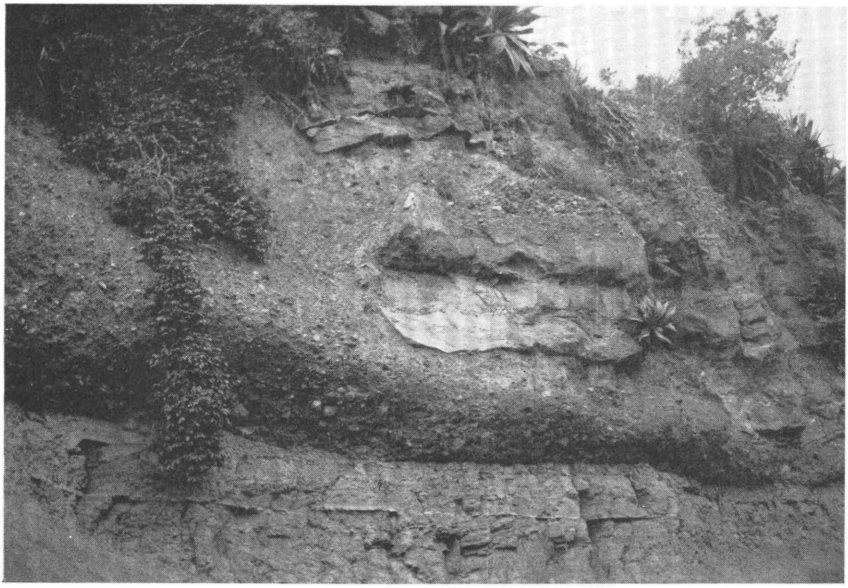

FIGURE 35.—Conglomerate-filled channel enclosing blocks of sandstone, in limy shale of San Luis formation near locality 34. Scale is indicated by lower block, 1 meter thick. Note tilt of upper block.

the lower part of the San Luis formation. The conglomeratic zone just described interfingers with and is interbedded with shaly and limy rocks that make up about half of the total thickness of this zone in which individual beds of conglomerate are from a few centimeters to 4 meters thick. To the east, the conglomeratic zone interfingers with interbedded limy shale and thin-bedded limestone, and these make up the lower San Luis rocks to the east for 10 kilometers beyond the Río Cauto.

The basal limy shale and minor thin limestone beds of the San Luis formation grade downward into the Charco Redondo limestone member of the Cobre formation south of locality 104. At locality 105, 45 meters above the base of the formation, sandy shale is interbedded with impure limestone beds 20 to 60 centimeters thick, which are conglomeratic in part, with volcanic cobbles of the Cobre formation as large as 15 centimeters in diameter. At locality 106, about 85 meters above the base of the formation, the exposed San Luis rocks are soft, fine- to coarse-grained sandstone.

The basal 35 meters of the San Luis formation just west of the Río Grande is made up of interbedded whitish-gray limy shale and platy limestone above which, at locality 108, are outcrops of coarser clastic rocks. These are interbedded sandstone, pebbly conglomerate with occasional cobbles of volcanic rock as large as 13 centimeters in diameter, limy shale, and one lens of foraminiferal reef limestone, which ranges from a knife edge to 1.1 meters thick, and is 6 meters long. The lowermost San Luis rocks are exposed in the Santa Cruz, Algodonal, Ponupo, Cuatro Caminos and El Aura areas; they are limy shale and marl which grade downward into the Charco Redondo limestone member of the Cobre formation. In the Jutinicú area, tuff and limy tuff of the Cobre directly underlie interbedded limy shale, marl, and thin-bedded limestone of the San Luis. Similar San Luis rocks, with limy sandstone, grade downward into the Charco Redondo limestone member southwest of El Cristo. In the Quinto mine area, the basal limy shale of the San Luis grades downward into limy tuff of the Cobre and discontinuous lenses of Charco Redondo limestone member. In addition to limy shale, the lower part of the San Luis formation here includes tuffaceous sandstone, and marl.

In the Emilia Valley section, the lower San Luis formation is made up of dark limy shale about 150 meters thick; these fine clastics here are overlain with local angular unconformity by the Camarones conglomerate member of the middle part of the formation, as at locality 210.

Brownish limy shale and limestone of the lower San Luis are interbedded with and grade downward into the Charco Redondo limestone member along the west side of the Jarahueca Valley and the eastern rim of the Nuevo Mundo Karstland north of Joturo Abajo. In the Pedernal Karstland and the central and western parts of the Nuevo Mundo Karstland, the lower part of the San Luis formation consists of interbedded grayish-white platy, shaly limestone, marl, and limy shale, which grade downward into the Charco Redondo limestone member. There are a few thin beds of somewhat tuffaceous limy sandstone exposed in the Arroyo Pedernal. In the southwestern Nipe Highlands, interbedded limy shale, platy limestone, and marl of the lower San Luis grade into the underlying rocks. These are chiefly limy tuff of the Cobre around the flanks of the San Nicolás Hills (except for thin lenses of the Charco Redondo limestone member in places), but the underlying rock is all Charco Redondo limestone member north of the Arroyo Indio and in the section of Marginal Hogbacks. A section measured on the north flank of the San Nicolás Hills, 6 kilometers east-northeast of Palmarito, is as follows:

	Meters
San Luis formation:	
Shale, limy (top not exposed).	
Limestone, thin-bedded, impure	11
Shale, limy	15
Cobre formation:	
Charco Redondo limestone member, well-bedded	13. 2
Tuff; and tuff, bedded green limy (base not exposed).	

Coarse clastic sediments commonly form the main rock types in the middle and upper parts of the San Luis formation, as contrasted with the chiefly fine clastic rocks of the lower part; however, in the northeastern part of the area mapped, limy and fine clastic sediments predominate. Coarse conglomerate is the chief rock above the lower part of the San Luis formation in the southeastern part of the south-central Oriente area. There, the middle part of the formation is a conspicuous rock unit which has been mapped as the Camarones conglomerate member.

Everywhere else in the area, rocks that probably are the stratigraphic equivalents of this very coarse clastic member contain only a little conglomerate, distributed as lenses and stringers throughout the sequence of limy sandstone with lesser amounts of interbedded shale. A conglomerate of the middle San Luis, 3 meters thick, disconformably overlies shale in outcrops along the Río Contramaestre 2.5 kilometers north-northeast of the Central Highway bridge; the conglomerate is composed of well-rounded pebbles and cobbles of dark-colored volcanic rocks as large as 20 centimeters in diameter. Thin limestones are interbedded with limy conglomerate, sandstone and shale 2 kilometers west of Candonga. At locality 107, 9 kilometers west of San Luis, cobbles as large as 25 centimeters in diameter are mostly of volcanic rocks. In the eastern outskirts of San Luis, interbedded coarse sandstone and fine conglomerate overlie limy shale with local unconformity.

Distinctly limy pebble conglomerates that contain marine fossils occur in the Aguacate Hills, on the north slope of the Soriano Hills, and in the Morcate area. On the Central Highway south of Palma Soriano, at localities 90 and 91, beds of limy pebble conglomerate 1 to 2 meters thick were traced for several kilometers eastward and westward along a persistent cuesta cut by the Río Cauto and its nearby affluents. Interbedded limy sandstone and conglomerate make up the middle part of the formation 7 kilometers west of San Luis where much of the conglomerate contains limestone pebbles and cobbles. Chert and siliceous shale pebbles are abundant in the conglomerates which crop out on the north flanks of the Aguacate and Soriano Hills, and also on the La Prueba Plateau southeast of La Prueba. Similar fragments, subangular to well-rounded, of whitish-gray, translucent chert, and whitish to cream-colored siliceous shales, are also a common constituent of the limestones of the San Luis, which generally are conglomeratic, if not invariably so. Such limestones are found in the above-mentioned areas and at localities 184–187 and 190 in lenticular beds as much as 2 meters thick. At localities 189 and 190 white limestone conglomerates crop out. They have a dense limy matrix that contains well-rounded pebbles predominantly of chert as much as 25 millimeters in diameter, and cobbles as much as 10 centimeters in diameter which are predominantly of cherty limestone.

In the upper part of the formation, lenses, commonly of limy and fossiliferous conglomerate, are interbedded with limy sandstone and shale. In places, a fine conglomerate of the San Luis directly underlies the next higher formation of Oligocene rocks. Coarser conglomerates of the upper San Luis are found only in the western part of the mapped area. At locality 42, 3.5 kilometers north by east of Contramaestre, limy shale of the San Luis about 100 meters below the top of the formation crops out in a small arroyo. On the east bank of the Río Contramaestre 2 kilometers east-northeast of locality 42, and in about the same stratigraphic position, a conglomerate is intercalated in the sandstone and shale sequence. This conglomerate contains cobbles of volcanic rocks and limestone as large as 15 centimeters in diameter. Conglomeratic sandstone and similar conglomerate crop out at locality 45, 1 kilometer north by west of Remanganaguas; these rocks contain small lenses of bioherm limestone. Northward from locality 45, the upper San Luis rocks are largely conglomeratic to the top of the formation. Conglomerates similar to the two just mentioned crop out in the upper part of the formation near Central Oriente. At Morcate village, fine and coarse sandstone make up the uppermost part of the San Luis formation, which here is overlain with apparent conformity by Oligocene rocks at locality 96 (fig. 38). At locality 94, 10 meters below the top of the formation, limy shale and conglomeratic sandstone are interbedded. Between Central Miranda and Cayo del Rey, the middle and upper parts of the San Luis formation are limy shale and sandstone, as at locality 222. The upper part of the formation is made up of interbedded limy shale, marl, and impure limestone at locality 278 northwest of Juan Mulato. Similar rocks northwest of the mouth of the Río Caoba are overlain with apparent conformity by Oligocene rocks at locality 279.

CAMARONES CONGLOMERATE MEMBER

North of the Emilia Valley, the limy shale of the lower part of the San Luis formation is overlain unconformably by 475 meters of coarse conglomerate here named the Camarones conglomerate member of the San Luis formation. It is exposed from the bases to the summits of Camarones Heights (fig. 36) and Loreto Mesa (fig. 25). The top of this member, and that of the formation have been eroded away here, and the original thickness of this conglomerate and perhaps higher parts of the formation cannot be determined or inferred, unless this be possible by further mapping east of Ramón de las Yaguas. These coarse clastic rocks contrast strongly with the underlying fine clastic and limy rocks, and make up an easily mappable rock unit in this area.

Taber (1934, p. 584–585) included this conglomerate in his brief definition and description of the San Luis rocks, and gave it relative importance. He devoted two-thirds of a page to this formation, and one-third of the passage pertains to the conglomerate, with specific references to the neighborhoods of Loreto Mesa, San Ricardo mine ("on a hill slope five kilometers northwest of Cristo"), and Alto Songo.

FIGURE 36.—Camarones Heights, type locality of Camarones conglomerate member of San Luis formation; summit about 670 meters altitude. Contacts shown in white: Cobre formation, *Tc*, underlies shale of the San Luis formation, *Tsl* at base of slope in saddle left of peak; shale is overlain by Camarones conglomerate member, *Tslc*, at break in slope; conglomerate well exposed in steep-sided ravines. Photograph by Stephen Taber.

Within the area mapped, the maximum thickness of this member is in the neighborhood of Camarones Heights and Loreto Mesa, whence the coarse clastic fragments gradually become finer and finer as the member thins westward and northward. The Camarones conglomerate member, with an aggregate area of mapped outcrop about 100 kilometers square, was distinguished and mapped westward to within 2 kilometers of El Cristo, northwestward to within 500 meters of the Río Jutinicú, and northward to within 500 meters of Sabanilla. The limits shown on the map approximate the zone where the Camarones rocks grade into clastic rocks of the middle San Luis, which are finer than the conglomerate but presumably of the same stratigraphic position as the Camarones rocks. To the south, the entire San Luis formation has been eroded away, but the formation and Camarones conglomerate member continue eastward into the Guantánamo Basin and Limones Mountains.

The summit of Camarones Heights, 6.5 kilometers south of La Maya, is about 670 meters above sea level. To the south, the Arroyo San Juan flows through the upper Emilia Valley, which is floored by the lower part of the San Luis formation to an altitude of about 300 meters above sea level at a point some 650 meters south of the summit of Camarones Heights. The intervening scarp, about 370 meters high, is one continuous outcrop of coarse Camarones conglomerate member with minor interbedded sandstone. The well-rounded coarse clastic fragments are mostly cobbles 10 to 15 centimeters in diameter, but some 45-centimeter boulders were seen; igneous rocks with subordinate limestones are the chief components. Outcrops with cobbles and boulders from 7 to 45 centimeters in diameter are common as far as 3 kilometers north of Camarones Heights (fig. 37). Further north, massive pebble and cobble conglomerates are interbedded with progressively greater amounts of coarse sandstone which contains Foraminifera in places, and the conglomerate fragments generally are of progressively smaller average size. However, outcrops in the southeastern outskirts of La Maya contain a few boulders 45 centimeters in diameter in a matrix of pebbles about 25 millimeters in diameter. Along the highway in the western outskirts of La Maya, conglomerate with 10-centimeter cobbles is interbedded with fine pebble conglomerate and coarse sandstone. About 475 meters of Camarones conglomerate member are exposed along section line *A-A′* from Emilia Valley to the top of the main east ridge of Camarones Heights, and some 300 meters are exposed along this section line 1 kilometer south of the Ponupo-Mucaral dome.

In the type area, there is an unconformity at the base of the Camarones conglomerate member along its southern limit of outcrop, but this unconformity is not demonstrable everywhere at this southern limit, for in places, particularly in the area north of the Quinto mine pit, where massive conglomerate grades down through a zone of sandstone at least 50 meters thick and into the underlying lower shale of the San Luis, the contact is conformable. North of the type area, too, the interbedded massive conglomerates and coarse sandstones conformably overlie finer sandstone and sandy shale. In such places, the location of the lower contact of the Camarones member is not definitely known and it has been placed arbitrarily at the base of the the coarsest conglomeratic sandstone even though much, if not all, of the underlying sandstone may be stratigraphically equivalent to the basal part of the member in the type area.

In the middle Emilia Valley, at locality 210, there is local angular unconformity between the dark limy shale of the lower part of the San Luis formation and the overlying basal Camarones conglomerate member whose pebbles average a few millimeters and have a greatest diameter of 25 millimeters. The conglomerate contains Foraminifera in interbedded limy sandstone at this place. Above the base, pebbles as much as 5 centimeters in diameter are common in the lower 50 meters of this member here and near locality 206, 4 kilometers to the northeast. Well-rounded pebbles and cobbles are the chief components of the conglomerate 100 to 250 meters above the base on the south scarp of Loreto Mesa; the average diameter of the pebbles is about

8 centimeters, but many cobbles are as much as 15 centimeters in diameter.

At the foot of the east slope of Camarones Heights, 2.4 kilometers northwest of locality 210, coarse sandstone is interbedded with conglomerate in which the well rounded boulders are almost all of igneous rocks, and as large as 45 centimeters in diameter. On the lower northeast slopes, about 3 kilometers north-northwest of locality 210, 90 percent of the conglomerate is made up of well-rounded fossiliferous limestone boulders as much as 60 centimeters in diameter. Coarse sandstone predominates over the interbedded conglomerate to the north beween Cuatro Caminos and the Río Guantánamo, but conglomerate with well-rounded cobbles of limestone and some igneous rocks as large as 15 centimeters in diameter crops out about 4 kilometers northeast of Cuatro Caminos.

All but the lower part of the Camarones conglomerate member has been eroded away west and northwest of Camarones Heights, where there is much interbedded sandstone and some shale. At the trail junction 3 kilometers east-northeast of the Quinto mine pit, there are good exposures of the basal Camarones conglomerate member, the well-rounded pebbles average about 8 centimeters in diameter with a 30-centimeter maximum, and interbedded sandstone makes up at least half the rock. Half a kilometer north-northeast of this trail junction, at locality 191, a 60-centimeter boulder of coral limestone was found. Limy sandstone and mudstone are interbedded with conglomerate from 200 meters to 1 kilometer north of locality 191.

North and northwest of locality 182, the outcrops of interbedded conglomerate and sandstone of the Camarones member are discontinuous, with wide intervening areas floored by the lower part of the San Luis formation. The base of this member generally appears to be in conformable contact with the underlying San Luis rocks in these outlying areas, but in places massive conglomerate rests directly on shale disconformably. Locally, the basal conglomerate fills steep-sided channels. At locality 152, a railroad cut 600 meters south-southwest of Alto Songo, the lowermost 6 meters of the Camarones conglomerate member fills such a channel in limy shale of the lower San Luis, and is overlain by coarse sandstone 5 meters thick to ground level at this point. The constituent fragments of the conglomerate are well rounded, and average 15 centimeters in diameter, but some boulders are 30 centimeters in diameter. Sixty percent of the fragments are of igneous or volcanic rock, 40 percent are of limestone. Similar relationships were seen along the road between Alto Songo and Arroyo Blanco, 500 meters southeast of Arroyo Blanco. In this area, just south of the Río Jutinicú, are the northernmost and westernmost outcrops of the Camarones conglomerate member that we were able to identify and map; erosion has left only 30 meters of the lowest part of the member here. In general, more interbedded sandstone is found here than further to the southeast, and the texture is much finer. In most outcrops, the pebbles average about 25 millimeters and do not exceed 5 centimeters in diameter, but there is one channel of conglomerate 3 meters thick near locality 160 where there are coarser fragments.

As has been observed previously, the Camarones conglomerate member seems to be the stratigraphic equivalent of many of the interbedded sandstones, shales, and minor conglomerates outside the Camarones mapped outcrop area: for example, the interbedded shales, sandstones, conglomeratic sandstones, and minor conglomerates exposed on the south flank of La Prueba Plateau, and the continuation of these same beds along the escarpment that runs east-northeastward from San Benito through locality 195 for at least 10 kilometers, are almost certainly stratigraphically equivalent to that part of the Camarones conglomerate member which lies south of this area.

There is, in fact, no certainty that there are San Luis conglomerates stratigraphically above the Camarones conglomerate member, even where conglomerates lie directly under Oligocene beds north of locality 45, because Oligocene beds are not present in the area where the Camarones conglomerate member crops out, and correlations based on faunal evidence are inconclusive.

PETROGRAPHY AND SOURCE ROCKS OF CONGLOMERATE CONSTITUENTS

The most abundant of the coarse clastic component fragments of the Camarones and other conglomerates of the San Luis are lavas or fine-grained intrusive rocks similar in texture and composition to many of those rock types in the Cobre formation. Their petrography as described in connection with the Cobre formation obviates repetition here, but it may be remarked that only the hard, dense, least altered, and therefore the most resistant of these Cobre-type igneous rocks predominate in the conglomerate fragments of the San Luis. Except in some of the lenses of conglomerate at or near the base of the San Luis formation, as at locality 105 in the area southeast of Aguacate, the softer, highly altered Cobre-type rocks are not a common constituent. In addition to the volcanic rocks of the Cobre, Vinent formation volcanic rocks may also be the source of part of the igneous components of the conglomerates of the San Luis, although other Vinent-type rocks are scarce. The boulder of Upper Cretaceous coral limestone found at locality 191 may have come from the Vinent formation, and Taber (1934, p. 585) mentions quartzite, one of the Vinent-type rocks, as being one of the components of the conglomerates.

Minor amounts of pebbles and cobbles of granitic rocks occur in the Camarones conglomerate member and in other conglomerates near the Camarones outcrop area, but were not found in the conglomerates which crop out west of the longitude of San Luis. Specimens of pebbles and cobbles of granitic rocks were collected from the Camarones conglomerate member at several places: on the divide near the west end of Loreto Mesa, at a locality 1.2 kilometers northeast of Cuatro Caminos, at a locality 150 meters north of the Consuelo mine, and from the railroad cut south of Alto Songo near locality 152.

In hand specimens, the granitic rocks all appear to be similar in composition: they are fine- to medium-grained, whitish- to pinkish-gray rocks that consist mainly of feldspar and quartz and contain only a minor amount of mafic constituents. The microscope confirms the essential similarity suggested by megascopic examination, and leaves little doubt that the granitic components of the conglomerates of the San Luis are genetically related rock types. The rocks were determined to be altered quartz diorites. They have an even-grained granitic texture and are made up chiefly of euhedral to anhedral, unzoned plagioclase (whose composition in different specimens ranges from albite to calcic oligoclase) and of interstitial quartz. The quartz content, from 30 to 50 percent, is strikingly high. In addition to quartz and plagioclase, these rocks contain minor amounts of chlorite (chiefly penninite), green hornblende, and, more rarely, augite. The chlorite was formed later than the hornblende, which it replaces, and both were formed later than the augite. Late-formed magnetite occurs as veinlets associated with the other mafic minerals. A little orthoclase was seen in one section, and two sections showed a little microcline. In one section, fine-grained anhedral quartz and feldspar (albite) cut and replace the rock; plagioclase (sodic oligoclase) at the contacts of this aplitic veinlet shows a narrow zone which appears to be a little more sodic than the feldspar away from the veinlet. A few of the sections show a granophyric intergrowth of quartz and plagioclase which appears to replace the normal quartz and feldspar of the rock.

The coarse clastic fragments of siliceous and tuffaceous limestone in the conglomerates of the San Luis generally are similar to the hard, dense limestones and limy siliceous rocks of the Cobre that contain a microfauna in which *Globigerina* and Radiolaria predominate. Few of the conglomerate fragments of this San Luis type appear to be fossiliferous, and none were studied. A few of the limestone fragments are dissimilar to any known from the Cobre, Charco Redondo member, or San Luis, and one of these fragments, which may have been derived from the Vinent formation, was found at locality 191 as already noted.

The chert and siliceous shale pebbles have no possible source in the Cobre formation unless it be in the upper part of the Charco Redondo limestone member, which is cherty in places. Some or all of these siliceous elements may be of intraformational origin, derived from subangular to well-rounded fragments which are a common constituent of the generally conglomeratic limestones in the middle and upper parts of the San Luis formation.

The sandstone blocks in the conglomerate near locality 34 (pl. 42) seemingly are of intraformational origin, and are believed to have slumped from the oversteepened, undercut walls of the channel in which they are found.

In a few places, the conglomerates of the San Luis contain scattered, crudely rounded cobbles and boulders of pebble conglomerate, the constituent pebbles of which tally with the rock types of associated homogeneous fragments. Such heterogeneous fragments of conglomerate were found near La Maya, and it is believed that they were derived from previously formed conglomerates of the San Luis and represent clay-cemented intraformational fragments.

FOSSILS

Mr. de Albear's study (in preparation, 1954) will supplement the paleontologic information published in the present report relative to Foraminifera of the San Luis and Oligocene rocks. Foraminifera are listed in tables 2 and 3 (in pocket).

Rarely, corals are found in the bioherm limestones which are intercalated in the limy clastic rocks of the San Luis. They have not been reported previously from this formation sensu stricto, but Vaughan described several specimens collected, possibly from the Guantánamo shale, by O. E. Meinzer (1933, p. 261–263).

Mr. John W. Wells identified three of the corals collected from the middle or upper part of the San Luis formation, and determined their age; one of these specimens is not a San Luis coral, but rather a pre-San Luis (Vinent?) coral found in a boulder contained in the Camarones conglomerate member. His identifications are summarized in the following table:

Corals of the San Luis formation

[Determination of genera and ages by John W. Wells]

	Localities			Remarks
	45	*191	264	
Upper Eocene(?):				
Alveopora n. sp.?	×	------	------	
Astreopora sp. cf. *A. walli* Wells	------	------	×	From the middle Eocene (Yellow limestone) of Jamaica.
Elasmophyllia n. sp	------	------	×	First record in the Americas in rocks younger than Lower Cretaceous.
**Calamophyllia* n. sp	------	*×	------	Genus unknown above Upper Cretaceous

*This locality is in the Camarones conglomerate member of the San Luis formation; the specimen was found in a boulder of limestone (pre-San Luis) contained in the conglomerate.

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INFERRED ORIGIN AND CONDITIONS OF DEPOSITION

The onset of sedimentation during San Luis time was marked by an inflow of clastic sediments into the area now underlain by the San Luis formation, where previously only pyroclastic and limy sediments had been deposited. This clastic inflow apparently came from the south for average coarseness of clastic grains increases from north to south within the area mapped. The clastic sediments are inferred to have had their origin in crustal uplift and erosion in the area south of the present southernmost line of outcrop of the San Luis formation. Limy sediments were deposited with the clastic sediments throughout San Luis time, at the beginning of which time they were being laid down in greatest relative abundance. During middle and late San Luis time, the amount of clastic sediments laid down greatly exceeded the amount of limestone deposited.

The clastic sediments of the lower part of the formation are chiefly fine grained. The inference is that their source was relatively distant, or that climatic conditions were not productive of coarse clastic sediments, or that the crustal uplift which gave rise to them did not produce steep slopes. Perhaps all three were factors in the problem. The presence of a few relatively coarse conglomerates in the lower part of the formation in the southernmost outcrop area implies that there were steep slopes in some coastal areas or nearby hills.

The regimen that produced fine clastic sedimentation in the area of present San Luis outcrop was supplanted abruptly with the flood of very coarse clastic materials which marked the beginning of deposition of the Camarones conglomerate member and approximate stratigraphic equivalents of a coarse clastic nature. It is hard to attribute this change of regimen to rapid climatic change. It seems more reasonable to infer a crescendo of uplift in a land mass to the south, with the shoreline extended northward by the uplift to within a short distance of the present southern limit of outcrop of the Camarones conglomerate member. If we assume that the Camarones conglomerate member at one time was at least 500 meters thick in the type area—about 475 meters thickness was measured from base to eroded top—the inference is that torrential streams carried huge quantities of gravels to the coast of the land mass south of the trough of deposition. Along this coast, the San Luis sea reworked the coarse clastic sediments. All the San Luis rocks, fine and coarse, contain marine fossils, although they are very rare in the coarsest Camarones conglomerate member. There are no petrologic or organic indications of a nonmarine type of San Luis sedimentation.

Thick marine conglomerate rock units are rare indeed, particularly in such an essentially conformable sequence as that represented by the thousands of meters of Cobre, San Luis, and Oligocene rocks within the mapped area of Oriente. R. A. Daly (1912, p. 480–486, 570) has described the Paysaten series, a very thick rock sequence that contains fossil marine-animal and land-plant remains. He believes that local volcanism, which produced 1,400 feet of massive volcanic breccia, initiated downwarping in the geosynclinal area, after which the very rapid erosion of nearby mountains uncovered granitic batholiths within the mountain masses. The erosion products were then carried to and deposited in the geosynclinal area on top of the volcanic rocks as some 29,000 feet of sandstone, conglomerate, and shale, some of the conglomerates being as much as 1,400 feet thick.

H. W. Hoots (1931, p. 90, 92–93) recorded a second and even thicker example of marine conglomerate which he referred to the Chico formation of California: in one part of the eastern Santa Monica Mountains, conglomerate makes up about 75 percent of a 3,250-foot section; in another part, the bulk of the apparent total thickness of at least 8,000 feet is coarse, cobblestone conglomerate. He believes that a continuously subsiding basin of marine deposition next to a continuously rising land mass of strong relief will account for the origin of such thick marine conglomerates.

The late Joseph Barrell, it must be remembered, was convinced that the average thickness of marine gravels is less than 100 feet and ordinarily considerably less "except under local and special circumstances;" he believed that this limiting figure could be attained where the sea is transgressing against a land of some relief, these being the most favorable conditions postulated for the accumulation of thick marine conglomerates (1910, p. 620; 1925, p. 306, 311). We believe that the Camarones member, the Paysaten series, and the Chico formation, all presumably deposited in relatively shallow water in a sinking trough as very thick gravels, disprove Barrell's generalization.

In his description of the conglomerates of the San Luis, Taber (1934, p. 585) makes brief mention of cobbles of diorite, in addition to those of quartz diorite; both types he regarded as having been derived from the Sierra Maestra batholiths. We found no coarse clastic fragments of diorite in the typical San Luis rocks or in those of the Camarones conglomerate member, and our studies of many specimens of the granitic rocks collected from the coarse clastics of the San Luis formation indicate that these fragments are not representative of the rocks which comprise the main masses of the batholiths as now known, although their sources may have been minor quartzose differentiates of the batholiths. The chief differences between the quartz diorite components of the conglomerates and the rocks of the batholiths are the relatively lower quartz content of the latter rocks and the more sodic plagioclase contained in the former. Both rocks do, however, contain the same types of mafic minerals. The presence of late magnetite and the alteration of augite to chlorite and green hornblende are also characteristics of both the coarse clastic fragments of granitic rocks of the San Luis, and the rocks of the batholiths. Therefore, it seems reasonable to conclude that the quartz diorite fragments were indeed derived from quartz rich, albitic differentiates of the batholiths, possibly similar to the quartz-rich aplitic dikes described by Roesler (1917, p. 85, 88–95) in the Firmeza district. Such rocks, since they are more quartz-rich than the normal dioritic rocks of the batholiths, would be more resistant and would survive conditions that the less quartz-rich rocks could not withstand. However, the possibility that the granitic constituents of the conglomerates came from older rocks not now exposed or known in the Sierra Maestra, or from a foundered former highland area south of the present coast, cannot be eliminated.

If Barrell's assumptions were correct, marine conglomerates such as the Camarones member and the two others cited above, which are from 20 to 80 times as thick as Barrell's assumed upper limit of 100 feet, must have been deposited under very special circumstances indeed. Barrell gives no examples of conglomerates thicker than 100 feet, formed "under local and special circumstances." In a recent publication, Twenhofel (1947, p. 122) discusses Barrell's ideas, and points out that

> there are places on the south coast of Newfoundland where it is now possible for coarse clastics to accumulate with stillstand position of sea level to a thickness of nearly 2,000 feet * * * The waters are that deep within a mile or two of the shore * * * With rising sea level on a coast like that of southern Newfoundland it would be possible for gravels to accumulate to a thickness of several thousand feet.

The waters of the Caribbean Sea 2 miles off the south coast of Oriente are from 900 to 1,800 meters (500 to 1,000 fathoms) deep from opposite Pico Turquino to opposite Santiago de Cuba; along this stretch of coast, gravels pour into the sea today, and presumably could accumulate to nearly 60 times Barrell's upper limit of thickness 2 miles from shore with stillstand position of sea level, an even more impressive possibility than that in the case cited by Twenhofel. Barrell argued that "marine gravels of fixed shorelines * * * though customarily deposited within * * * 1 mile from land, may, under exceptional circumstances, extend to ten times" this limit. It is significant, therefore, to point out that, beyond the 2-mile limit cited above for comparison with conditions off the south coast of Newfoundland, the waters of the Oriente Deep reach depths of 6,400 meters (3,500 fathoms) only 10 miles from shore southeast of Pico Turquino, which might mean that, with stillstand, gravels could accumulate there to more than 200 times Barrell's upper limit of thickness. If the sea bottom is still sinking there, an even greater possible thickness might be assumed. Careful studies of present-day sedimentation in

Oriente Deep, and in the Philippine Sea between the upfaulted east coast of Formosa and the west end of the Nansei-shoto Trench, might reveal new facts pertinent to the study of marine conglomerates.

The foregoing, while taking issue with Barrel's thesis, is not meant to imply a deep-water origin for the Camarones conglomerate member, which we believe to be neritic. Most of the constituent pebbles, cobbles, and boulders of the member have flattened, ellipsoid or discoid shapes (fig. 37), and are dense, apparently homogeneous rocks mostly of volcanic origin, whose fabric does not seem to be responsible for these shapes. The coarser constituents are fairly well sorted and the

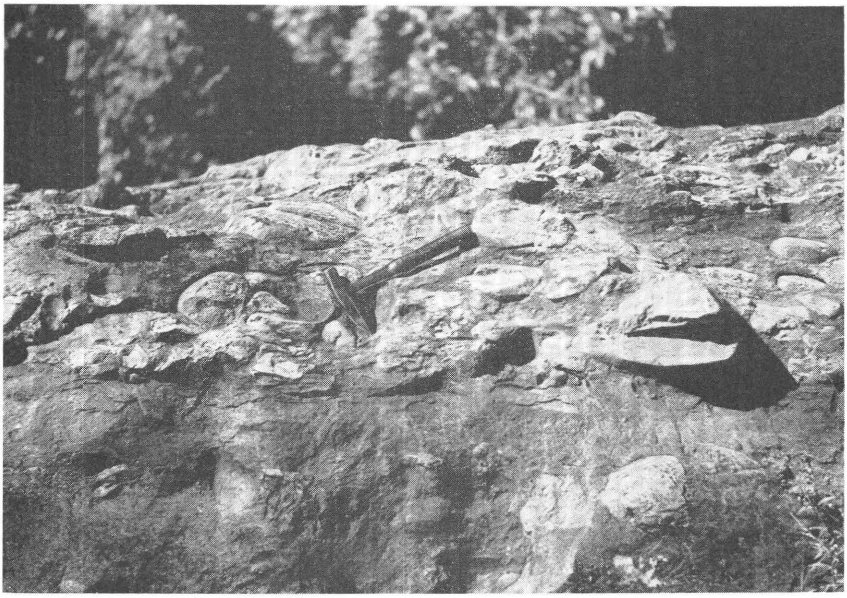

FIGURE 37.—Outcrop of Camarones conglomerate member of San Luis formation in bed of Río Barrancas 4.8 kilometers southeast of La Maya.

interstitial sand is clean and mostly very coarse. According to Twenhofel (1947, p. 122, 124), the shapes of most conglomerate particles that have been transported long distances range from ellipsoidal or spheroidal to disk shaped, and the disk shape may develop in stream deposits as well as on beaches. He states that an occurrence of well-rounded gravel of considerable distribution suggests, but does not prove, that deposition was over neritic bottoms, where the interstitial sands may or may not have good sorting but are usually clean.

The present southern limit of outcrop of the Camarones conglomerate member indicates that the quartz diorite and Vinent-type coarse clastic constituents of this member were transported at least 18 kilometers from the south where the nearest known outcrops of these rocks are found. Presumably, some of these constituents came from further south than this known minimum distance, and certainly most were carried further north than the present southern limit of outcrop. Of course, gravels once in the neritic environment may travel back and forth for a total distance of hundreds of kilometers without moving more than a few kilometers from the place where they first entered the neritic environment.

The flattened, discoid or ellipsoid shapes found so commonly in the coarse constituents of the Camarones conglomerate member are rare in the other conglomerates of the San Luis formation. From this, it might be inferred that the place of deposition was nearer to the source rocks, and that there was less reworking in the neritic environment of these other conglomerates.

A great thickness of overlying Cobre rocks had to be eroded away in order to expose the rocks of the Sierra Maestra batholith and Vinent formation. This stripping away of overburden produced the finer clastics of the lower part of the San Luis formation. The inference is that sedimentation of the lower part of the San Luis formation either was a relatively slow process which took a long time while a great thickness of Cobre rocks was eroded from over the older rocks and transported, or was a relatively fast process which took a short time while a locally thin cover of Cobre rocks was eroded and transported to the zone of deposition. Within the area mapped, we found no San Luis constituent sediments identifiable with the pre Charco Redondo rocks of the Nipe-Cristal Highlands.

In the zone of deposition, the San Luis sediments apparently were laid down in a warm, shallow trough between a southern land mass and the Central Massif of the present Nipe-Cristal Highland region, which was submerged and seems finally to have been buried towards the end of San Luis time if not during Charco Redondo time. Sinking of the sea bottom in the trough apparently kept pace with the accumulation of sediments for the rocks and the contained fauna show no signs of a change in depth during sedimentation. The local and thin conglomerates well out in the trough region may reflect local changes in currents or in the coarse clastic supply regimen.

We do not believe that any authoritative opinions or true understanding of San Luis sedimentation and paleogeography can be reached without careful and extensive study and mapping of the Sierra Maestra, Guantánamo Basin, and the southern Sierra del Cristal and Sierra Guaso.

UNNAMED ROCKS (OLIGOCENE)

CHARACTER AND DISTRIBUTION

Oligocene rocks overlie the San Luis formation with apparent conformity along the northwest boundary and also in the extreme northeastern part of the mapped area of south-central Oriente. The top of the formation represented by these Oligocene rocks was not seen, because no work was done north of the boundary of the mapped area, within which area only the lower part of this formation crops out. The rocks are mainly brownish-yellow marl, limy mudstone, and chalk. So far as is known, the formation has no economic importance other than that of the soil derived from it. Where not underlain by San Luis rocks, tracts planted to sugar cane in the mapped area are underlain by the Oligocene rocks.

Keijzer (1945, p. 50–51) described and named the "Oligomiocene Nipe series * * * covering most of the Nipe Basin," and mapped its southernmost outcrops about 8 kilometers north of the Río Cauto at Morcate village, and about 15 kilometers north of Central Miranda. We located the southernmost outcrops of the Oligocene rocks in the same two longitudes at points considerably to the south of those mapped by Keijzer, at Morcate village on the Río Cauto, and in the Cayo del Rey Hills about 4 kilometers north of Central Miranda, respectively. This difference of from 8 to 11 kilometers in the positior of southernmost outcrops may indicate that the Oligocene rocks described herein are not part of the Nipe series of Keijzer. We did not map as far north as the base of the Nipe series mapped by Keijzer, and his results were published after the conclusion of our field work. He described the Nipe series, in the marginal portion of its outcrop area, as a facies "mainly of yellow limestones with intercalated yellow and white marls * * * no actual unconformity has been found" between the Nipe series and the underlying Eocene rocks, which he (Keijzer, 1945, p. 49–50) describes as consisting "mainly of white limestones and marls * * * transgressive * * * over the serpentine of the Sierra de Nipe."

Keijzer's description of the Nipe series and underlying rocks agrees fairly well with our observations of the Oligocene rocks, on the one hand, and the San Luis and Cobre (Charco Redondo member) rocks on the other, in the northwestern and northeastern parts of the south-central Oriente mapped area. White chalk and lenses of bioherm limestone that weathers to a yellowish brown are intercalated in the brownish-yellow Oligocene marl, limy mudstone, and chalk which make up the basal portion of the first formation. The underlying

Eocene rocks within the area covered by Keijzer's map are interbedded marl, impure limestone, limy shale and sandstone (San Luis formation) which might be equivalent to Keijzer's "marls", and bedded to massive limestone (Charco Redondo limestone member of the Cobre formation), which might be equivalent to Keijzer's "white limestones". This last rock unit is transgressive upon the serpentine and ultramafic complex of the Sierra de Nipe.

Except for a small tract of outcrop northwest of the mouth of the Río Caoba, the known outcrops of the Oligocene rock unit here described closely parallel the northwest edge of the mapped area. The greatest and least thicknesses are not known, nor is the entire outcrop area known. However, these rocks surely underlie wide areas in the Cauto Valley and further north, as well as a small area of unknown extent northward beyond the mapped outcrops northwest of the mouth of the Río Caoba. Equivalent rocks may crop out east of the Jarahueca Valley, Sabanilla and La Galleta Lowlands. Woodring and Daviess (1944, p. 382) mention "strata, apparently of Oligocene age * * * in the drainage basin of Guaninicum River north of San Luis." W. P. Woodring (written communication) indicates that this statement was based on unverified field impressions gained during a brief trip: he thought that the strata, which overlie conglomerate and contain a large, somewhat selliform *Lepidocyclina*, might be Oligocene. Although we found no Oligocene rocks in this locality, future mapping may reveal some.

The Oligocene rocks, along their southernmost limit of outcrop southwest of the Nipe Highlands, overlie the San Luis formation with apparent conformity and rise above the San Luis rocks in a low cuesta. The cuesta scarp faces southward, and is conspicuous but not steep; the back slope dips gently to the north. This cuesta, Morcate Ridge, stretches from Cayo del Rey in a southwesterly direction across the Río Cauto for 35 kilometers to the western edge of the mapped area, 4.5 kilometers north-northwest of Contramaestre.

At locality 43, 6 kilometers north-northeast of Contramaestre, the lowermost Oligocene rocks are largely marl and limy mudstone, with some intercalated chalky beds and bioherm limestones. In the neighborhood of locality 44, 4 kilometers north-northeast of Remanganaguas, the highly fossiliferous limy mudstone with intercalated bioherm limestones overlies conglomeratic San Luis rocks. Fully 90 percent of one bed of shaly limestone, 30–60 centimeters thick, is made up of loose large Foraminifera, with matrix, pelecypod and gastropod shells. The lowermost Oligocene rocks at locality 96, on the southwestern outskirts of Morcate village, are white, chalky, and almost entirely made up of small Foraminifera; this rock could be called a foraminiferite. It conformably overlies coarse sandstone of the San

FIGURE 38.—Oligocene rock outcrops in quarry in Morcate Ridge at Morcate, locality 96. Chalky white Oligocene foraminiferite exposed in quarry face; grassed-over quarry floor is fine-grained conglomerate and conglomeratic sandstone of San Luis formation.

Luis formation (fig. 38). About 1 kilometer downstream from Morcate village on the Río Cauto, at locality 97, the marly Oligocene rocks contain lenses of bioherm limestone about 50 meters above the base of the formation.

In the Cayo del Rey Hills, bioherm limestone lenses are intercalated in marly and chalky Oligocene rocks that seem to lie conformably upon marl and limy shale of the San Luis at localities 213–221. A similar sequence crops out at localities 279 and 280, northwest of the mouth of the Río Caoba.

FOSSILS

Mr. de Albear's identifications of Foraminifera are listed in the following table:

Foraminifera found in Oligocene rocks of south-central Oriente

	Localities														
	43	44	96	97	99	100	214	216	217	218	219	220	221	279	280
Textularia mexicana cubensis Palmer and Bermúdez			×												
T. sp			×												
Vulvulina jarvisi Cushman			×			cf.									
Verneuilina sp			×												
Clavulina cylindrica Hantken			×												
Dictyoconus cookei (Moberg)														(*)	
Spiroloculina depressa d'Orbigny			×												
Pyrgo sp			×												
Robulus arcuato-striatus (Hantken)			×												
arcuato-striatus carolineanus (Cushman)	×														
chambersi Garrett			×												
gutticostatus cubensis Palmer and Bermúdez			×												
Lenticulina sp			×												
Marginulina aff. *Marginulina hirsuta* d'Orbigny			×												
Dentalina halkyardi (Cushman)			×												
semilaevis Hantken			×												
D. sp			×												
Pseudoglandulina conica (Neugeboren)			×												
Vaginulina elegans mexicana Nuttall			×												
V. sp			×												
Lagena acuticostata Reuss			×												
L. sp			×												
Pyrulina gutta (d'Orbigny)			×												
Heterostegina texana Gravell and Hanna													×		
Gümbelina cubensis Palmer			×												
Plectofrondicularia vaughani Cushman			×												
Bulimina ovata d'Orbigny			×												
semicostata Nuttall			×												
sculptilis Cushman			×												
B. sp			×												
Virgulina vicksburgensis Cushman			×												
V. sp			×												
Bolivina byramensis (Cushman)			×												
matanzana Palmer and Bermúdez			×												
tortuosa Brady			×												
B. sp						×									
Rectibolivina mexicana (Cushman)			×												
Uvigerina gardnerae nuttalliana Howe and Wallace			×												
mexicana Nuttall			×												
vicksburgensis Cushman and Ellison			cf.												
sp			×			×									

Pleurostomella alternans Schwager			×												
Nodosarella multicostata (Galloway and Morrey)			×												
subnodosa (Guppy)			×												
Ellipsonodosaria caribaea Palmer			×												
gracilis Palmer and Bermúdez			×												
verneuili paucistriata Galloway and Morrey			×												
Ellipsoglandulina labiata (Schwager)			×												
Discorbis subaraucana Cushman			×												
Gyroidina soldanii d'Orbigny			×												
Eponides advena Cushman	×														
byramensis (Cushman)			×												
byramensis cubensis Palmer and Bermúdez	×		×			×									
nanus (Reuss)	×		×												
umbonatus (Reuss)	×					×									
E. sp.			×												
Rotalia byramensis Cushman			×												
Siphonina advena cubensis Cushman and Bermúdez			×												
tenuicarinata Cushman			×			×									
S. sp.	×		×												
Asterigerina subacuta Cushman						×									
Amphistegina floridana Cushman						×									
Parrella mexicana Cole			×												
Cassidulina subglobosa Brady			×			×									
sp.			×												
Globigerina triloculiaris d'Orbigny	×		×												
G. sp.	×		×			×									
Anomalina alazanensis Nuttall			cf.												
grosserugosa (Gümbel)			×												
Planulina marielana Hadley			×												
Cibicides americana (Cushman)			×												
floridanus (Cushman)			×												
mexicana Nuttall	×		×												
perlucida Nuttall			×												
pseudoungerianus (Cushman)	×		×												
subtenuissima (Nuttall)	×		×												
C. sp.						×									
Lepidocyclina (Lepidocyclina) parvula Cushman	×			×									×		
(Lepidocyclina) tschoppi Thiadens							cf.	cf.				×			
yurnagunensis Cushman	cf.												cf.		
yurnagunensis morganopsis Vaughan							×						×		
sp.	×			×	×		×			×		×		×	×
(Nephrolepidina) perundosa Cushman								×						×	
(Eulepidina) favosa Cushman	×								×					×	×
gigas Cushman	×	×				×								×	×
petri Thiadens								×			×			×	×
undosa Cushman	×	×		×				×					×		

*Probably secondarily derived.

Corals are relatively common in the bioherm limestones which are intercalated in the Oligocene marl, limy mudstone, and chalk. Keijzer (1945, p. 50–56) records 5 genera of corals, usually found associated with abundant calcareous algae, from his Oligomiocene Nipe series localities near Nipe Bay on the north coast, but states that "their evidence is inconclusive as regards the subdivision of the Oligomiocene."

We found the Oligocene bioherm limestones to contain abundant corals, but it is somewhat cavernous and the macrofossils found were all molds, only one of which agrees generically with those described by Keijzer (*Stylophora*). Mr. John W. Wells identified the corals and determined their ages; his results are summarized as follows:

Corals from Oligocene rocks [1]

[by John W. Wells]

	Localities			Remarks
	97	99	217	
Lower and middle Oligocene:				
Stylophora sp. cf. *S. minutissima* Vaughan	------	------	×	Of the middle Oligocene of Georgia.
Astreopora n. sp	------	×	------	
sp	------	------	×	May be the same as the new species from locality 99.
Indeterminate solitary coral	------	------	×	A flabellid, possibly a new genus.
Oligocene(?):				
Actinacis n. sp	×	------	------	
Cladocora sp	×	------	------	

[1] All specimens are molds and determinations are unsatisfactory.

The bioherm limestones contain some molds of mollusk and echinoid remains, but none were determinable; one mold of a pelecypod fragment might possibly be referable to the Pectinidae.

LA CRUZ FORMATION (MIOCENE)

CHARACTER AND DISTRIBUTION

The La Cruz formation was mapped in a small area northeast of Santiago Bay. This formation, which is nearly flat lying, overlaps the strongly deformed Cobre formation with angular unconformity. The lower part of the La Cruz formation is represented near the Central Highway and the Cristo road and contains conglomeratic and sandy clastics derived from the Cobre rocks of the Sierra Maestra.

Hayes, Vaughan, and Spencer (1901, p. 23) were the first to report that "a very great development of marls and limestones, containing large numbers of reef corals, is seen in and around the city of Santiago." Later, Vaughan (1918, p. 276) named and described these same rocks as the "La Cruz marl * * * The type exposure * * * is on the east side of Santiago Bay * * * The material is a yellowish, very calcareous marl, or an argillaceous limestone, which is as a rule well bedded."

Taber (1931, p. 541) noted that the La Cruz formation

> occupies a considerable area in the vicinity of Santiago Bay. It was laid down on tilted and eroded beds of the Cobre series within a baylike indentation of the land. The former extent * * * is unknown, as it is abruptly cut off * * * along the present coast.

He further states (1934, p. 588):

> It is only a few hundred feet thick, and consists chiefly of marl, with sandy beds and conglomerate near the base. Limited to an area of about 125 square kilometers in the vicinity of Santiago, it extends eastward almost to Siboney, and westward a short distance beyond the entrance to the bay * * * Its boundary crosses the El Caney road a kilometer or more northeast of Río Purgatorio [Río San Juan], and the Carretera Central and the Cristo road, four to five kilometers north of Santiago, where there is a heavy bed of gravel.

The La Cruz rocks underlie much of the Santiago Bay Lowland.

The La Cruz is designated as a formation rather than as a "marl", because marl seems to be a minor constituent of the formation as a whole. Woodring and Daviess (1944, p. 381) have observed that "the designation 'marl' is hardly appropriate for the La Cruz formation, which contains very little marl."

FOSSILS AND AGE

No fossils were collected from this formation. Published opinions assign a middle Miocene age to the La Cruz formation. The following faunal lists have been published with the comments quoted:

C. W. Cooke (1919, p. 109; 1921, p. 137):

> Appear to have come from a single geologic horizon which is exposed at numerous localities in the vicinity of Santiago. The fauna * * * bears a close resemblance to those of Tampa and Anguilla, but may be a little younger. [Note: the Anguilla formation of the Lesser Antilles and the Tampa formation of Florida are of early Miocene age, according to Woodring (1928, p. 64, 90).]

Strombus sp.
Ostrea haitensis Sowerby
Pecten thetidis Sowerby
Pecten ventonensis Cooke
Pecten crucianus Cooke
Pecten vaun var. *flabellum* Cooke
Pecten gardnerae Cooke
Pecten jacobianus Cooke
Pecten landi Cooke
Pecten pittieri Dall
Plicatula densata Conrad
Modiolus cinnamomeus Lamarck
Lithophaga nigra (d'Orbigny)
Teredo sp.
Tellina sp.
Metis trinitaria Dall
Phacoides aff. *P. hillsboroënsis* (Heilprin)

W. P. Woodring (1928, p. 61): "The correlation * * * of the La Cruz marl * * * with the Bowden formation rests on the corals."

T. W. Vaughan (1922, p. 115–116; 1919, p. 263, 218–219):

Santiago de Cuba: specimens of three species [of echinoids listed below were] not accompanied by stratigraphic data. Of these species, [the first and last] are still living in the West Indies; [all three] occur at the Anguillan horizon * * * These species may come from the Miocene La Cruz marl.

Cidaris tribuloides (Lamarck)
Echinometra prisca Cotteau
Echinoneus cyclostomus Leske

The La Cruz marl is a bedded formation in which there are a few reef corals. The presence of pebbles in the basal part of the formation * * * suggests an erosional unconformity with some older Tertiary formation * * * The horizon appears to be above that of the Bowden marl * * * The corals are as follows:

Stylophora affinis Duncan
Pocillopora sp.
Stephanocoenia intersepta (Esper)
Orbicella limbata (Duncan)
Solenastrea hyades (Dana)
Solenastrea bournoni M. Edwards and Haime
Thysanus aff. *T. excentricus* Duncan
Siderastrea siderea (Ellis and Solander)
Goniopora jacobiana Vaughan
Porites porites (Pallas)
Porites astreoides (Lamarck)

F. G. Keijzer (1945, p. 116–118):

The age of the La Cruz marl is generally accepted to be Miocene * * * Smaller foraminifera * * * from a number of Tschopp's samples * * * the same typical assemblage as found in the Guines limestone of Middle Cuba, and the Miocene and Pliocene of Florida. It is also present in the vicinity of Habana and Matanzas.

Ostrea haitensis Sowerby
Pecten jacobianus Cooke
Porites porites (Pallas)
Clavulina tricarinata d'Orbigny
Quinqueloculina seminulum (Linnaeus)
Quinqueloculina vulgaris d'Orbigny
Quinqueloculina spp.
Spiroloculina ornata d'Orbigny
Triloculina oblonga d'Orbigny
Triloculina spp.
Pyrgo subsphaerica (d'Orbigny)
?*Vertebralina* sp.
Nonion grateloupi (d'Orbigny)
Nonion pizarrense Berry
Nonion sp.
Elphidium poeyanum (d'Orbigny)
Elphidium rota Ellis
Elphidium rugosum (d'Orbigny)
Elphidium sagrum (d'Orbigny)

Elphidium sp.
Archaias angulatus (Fichtel and Moll)
Amphisorus sp.
Peneroplidae spp.
Discorbis bertheloti (d'Orbigny) var. *floridensis* Cushman
Discorbis floridana Cushman
Discorbis orbicularis (Terquem)
Rotalia beccarii (Linnaeus) var. *tepida* Cushman
Rotalia caloosahatcheensis Cole
Asterigerina subacuta Cushman
Amphistegina lessonii d'Orbigny
Globigerina triloba Reuss
Globorotalia menardii (d'Orbigny)
Cibicides lobatulus (Walker and Jacobs)
Planorbulina mediterranensis d'Orbigny
Gypsina globulus (Reuss)

J. A. Cushman (1919, p. 44, 70):

Gypsina globulus (Reuss) var. *pilaris* Brady
Orbitolites (*Sorites*) *duples* Carpenter

ALLUVIUM (QUATERNARY)

Woodring and Daviess (1944, p. 379) distinguished between older and younger alluvium in the Guisa—Los Negros area, but thought that even the older alluvium might be Recent.

We have mapped undifferentiated alluvium only in a few places where it is widely developed, as in the Cauto Valley (fig. 28). It was not mapped in smaller areas such as the Guaninicum Valley between Dos Caminos and El Cristo. No fossils were collected, and no precise age reference is made. The mapped alluvium is probably as old as Pleistocene for the most part, but some unmapped deposits as old as Pliocene may be represented in the unconsolidated sediments at several places, such as the head of Santiago Bay, and between the Río San Juan and Arroyo La Guamá south of El Caney.

IGNEOUS ROCKS

Intrusive rocks, chiefly dikes and small stocks of fine-grained, commonly porphyritic rocks, are sporadically distributed throughout south-central Oriente. Batholiths of dioritic rocks crop out along the south flank of the Sierra Maestra, and on the southwestern slopes of the Sierra de Nipe the ultramafic complex is exposed. By far the greatest number of intrusive bodies is in the Cobre formation, principlly in its lower part, and a few dikes cut the rocks of the San Luis formation but no intrusive rocks have been found in areas underlain by the Oligocene rocks.

The rocks represent a varied range of petrographic character and geologic age. Their mineralogic composition as well as age therefore serve as a logical basis for their consideration and description and accordingly they are separated into two groups: a pre-Tertiary group in which are included the definitely pre-Campanian ultramafic complex of the Sierra de Nipe, together with certain small, probably pre-Tertiary stocks of dacite or quartz diorite in La Burra basin; and a Tertiary group believed for the most part to have been emplaced during the early and middle Eocene period of volcanism, but in part emplaced in late Eocene time and which consist of small stocks and dikes of dacite, andesite, and basalt. The Sierra Maestra dioritic batholiths are included in the late Cretaceous or early Tertiary group of intrusive rocks.

PRE-TERTIARY INTRUSIVE ROCKS

The pre-Tertiary assemblage of rocks includes two groups whose geologic relations are indicated by the structural and erosional history of the area and by their differences in petrographic character. The first group is that of the ultramafic rocks that make up the bulk of the Central Massif of the Sierra de Nipe, together with gabbro and certain diorites regarded as being genetically related to the ultramafic rocks. The second is the dacites or fine-grained quartz diorites that occur in La Burra basin.

ULTRAMAFIC ROCKS

The ultramafic rocks include more or less serpentinized peridotite, dunite, and pyroxenite, and the genetically related feldspathic rocks, gabbro, troctolite, and anorthosite, all of which are represented, according to Thayer (1942) and Guild and Thayer [3] in the intrusive complex comprising the great bulk of the Sierra de Nipe (fig. 26) and Sierra del Cristal. But as these rocks are represented only in part in that portion of the Sierra de Nipe which has been mapped by the writers and as the area involved is only a small fraction of the area over which the ultramafic complex is exposed they have not been studied in detail and will be but briefly described.

The ultramafic rocks, characterized by the preponderance of olivine and pyroxene, greatly predominate in the southern end and flank of the Sierra de Nipe. No feldspathic rocks were found in contact with the ultramafic rocks, although they were found in place in the younger rocks. Peridotite, partly or wholly altered to serpentine, is the principal component of the ultramafic rocks; both dunite and pyroxenite form but a minor part of these rocks. The peridotite is medium-grained and equigranular and is light to dark green or greenish black on fresh surface, whitish gray, greenish gray, or yellowish to reddish brown on weathered surface. Much of the rock that has been most serpentinized is veined by chrysotile or tremolite. Such expo-

[3] Guild, P. W., and Thayer, T. P., Chromite deposits of Cuba, unpublished report.

sures as that on the trail 5.7 kilometers east of Central Miranda show a highly serpentinized peridotite, almost white in color on weathered surface but gray on fresh surface. The peridotite elsewhere, around and north of Pinar Redondo and Pinalito, is a darker colored rock in which pyroxene grains, nearly all altered, can be recognized especially on weathered surface where reflections on prominent cleavages are conspicuous.

According to Guild and Thayer (unpublished report) the feldspathic rocks are not common in eastern Cuba. The rocks exhibit a great variation in composition and texture. With decrease in pyroxene content they pass into troctolite, and with decrease in olivine, into normal gabbro. The most common rock is a medium-grained equigranular olivine gabbro containing approximately equal proportions of bytownite or labradorite and the mafic minerals augite and olivine. The feldspathic bodies form pockets or layers in the ultramafic members. Diabasic dikes, herein described as fine-grained diorites, have been found in the Mayarí district and in other parts of Cuba. Keijzer (p. 64–65), described gabbroic dike rocks including uralitic diabases and uralitic gabbro on the Río Mayarí, about 6.3 kilometers south of the town of Mayarí. According to Guild and Thayer (unpublished report) these fine- to medium-grained, light to dark greenish-gray rocks appear to be genetically related to the ultramafic rocks. The dikes have no finer grained selvages though their contacts are sharp, and appear therefore to have been emplaced in the ultramafic rocks while the mass was rigid but while it yet retained a relatively high temperature. The dioritic dike rock is composed chiefly of labradorite laths in augite largely altered to uralitic hornblende, and accessory magnetite.

Gabbroic and dioritic intrusive rocks are not known to occur within the areas underlain by ultramafic rocks at the south end and flank of the Sierra de Nipe though they are known elsewhere in this range and in the Sierra del Cristal. They crop out in the areas of younger rocks at distances as much as 2.4 kilometers from the nearest exposures of ultramafic rocks. Gabbroic and dioritic rocks were found in three areas.

The rock near the Río Piloto, 4.2 kilometers northeast of Pinar Redondo, crops out in the Picote conglomerate member of the Habana(?) formation. It is fine- to medium-grained diorite, gray on fresh fracture and brown on weathered surface and has a diabasic texture. In hand specimen thin laths of plagioclase as much as 3 millimeters in length are conspicuous. A thin section shows subhedral laths of zoned plagioclase ranging in composition from An_{60} to An_{10}, and pale-green hornblende. Approximately equal proportions of plagioclase and hornblende are present. The hornblende is in small part altered to penninite and some of the plagioclase, particularly the more calcic centers, are in part altered to a white clay mineral. Late or secondary magnetite is the accessory mineral.

The rock which crops out in an area underlain by the Charco Redondo limestone member near the Río Jagua, 3 kilometers west of Monte Picote, is an olivine gabbro. It is medium grained, equigranular, dark gray, and very fresh. The minerals seen under the microscope are anhedral to euhedral labradorite of about An_{70} composition, anhedral diallage, altered in small part to uralitic hornblende, and olivine, most of which is fresh but a part of which is altered to serpentine and chlorite(?). The plagioclase is unusually fresh and exhibits but little zoning. Olivine is associated with the diallage, and nearly all of the grains of olivine are entirely surrounded by the pyroxene. Magnetite, probably secondary, occurs as irregular patches and stringers that surround and cut the olivine. Except that this rock is comparatively fresh it is very similar to the altered gabbro, which is an abundant component of the Picote conglomerate member.

An intrusive rock of similar character occurs 1.6 kilometers south-southwest of Pinar Redondo, where it crops out in an area underlain by the Picote conglomerate member. The rock is fine- to medium-grained and has a granitic rather than a diabasic texture. It appears to be similar to the gabbro on the Río Jagua but the rock was not examined under the microscope.

Exposures of the above intrusive rocks indicate that they do not intrude the rocks with which they are in contact but rather are older. No finer grained border zones are seen nor are the surrounding rocks metamorphosed. Moreover the gabbroic and diabasic intrusive rocks differ markedly in composition, texture, and type of alteration from the younger rocks that intrude Eocene and Upper Cretaceous rocks. Finally, boulders and pebbles of rocks of similar if not identical physical and petrographic character form the bulk of the coarser constituents of the Picote conglomerate member, indicating that such rocks were exposed and subject to erosion at the time the conglomerate was formed. These gabbroic and dioritic rocks appear to be similar to the feldspathic rocks of the ultramafic complex, as described by Guild and Thayer, and by Keijzer, and are therefore also considered to be genetically related to the ultramafic members of the complex. They may, however, be distinctly later than the rocks of the ultramafic complex and related to some volcanic epoch older than the Habana(?) rocks exposed in the area.

The age of the ultramafic complex is not known, but as serpentine fragments are common in the clastic rocks of the Upper Cretaceous Habana(?) formation, and the Picote conglomerate member of this formation unconformably overlies the ultramafic rocks, the complex is at least as old as Campanian.

DACITIC OR QUARTZ DIORITIC ROCKS

Certain small stocks of weathered and intensely altered, fine-grained rocks that intrude the rocks of the Habana(?) formation in La Burra Basin are tentatively regarded as pre-Tertiary in age. The topographic expression of these rocks does not differ appreciably from the surrounding Habana(?) rocks and exposures are so poor that they were not mapped in this area, but specimens of the rocks were collected from five localities along the road from Escondida to Sabana la Burra, and one specimen was collected from an intrusive on the trail to La Peluda, 2.5 kilometers southeast of Sabana la Burra. The rocks are commonly tan or brown on weathered surfaces and, except for lack of bedding, are in places difficult to distinguish from the brown, weathered tuffs and tuffaceous sandstones of the Habana(?). On fresh surfaces the rocks are brownish to greenish gray. Altered feldspar and pyroxene can sometimes be recognized in hand specimens. Fine-grained border facies exhibited by the intrusives grade into coarser-grained rocks away from the contacts, and the intruded rocks are slightly baked and somewhat silicified. In thin section the rocks are similar in composition and texture. The dominant mineral is plagioclase, commonly turbid because of partial alteration to clay; some of the phenocrysts are completely altered to zeolite and clay. The fresher grains of plagioclase range in composition from albite to oligoclase or possibly andesine. Orthoclase may be present in the groundmass but none was identified. Interstitial quartz is present in amounts up to 20 percent and though most of the mineral appears to be primary some of it is probably secondary as it veins and replaces the other rock minerals. Augite is also present in some of the specimens but most of this mineral has altered to chlorite. Zeolites make up 20 to 30 percent of some of the specimens. The rocks are classified as altered dacites or fine-grained quartz diorites.

The dacitic or quartz dioritic rocks are considered to be pre-Tertiary in age because they do not intrude the Cobre rocks in the area nor do they intrude the Upper Cretaceous(?) Peluda volcanic member. Moreover the severe alteration of these intrusive rocks is not a characteristic feature of intra- or post-Cobre intrusives which are less highly altered and contain less visible free quartz. The rocks may be genetically related to the volcanic rocks of the Habana(?) formation and may well have been emplaced during the later stages of the late Cretaceous (Habana?) volcanic activity.

LATE CRETACEOUS OR EARLY TERTIARY PLUTONIC ROCKS

CHARACTER AND DISTRIBUTION OF THE SIERRA MAESTRA BATHOLITHS

Batholiths of dioritic rocks crop out along the south flank of the Turquino and Gran Piedra ranges. These intrusives have not been studied in detail but, as there is a possible genetic relation with the smaller intrusive bodies and with the volcanic rocks of the region, a description of these rocks is deemed warranted.

Spencer (1908), Kemp (1915), Singewald and Miller (1916), and Roesler (1916) briefly describe the batholithic rocks in the Vinent and Firmeza area, 24 kilometers to the east of Santiago Bay. Taber mentions these intrusive rocks not only in the aforementioned areas but points out the existence of the same or similar rocks along the south slope of the Turquino Range. Kemp and Roesler studied the rocks in the Daiquirí-Firmeza area in greater detail than any previous investigator. They divided the differentiates of the batholith into a dioritic and granitic group.

Kemp describes the "granite" of the Daiquirí district as a rock which contains abundant quartz and in which the predominant feldspar is either orthoclase or more commonly oligoclase. Biotite is the most common dark constituent but hornblende and augite are also present. The rocks of the "diorite" group, according to Kemp, are medium-grained rocks in which the most abundant constituent is plagioclase ranging in composition from andesine to labradorite and more rarely bytownite. Green hornblende is next in abundance and biotite and quartz are minor constituents.

Roesler describes the rocks of the "granitic" group as being hornblende bearing and containing very little quartz. Highly quartz-rich aplites are the youngest rocks of the "granitic" group. Some of the more quartz rich "granites" locally contain micrographic intergrowths of quartz and feldspar. The "dioritic" rocks according to Roesler are fine-grained rocks made up of plagioclase ranging in composition from labradorite to bytownite, and of hornblende.

The north contact of the batholith west of Santiago was investigated at two points in the El Gato Massif, but the batholithic rocks of the Daiquirí-Firmeza districts do not extend into that part of the Santiago-El Caney area covered by the present investigation. On the Río Nima Nima about 4.8 kilometers south-southwest of El Cobre the rock is light gray, massive, and medium grained. Near its contact with massive fine-grained hornfelsed volcanic rocks the rock is distinctly layered. Southwest of the Lomas de Uraguá the batholithic rock is also in contact with fine-grained massive volcanic rocks that are probably flows. It is greenish gray, fine grained, and contains abundant disseminated pyrite near the contact but grades into the normal light-gray medium-grained rock.

A thin section of a specimen of massive rock collected on the Río Nima Nima 0.8 kilometer south of the contact was examined under the microscope and found to be diorite in which the dominant minerals are zoned plagioclase, ranging in composition from oligoclase to calcic labradorite, and pale-green hornblende. Augite and biotite are present in small amount and apatite, sphene, and magnetite are accessory minerals. The rock has undergone progressive late magmatic alteration with the development of green hornblende from augite and of chlorite and epidote from the hornblende. Minor amounts of prehnite are associated with the chlorite and epidote. Numerous irregular patches of quartz, which makes up approximately 5 percent of the rock, have been formed and in part replace plagioclase. Plagioclase at the quartz contacts is albite and nearby plagioclase shows rounded patches of albite. The rock to the southwest of the Lomas de Uraguá is like that at Río Nima Nima but contains a little more late quartz, and late calcite is a minor constituent.

The diorite of the El Gato Massif appears then to be similar to the rocks of the "dioritic" group described by Kemp and Roesler but, as the quartz content is low, does not fall into their "granitic" group.

These batholithic rocks may well be related genetically to part of the eruptive rocks of the Cobre as the similarity of mineralogic and apparent chemical compositions suggest that the batholithic rocks could represent a part of the magmatic reservoir from which some of the volcanic rocks of the Cobre were derived.

AGE OF THE BATHOLITHS

Determination of the age of the batholiths within narrow limits is precluded by the absence of direct evidence. We tentatively assign the time of intrusion to the early Tertiary. Taber (1934, p. 583–584) assigned an Eocene age to the batholiths for he believed their debris to be present in the upper Eocene rocks of the San Luis formation, and that they intruded Eocene rocks of the lower part of the Cobre formation. Keijzer (1945, p. 104–107) on the other hand regarded the batholiths as late Cretaceous in age for he found that the components of a pebble of conglomerate collected on a river 25 kilometers southwest of Guantánamo included quartz-orthoclase aplite and granophyric intergrowths of quartz and orthoclase, rocks which he postulated to have been derived from the batholiths of the Sierra Maestra. The matrix of the conglomerate pebble contained late Cretaceous fossils.

We were unable to prove the conclusions of either Taber or Keijzer. Nowhere are the batholiths known to be in contact with unequivocal rocks of the Cobre formation. Fossils have not been found in the section of massive volcanic rocks, at least 1,500 meters thick, that lie between known Cobre rocks and the batholiths. However, we agree with Taber that the pebbles of granitic rocks in the Camarones conglomerate member of the San Luis formation could have been derived from differentiates of the Sierra Maestra batholiths. Therefore, the batholiths presumably were intruded before late Eocene time.

An Eocene age for the diorite batholiths is supported by the fact that an unconformity or disconformity, which would indicate a hiatus in the volcanic rocks above these intrusives, has not been found. Although a stratigraphic or structural break would not be readily discernible in this section of massive volcanic rocks, the few attitudes that are available do not suggest that a major unconformity exists in the section. Moreover, a marked difference in composition of the rocks in this section as compared to known Cobre rocks is not apparent from the rather meager data at hand, although a more intensive study might indicate a recognizable dissimilarity such as would suggest the existence of a disconformity. Other factors which support Taber's contention are that small stocks of dioritic rocks intrude known Cobre rocks, and that copper deposits, which appear to be most numerous near the contact of the dioritic batholiths but which may or may not be genetically related to these rocks, occur in known Cobre rocks near El Caney and at El Cobre. The stocks of dioritic rocks in the Cobre differ little mineralogically from the diorites of the batholiths. The alteration of the augite to chlorite is marked by an intermediate hornblende stage in both the Alto Songo and Sigua rocks just as it is in the rocks of the batholiths, but such evidence does not conclusively demonstrate the relation between these rocks. It is conceivable that two stages of intrusion, separated by a long time interval, may have yielded the same rock type.

Keijzer' evidence of a Cretaceous age for the diorite batholiths cannot be regarded as conslusive inasmuch as the stratigraphic relations between the Cobre and Vinent formations are still obscure, and the fragments of rocks in the conglomerate pebble found by Keijzer could well have come from intrusive rocks emplaced earlier than the Sierra Maestra batholiths.

TERTIARY INTRUSIVE ROCKS

The Tertiary intrusive rocks have tentatively been segregated into three main groups: dacites, andesites and diorites, and basalts. The rocks occur principally as small stocks that are widely distributed most commonly in and around the Santiago Basin and in the Boniato Piedmont of the Turquino Range, and subordinately as dikes that are scattered in the northern foothills of the Turquino and Gran Piedra ranges and in the Cauto Lowlands. Most of these rocks intrude the Cobre formation but a few dikes and one stock intrude the San Luis formation. The more felsic of the intrusive rocks stand out as hills more than a hundred meters high, but the rocks that range from andesitic to basaltic weather nearly as rapidly as the enclosing younger rocks and have little topographic expression.

DACITIC ROCKS

Dacitic rocks form two subgroups that include light-colored porphyritic rocks and dark, generally nonporphyritic rocks. They occur as regular, rounded to oval-shaped stocks of fine-grained rock that range in size from a hundred meters to a kilometer or more in diameter and stand out as positive relief features because of their resistance to erosion. The stocks have a finer-grained border zone and the intruded rocks have undergone slight baking over a zone a meter or more wide bordering the intrusive rocks. In some places the contact zone is so poorly exposed that these phenomena are not easily observed, and in a few cases are not discernible.

The light-colored dacites are light-gray, purplish-gray, or light-brown, fine-grained porphyritic rocks that, except for variation in color, are very similar in general megascopic and microscopic appearance. The dominant constituents seen under the microscope are plagioclase ranging in composition from albite to sodic oligoclase, and quartz. Most of the groundmass and much of the plagioclase in these rocks is replaced by zeolite. In one specimen a small amount of augite was present, and all the rocks contain a little chlorite which is probably secondary after augite. The accessory mineral is magnetite. At least seven stocks of this rock type have been mapped in and around the Santiago Basin. These include the three small stocks northeast of El Cobre, the stock at Cuabitas, and that 1.2 kilometers northwest of El Caney. Only one stock of light-colored, porphyritic dacite was mapped in the Nipe Highlands at the northeast end of the Sumidero Basin.

The dark-colored dacites include one stock, 2.5 kilometers north-northwest of El Caney, two small stocks 2.5 kilometers west-northwest of the Amarito mine, and three small stocks about 1.6 kilometers south of Los Negritos, in the La Burra Basin. Except for a few scattered phenocrysts of plagioclase averaging about 2 millimeters in length the rocks are uniformly fine grained. The small intrusive stocks at the south end of La Burra Basin are fine-grained and black in color. Fresh, unzoned plagioclase (calcic andesine) in euhedral to subhedral grains averaging about 0.5 millimeter in diameter, anhedral quartz, and augite are the chief minerals. Magnetite and apatite are acessory minerals. The dacite stock near El Caney is a dark greenish-gray rock that contains a few scattered phenocrysts of plagioclase in a fine-grained, but apparently holocrystalline, groundmass. Other intrusive rocks in this area are similar in appearance but were not studied.

The textural and mineralogic similarity of the light-colored dacites is a strong indication of their magmatic relationship. These rocks intrude lower to middle Cobre rocks and are believed to have been emplaced during the late stages of Cobre volcanism. The dark-colored dacites may be the same age but the relative ages of the two dacite subgroups is not known definitely.

ANDESITIC AND DIORITIC ROCKS

Stocks and dikes of andesitic and dioritic intrusive rocks are distributed at random in the Sierra Maestra Highlands. One stock occurs in the Villafaña basin in the Nipe Highlands, and another stock is in the Cauto-Guantânamo Lowlands. The largest stock, near the Sigua mines, may be several kilometers in diameter though its full extent is not known, but most of the intrusive bodies do not exceed a hundred meters in diameter. Outcrops of these rocks are not prominent although some of the intrusive bodies stand out as low knolls and some are conspicuous because of their massive nature and their tendency to weather into spheroidal boulders. The rocks are generally distinctly finer in grain at their borders and the intruded rocks are slightly indurated near the contacts. Some of the tuffs intruded by the stock at Sigua are hornfelsed.

Intrusive stocks of andesite include a small one about 5 kilometers south-southeast of the Amarito mine, five small oval stocks that crop out from 1 to 1.5 kilometers northwest of El Caney, one small stock 2 kilometers east of Boniato, a poorly exposed dike 1.2 meters wide, which is 4.5 kilometers east-southeast of El Cristo, and the stock in the Villafaña Basin. The rocks are massive, gray to greenish gray, and fine grained, but some show a few scattered phenocrysts of plagioclase. Included also in this group are the fine-grained stocks and dikes that border the dacite complex of the Manacas district and the small stock and dike offshoots that intrude Cobre rocks at the Esperancita mine, but these rocks were not studied in thin section and may therefore be dacitic rather than andesitic in composition.

In thin sections of the andesitic rocks, augite and plagioclase, which ranges in composition from calcic albite to andesine, are the principal minerals. Chlorite is present in all specimens and, in some, zeolite replaces plagioclase and the finer grained matrix of the rock. The groundmass in some sections is holocrystalline and contains the same minerals represented by the larger grains, but in most specimens it consists of palagonite and devitrified glass. Magnetite and apatite are accessory. Northwest of El Caney, quartz was recognized only in the andesites which appear to contain about 5 percent of this mineral. Except for their diabasic texture and lower content of quartz, these rocks are much like the dark-colored dacites.

The diorite intrusive rocks are similar in composition to the andesites but are coarser grained and nonporphyritic. The diorites are represented by two stocks, a small body less than 60 meters in diameter that evidently intrudes the San Luis formation 2 kilometers southwest of Alto Songo, and a large mass, which is intrusive into lower Cobre(?) rocks about 37 kilometers east of Santiago de Cuba at the Sigua manganese mines. The rock near Alto Songo is light gray and is cut by dikes of aplite 10 to 25 millimeters thick. The rock has a distinct diabasic texture, and thin sections show highly altered euhedral sodic oligoclase together with a small amount of augite, green hornblende which replaces augite, and interstitial quartz. Accessory minerals include apatite and magnetite. The diorite at Sigua is a dark greenish-gray, medium-grained diabasic rock that intrudes and metamorphoses limy tuffs and agglomerates. The rock is intensely altered. In thin section plagioclase, which is albite, is almost completely replaced by a white clay mineral, possibly kaolinite, and in part by chlorite. Augite, nearly all altered to pale-green hornblende and chlorite, and ilmenite, in part altered to leucoxene, are largely interstitial to the plagioclase. No quartz was seen. The rock probably is an albitized diorite or gabbro.

The relation of the andesitic and dioritic intrusive rocks to the dacites is not clear, but the resemblance of these rocks to the dark-colored dacites, and the close areal relation between these rocks in the El Caney region suggests that they belong, at least in part, to the same intrusive cycle. Most of the rocks intrude lower and middle Cobre rocks and are therefore at least as old as middle Eocene. The diorite stock near Alto Songo probably intrudes the basal part (middle Eocene) of the San Luis formation, although the contact is poorly exposed and the relation of the intrusive to the shales of the San Luis formation is not definitely known; the rock may be younger than the other intrusives of this group.

BASALTIC ROCKS

Dikes and stocks of basalt intrude rocks of the Cobre formation in the Santiago Basin and the eastern end of the Turquino Range, and several dikes intrude rocks of the San Luis formation in the Cauto Lowlands. The basalt intrusive rocks in the Santiago Basin include two small oval stocks along the Central Highway; one, 1.6 kilometers northwest of Cuabitas, and the other 10.1 kilometers west of Cuabitas. Near Puerto de Moya, on the Central Highway 3.2 kilometers west-northwest of El Cobre, a basalt sheet about 46 meters thick and about 620 meters long forms a conspicuous outcrop that shows well-developed columnar jointing (fig. 39). Two northward-trending dikes crop out in the highway cut at the western end of the intrusive sheet. A basalt stock about 550 meters in diameter intrudes Cobre rocks on the west side of the Uraguá Hills 11 kilometers west-northwest of El Cobre. Taber mentioned a dike that cuts San Luis rocks under the highway bridge at Contramaestre. This dike, whose dip is steep to the west, is about 3.7 meters wide and trends north-northeastward. It

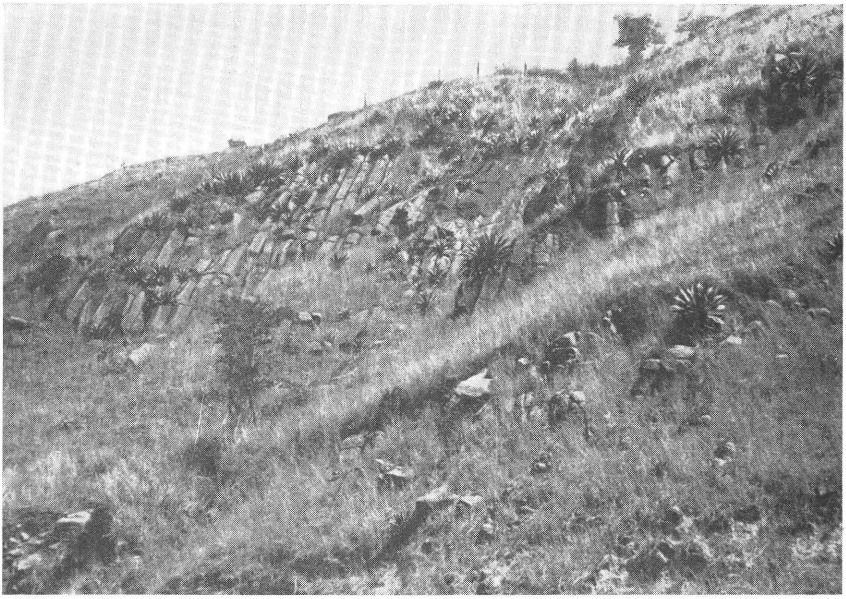

FIGURE 39.—Columnar-jointed, sill-like body of basalt in pyroclastic rocks of Cobre formation along Central Highway about 1 kilometer east of Puerto de Moya. Intrusive rock cuts across bedding at low angle.

may be the continuation of a dike of similar rock that crops out in the Río Contramaestre 2 kilometers north-northeast of Contramaestre. A 1.2 meter dike cuts shales of the San Luis 2 kilometers south of Palma Soriano, and at least two dikes of a highly altered, soft, greenish-gray rock, possibly basalt, cut the Camarones conglomerate member of the San Luis formation. These dikes range in thickness from 0.5 to 1 meter and trend northward.

The intrusive basalts in the areas underlain by the Cobre formation are dark-gray to black fine-grained massive unweathered rocks in which plagioclase feldspar can be recognized. Zoned plagioclase ranging in composition from labradorite to bytownite, augite and early-formed magnetite are the chief primary minerals seen in thin section. Iddingsite, possibly derived from the alteration of olivine, and chlorite are the chief secondary minerals. The groundmass contains a little altered glass. The intrusive body near the Uraguá Hills contains 3-millimeter amygdules of calcite, zeolite, and chlorite.

The basalt dikes that cut the rocks of the San Luis formation are dark greenish-gray, fine-grained, amygdaloidal rocks more highly altered than the intrusive rocks exposed in the Santiago Basin and near El Cobre. In thin section, plagioclase, ranging in composition from calcic andesine to sodic labradorite, and augite are the dominant primary minerals. Analcite, calcite, and much chlorite, which replaces augite, are present, and in one of the specimens altered glass occurs in the groundmass. Magnetite and apatite are accessory minerals. Amygdules as much as 5 millimeters in diameter are composed of calcite and chlorite.

Some dikes cut the middle Eocene Camarones conglomerate member and are therefore latest Eocene or younger in age, but the age of the intrusive basalts in the Sierra Maestra is not known. If there are two cycles represented by the intrusive basalts, the final cycle may represent the last stage of igneous activity following Cobre volcanism. It is possible however that the basalts represent but one cycle of intrusion. The greater alteration of the dike rocks in the San Luis may then be attributed to a higher proportion of volatile substances in the upper parts of the intrusive bodies. They may have been intruded into unconsolidated and wet San Luis sedimentary rocks and altered by resurgent waters. Such a theory is supported by the fact that the basalt dikes that cut lower San Luis rocks are less altered than the rocks that cut middle or upper San Luis rocks.

STRUCTURAL GEOLOGY

GENERAL TECTONIC FEATURES

Hayes, Vaughan, and Spencer (1901, p. 10–12, 26–28) went far beyond the early work of Ansted (1856, p. 145) and intervening writers to become the pioneers who recognized the broad tectonic features of Oriente. From north to south, they identified three chief structural provinces as follows: the broadly anticlinal Nipe-Cristal Highlands, described in greater detail by Thayer and Guild (1947, p. 928–929) as domical structures separated by a northward-trending synclinal fold; the Cauto-Guantánamo Lowlands are developed on a great, complex and irregular synclinal area in which the strata are weakly folded to essentially flat lying; the Sierra Maestra Highlands, in a broad structural sense, comprise a belt of moderately to intensely deformed rocks that make up a complex, northward-dipping homoclinal area. These main structural provinces seem to be the result of the compression of the rocks of south-central Oriente, possibly in connection with the early stages of the formation of the Caymán Trough. In the Santiago Basin of the narrow, discontinuous South Coast Lowlands, essentially flat-lying upper Cenozoic rocks overlie strongly deformed older rocks. Structure sections (pl. 20) show both general and specific features.

Within the mapped area, the main structural trend is westerly, parallel to the general structural trend of the Sierra Maestra. Northwesterly-trending structures, such as those mapped by Woodring and Daviess in the Guisa-Los Negros area (1944, p. 380) are inconspicuous or absent in the area mapped in the present report. Marked departures from the general westerly trend do exist, but most are local features to judge from their known areal extent: examples are the northward-trending Cobre strata beneath the unconformity near Mogote San Nicolás, and the northwesterly-trending Peluda volcanic member. Weakly deformed, westerly-trending Eocene Cobre and San Luis strata are underlain by moderately to strongly deformed Cretaceous Habana(?) strata in the Sumidero Basin, where these Cretaceous strata generally trend westerly, and in La Burra Basin where there are northwesterly as well as westerly trends in the Habana(?) rocks. Along the Río Jarahueca, the chief structural trend in Cobre and San Luis strata is northerly.

Over much of the Sierra Maestra, particularly in the southern part of the mapped area just east and west of the Santiago Basin, the structure is inadequately known; major folds and faults not now known to exist probably will be revealed by diligent searching for and tracing of marker beds, and collection of much more dip-strike data. Detailed mapping, such as that carried out in parts of the Santiago Basin and Cuabitas-Cristo Corridor, surely would reveal more systematic folding than is now apparent in adjoining parts of the Sierra Maestra. However, detailed mapping has shown that in some parts no regular superficial structural pattern is demonstrable; rather, as in the great Cauto-Guantánamo synclinal area of low dips, the strata appear to be irregularly warped.

Dips generally are less than 35° within the mapped area as a whole. Steeper dips are common only locally: in small zones of the Santiago Basin and Sierra Maestra, and in the Cretaceous rocks of the Sumidero and La Burra Basins, dips steeper than 35° are mainly the result of folding and are not associated with major faulting, although some steep dips are localized along faults.

Folding predominates over faulting but persistent major folds and faults are rare. Minor folds and faults are very common, much more so than could be shown on the map.

Overturned beds are found only in the Santiago Basin and adjoining Cuabitas-Cristo Corridor (figs. 23, 31) where strong folding and faulting are localized. There may be overturned beds in the southern part of the mapped area adjoining the Santiago Basin, but their recognition—if they do exist—awaits more detailed mapping.

FOLDS

LINEAR FOLDS

Most of the chief anticlines and synclines that flank Santiago Bay generally strike eastward; however, the western part of the Cuabitas anticline (pls. 19, 20) trends N. 55°–60° E. and reflects a general swing in the strike of beds northwest of Santiago Bay. Evidence for the existence of the Cuabitas anticline is strong, if not positive.

The Cuabitas limestone lentil of the Cobre formation seems to be repeated south of the main line of outcrop, in one lens about 0.5 kilometer long, east of Cuabitas, and in another more than 1 kilometer long, 700 meters north of El Caney. Both lenses are lithologically similar to the Cuabitas limestone lentil, but neither yielded diagnostic fossils. Dips observed in both of these lenses and in the enclosing pyroclastic rocks indicate an anticlinical axis between the lenses and the Cuabitas limestone lentil. The Cuabitas anticline is asymmetrical; the dips observed in the Cuabitas limestone lentil show that the north limb of the anticline is overturned to the north, except at its eastern end. Dips in the north limb range from 60° N. to vertical at the eastern end of the Cuabitas anticline, and from 65° S. to 70° S. in the overturned western part. The dips in the south limb are also steep, and range from 60° S. to 85° S. It is possible that the fold is isoclinal in character southwest of Cuabitas, but outcrops along and south of the main fold axis in this area are poor or absent.

North of the Chalóns reservoir, Cobre rocks are folded into the well-defined Chalóns syncline, which is paralleled on the north by the Santa María anticline. These folds have been traced for more than 4 kilometers between the Pelado fault and the inferred Boniato fault. The Chalóns syncline appears to pass eastward into highly deformed rocks in a triangular fault block which encloses the Caridad manganese prospect. This complex structure possibly is the result of compression acting on the rocks caught between the converging Pelado and inferred Boniato faults, the eastern part of the wedge having yielded most to these forces was thus the most deformed. The Chalóns syncline and Santa María anticline were not traced westward beyond the points shown on the map; they may die out, may be cut off by unobserved faults, or may connect with minor folds in the highly deformed rocks shown at the west end of Pelado Ridge, 1.2 kilometers west of locality 114.

The Boniato syncline, an open structure trending N. 80° E., lies just south of Boniato and to the east of the Pelado fault. Its western end intersects the Pelado fault; to the east, this fold seems to die out. The relation of the Boniato syncline to the Chalóns syncline, as discussed under the description of the faults flanking Santiago Bay, is uncertain. No distinctive marker beds were found and no fossiliferous beds appear to be present. The manganiferous bed at the Mammoth prospect and the Santa Clara—Santa María bed cannot be correlated with certainty because the complicated structures involved preclude sufficiently accurate determination of the relative stratigraphic positions of these beds within the Cobre formation.

The Bellaco syncline, on the north slope of Boniato Ridge 3 kilometers north of Boniato, is a conspicuous structure that involves the

Charco Redondo limestone member and lower beds of the San Luis formation. It is an open fold whose limbs dip at moderate angles, and whose sinuous easterly-trending axis plunges eastward at a low angle. Because of this direction of plunge, the axis of the fold is near the top of Boniato Ridge at the west end, but the axis is at the foot of the ridge at the east end. In the eastern half of the syncline, a central valley has developed in the soft shales of the San Luis formation. The eastern end of the Bellaco syncline probably is cut by a fault.

A major fold, El Cristo syncline, may be the faulted eastward continuation of the Bellaco syncline (p. 289). The approximately located axis of El Cristo syncline trends N. 75° E. to a point just east of El Cristo, where it is thought to veer to about S. 85° E., and to be offset by two inferred faults projected from known faults. Because of the lack of good exposures, there is no assurance that the east end of the El Cristo syncline is properly located, or that its axis can be extended as far as shown on the map. Its presence is inferred in order to explain the unduly thick (500 meters) sequence of non-conglomeratic San Luis sedimentary rocks at this place. However, it is possible that this lower San Luis section appears so thick because it is involved in many smaller folds, or because of strike faults, or for both reasons. It seems less likely that the normal section of shales and sandstones would be so excessively thick here, inasmuch as the San Luis sedimentary rocks below the Camarones conglomerate member elsewhere nearby appear to be between 150 and 250 meters thick. This is demonstrable at three localities as far as 12 kilometers east of El Cristo syncline: at the San Ricardo mine, along the Arroyo San Juan south of Camarones Heights, and along the Río Baconao, near Loreto Mesa, comparable lower beds of the San Luis are estimated to be between 150 and 175 meters thick, indicating that this part of the section does not thicken noticeably to the west. Moreover, medium- to coarse-grained, partly conglomeratic sandstone beds at El Cristo are thought to be equivalent to sandstone beds of the basal part of the Camarones conglomerate member, or to the upper beds of the San Luis just below the conglomerate member, which are exposed in outcrops north of the Quinto pit. These sandstone beds probably are less than 250 meters, and possibly less than 200 meters, above the base of the San Luis formation, indicating little if any change in the thickness of the strata just below the Camarones member.

The syncline between the Quinto pit and the Botsford mine apparently is the eastern continuation of El Cristo syncline, but the structure in this area is complicated by numerous small parallel folds and faults, and by transverse faults. The trace of the fold axis is S-shaped here: it veers eastward from a N. 85° E. direction on the west, through S. 60° E., to about N. 75° E. on the east. This syncline apparently dies out about 2.5 kilometers east of the Quinto pit.

El Cristo syncline is not a normal fold. East of El Cristo, beds of the south limb are right side up and dip north, but as their outcrops are followed westward the dips are progressively steeper until they are vertical south of El Cristo. These same beds are overturned west of the Boniato-Alto Songo highway, the degree of overturning being progressively greater westward. The overturned beds dip 70°S. just west of the highway, and 25°S. about 2 kilometers further west-southwest, where the western end of El Cristo syncline is marked by a fault. The asymmetry of the south limb of this fold carries through the Quinto pit (Straczek and Simons, report in preparation). Beds of the San Luis formation dip southward on the north limb of El Cristo syncline, but Cobre rocks are not exposed to the north except in the faulted Botsford—San Ricardo mine area.

Another syncline, the axial direction of which diverges northeastward from that of El Cristo syncline, has been located a few hundred meters north of El Cristo syncline and about 2 kilometers east of El Cristo. A fault that approximately parallels the N.60°E. axis of the northern syncline separates these two folds, the northern one of which seems to die out in the beds of the Camarones conglomerate member near the Botsford mine.

A broad, very irregular anticlinal structure lies between the Sierra de Nipe dome on the north and the Cauto-Guantánamo synclinal area to the south; its rather ill-defined axis is not shown on the map, but runs from near Palmarito east-southeastward almost to Manguitos, veers east-northeastward through La Burra Basin and across the north edge of Florida Blanca Plateau, and is bounded on the east by the Corinto fault and the Mayarí syncline Outcrops of Charco Redondo and San Luis rocks broadly outline this anticline, but Cobre volcanic and Habana(?) strata lower in the section show very irregular structure, and in places their basic structure does not follow the regional trend of the anticline. At the western end of the anticline near Mogote San Nicolás, the trend of the pyroclastic rocks of the Cobre beneath the unconformity at Manganeso is transverse to the anticlinal trend. The anticline plunges at both ends. The western end is well-defined and almost domical because of a north-south constriction of the limbs just west of Manguitos. The anticlinal structure is least defined midway between the ends, especially in adjacent parts of La Burra Basin and Florida Blanca Plateau, where volcanic rocks and Charco Redondo rocks of the Cobre are flat lying or have very low dips. It seems significant that both of the broad, rounded ends of the anticline are localized over possible centers of volcanic activity: the volcanic rocks of the Cobre are much thinner where the anticline is least well-defined between these inferred centers, and much thicker where it is best defined around these inferred centers. The anticlinial structure may have developed as the result of horizontal stresses, but its irregularity may be explained by the modifying effect of primary pyroclastic domes on these stresses.

Few folds flank this broad anticlinal structure. North of the San Nicolás Hills is the Indio syncline, whose axis has a general S.60°E. trend but curves eastward at its eastern end. Here it is approximately parallel to the Jesús syncline trending N.80°E., a fold of intermediate size that lies just south of the Jesús Segundo mine. The latter fold evidently dies out westward beyond the Polaris mine, opposite to and north of the place where the Indio syncline is presumed to die out.

In the Mayarí and Jarahueca Valleys, the Mayarí syncline evidently is the southern extension of the great syncline that separates the domical uplifts of the Sierra de Nipe and the Sierra del Cristal, as described by Thayer and Guild (1947, p. 928).

DOMES

Nine small domes were found and mapped along the north slopes and foothills of the Sierra Maestra, and in the Cauto-Guantánamo syncline near the divide between the Río Guantánamo and the Río Guaninicum. Most of these domical structures are marked by low hills developed on the relatively more resistant rocks exposed in their cores or on their flanks. With the exception of the Manacas and Uraguá domes, which consist entirely of Cobre rocks insofar as outcrops are concerned, the domes have outcrops of Cobre rocks surrounded by outcrops of San Luis rocks. Limestone beds of the Cobre formation, chiefly the Charco Redondo limestone member, occur in every structure except the Jutinicú dome, where limestone beds of the San Luis formation (and possibly some uppermost Cobre rocks) are present in the beds that crop out on the flanks of the dome, but where no mappable limestones certainly referable to the Cobre formation were found. The oldest rock mapped in the Cuatro Caminos and Mucaral domes is the Charco Redondo limestone member, although there is a small area underlain by tuffs of the Cobre, too small to show on the map, on the south side of the Mucaral dome. Lava is the principal rock in the Manacas dome. Large jasper lenses crop out in the crests or upper flanks of the Ponupo-Mucaral, El Aura, and Jutinicú domes. Manganese deposits are known to occur in every dome except the small Santa Cruz dome.

The Manacas, Cuatro Caminos, and Uraguá domes, and possibly the faulted Botsford dome all are close to or within the more strongly-folded strata of the Sierra Maestra, and are distinctly elliptical and their longer axes parallel the general structural trend of the Sierra Maestra. Other domes further away from the Sierra Maestra are irregular in outcrop outline, and show less tendency to an elongate shape. Structural closures are estimated to be as much as 300 meters in the Uraguá dome, but in most of these structures the closure does not exceed 200 meters. In three domes—the Santa Cruz, Mucaral, and Ponupo—closures probably do not exceed 100 meters, measured on the top of the Cobre formation.

The origin of these domical structures is puzzling and conjectural. That they have resulted solely through the action of horizontally-directed stresses seems improbable in view of their domical form and the fact that some, such as the Jutinicú and Ponupo domes, are not elongate, and others such as El Aura dome, have a longer axis transverse to the regional structural trend. Yet the fact that five (six, if the faulted Botsford structure be included) of the domes are elliptical, with their longer axes conformable to the regional structural trend, is strong evidence that horizontal stresses have played an important part in forming these structures. Moreover, the closure of the domes seems much too great in proportion to their surface area to be explained entirely as a result of vertically directed forces. Although the evidence is inconclusive, it seems most probable that a combination of horizontal and vertical force components were responsible for the forming of these structures: an initial upwarping caused by a vertical force component could well be intensified by a horizontal force component. Because the domes differ geologically and structually, no single, unmodified explanation of their origin seems adequate for all. Therefore the origin of each is considered briefly in the following individual descriptions.

The elliptical Manacas dome has an eastward-trending longer axis about 4.5 kilometers and a shorter axis about 3 kilometers in length. Pyroclastic rocks and limestone beds of the Cobre dip away from the Manacas dacite porphyry lava dome and flows that underlie most of the dome. In places, particularly along the southwest side, Cobre strata are upturned and faulted against the porphyry. The limestone bed along the north flank of the dome overlaps the underlying pyroclastic rocks and rests directly upon the porphyry on the crest and south flank of the dome. Moreover, the limestone is thickest to the north and west, away from the Manacas porphyry. This suggests that doming was, at least in part, primary with Cobre rocks laid down over a positive area including the lava dome and flows. However, it is believed that doming was accentuated by differential compaction of easily compressed, soft pyroclastic rocks over the relatively competent porphyry, thus explaining locally upturned and faulted beds along the porphyry contact. The elongate form of this structure may be a primary feature, but it could be the result of horizontal stresses that modified a preexisting dome.

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The elliptical Uraguá dome is outlined by Cobre limestone that is flat lying on the crest but dips at moderate angles around the flanks. Its longer axis, nearly 5 kilometers in length, trends about N. 75° E. The elongate shape of the dome, its nearly straight southern flank with steeper dips, and its apparent great closure (estimated to be more than 300 meters) would seem to be best explained by horizontally directed forces, but it is difficult to imagine that such forces alone were responsible for producing the dome. It is possible that the structure began with differential compaction of bedded tuffs about a vent agglomerate formed before the limestone and now represented by the massive agglomerates and tuffs in the core of the structure, by the force of intrusion of magma below the exposed core of the dome, or by differential compaction of pyroclastic beds about such an intrusive. Later crustal movements may have determined the present form of the Uraguá dome and its great closure. There is no evidence that the Cobre rocks are thicker on the flanks of the structure than on its crest, and it is not possible for us to say whether or not the crustal movements that determined the structure began during deposition of the beds involved.

The Santa Cruz dome, named after the low Santa Cruz hill localized on the structure between San Luis and Dos Caminos, is the smallest of the domical structures found. The dome is slightly elongate in an easterly direction, the longer axis having a length of less than 1 kilometer. The Cobre strata on the north flank dip more steeply than those on the south. This, plus the fact that the structure is slightly elongate, appears to indicate that horizontal forces were active at least in the later stages of formation, but the true mechanism is uncertain. Only pyroclastic rocks of the Cobre are exposed in the core of the structure, and they underlie the Charco Redondo limestone member exposed on the flanks.

The Botsford dome, 1.5 kilometers northeast of the Quinto pit, is a faulted structure whose prefaulting form is conjectural. It appears to have been an elongate, eastward-trending structure, but in view of the steepened dips of Cobre and San Luis strata near the fault there is little doubt that the forces that made the fault also have modified the form of the dome, whose origin is unknown.

A complex and irregular structure in the Ponupo mining district involves two small domes separated by a narrow, faulted syncline. The Mucaral dome is an elongate structure whose longer axis, 1.4 kilometer long, trends S. 77° E. parallel to the regional structural trend of the Sierra Maestra to the south, but the Ponupo dome to the east is an irregularly rounded, unelongate structure. San Luis rocks have been uparched and eroded to expose a Cobre core in both domes. Drill-hole data obtained through the courtesy of the Cuban Mining Co., together with detailed maps, indicate that the Charco

Redondo limestone member in the Mucaral dome is a lens, thickest at the crest of the dome, and thinnest on the south, east, and northeast sides. A lens of jasper of similar form crops out at the crest of the Ponupo dome; tuff beds along the western margin of the jasper lens are upturned and faulted against the jasper. Each of the domes may therefore have been formed by the differential compaction of pyroclastic rocks of the Cobre and shales of the San Luis formation about the resistant lenses of limestone and of jasper. However, the broad structure may well be localized on a volcanic vent (pre-Charco Redondo) if the massive agglomerate and tuffs exposed in the Ponupo dome are actually in or near a vent. No doubt later crustal movements could have modified and accentuated the domical structures, the Mucaral dome having been more affected.

The Cuatro Caminos dome is an elongate structure in which only the Charco Redondo limestone member of the Cobre formation is exposed, flanked by San Luis strata as in the Mucaral dome. The longer axis of the dome is more than 2 kilometers long and trends about S. 55° E., approximately paralleling the mountain structure to the south. Like the Mucaral dome, the Cuatro Caminos dome may be the result of differential compaction of Cobre and San Luis strata about a lens of Charco Redondo limestone member, but it is probable that horizontal stresses were largely instrumental in giving the structure its present outline.

El Aura dome, northwest of the Ponupo mining district, is an irregularly elongate structure whose longer axis is about 2 kilometers long and trends N. 25° E., transverse to the structure of the Sierra Maestra. A sag divides this structure into two parts. Cobre rocks crop out in small areas at each end of the structure, most of which is underlain by San Luis strata. Beds on the north side of the south end are essentially flat lying, in contrast to the steeper dips on the south, east, and west flanks of this part of the structure. On the north end a dome nearly 1 kilometer in diameter is superimposed on the larger structure. Large lenses of jasper crop out at both ends, but the crest of the north end is underlain by a massive, coarse agglomerate which may be a vent agglomerate that marks a center of volcanic activity before Charco Redondo time. Therefore, El Aura dome may have been a low volcanic dome during the late stages of deposition of the Cobre formation, over which the San Luis sediments were deposited, the strata assuming a primary domical form that possibly may have been accentuated and modified somewhat by differential compaction. Apparently this structure was not deformed appreciably by horizontal stresses.

The Jutinicú dome is a low, broad, irregular structure, roughly circular in outline and between 2 and 3 kilometers in diameter.

Pyroclastic rocks of the Cobre, enclosing a large jasper lens, are exposed in the crest of the dome and along the southeast flank where the structure is cut across by the Río Jutinicú. Thin-bedded limestones occur in the formation of the lower San Luis limy shales that surround the Cobre outcrops but no limestone was found that could with certainty be correlated with the Charco Redondo limestone member. The origin of this dome is very obscure; the only suggestive evidence, the massive agglomerates and coarse tuffs that crop out below and south of the jasper lens, may indicate that initially the structure was a low pyroclastic dome. There is no evidence that horizontally directed forces were at all important in its formation.

MONOCLINAL STRUCTURES

A striking eastward-trending monocline (fig. 28) marks the northern limit of the Boniato Piedmont section of the Turquino Range, and generally follows the boundary between the Cobre and San Luis formations for some 18 kilometers between Dos Caminos and the Río Domingo. The dips of the Cobre beds in this Boniato Piedmont monocline, with conspicuous outcrops of resistant Charco Redondo limestone member, steepen abruptly to as much as 55° N. along a remarkably continuous but somewhat sinuous narrow band of outcrops trending in a westerly direction. South of this band, the Cobre strata are flat lying or dip gently northward; north of this band, the Cobre rocks are buried under very gently dipping San Luis rocks in the Cauto-Guantánamo synclinal area. This consistent monoclinal steepening cuts across a structural sag just east of the Río Grande, where an extension of the San Luis formation marks a southward flexure in the Boniato Piedmont monocline. About 1 kilometer southwest of Dos Caminos, the flank of the Boniato Piedmont monocline veers southward and may extend to the fault at the Santa Rosa mine. West of the Río Domingo, the Boniato Piedmont monocline dies out and passes into the broad homoclinal structure of the Sierra Maestra.

FAULTS

GENERAL FEATURES OF FAULTS

Few major faults were found in the mapped area of south-central Oriente in contrast to the dense pattern of conspicuous, but generally minor, faults that cut Cobre rocks, particularly the Charco Redondo limestone member, in the adjoining Guisa-Los Negros area to the west. In part, this seeming paucity of major faults may be attributed to difficulty in detecting faults in the pyroclastic Cobre and clastic San Luis rocks that predominate in the eastern area, and to the lack of detailed mapping outside the mining districts where some of the faults were found in the eastern area. However, a real difference in the relative number of demonstrable faults does seem to exist between the two areas, perhaps because more faults might reasonably be expected to occur in the extremely thick Charco Redondo limestone member which crops out over such a large part of the Guisa-Los Negros area. This limestone, which is as much as 150 meters thick in the much-faulted western area, is more competent and more easily fractured than the predominantly pyroclastic and clastic rock of the less-faulted eastern area. No single fault has been traced from the Guisa-Los Negros area eastward across the Río Contramaestre. The northeastward-trending fault that marks the eastern limit of the Charco Redondo limestone as mapped by Woodring and Daviess (1944, pl. 68) could not be traced beyond the Río Contramaestre but, as indicated by them, is presumed to veer eastward and die out as a strike fault; it may be a fault within Cobre formed during the deposition of the uppermost beds of the Cobre.

In general, such faults as were found in the south-central Oriente area were readily located, followed, and their displacements measured only where they cut conspicuous stratigraphic markers such as prominent limestone beds or formation contacts. It was almost impossible to detect faults within most of the volcanic Cobre and clastic San Luis rocks except in road or stream cuts and in mines. It was hard to determine the locations and displacements of the large known and inferred faults in and around the Santiago Basin because these are essentially strike faults that cut no readily traceable stratigraphic markers.

Most of the faults found have dips that range from about 60° to vertical. Displacements of as much as 1,500 meters were estimated, the largest being on some of the faults in the Sierra Maestra, particularly in highly folded, steeply dipping rocks in the southern part of the area mapped. A few minor thrust faults were found; most have easterly trends and southerly dips, but one of the largest has a north trend and dips east.

The few known and inferred major faults occur in two geographic groups: within a southern belt that runs from Charco Mono reservoir and the Uraguá dome eastward through the Cuabitas-El Cristo Corridor and the Quinto mine district to the Ponupo mine district, and within a broad northern zone from the southern Sierra de Nipe through the Fringing Uplands to the south. In the southern belt, at least two of the major faults have reverse throws; in the northern zone the faults, with only a few exceptions, appear to be normal, although several large faults were not directly observed on the ground. In the southern belt, all of the major fault trends are nearly parallel to the regional easterly structural trend; in the northern zone, by contrast, eastward-trending faults are associated with northerly-trending faults.

Because the relatively few faults are so widespread and are not readily segregated as to type or relative age, they are discussed in geographic sequence, beginning with those in the southwest and ending with those in the northeast part of the mapped area.

FAULTS IN THE SIERRA MAESTRA WEST OF EL COBRE

The only faults found between the Río Contramaestre and the Río Cañas were those at the Manacas and Uraguá domes. The known faults in the Manacas district are localized in the western part of the dome. On the northwest side of the dome, a transverse normal fault trends N. 35° W., dips 70° NE., and has a throw of about 100 meters; it cuts the Manacas dacite porphyry, overlying limestone bed, and enclosing pyroclastic rocks. Just east of the mine road between the Amarito and Guadalupe mines is a normal fault that trends N. 25° E., dips 70° E., and has an apparent throw of more than 100 meters at its south end but only a few meters at the northernmost point to which we could trace it. Much of the southwest contact of the dacite porphyry appears to be a fault contact of steep dip; faults here may have developed as a result of compaction of the pyroclastic rocks against the more resistant dacite porphyry. A fault at the west end of the porphyry that trends N. 30° W., dips about 45° W., and has a normal throw of about 50 meters. Small andesitic dikes have been intruded along some of the Manacas dome faults, suggesting that these faults are of Cobre age.

Two eastward-trending faults have been mapped in the Uraguá Hills. A large, probably high-angle fault cuts the southwest flank of the Uraguá dome, with the north block downthrown an estimated 400 m so that limestone beds on the north abut against pyroclastic rocks on the south. This northern fault has been drawn as a high-angle normal fault on the cross section (pl. 20) but it may well be a high-angle reverse or vertical fault. Another fault has been inferred to be present near the axis of an eastward-plunging syncline about 900 meters south of and parallel to the first fault. The throw appears to be a few hundred meters, to judge from the attitude and distribution of limestone beds in the flanks of the syncline. The north side of this inferred fault would be the downthrown side if, as seems possible, the limestone beds north of the inferred fault are the same as the uppermost limestone beds south of it.

The faults in the Uraguá Hills may be continuous with two parallel faults that trend east-northeastward on the east side of Charco Mono, but because these faults have not been traced through the interval they have not been connected on the map (pl. 19). Both of the faults near Charco Mono probably dip steeply; the relative displacements are uncertain, but the downthrown sides appear to be on the north, as is the case in the tentative determinations for the faults in the Uraguá Hills. The Charco Mono faults have not been traced further east than shown on plate 1, but there is a possibility that they continue eastward and connect with the Boniato fault.

FAULTS BETWEEN EL COBRE AND SABANILLA

THE BONIATO FAULT

Taber (1921, p. 547–556; 1934, p. 608–610) first described the system of eastward-trending major faults, including the Boniato and Pelado faults, each following the south scarp of the ridge bearing the respective name (map, pl. 22). The impressive south scarps of these hogback ridges are strongly suggestive geomorphic features indeed.

We found little direct evidence of the Boniato fault. Therefore, the Boniato fault is drawn as an inferred fault, which follows the nearly straight but well-dissected south scarp of Boniato Ridge. This scarp has an average height of about 300 meters for some 24 kilometers between the Santa Rosa mine and Puerto de Moya, where the Central Highway crosses Boniato Ridge. The scarp slopes down southward about 30° on the average; its upper slopes generally are steeper than the lower, because the upper slopes are developed on more limy, more gently dipping, and therefore more resistant Cobre rocks than those of the lower slopes. (See maps and geologic cross sections, pls. 19, 20, and 21.)

Boniato Ridge (figs. 22, 40) is nearly a strike ridge but seems to cut across the strike of Cobre strata at a small angle. Uppermost beds of the Cobre, including the Charco Redondo limestone member, form the crest at its eastern end, but the western end is capped by Cobre rocks between 500 and 1,000 meters below the top of the formation. This feature and the remarkable continuity of the ridge are perhaps the best reasons for believing that the ridge marks a dissected fault scarp as suggested by Taber, or, as we would suggest, a fault line scarp. The only eastward-trending fault found along the south slope of Boniato Ridge is 2.5 kilometers northwest of El Cobre in a Central Highway road cut (fig. 41). There a well-exposed fault cuts pyroclastic rocks of the Cobre, strikes about N. 60° E., and dips about 75° S.; drag indicates a normal displacement whose magnitude cannot be estimated because of poor exposures beyond the highway cut and the lack of good stratigraphic markers. Massive agglomerate on the hanging wall is faulted against poorly bedded coarse tuff. The sketch of the road cut (fig. 42) shows this fault and also a second, southward-dipping fault, probably a thrust of small displacement, that brings well-bedded tuffs against the agglomerate and poorly bedded tuff, and passes upward from a crosscutting strike fault into a bedding plane fault.

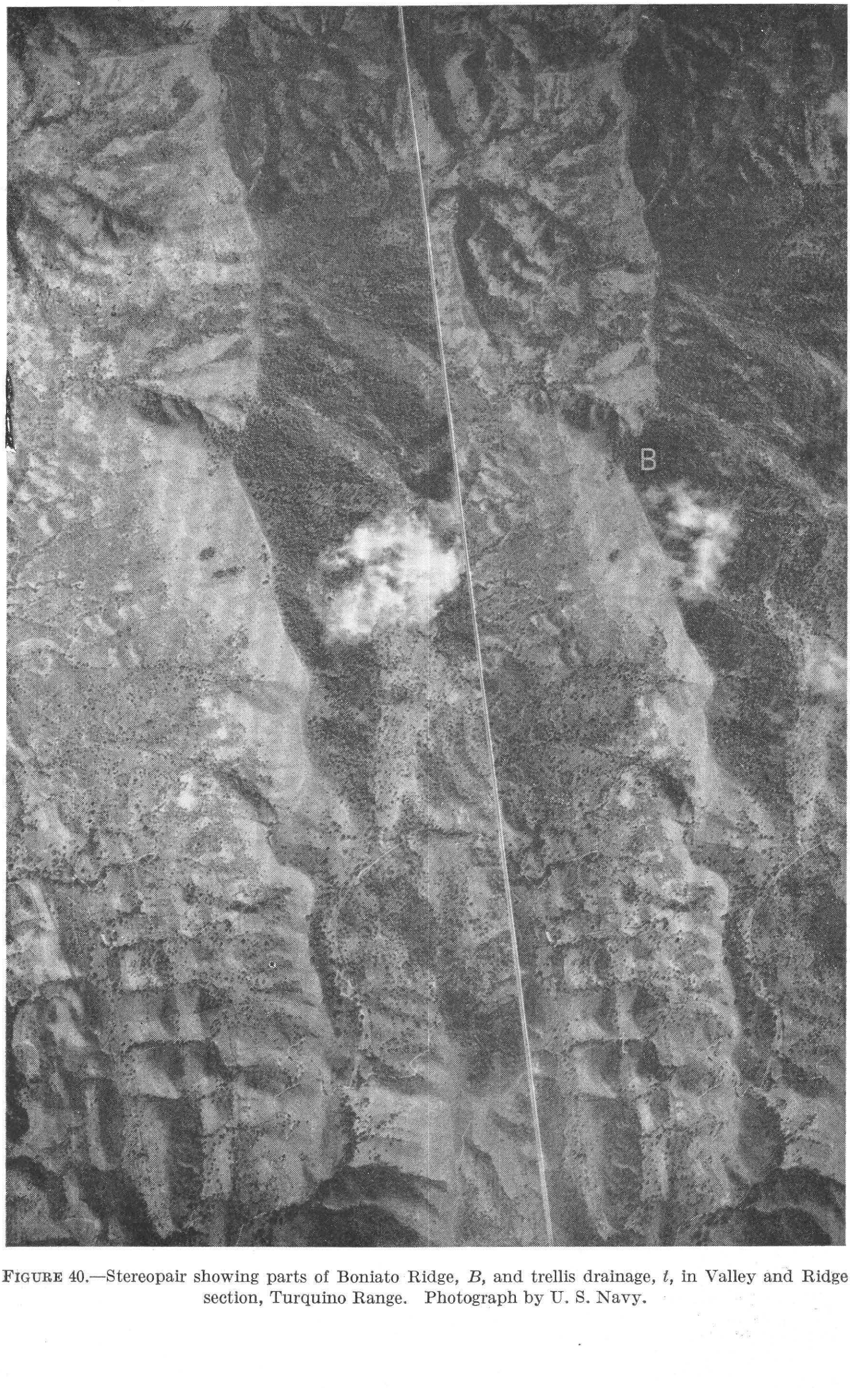

FIGURE 40.—Stereopair showing parts of Boniato Ridge, *B*, and trellis drainage, *t*, in Valley and Ridge section, Turquino Range. Photograph by U. S. Navy.

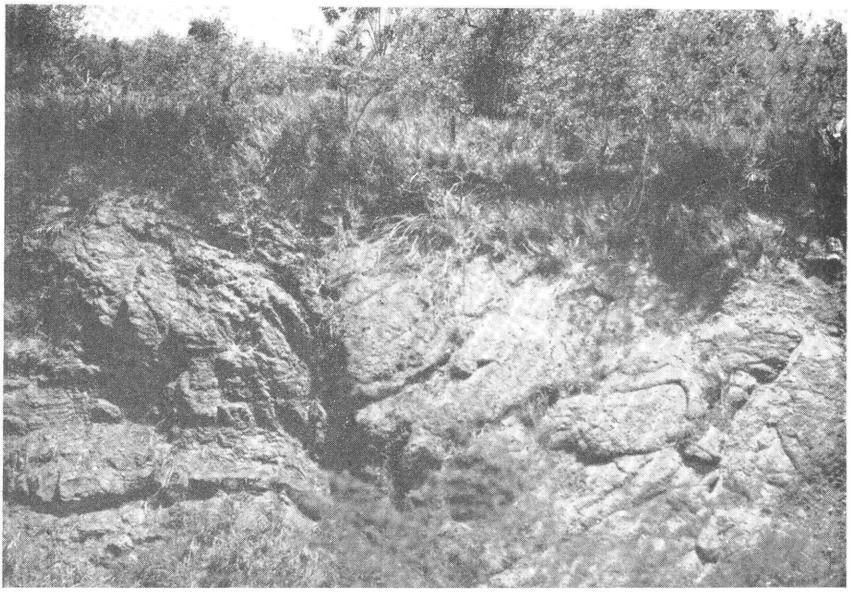

FIGURE 41.—South dipping normal fault in pyroclastic rocks of Cobre formation exposed on scarp of Boniato Ridge along Central Highway 2.5 kilometers northwest of El Cobre. Massive agglomerate and tuff of hanging wall on right abut bedded tuff of foot wall on left.

Between localities 114 and 115 about 150 meters above the base of the ridge, highly folded beds were interpreted as being in a possible fault zone, but the amount and direction of displacement could not be determined along the inferred fault drawn here (pl. 19). Apart from the numerous minor transverse faults mapped at Puerto de Moya and along the Central Highway 1.5 kilometers to the east, and one (unmapped) near the Boniato Ridge crest on the road to Dos Caminos, the only other fault seen along the ridge is an eastward-trending minor fault that parallels the axis of the Bellaco syncline and is downthrown about 50 meters on the south.

The many lower but conspicuous strike ridges developed on resistant Cobre strata south of the Boniato Ridge scarp, easily seen on the ground and on the aerial photographs, limit the location of

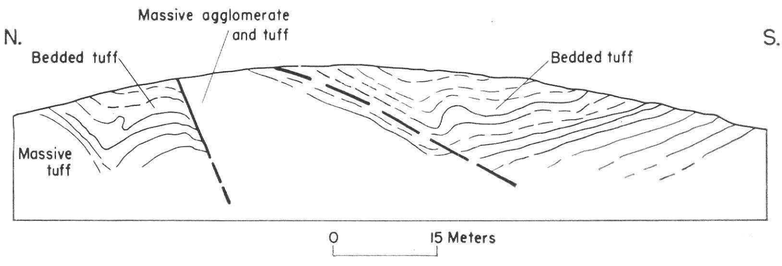

FIGURE 42.—Sketch of faults exposed in road cut 2.5 kilometers northwest of El Cobre.

any possible fault; there is little evidence that any of these ridges is offset by any but minor faults. One such ridge of limy tuff was crossed at five places on the ground. It is a prominent but low hogback 7.2 kilometers long, traced westward continuously from 2.1 kilometers northwest of locality 114 to the San Ildefonso manganese prospect; the beds exposed along the ridge are believed to be equivalent to the limy tuff above the main manganiferous bed at the prospect as mapped by Park and Cox (1944, pl. 65), and the same beds apparently are traceable through the town of El Cobre. Therefore, it seems evident that no major fault passes south of this ridge, so the trace of the inferred Boniato fault was drawn on the map just north of and parallel to this low hogback as far west as the San Ildefonso prospect, beyond which the trace was extended westward to Puerto de Moya. However, we doubt that it is a major strike fault, because nowhere does the attitude of the beds immediately north of the inferred Boniato fault trace in this area differ markedly from the attitude of the beds immediately to the south. After reviewing all the data, the trace of the inferred Boniato fault was drawn on the map along what seems to be the only possible location for a continuous fault or fault zone south of the crest of Boniato Ridge.

Just west of the Dos Caminos highway, the crest of Boniato Ridge veers southward about 750 meters and then veers westward again. Taber therefore inferred a fault splinter here diverging from the main Boniato fault (1934, p. 609, pls. 62 and 82A). Good exposures along the trail about 2 kilometers west of the Dos Caminos highway show a series of interbedded limy and nonlimy pyroclastic beds whose dips steepen abruptly from 30° to 80° on the possible trace of such a splinter, but no fault was seen. Such abrupt changes in dip are common in the Cobre rocks of Boniato Ridge; most appear to be the result of folding not associated with faulting. The change in direction of the ridge crest here may be the result of differential erosion controlled by intense local folding, although admittedly a strike fault might easily be overlooked. About 2.5 kilometers west of locality 115, a similar offset of Boniato Ridge 1.5 kilometers southward may be the result of erosion controlled by a possible fault zone diverging west-northwest from the inferred Boniato fault about 2 kilometers northwest of locality 114. If a fault or fault zone is in fact located here, it might connect with the faults near Charco Mono, but no actual fault was found, and more detailed work would be needed to prove or disprove its existence.

The type of faulting, amount and direction of displacement, age, and location of the inferred Boniato fault are all conjectural. On the basis of geomorphic data, Taber (1934, p. 609) believes that the Boniato fault dips south and is a normal fault with a throw "not far from 400 meters," which is little more than the height of the scarp.

He observed (1931, p. 547–548) that "In places along the base of the scarp a deep narrow ravine is found running parallel to the ridge, and some of the spurs separating the gullies show side hill ridges such as are indicative of recent displacements" and concluded (1934, p. 610) that "the Boniato fault scarp is so fresh that the displacement must have occurred mostly, if not entirely, in post-Pleistocene time." We believe that the observed topographic features can be best explained as developed by the differential erosion of Cobre rocks which strike essentially parallel to Boniato Ridge, and whose resistance to erosion is not uniform at different stratigraphic levels. It is doubtful that a vertical displacement of the amount and character indicated by Taber could be reconciled with present stratigraphic and paleontologic evidence: the rocks at the foot and south of the scarp are older and lower in the stratigraphic column than the rocks higher on the scarp and crest of Boniato Ridge. The very limy upper pyroclastic rocks of the Cobre that crop out in the upper third of the scarp have not been recognized south of the scarp. Similarly the fossiliferous middle Eocene limestones of the Cobre (localities 75, 113, 115, 123, and 124) are not repeated south of the scarp; rather, the fossiliferous limestones of the Cobre south of the scarp (localities 111, 112, and 114) are referred to a lower Eocene position because, according to Albear, they contain a distinctive fauna.

Therefore, it does not seem possible that Boniato Ridge is a fault scarp; rather, we suggest that it is a fault line scarp localized along a zone of faulting and folding, with the ridge top held up by erosion-resistant rocks. If a single major fault is in fact located along Boniato Ridge, it either must be a steep-dipping reverse or normal fault with the north block downthrown, or it must be a tear fault with a greater horizontal than vertical component of displacement. Final solution of the Boniato fault problem will rest upon more detailed field mapping. The problem should be soluble, because outcrops are extensive enough so that individual beds or groups of beds can be traced for many kilometers along the strike. Mapping these beds would permit drawing such faults as are present, even though the faults themselves be exposed at few places. The inferred Boniato fault may prove to be similar to the fault in the Dos Bocas Valley, discussed in subsequent paragraphs, which it probably joins.

THE PELADO FAULT

The Pelado fault is drawn on the map (pl. 1) along the south foot of Pelado Ridge, a hogback whose nearly straight south-facing scarp is more than 7 kilometers long and has an average height of about 125 meters (figs. 22, 43). In contrast to Boniato Ridge, the scarp of Pelado Ridge is almost undissected; most of the scarp is furrowed only by small shallow gullies, yet it is completely cut through by the

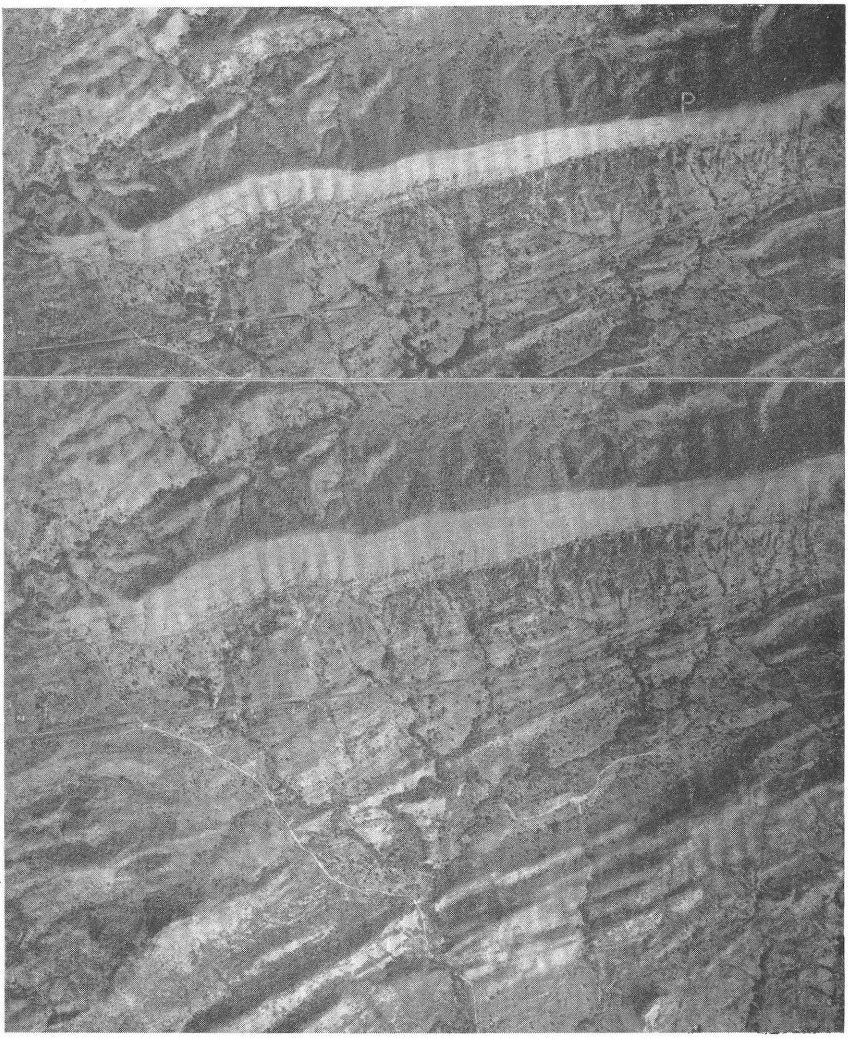

FIGURE 43.—Stereopair showing part of Valley and Ridge section of Turquino Range. Note oblique trend of Pelado Ridge (P) as compared to more northeasterly trend of strike ridges. Photograph by U. S. Navy.

Chalóns valley near its eastern end. At first glance, the Pelado scarp appears to be a veritable "textbook example" of a fault scarp of extremely recent age, but no nongeomorphic criteria can be adduced to bear out this first impression, whereas the stratigraphic evidence and some geomorphic evidence deny it.

Pelado Ridge is formed by resistant, indurated, thin-bedded, fine-grained tuffs and limy tuffs, whereas the rocks that crop out on the flat to the south are chiefly massive to thick-bedded coarse tuffs and agglomerates as far as the Central Highway 600 meters away. In general, the fine-grained tuffs crop out at most horizons in the scarp, but they grade into less resistant coarse tuffs and agglomerates at the western end of the ridge where the scarp ends, and coarse pyroclastic rocks are exposed in some of the gullies in the lower part of the scarp at its eastern end. The Cobre rocks involved have approximately the same strike as those to the south, but the trend of the scarp cuts slightly across the regional strike. The ridge crest transects the Cobre strata so that beds lower and lower in the section are exposed from west to east; it is estimated that at least 100 meters of beds are transected in this way, but some of this transection is due to differences of relief along the scarp, the western part being higher than the eastern part.

Strike ridges developed on resistant beds to the south converge on Pelado Ridge eastward at an angle of 10° to 15° (fig. 43), but in part this apparent crosscutting results from the progressively steeper dips of these beds toward the east end of the ridge, and to the apparent thickening of the section westward as a result of the greater development of minor folds. Any actual difference between the strike of the strata in Pelado Ridge and the strata immediately to the south was not measurable on the ground; if there is a difference, it must be less than 5°.

Taber (1931, p. 555) held that Pelado Ridge is the result of movement along a normal, south-dipping fault, the Pelado fault, and that because the ridge is relatively undissected "its age must be measured in hundreds of years rather than tens of thousands." However, the distinctive tuff beds in the scarp have not been recognized in the flat to the south, and a lens of reef limestone (locality 114) found intercalated in the coarse pyroclastic rocks of the flat near the foot of the scarp could not be found in the scarp rocks; moreover, the Chalóns valley has been cut through Pelado Ridge in spite of the fact that Arroyo Chalóns is but a small ephemeral stream. These facts would seem to indicate that the fault has a complex history. It is possible that after original uplift on the south side of the fault and subsequent bevelling, a reversal of movement and upthrow of the northern block has occurred but still has left a net downthrow on the north; such a reversal would then have made a true fault scarp. An alternative possibility is that a large horizontal component of displacement has occurred along the Pelado fault, but this seems to be ruled out by reason of the structural accordance of the beds north and south of the fault trace, unless the progressive eastward steepening occurred after the fault A horizontal component of several hundred meters might be inferred if the Pelado fault could be shown to be similar to the fault trending north-northeast at the east end of Pelado Ridge. The fault at the east end of the ridge appears to be a tear fault along which the apparently vertical axial plane of the Santa María anticline has been offset 180 meters horizontally. A third possibility is to consider Pelado Ridge as a fault line scarp developed by differential erosion along a fault on the south limb of the Chalóns syncline, but were this true, the ridge should be more greatly dissected Even so, the scarp appears to have been little affected by erosion during the time when the steep-sided Chalóns valley was cut; in this same connection, the small Arroyo Chalóns might have been expected to be diverted by very recent faulting.

The initial faulting may have occurred at any time between late Eocene and middle Miocene. The scarp may be a feature older than Recent, preserved by the relatively resistant beds exposed; it may be an exhumed scarp and may date from before La Cruz (middle Miocene) time. Such an exhumed scarp could have been protected by La Cruz sedimentary rocks which may well have covered this ridge, so that the drainage system developed on the Miocene rocks was superposed across Pelado Ridge as the Miocene rocks were eroded away from the periphery of Santiago Basin. At present, the nearest La Cruz outcrops are less than 2 kilometers south of Pelado Ridge, and the altitude of the base of the La Cruz formation there is near the altitude of the foot of Pelado Ridge. Conceivably, the scarp could have been protected from erosion through Pliocene and much of Pleistocene time.

FAULTS IN AND NEAR DOS BOCAS VALLEY

The Pelado fault is not traceable west of Pelado Ridge, and it either dies out or continues westward as a strike fault. The shear zone parallel to the tight, northeast-trending syncline at the west end of Pelado Ridge indicates the presence of another fault of unknown magnitude. At Charco Chalóns, however, the strike of the Pelado fault probably curves east-northeastward parallel to the curving east end of Pelado Ridge and the trace of the Chalóns syncline, so as to pass from a strike into an oblique fault that trends up Dos Bocas Valley. Even though these two faults may not be the same, they must be closely related. The existence of the fault in Dos Bocas Valley is indicated by truncated beds and folds—the Santa María and Santa Clara manganiferous beds, the Santa María anticline, and the Boniato syncline apparently are cut off at the trace of this fault. Evidence of this fault is even stronger beyond the point where it may be joined by the Boniato fault: beds trending northwestward to west on the northwest side of the trace abut against beds parallel to the fault and dipping away from it on the southeast side, and the eastward-trending folds and Charco Redondo limestone member in Boniato Ridge are cut off northeast of Dos Bocas. The fault in Dos Bocas Valley probably joins the eastward-trending fault at the Santa Rosa mine, and probably continues east-northeastward to the Caridad mine where it passes into faults in the Quinto mining district.

No name has been given to the fault in Dos Bocas Valley because its relations to the inferred Boniato fault and to the fault at the Santa Rosa mine are uncertain. The fault is believed to dip southeastward; this dip is reflected in the irregularly curving trace over the hilly tract north of the San Luis and Tordera mines where the dip appears to be less than 60°. But the dip may be only a few degrees at the surface in these two mine areas because a small klippe or outlier just north of the fault trace and San Luis mine (locality 132) contains nearly flat-lying beds which are separated from underlying vertical strata by a fault that dips to the south at a low angle. A similar relation appears to exist where the main fault crosses the San Luis–Tordera mine road.

The fault in Dos Bocas Valley is a reverse or thrust fault, because the southeast block has been upthrown. A large displacement is indicated by folds on one side of the fault that cannot be correlated with those on the other. Assuming that the fault dips 60° SE., an apparent dip slip of as much as 1,500 meters is indicated by the relative positions of the Charco Redondo limestone member and the Guadalupe manganiferous bed, which is estimated to be 400 meters below the top of the Cobre formation. The apparent slip seems to be less and less southwestward along the fault, and the southeast block may even be downthrown toward the southwest, as indicated by differences between the estimated thickness of the normal uninterrupted stratigraphic section and that of the faulted section from the Cuabitas limestone lentil to the top of the Cobre formation. Such a relation would be explicable only if a large horizontal component of movement had been effected, or if a hinge movement were involved

Evidence of oblique movement on the fault in Dos Bocas Valley, near this fault's junction with the fault at the Santa Rosa mine, is also indicated by the drag-fold relations observed. The axis of the east-trending anticline just south of the Santa Rosa mine veers northeastward, steepens and plunges 30° to 50° E. as the fault in Dos Bocas Valley is approached. Small, tight drag folds noted only on the south flank of the anticline where it plunges near the fault trace have axial planes that dip 50° to 60° S., and the drag fold axes plunge 45° E. It seems likely that these drag folds were caused by movement along the fault in Dos Bocas Valley, and their attitude should therefore reflect the attitude of the fault and the direction of movement along it. If this is true, then a large horizontal component of movement is involved, with the direction of movement on the fault being to the southwest, normal to the 45° E. plunge of the drag folds, and oblique to the indicated southeast dip of the fault plane. Such a movement is also indicated by the steep-dipping northeastward-trending faults mapped in the San Luis and Tordera mines. The throw on these faults ranges from a few meters to about 12 meters, the slip is progressively greater northeastward toward the main fault, and the steeply dipping fault faces are curved so that they dip in opposite directions at opposite ends of the faults.

The wedge-shaped end of the fault block between the fault in Dos Bocas Valley and the fault at the Santa Rosa mine is downthrown with respect to both faults. The estimated dip slip of this wedge on the fault at the Santa Rosa mine seems to be nearly as great as that on the fault in Dos Bocas Valley. In contrast, the apparent dip slip does not seem to be more than a few hundred meters, northeast of the junction of the two faults, where the south block is upthrown, because the San Luis-Tordera manganiferous bed is thrust against what seems to be the continuation of the Augusto Luis manganiferous bed on the north side of the fault at the San Luis mine; the San Luis-Tordera bed is not more than 300 meters stratigraphically below the Augusto Luis bed. This relation makes the fault at the Santa Rosa mine appear to be an independent, south-dipping normal fault, but this seems to be impossible, because along the fault trace west of the Santa Rosa mine, where the trace veers sharply northwestward, overturned beds of the south limb of the El Cristo syncline are faulted against normally dipping beds on the south limb of the Bellaco syncline. There may have been two movements on the fault at the Santa Rosa mine: first, thrusting from the southwest, and second, normal down faulting of the wedge-shaped block. The northward continuation of the fault at the Santa Rosa mine is uncertain. As shown by the strike, the fault seems to merge with the plunging flank of the Boniato Piedmont monocline. The fault may be related genetically to the Boniato Piedmont monocline; possibly the fold passes southward into a thrust or tear fault, but no fault is traceable in the poorly exposed San Luis strata that underlie the valley of the Río Guaninicum.

FAULTS IN THE QUINTO MINE DISTRICT

The chief faults between the Quinto pit and the San Ricardo mine appear to join the fault at the Caridad mine, but because of the lack of exposures no single fault can be traced through. The most conspicuous fault is exposed only along the north side of the Botsford dome. Seemingly it is a reverse fault on which Cobre strata in the dome are heaved northward over beds of the Camarones conglomerate member. This fault has an easterly trend; the only dip seen, at the San Ricardo mine, is 60° SE. The fault is traceable for only 0.5 kilometer northeast of the San Ricardo mine but has been shown on the map further northeastward to the west edge of the Ponupo district in order to explain the apparent repetition of the Camarones conglomerate member on the northwest flank of the structural basin between the Mucaral and Botsford domes. The fault was not seen west of the Botsford mine but is inferred to swing southwestward to join the fault at the Caridad mine; also, a branch may split off near the west end of the Quinto pit and continue westward along the El Cristo syncline. The apparent throw is estimated to be more than 500 meters along the Botsford dome but not more than 200 meters about 0.9 kilometer northeast of the San Ricardo mine, and the throw may be still less southwest of the Botsford dome. This wide range in displacement may be explained chiefly by the fact that the down-faulted segment of the Botsford dome appears to have been covered by the upfaulted block so that there is a major discordance of structures between the blocks separated by the fault. The displacement may be explained in part by the different strikes of different parts of the fault. The ratio of dip slip to strike slip must change with change in fault strike, and the dip slip component appears to be least on the more northerly-trending parts of the fault, and greatest on the eastward-trending portions, in accord with movement of the southern block northward on a reverse or thrust fault.

Tear faults and small thrusts outnumber other kinds of faults in the Quinto pit. A tear or oblique slip fault at the east end of the pit trends northeast, and presumably joins the fault at the Caridad mine although this tear fault is not exposed outside the immediate vicinity of the pit. The southeast block has been displaced some tens of meters northeastward relative to the northwest block. A vertical fault, marked by a shear zone a few meters wide, trends east and is exposed along the north rim of the Quinto pit; it is parallel to the axis of a strong flexure along which beds that dip about 40° N. steepen abruptly to as much as 90°, but its magnitude is unknown. South of the axis of the flexure there is a reverse fault that trends east, dips about 70° N., and has a throw ranging from a few to 25 meters. These eastward-trending faults appear to be genetically related to the flexure. Other faults in the Quinto pit trend east and north but have very small displacements.

FAULTS IN THE GRAN PIEDRA MASSIF

Many faults too small to map have been observed in the overwhelmingly volcanic rocks east of the Santiago Basin; others of more importance probably have not been detected. On the map (pl. 19) the faults described by Park and Cox (1944, p. 352–355) in the Sigua mine area are shown, but not those at the Chévere mine. The main fault in the Sigua area trends east-northeastward and presumably dips north; the north block is downthrown some tens of meters.

FAULTS IN THE CAUTO-GUANTANAMO LOWLANDS

Few faults were seen in the synclinal area of the Cauto-Guantánamo Lowlands, and most of those found were in or near the structural domes. Only some of the faults that were found are shown on the map and described. The Ponupo dome is cut by several faults traceable only where Cobre rocks have been faulted against San Luis rocks. On the east flank of this dome a low-angle thrust fault strikes north-northeast and dips about 16° E.; it is well exposed in the east wall of the Sultana pit where Cobre strata have been thrust an estimated 200 meters westward over basal shales of the San Luis with a resultant throw of 10 to 15 meters. Movement essentially parallel to the dip is indicated by small drag folds whose axial planes dip approximately east-southeast. This thrust was not exposed anywhere outside the Sultana pit except in the bed of the Río Ponupo where a reverse fault was inferred to be a continuation of the same thrust. Near the crest of the Ponupo dome, the Ponupo jasper lens on the west is down-thrown about 60 meters against pyroclastic rocks of the Cobre on the east along a high-angle fault that trends N.25° E. Just north of the Ponupo jasper lens a small fault that was mapped trends east, dips south, and has a throw of about 15 meters. One minor transverse fault cuts the north flank of the Mucaral dome. A fault that trends about N.32° W. is inferred to be present in the structural sag between the Mucaral and Ponupo domes because outcrops of basal shales of the San Luis along the southwest bank of a small arroyo are topographically lower than outcrops of the flat-lying Charco Redondo limestone member on the opposite bank of the arroyo; the throw is estimated to be 15 to 25 meters.

In the north part of El Aura dome two faults of unknown dip and a few meters displacement have divergent northward trends; in the south part a steeply dipping fault of small displacement trends east-northeast. A small thrust at the Sabanilla station southeast of the dome involves only San Luis rocks at the surface; it dips 25° southwest and its displacement is not known, but sandstone and shale abut against each other and are dragged on the fault.

FAULTS IN THE NIPE HIGHLANDS

The Nipe-Cristal Highlands physiographic and structural provinces are represented in the mapped area only by the south end of the Sierra de Nipe, the Fringing Uplands to the south, the Jarahueca Valley, and the southernmost part of the Jarahueca-Mayarí Canyon. One group of major faults in the Fringing Uplands follows the south and east flanks of the broad anticline that stands out as the chief structural feature of these uplands. The largest of these faults has been named the Corinto fault after the Corinto mine where it is best exposed. The Corinto fault lies between the north-trending axis of the Mayarí syncline and the northeastward-trending axis of the anticline on the west. It is a normal fault that trends north near the Corinto mine, dips about 60° E., and has an apparent throw of at least 100 meters and perhaps as much as 200 meters that butts shales and limestones of the San Luis on the east against pyroclastic rocks of the Cobre on the west. The Corinto fault was traced northward for more than 2 kilometers into the Guanabá mine area where it is believed to veer north-northeast, run nearly to the Río Mayarí and end in the trough of the Mayarí syncline. The Corinto fault was traced southward from the Corinto mine area with certainty to the Río Sumidero, beyond which it is believed to veer south-southwestward and to continue into a fault with similar displacement and dip in the Valle de Manganeso mine area. On the road between Nuevo Mundo and La Caoba there is a high-angle normal fault along which the Charco Redondo member on the south has been dropped a few tens of meters and abuts against pyroclastic rocks of the Cobre on the north. This fault apparently extends westward toward the Esperancita mine and ends; it may end east of the exposures along the road or may veer northeast to join the Corinto fault southwest of the Valle de Manganeso mine. A normal fault of steep east dip like that of the Corinto fault but with only a few tens of meters displacement runs northeast from good exposures at the Valle de Manganeso mine, through the Tejón mine, and to the south end of the Mayarí syncline at Joturo Abajo.

Minor, probably normal, faults bound erosion remnants of the Charco Redondo limestone member which cap pyroclastic rocks of the Cobre on the Florida Blanca Plateau near El Iris. The normal fault just south of the Federico and Ibars de Urgel mines dips 55° NE. and has the greatest throw (50 to 100 meters) of all these minor faults. It seems to be continuous with a southeastward-trending fault at the Briseida mine, where the throw is only a few meters, but the fault veers eastward east of the Ibars de Urgel mine.

An eastward-trending fault in pyroclastic rocks of the Cobre was seen 1.3 kilometers north of Florida Blanca; the dip of the fault is 65° S. and drag indicates a reverse displacement which cannot be great because no Charco Redondo limestone is found immediately north of the fault. Between the Sumidero Basin and Palmarito a few minor faults that cut Cobre and San Luis rocks were mapped: they trend north to northeast, appear to be high-angle normal faults, and the amount of throw ranges from a few meters to several tens of meters. However, there are two small unmapped thrust faults involving San Luis rocks seen in a cutbank of the Arroyo Indio just north of the axis of the Indio syncline about 2 kilometers west of La Gloria mine; one strikes N. 60° W. and dips about 39° S.; the other, 100 meters to the south, strikes N. 70° E. and dips 50° S.

North of the Indio and Jesús synclines, between the Río Jagua and Pinar Redondo, a complex of interlinked high-angle faults shows trends from west to northwest. Some downthrown blocks lie north and some lie south of these faults. However, the net aggregate downthrow is to the south, and the greatest downthrow is in the two southernmost faults of the complex: a west-trending fault on the Río Jagua has a throw of several tens of meters, and on the north it appears to be joined by a northwest-trending fault that has a throw of more than 50 meters. North of this fault complex and west of Pinar Redondo, a north-trending fault downthrown about 30 meters on the east runs northward about 3 kilometers to the Central Massif, where it joins a fault that trends east-northeastward. This last fault, the northermost fault mapped, is inferred to be present because of the north-facing scarp bordering the Pedernal Karstland just south of the Central Massif, and because it appears to have downthrown a block of Charco Redondo limestone member that overlies the ultramafic rocks of the Central Massif north of Pinar Redondo. This boundary scarp runs for several kilometers down the Río Piloto and stands out on aerial photographs as a striking scarp (figs. 26, 44).

A fault is inferred to run northwestward from Pinalito because of a prominent southwest-facing scarp developed on the Charco Redondo limestone member along the northern part of the fault trace, where flat-lying Charco Redondo strata steepen abruptly and dip southwestward. Along the southeastern part of the fault trace, the Charco Redondo limestone member on the southwest is in direct contact with ultramafic rocks on the northeast. Possibly these relations are explainable by a sharp, southwest-dipping monoclinal flexure, rather than by a fault.

STRUCTURAL HISTORY

There is indisputable evidence for uplift and deformation in south-central Oriente from late Senonian time to sometime before deposition of the Cobre formation, and again after Cobre time and before La Cruz time. Closer dating of the latter, main deformation is not warranted by any direct evidence available. Hayes, Vaughan, and Spencer (1901, p. 31) were able to suggest the time limits for the main Cenozoic deformation nearly half a century ago:

> the history of the Island during Eocene time is vague, but * * * a large portion of it was submerged * * * This is certainly true of Santiago [that is, the modern Oriente]. The mountain building * * * had begun before the deposition of [La Cruz [4]] strata and the Sierra Maestra had already been elevated to a considerable height above sea level.

Woodring and Daviess (1944, p. 382) reaffirmed that "in the Santiago de Cuba basin * * * the main deformation must have taken place within the interval between upper Eocene and middle Miocene."

[4] "La Cruz" has been substituted for "Upper Oligocene", inasmuch as Vaughan named this formation later and redetermined its age as middle Miocene.

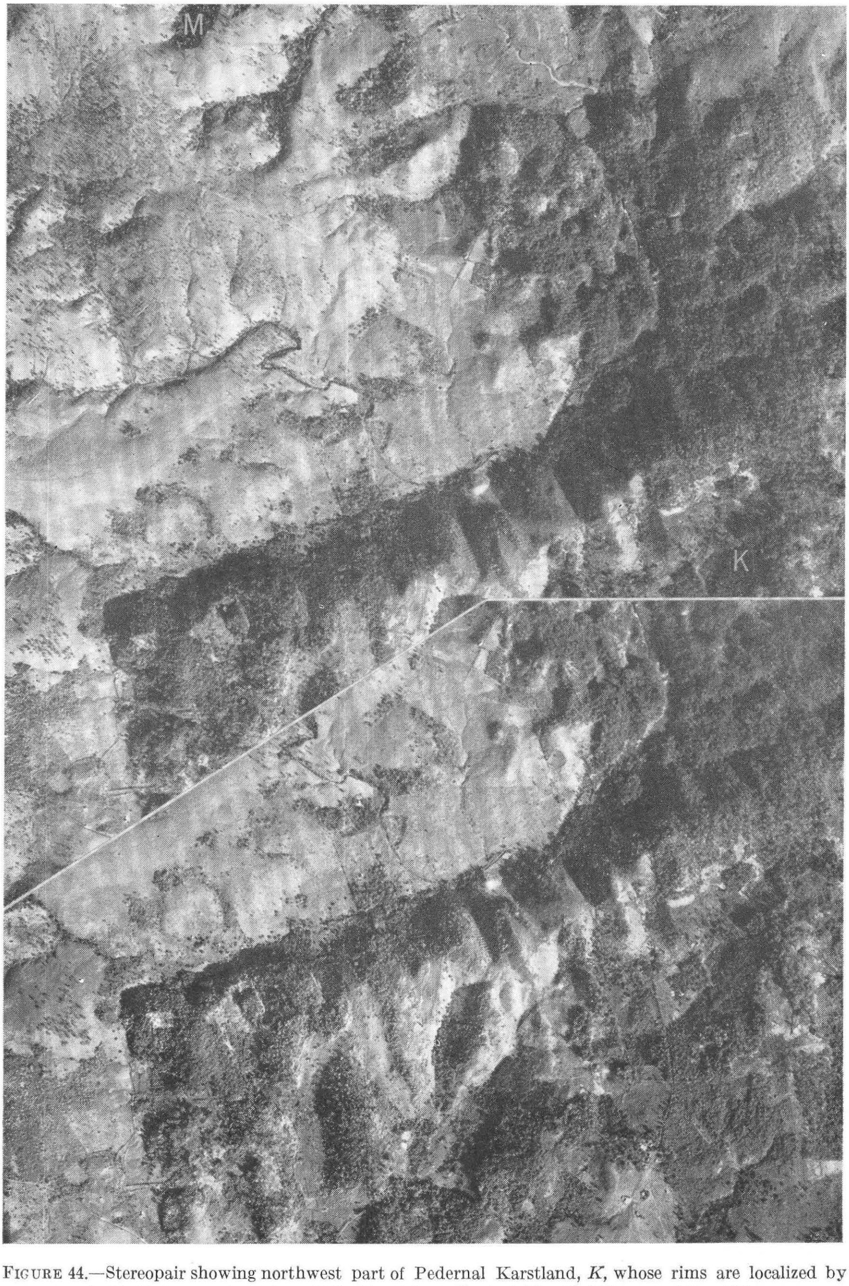

FIGURE 44.—Stereopair showing northwest part of Pedernal Karstland, *K*, whose rims are localized by faults that separate Pedernal Karstland from Central Massif of Sierra de Nipe (M).

Taber (1931, p. 556-557) believed that "at the close of the Eocene the land was uplifted with some tilting" in the Santiago area, but found

> no evidence that this region shared in the folding which is said to have formed mountains in some of the Greater Antilles between late Eocene and middle Oligocene. During middle Miocene time the region around Santiago Bay was depressed to receive the La Cruz * * * During the Pleistocene there was emergence * * * in part due to uplift and northward tilting along the coast * * * continued intermittently during Recent time. Also, during this last phase * * * block faulting has extended northward with the formation of additional ridges along the coast.

Taber concluded (1934, p. 618–619) that the Eocene rocks were merely "tilted northwesterly [and] bevelled by erosion" prior to La Cruz time, but that "after extensive peneplanation, faulting along east-west lines began in late Pliocene or early Pleistocene and has continued through Recent time."

The following conspectus of structural history is suggested by the data gathered to date:

Late Cretaceous uplift of the Sierra de Nipe Central Massif resulted in erosion of rocks of the Central Massif to form clastic sediments, which were deposited as the Habana(?) formation. Then followed deformation and erosion of the Habana(?) formation (including the Picote conglomerate member) of the Sumidero and La Burra Basins, after which Cobre deposition began. The deformation involved late Senonian rocks and preceded deposition of the Peluda volcanic member of the Cobre, so it may have taken place entirely in Maestrichtian time, although a Danian, Montian, or slightly later date is possible. Intrusion of the Sierra Maestra batholiths may have begun at this time, but it seems more probable that they were emplaced during Cobre time.

Some folding and faulting must have taken place during Cobre time. This has been suggested in the descriptions of the various tectonic features, and it would have been most unusual if such deformation had not occurred. Important changes in local crustal structure must necessarily have accompanied the enormous outpourings of volcanic material from within the earth, and its accumulation as extremely thick deposits on the sea bottom. Some of the present folds and domes may be primary features, the results of the deposition of unequal thicknesses of Cobre rocks. The character of the Cobre formation suggests that there may well have been subaerial and submarine volcanic mountains on or near an island or islands located on a relatively high part of the crust near sea level. The association of manganese deposits with the Cobre formation does not help to clarify the structural history, for all are believed to be syngenetic and unrelated to faulting in south-central Oriente, although some deposits in the Guisa-Los Negros area are localized along faults that cut the Charco Redondo limestone member. This phase of the problem is discussed at length in the report by Straczek and Simons.[5]

Most of the Tertiary volcanic activity recorded in south-central Oriente occurred before the onset of San Luis deposition in middle Eocene time. The conduits that supplied the flows and stocks of the Cobre, and many of the dikes known to cut Cobre rocks, may have followed faults developed in Cobre time. Only a very few intrusions are known to have taken place after the late Eocene deposition of upper San Luis rocks. An altered basaltic dike at localities 160 and 161 northwest of Alto Songo cuts the Camerones conglomerate member.

The nature of the San Luis rocks attests widespread tectonic activity. San Luis time began with middle Eocene deposition of fine clastics derived from the south; the late Eocene Camarones conglomerate member contains boulders, cobbles, and pebbles of Vinent(?) and Sierra Maestra batholithic(?) rocks, in addition to those derived from the Cobre formation. Uplift, folding, and faulting seem to have begun south of the present Sierra Maestra region and to have spread northward from middle to late Eocene time.

Rocks of south-central Oriente as young as late Eocene have been strongly deformed whereas those younger than Eocene are only slightly deformed. The overturning, major folding, and faulting of the northern Santiago Basin and adjacent sections where strong folding seems to be localized involve no rocks younger than San Luis and may antedate deposition of the Oligocene rocks of the Nipe Highlands and northeastern Cauto Valley; they certainly took place before or during the implied uplift and erosion of the Sierra Maestra which was followed by La Cruz deposition in middle Miocene time. A meaningful comparison between the degrees of deformation of the Oligocene and Miocene rocks is not possible in south-central Oriente, because these rocks do not crop out in the same areas; the nearest outcrops of one to the other are 45 kilometers apart in very different structural environments. The Oligocene rocks overlie San Luis rocks with apparent conformity in two small tracts of the northern part of the area mapped, where both formations show mild deformation; the faults that involve Eocene rocks in the Nipe Highlands could not be traced into the Oligocene outcrops, so these faults are known only to cut San Luis rocks. The La Cruz rocks of the middle Miocene, which contain coarse clastic components derived from the Sierra Maestra, directly overlie the strongly deformed and eroded Eocene and older rocks of the Santiago Basin; the La Cruz formation is only slightly warped and cut by a few minor faults. We conclude from this that the south coast of Oriente

[5] Straczek, J. A., and Simons, F. S., Manganese ore deposits of Cuba (manuscript in preparation).

must have been localized near the present Santiago Bay by middle Miocene time.

It seems quite probable that the forerunners of the present Sierra Maestra and Cayman Trough existed as early as middle Miocene time. Some of the scarps northwest of Santiago Bay that are young in appearance may be on faults along which there was initial movement as long ago as Eocene time, with renewed later movement. The Sierra Maestra must have been formed by deformation and uplift mainly before La Cruz time, if we are to account for either the deposition and complete eroding away or the nondeposition of Oligocene rocks in the Sierra Maestra area, and the presence of the La Cruz rocks in the Santiago Basin. This orogeny may have produced mountains that originally extended well south of the present coast and Sierra Maestra; foundering of this southern ancestral Sierra Maestra in the Cayman Trough, possibly while the northern portion was still rising, would have permitted the marine erosion and deposition recorded in the La Cruz outcrop area. This view seems more favorable than Taber's (1934, p. 601) belief that "the Turquino and Gran Piedra ranges are large fault blocks that have been uplifted and tilted toward the north, their present altitude being due almost entirely to uplifts during post-Pliocene time."

Nothing definite is known of the structural history of south-central Oriente in Pliocene time, but broad warping and possibly faulting may have affected the region in Pliocene time and certainly did in Quaternary time, because submergence and emergence, obviously not the result of eustatic changes in sea level, are indicated by the extensive development of shoreline features at several levels along the Caribbean coast (Hayes, Vaughan, and Spencer, 1901, p. 19–20; and Taber, 1934, p. 571, 589–590, 604–606). The present south coast of Oriente is a region of seismic activity to this day.

Woodring (in Woodring, Brown, and Burbank, 1924, p. 332, 337–338) reports the following structural history for Haiti, just across Windward Passage from Oriente:

> Folding probably took place at the end of Cretaceous time * * * This folding was accompanied or followed by intrusion of relatively large batholiths and stocks of quartz diorite * * * Eocene * * * beds are folded and crumpled, in some areas more complexly folded than the younger rocks, so that there may have been a period of folding at the end of Eocene time and in early Oligocene time * * * The folding at the close of Miocene time determined the location of such geographic features as the Central Plain, Artibonite Valley, and Cul-de-Sac Plain, which if submerged would be similar on a small scale to the great submerged troughs of the West Indies * * * Accumulating evidence indicates that the submerged troughs were at least deepened if not entirely formed at the close of Miocene and during Pliocene time * * * The submerged troughs which have been recently described by Taber, have been interpreted by Vaughan and Taber as downfaulted blocks bounded by normal faults * * * The subaerial troughs are deep synclines bounded in part by a zone of imbricated high-angle thrust

faults. It has recently been suggested that it is more reasonable to believe that the submerged troughs are similar deep synclines probably limited by high-angle thrust faults. Possibly both the subaerial and the submerged troughs were deepened by vertical movements later than the folding.

Hess (1938, p. 87) assumed that in late-Tertiary time a great tear fault system, bounding the south coast of Oriente and the northern scarp of the Cayman Trough, was present from Guatemala to the Windward Passage: he

believes it was formed during the late Miocene deformation. Hill says that the conglomerates of the Richmond beds (early Eocene) in Jamaica indicate land at that time to the northeast (now the eastern part of the trough) . . . The south side moved east; the area south of the fault was thus relieved of compression and became complexly block faulted. The area north of the fault, Cuba, suffered only a moderate amount of Tertiary deformation, whereas Haiti, which was not so relieved, became very intensely folded in Miocene and Pliocene time.

It seems clear that although there are many points of similarity in the stratigraphy, structure, and geologic history of Oriente and nearby Haiti, their detailed structural histories do differ in important respects. If the Miocene and later structures reported by Woodring in Haiti continue westward along the south coast of Oriente, they are submerged in the Cayman Trough. As Hess has suggested, the south-central Oriente area was much less deformed in Miocene and Pliocene time than was Haiti. We suggest that faulting before La Cruz time, near the present south coast of Oriente, followed by later movement along the same fault zone, permitted relief of stress after La Cruz time so that there has been no significant deformation of Miocene and younger rocks of south-central Oriente. We believe that the main Tertiary deformation of south-central Oriente began at the same time as the possible late Eocene and early Oligocene folding in Haiti suggested by Woodring, but possibly continued through early Miocene time, and that the south coast of Oriente has been determined by tear faulting, folding, and high-angle thrust faulting, possibly with subordinate block faulting.

In summary, the evidence indicates that there have been two times of major deformation in south-central Oriente: a latest Cretaceous or earliest Tertiary deformation established the main structural trends of the area, and a second major deformation productive of similar structural trends occurred between late Eocene and middle Miocene time.

MANGANESE DEPOSITS

GENERAL OBSERVATIONS

South-central Oriente is the major source of manganese ore in Cuba. Part of the deposits in this region have been described by Park (1942, p. 75–97), and by Park and Cox (1944, p. 313–355), and others in the area covered by this report are described by Straczek and Simons in their report (in preparation) on Manganese Ore Deposits of Cuba. Geology of the principal mine areas shown on the areal map (pl. 19) was done by Straczek, Simons, Park, and Cox during investigations carried on from 1941 to 1945, and the results of these investigations are freely used in this report, particularly such data as demonstrate the relations of the deposits to general stratigraphic and structural features of the region. Consideration of the deposits in their relation to structure and stratigraphy is based upon the theories of origin and deposition first brought out by Park, which postulate that the bedded deposits are syngenetic, deposited at the same time as the enclosing rocks, and that the nonbedded deposits are epigenetic, deposited later than the enclosing rocks.

The manganese minerals of the deposits are primary oxides of the psilomelane group, secondary oxides that include manganite and pyrolusite, and in a few deposits, silicates. Pyroclastic rocks associated with many of the bedded deposits are strongly altered to clay minerals of the montmorillonite group. Lenticular bodies of brown to reddish brown jasper are found in most of the deposits of bedded ores. These lenses lie along the manganese beds and as a whole are parallel to the enclosing beds of country rock. Some lenses are as much as 450 meters long and 300 meters wide, as shown on the areal map (pl. 19), and some are more than 30 meters in maximum thickness, but most are smaller bodies a few meters thick. Concentration of manganese is invariably greatest near the jasper but the amount of manganese in a deposit evidently bears no relation to the size of the jasper lenses; some beds of manganese extend hundreds of meters away from jasper, and in some beds there is little or no associated jasper.

CLASSIFICATION OF THE DEPOSITS

Classification of the manganese deposits is based primarily upon their general mode of occurrence and association; secondarily, upon the nature of the manganese minerals of the deposits, and upon the presence or absence of jasper. This is the classification used by Woodring and Davies (1944, p. 383), and is the one adopted by Straczek and Simons. It differs in detail from the classification of Park and Cox, who subdivided their bedded ores into tuff ores and limestone ores, depending upon the character of the matrix associated with the manganese minerals, and subdivided their nonbedded ores into two groups, depending on association or nonassociation with faults. Either system has merit but for the purpose of this report, which stresses the stratigraphic relations of the ores, it is believed that the classification herein adopted is the more useful.

Relation of the deposits to structural features, folds or faults, is not brought out in the classification, as the relation to such features is in many cases obscure or uncertain, and if applied, would involve description of the deposits not within the scope of this report.

Classification of the manganese deposits of south-central Oriente, Cuba

Bedrock deposits:
- Bedded deposits
  - Oxide deposits
    - Deposits in tuff beds in limestone
    - Deposits in tuff
      - Associated with jasper
      - Not associated with jasper
  - Silicate-oxide deposits
    - Deposits in tuff
      - Associated with jasper
      - Not associated with jasper
- Nonbedded or irregular deposits
  - Oxide deposits
    - Deposits in limestone
    - Deposits in tuff or other volcanic rocks

Surficial deposits: "Granzón" (pellets of manganese oxide and detrital lode ore in soil)

Estimated production from the different types of manganese deposits in south-central Oriente, 1942–1945

Type of deposit	Approximate recorded production of concentrates and crude ore (long tons)	Percentage of total production	Names of principal mines
Bedded oxide deposits in pyroclastic rocks, associated with jasper.	[1] 132,500 [2] 608,500	94.7	Quinto, Ponupo, Manacas, Guanabá, La Llave, Jutinicú, Sabanilla, Boston groups; Tordera, San Luis, España, Augusto Luis, Esperancita, Valle de Manganeso, Abundancia, Portugal, San Ricardo, Consuelo.
Bedded oxide deposits in pyroclastic rocks, not associated with jasper.	2,250	.3	Botsford, Tres Josefas, Jesús Segundo, Briseida, Ibars de Urgel, Tejón, Santa Rosa, San Ildefonso.
Bedded oxide deposits in pyroclastic rocks in limestone.	8,000	1.0	Corinto, Polaris, La Gloria, Elvira.
Bedded silicate-oxide deposits in pyroclastic rocks, associated with jasper.	1,000	.1	Chévere. No recorded production for Sigua.
Surficial deposits	30,500	3.9	Briseida, Guanabá, La Gloria, Elvira, La Llave, Federico.

[1] Crude ore.
[2] Sintered concentrates from Quinto-Ponupo mines.

Only bedded deposits and minor associated surficial deposits are represented in the area mapped during this investigation. Therefore, because the bulk of the deposits belong to one class no attempt is made to list on the areal map the various types of deposits, using map symbols, as have Woodring and Daviess (1944, p. 385).

RELATION OF THE DEPOSITS TO REGIONAL GEOLOGY

The manganese deposits occur only in the Cobre formation and the great bulk of deposits is near the top of the formation. The largest ore bodies are in the uppermost 30 meters of the Cobre in the Quinto, Ponupo, Jutinicú, and El Aura mine areas. Others, including the Esperancita, Briseida, Tejón, Guanabá, and Valle de Manganeso deposits, are as much as 80 to 120 meters below the top of the Cobre formation. The Tordera-San Luis, España, Augusto Luis, and Boston deposits are 300 to 500 meters stratigraphically below the top of the Cobre. The deposits of only one economically important district—Manacas—are known to occur in the middle to lower part of the Cobre. This deposit includes the Amarito, Guadalupe, La Central, Pasaje, and other mines, most of which are located on the same beds of ore, about 2,000 to 2,500 meters below the top of the Cobre. The Chévere mine and mines in the Sigua area are at least the same distance below the top of the formation as the Manacas deposits, and deposits in the Santiago Basin are evidently 1,500 to 2,000 meters below the top of the Cobre, but production from these mines has been only a few thousand tons.

The close relation of the deposits to contacts between pyroclastic rocks and limestone, first noted by Park, later reemphasized by Park and Cox, and by Woodring and Daviess, is apparent also for many of the deposits in south-central Oriente, but several, including the San Luis-Tordera, España, Sigua, Chévere, San Ildefonso, and others are in pyroclastic rocks that are not near limestone, nor is limestone found nearby along strike extensions of the manganese-bearing beds. Moreover, most of the deposits that are near limestone are not actually in contact with this rock, but are separated from it by several centimeters or several meters of barren tuff or agglomerate. Such a relation is true, for example, at the largest single ore body of the area, the Quinto deposit. Insofar, then, as association of the deposits with any particular rock type is concerned, the only generalization that can be applied to all of the deposits is that they are associated with water-laid tuff and agglomerate. This generalization applies also to the bedded deposits in limestone, all of which follow beds of tuff interbedded in limestone. Evidently the periods during which manganese was deposited commonly were preceded and followed by, or simply followed by, periods favorable for the accumulation of limy sediments, an apparently fortuitous relation in view of the fact, as already pointed out, that some deposits are not found near limestone, and even those near a limestone contact always occur in a bed of pyroclastic rock.

The manganese deposits are scattered throughout the area underlain by Cobre rocks. No regional structural control can be demonstrated, and, insofar as the bedded deposits are concerned, local structures were formed after mineralization. The striking association of manganese deposits with structural domes (Ponupo-Mucaral, El Aura, Jutinicú, Cuatro Caminos) seems anomalous in view of the fact that evidence of contemporaneous deposition of manganese with enclosing rocks is as strong for these deposits as it is for many of the deposits that are not associated with domical structures. Such evidence, described in detail by Straczek and Simons (report in preparation), includes tuff dikes that cut the ore beds, and beds of intraformational conglomerate consisting of manganese oxide fragments in a limestone or tuff matrix that directly overlie some beds of manganese oxides. The tuff dikes are traceable to overlying beds and were obviously formed before these beds were consolidated; the conglomerates were formed after the manganese oxides were deposited, by the breaking up of the consolidated oxides by sea currents and the mixing of the resulting fragments into limy muds and ash accumulating over the manganese beds. The above evidence is unequivocal in the largest deposits of the area, the Quinto and Ponupo, and has been noted at many of the other deposits. Park and Cox (1944, p. 314–316) describe similar intraformational conglomerates at the Taratana and Charco Redondo mines in the Guisa-Los Negros district, and an example of a small tuff dike in manganese oxide is shown by Park (Park, 1942, pl. 23).

A possible indirect relation of manganese deposits with structural domes is postulated by Straczek and Simons (report in preparation), who suggest that the manganese was deposited by warm submarine springs in or near centers of volcanic activity over which some of the domes seem to be localized.

The bedded manganese deposits are cut by many minor faults and some major faults which affect the continuity of the deposits and must be considered in their exploration and exploitation, but which are indicated by the field evidence to be post mineral and therefore to play no part in the localization of the manganese. Most nonbedded deposits, on the other hand, are clearly associated with premineral faults along which they are localized. In the Guisa-Los Negros district there are several examples of nonbedded deposits, including La Única, Cádiz, and La Prueba, but only one is known outside this district, the Luis Antonio-Doncella deposit near Jarahueca, just east of the mapped area.

GUIDES TO PROSPECTING

It is important to note in the field the positions of manganese beds relative to mappable rock units. Limestone beds, even if they do not directly control the localization of ore deposits, often serve as a useful guide in prospecting, especially near these beds with which known manganese deposits are associated. The bulk of the economic deposits are near the top of the Cobre formation, commonly in or near the base of the Charco Redondo limestone member. In the Picote area, for example, the Jesús Segundo mine lies in tuff and agglomerate, about 15 meters stratigraphically below a 10-meter thick limestone bed, which is the basal bed of the Charco Redondo limestone member.

The deposits of nearby Polaris, La Gloria, and Elvira mines, on the other hand, are in the interbedded limestones and tuffs of the upper part of the Charco Redondo limestone member, 50 to 75 meters stratigraphically above the basal bed of the Charco Redondo, and less than 15 meters below the top of the Cobre formation.

Where little or no limestone is present near a deposit the manganese-bearing horizon often can be referred to a contact between nonlimy and limy tuff, or to an agglomerate contact, as was done by Park and Cox at the San Ildefonso mine near El Cobre, and at the group of mines in the Sigua area (Park and Cox, 1944, pls. 65 and 67).

Structural domes also appear to be indirectly related to the deposition of manganese and should not be overlooked in prospecting for new ore bodies, especially if horizons known to be favorable are involved in the structures.

ECONOMIC POSSIBILITIES OF THE AREA

There are several areas in which manganese deposits might be found. For immediate results the extensions of known ore bodies offer the best possibilities, but there are also areas in which deposits might be located by deep drilling. Such deposits as might be found will probably be similar in character and grade to known deposits of the region.

The most promising procedure for future prospecting would be an effort to locate the faulted portion of the Quinto ore body north of the Quinto pit. Because exposures in this area are poor and because the faults are in shales and sandstones of the San Luis formation (which makes it difficult to estimate the amount and direction of relative displacement), the depth to the manganese horizon, known to be in the uppermost 20 meters of the Cobre, is highly uncertain. The fault on the north edge of the pit is evidently a vertical or steep reverse fault parallel to the front of a strong flexure whose north limb approaches vertical along the Quinto pit and in places may be overturned. The base of the San Luis is evidently at least 150 meters below the surface north of the fold-fault structure. The fault further to the north is very approximately located and the amount of relative displacement along it is even more difficult to estimate than that along the structure in the open pit.

Another area in which low grade manganese deposits might be found is the irregular and complex anticline that extends from La Maya through Alto Songo, particularly the eastern part, on the assumption that this structure may be similar to that of the Ponupo domes. The cover of San Luis rocks in this area is estimated to be at least 200 meters thick and the manganese ore zones favorable for exploitation lie in the uppermost 30 meters of the underlying Cobre formation.

The Cuatro Caminos dome is still another area in which new ore bodies might be located by drilling through the Charco Redondo limestone member on the top and flanks of the structure. The thickness of the limestone there is not known but it may be as much as 50 meters judging by the nearest occurrences.

LIST OF FOSSIL LOCALITIES [1]

No. used in this report	Field No.	Description of locality
		UPPER CRETACEOUS SERIES
		Habana(?) formation
243	45GEL558	13.2 km east-southeast of Central Miranda.
244	45GEL556	11.6 km east-southeast of Central Miranda, on Sabana la Burra road.
245	45GEL546	13.2 km east-southeast of Central Miranda, on Sabana la Burra—La Peluda road.
246	45S80	14.7 km east-southeast of Central Miranda, on La Peluda—Magayal road.
247	45S81	14.6 km east-southeast of Central Miranda, on La Peluda—Magayal road.
248	45GEL564	25.2 km east of Central Miranda, on south bank of Río Sumidero.
249	45GEL563	25.5 km east of Central Miranda, on La Caoba-Sumidero road.
250	45GEL565	25.3 km east of Central Miranda, on south bank of Río Sumidero.
		UPPER CRETACEOUS(?), PALEOCENE(?), AND EOCENE SERIES
		Cobre formation
		Peluda volcanic member of the Cobre formation
236	45S79, 45S88	11.8 km east-southeast of Central Miranda.
237	45S89	11.7 km east-southeast of Central Miranda.
238	45S78	12.5 km east-southeast of Central Miranda.
240	45S75	12.6 km east-southeast of Central Miranda.
		Cuabitas limestone lentil of the Cobre formation
118	45GEL578	1 km north-northeast of Santiago airport, limestone quarry.
119	44GEL512	3 km north-northeast of Santiago de Cuba, limestone quarry.
120	44GEL513	0.5 km northwest of Cuabitas, limestone quarry.
121	44GEL514	0.75 km east-northeast of Cuabitas.
122	44S85a	1 km north of El Caney, on trail.
		Undifferentiated lower Eocene or older rocks of the Cobre formation
58	45S263	14 km south of Contramaestre, on trail west of Río Contramaestre.
60	45S284	19 km west-southwest of Palma Soriano, on trail.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		UPPER CRETACEOUS(?), PALEOCENE(?), AND EOCENE SERIES—Continued
		Undifferentiated lower Eocene or older rocks of the Cobre formation—Continnned
61	45S277	12.2 km west of El Cobre, on trail.
62	45S275	11.8 km west of El Cobre, on trail.
63	45S313, 45S315	11.8 km west-northwest of El Cobre, on Hongolosongo road.
64	45S274	11.1 km west-northwest of El Cobre, on trail.
65	45S273	10 km west-northwest of El Cobre, on Hongolosongo road.
66	45S272	10.2 km west-northwest of El Cobre.
67	45S267	9.7 km west-northwest of El Cobre, on trail.
68	45S266	10.7 km west-northwest of El Cobre, on trail.
69	45S270, 45S271	8.4 km west-northwest of El Cobre, on trail.
70	45S268, 45S269	8.1 km west-northwest of El Cobre, on trail.
71	45S314	4 km south-southwest of El Cobre, on trail.
72	45S312	2 km southwest of El Cobre, on trail.
73	45S311	1.7 km southwest of El Cobre, on trail.
111	45S264	3.5 km east-northeast of El Cobre.
112	45S179	5.5 km east-northeast of El Cobre.
114	44GEL521	5 km north-northwest of Santiago de Cuba, at south foot of Pelado Ridge.
		Undifferentiated middle Eocene rocks of the Cobre formation
74	45S242	3.5 km west of El Cobre, on trail.
75	45S181	2.3 km north-northwest of El Cobre, on trail.
76	45S190	4.8 km northwest of El Cobre, on Central Highway.
77	45S194	5.2 km northwest of El Cobre, at María prospect.
78	45S197	5.3 km north-northwest of El Cobre.
79	45S198	4.8 km north-northwest of El Cobre, on trail near Piedra Pisada prospect.
80	45S210	4.8 km north of El Cobre, on trail.
81	45S207	5.1 km north of El Cobre, on trail.
82	45S243	8.3 km northwest of El Cobre, on road.
83	45S195	8.4 km north of El Cobre, on trail.
85	45S182	7.7 km south of Palma Soriano, on Carretera Central.
101	45S211	10 km west-southwest of San Luis, on trail.
113	45S180	4.5 km northeast of El Cobre, on trail.
115	45S178	8 km north-northwest of Santiago de Cuba, on trail atop Boniato Ridge.
116	45S188	9 km north-northwest of Santiago de Cuba, on San Luis trail.
117	45S189	10 km north-northwest of Santiago de Cuba, on San Luis trail.
125	44FS261	3 km southwest of El Cristo, on trail.
126	44GEL508	2.5 km southwest of El Cristo.
127	44S20	1.5 km southwest of El Cristo.
131	44S77, 44S78	2.5 km south of El Cristo, on trail.
132	44GEL507, 44S6	1 km south of El Cristo, in Barbacoa Pass.
137	44S75	2 km east-southeast of El Cristo, at Caridad prospect.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		UPPER CRETACEOUS(?), PALEOCENE(?), AND EOCENE SERIES—Continued
		Undifferentiated middle Eocene rocks of the Cobre formation—Continued
138	44GEL504	3.5 km east-southeast of El Cristo, at Boston mine.
139	44S86	2.6 km east of El Cristo, on road at north end of Quinto reservoir.
148	44S81	4.5 km east-northeast of El Cristo, east of Botsford mine.
194	45S10	8.2 km east-southeast of El Cristo, on upper Guaninicum valley trail.
231	45S65	8.9 km south of Central Miranda, on trail.
		Charco Redondo limestone member of the Cobre formation
36	45S285	4 km west-southwest of Mafo, on trail.
37	45S286	4 km west of Mafo, on trail.
84	45S196	8.3 km north of El Cobre, on trail.
87	44GEL505	6.2 km south-southeast of Palma Soriano, on Carretera Central.
102	45S213	10 km west-southwest of San Luis, on trail.
103	45S212	10 km west-southwest of San Luis, on trail.
123	44FS263	2.5 km north-northwest of Boniato, on north slope of Boniato Ridge.
124	44GEL511	2.5 km north of Boniato, on north slope of Boniato Ridge.
129	44S17	1 km southwest of El Cristo, on trail.
203	44FS262	2.5 km south-southeast of La Maya, on trail.
211	44GEL541	10 km south-southeast of La Maya, on west bank of Río Baconao.
227	44GEL538	3.5 km northeast of Central Miranda, on quarry road.
229	45S64	5.7 km south of Central Miranda, on Manganeso road.
230	45S63	7.1 km south of Central Miranda, on southwest cliff of Mogote San Nicolás.
234	45GEL545	10.4 km east-southeast of Central Miranda, on Sabana la Burra road.
251	45GEL551	14.8 km east of Central Miranda, on Pedernal-Magayal trail.
252	45GEL552	15.5 km east of Central Miranda, on Magayal-Chamarreta road.
253	45GEL547	15.2 km east of Central Miranda, on Pedernal-Chamarreta trail.
254	45GEL562	17.7 km east of Central Miranda, on Chamarreta-Platanal road.
256	45S99	25.4 km east of Central Miranda, north of Río Caoba.
257	45GEL522	24 km east-southeast of Central Miranda.
258	45GEL523	23.7 km east-southeast of Central Miranda, on trail.
259	45S37	21.3 km east-southeast of Central Miranda.
260	45S82	15 km east-southeast of Central Miranda.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

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LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		EOCENE SERIES
		San Luis formation
		Undifferentiated middle Eocene San Luis rocks
31	45S293	1.5 km south-southeast of Mafo, at Sorpresa mine.
33	45S294	2.5 km east-southeast of Mafo, on east bank of Río Contramaestre.
46	45S258	7.5 km southeast of Contramaestre, on Central America railroad.
47	45S257, 45S259, 45S262	11 km southeast of Contramaestre, on trail.
48	45S261	10.5 km east-southeast of Contramaestre, on Carretera Central.
49	45S260	11.5 km east-southeast of Contramaestre, on Carretera Central.
50	45S256	12 km east-southeast of Contramaestre, on Carretera Central.
51	45S254	14 km west-northwest of Palma Soriano, on Carretera Central.
52	45S246, 45S249	13 km west-northwest of Palma Soriano, on Carretera Central.
53	45S245, 45S250	10.8 km west-southwest of Palma Soriano, on trail.
54	45S247, 45S248	10.8 km west of Palma Soriano, on trail.
104	45S214	10 km west-southwest of San Luis, on trail.
105	45S215	10 km west-southwest of San Luis, on trail.
106	45S216	10 km west-southwest of San Luis, on trail.
108	45S192	4 km southwest of San Luis, on trail.
109	45S191	3 km southwest of San Luis, on trail.
110	45S175	2 km south of San Luis, on trail.
130	44S18, 44S19	1 km southwest of El Cristo, on trail.
133	45GEL582	0.5 km north of El Cristo, on railroad.
134	45GEL580	0.3 km north-northeast of El Cristo, on road.
135	45GEL579	0.4 km north-northeast of El Cristo, on road.
136	45GEL581	0.7 km north-northeast of El Cristo, on Río Guaninicum.
140	44S68	North side of Quinto pit.
141	44S65a, 44S66	East side of Quinto pit.
142	44S67, 44S69	Northeast side of Quinto pit.
143	44GEL501, 44GEL502, 44GEL503.	Northwest side of Quinto pit.
144	44S71	North of Quinto pit, in Arroyo Santa Ana.
145	44S70	North of Quinto pit, in Arroyo Santa Ana.
146	45S152	2.5 km north-northeast of El Cristo, on Alto Songo road.
147	44S85b	3.5 km east-northeast of El Cristo, on trail.
149	45S142	4.2 km northeast of El Cristo, on Alto Songo road.
150	45S143	4.5 km northeast of El Cristo, on Alto Songo road.
153	45S138	0.5 km east-southeast of Alto Songo, on trail.
156	45S140	1.5 km east of Alto Songo, on the railroad.
158	45S154	1 km west-northwest of Alto Songo, on Jutinicú road.
163	45GEL592	6 km northeast of Jutinicú, on Jutinicú-La Prueba road.
164	45GEL590, 45GEL591	5.8 km northeast of Jutinicú, on Jutinicú-La Prueba road.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		EOCENE SERIES—Continued
		San Luis formation—Continned
		Undifferentiated middle Eocene San Luis rocks—Continued
167	45S169	5.1 km northeast of Alto Songo, on Alto Songo-La Prueba road.
168	45S168	5 km northeast of Alto Songo, on Alto Songo-La Prueba road.
174	45S53	4.8 km northeast of Alto Songo, on Alto Songo-La Prueba road.
175	45S150	3.4 km east-northeast of Alto Songo, on trail.
176	45S151	3.2 km east-northeast of Alto Songo, on trail.
177	45S146	3.6 km east of Alto Songo, on trail.
179	45S174	2.5 km east of Alto Songo, on La Maya road.
182	45GEL571	3.5 km south-southeast of Alto Songo.
183	45GEL573	3.5 km southeast of Alto Songo.
193	44S84	5.8 km southwest of La Maya, on trail.
195	45S343	6.2 km northeast of La Maya, on trail.
196	45S344	3.1 km northeast of La Maya, on railroad.
197	45S163	2.2 km northeast of La Maya, on Los Ramos trail.
198	45S164	0.7 km northeast of La Maya, on Sabanilla road.
201	45S160	1.7 km southeast of La Maya, on Ponupo road.
210	44GEL542	9.6 km south-southeast of La Maya, on trail north of Río Baconao.
232	45S56	9.9 km south of Central Miranda, on trail.
261	45GEL589	23.7 km east-southeast of Central Miranda, on Jutinicú-Nuevo Mundo road.
262	45S36	25.2 km east-southeast of Central Miranda, on Jutinicú-Nuevo Mundo road.
268	45S55	29.6 km east-southeast of Central Miranda, on La Prueba-Seboruco road.
269	45S54	29.9 km east-southeast of Gentral Miranda, on La Prueba-Seboruco road.
271	45S66	33 km east-southeast of Central Miranda, on La Prueba-Seboruco road.
273	45S67	28.6 km east-southeast of Central Miranda, on La Prueba-Seboruco road.
		Undifferentiated upper Eocene San Luis rocks
32	45S295	2.5 km east-southeast of Mafo, east of Río Contramaestre.
34	45S296, 45S297	0.3 km southeast of Contramaestre, on west bank of Río Contramaestre.
35	45S298	0.3 km east of Contramaestre, north of Carretera Central.
38	45S288	5 km west of Contramaestre, south of Carretera Central.
39	45S299	2.5 km west of Contramaestre, north of Carretera Central.
40	45S290	4 km west-northwest of Contramaestre, on trail.
41	45S291	4 km north-northwest of Contramaestre, on trail.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		EOCENE SERIES—Continued
		San Luis formation—Continued
		Undifferentiated upper Eocene San Luis rocks—Continued
42	45S292	3.5 km north of Contramaestre.
45	45S283	8.5 km east-northeast of Contramaestre, on Remanganaguas road.
55	45S251	10 km west-northwest of Palma Soriano, on Carretera Central.
56	45S244	10.2 km west-northwest of Palma Soriano, on Carretera Central.
57	45S253	6 km west-northwest of Palma Soriano, on Carretera Central.
88	45S219	5.1 km west-southwest of Palma Soriano-north of Río Caney.
89	45S252	4.8 km west-southwest of Palma Soriano, on trail.
90	45S222	2.3 km south-southeast of Palma Soriano, on Carretera Central.
91	45S220	2.4 km south-southeast of Palma Soriano, on Carretera Central.
93	45S226, 45S227, 45S228	7 km west-northwest of Central Miranda, south of Río Cauto.
94	45S229	7.8 km west-northwest of Central Miranda, at Morcate.
95	45S230	7.9 km west-northwest of Central Miranda, at Morcate.
98	45S231	8 km west-northwest of Central Miranda, on the railroad between Paso Estancia and Puyáns.
162	45GEL593, 45S224	6.5 km northeast of Jutinicú, on Jutinicú-La Prueba road.
165	44GEL525	5 km north-northeast of Alto Songo.
166	44GEL526	4.9 km north-northeast of Alto Songo.
170	44GEL524	4.2 km north-northeast of Alto Songo.
171	45S59	4 km north-northeast of Alto Songo.
172	45S3	4.5 km northeast of Alto Songo.
173	45S2	4.4 km northeast of Alto Songo.
184	45GEL572	3.7 km southwest of La Maya, on trail.
185	44GEL518	3.2 km southwest of La Maya, on trail.
186	44GEL517	2.8 km southwest of La Maya, on trail.
187	44GEL516	2.6 km southwest of La Maya, on trail.
188	45S12	4. 3 km southwest of La Maya.
189	45S13	4 km southwest of La Maya.
190	45S13a	3.8 km southwest of La Maya.
192	44GEL509	7 km southwest of La Maya, on trail.
204	44FS261	1.5 km south of Cuatro Caminos, on La Galleta road.
205	44FS264	2.2 km south-southeast of Cuatro Caminos
224	45S237	4.9 km north of Central Miranda, on trail.
225	45S238	7.1 km north of Central Miranda, on trail.
233	45S62	9.1 km south-southeast of Central Miranda.
263	45GEL594, 45S26	27.4 km east-southeast of Central Miranda, on Jutinicú-La Prueba road.
264	45S27	27.4 km east-southeast of Central Miranda, on Jutinicú-La Prueba road.
265	45S25	28 km east-southeast of Central Miranda, on Jutinicú-La Prueba road.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES [1]—Continued

No. used in this report	Field No.	Description of locality
		Eocene Series—Continued
		San Luis formation—Continued
		Undifferentiated upper Eocene San Luis rocks—Continued
266	45S32	28. 8 km east-southeast of Central Miranda, on Alto Songo-La Prueba road.
267	45S223	28.6 km east-southeast of Central Miranda, on Alto Songo-La Prueba road.
270	45S221	29.4 km east-southeast of Central Miranda, on La Prueba-Joturo Abajo road.
272	45S119	29.6 km east-southeast of Central Miranda, on Joturo-El Arpón road.
274	45S112	29.2 km east of Central Miranda.
275	45S108	27.7 km east of Central Miranda.
276	45S104	22.2 km east of Central Miranda, on Platanal-Juan Mulato trail.
277	45S103	22.7 km east of Central Miranda, on Platanal-Juan Mulato trail.
278	45S101	23.5 km east-northeast of Central Miranda.
		Camarones conglomerate member of the San Luis formation
151	45S15	1 km south of Alto Songo, on Santiago road.
152	45S14	0.5 km south of Alto Songo, in railroad cut.
155	45S135	1 km southeast of Alto Songo, on trail.
157	45S139	1.5 km east-southeast of Alto Songo.
160	45S30	2.3 km northwest of Alto Songo, on Jutinicú road.
161	45S31	2.5 km northwest of Alto Songo, on Jutinicú road.
178	45S57	4 km east of Alto Songo, on La Maya road.
180	45S170	2.7 km east-southeast of Alto Songo, on trail.
181	44GEL519	5 km west-southwest of La Maya, on trail.
191	44GEL510	5.5 km southwest of La Maya, on trail.
199	45S61	3.5 km east of La Maya, on Cuatro Caminos road.
200	45S162	1.5 km southeast of La Maya, on trail.
206	44FS268	2.5 km south-southeast of Cuatro Caminos.
207	45S9	3 km south-southeast of Cuatro Caminos, on La Galleta road.
208	45S51	9.5 km south-southeast of La Maya, on trail.
209	44GEL544	9.9 km south-southeast of La Maya, on trail.
210	44GEL543	9.6 km south-southeast of La Maya, north of Río Baconao.
		Oligocene Series
		Unnamed Oligocene rocks
43	45S21, 45S22	6 km north-northeast of Contramaestre, east of Río Contramaestre.
44	45S278	7.5 km northeast of Contramaestre, on Remanganaguas road.
96	44GEL527, 45S232, 45-S233	8 km west-northwest of Central Miranda, at Morcate quarry.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

LIST OF FOSSIL LOCALITIES[1]—Continued

No. used in this report	Field No.	Description of locality
		OLIGOCENE SERIES—Continued
		Unnamed Oligocene rocks—Continued
97	44GEL528	8.7 km west-northwest of Central Miranda, southwest of Río Cauto.
99	44GEL529	7 km northwest of Central Miranda.
100	45S235	5.7 km north-northwest of Central Miranda, in railroad cut.
214	45GEL531	5.9 km north-northwest of Central Miranda, on Cayo del Rey road.
216	45GEL536	4.8 km north-northwest of Central Miranda.
217	45GEL534	4.3 km north of Central Miranda.
218	45S236	3.6 km north of Central Miranda.
219	45GEL533	4.4 km north of Central Miranda.
220	45GEL532	4.5 km north of Central Miranda.
221	45S241	6.1 km north of Central Miranda.
279	45GEL561	27.3 km east-northeast of Central Miranda.
280	45GEL560	27.5 km east-northeast of Central Miranda.

[1] Localities numbered 31 or lower established by Woodring and Daviess (1944).

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