CARLOS SCHUBERT *Dirección de Geología, Ministerio de Minas e Hidrocarburos, Caracas, Venezuela*

Geologic Structure of a Part of the Barinas Mountain Front, Venezuelan Andes

Abstract: The following lithologic units are exposed in the Barinitas-Santo Domingo region, southeastern Venezuelan Andes: (1) the Precambrian (?) Iglesias Group, forming the metamorphosed basement; (2) the Lower Paleozoic (?) Cerro Azul Formation, a phyllite sequence; (3) the Upper Paleozoic Palmarito Formation, mostly fossiliferous limestones and shales; (4) the Triassic-Jurassic La Quinta Formation, a continental sequence of red beds; (5) the rocks of the Cretaceous transgression and regression, consisting of the Río Negro, Apón, Aguardiente, Maraca, La Luna, and Colón-Mito Juan Formations; and (6) the Upper Eocene Gobernador and Pagüey Formations, disconformably overlying the Cretaceous sequence.

Three granitic intrusions crop out, two of which, the La Soledad Quartz Monzonite and the hornblende granodiorite of Cerro Azul, intrude the Cerro Azul Formation. They were dated by the potassium-argon method as Middle Pennsylvanian and Early Devonian, respectively.

The principal structural units present in the map area are enormous blocks of basement rocks (Iglesias Group) which are separated by steeply northwestward-dipping, or nearly vertical reverse faults (upthrusts), along which the blocks have been uplifted or depressed. Along the east flank of the mountain range toward the Barinas Basin the sedimentary cover has been folded into a monocline which is itself broken into blocks by steep faults. In the higher parts of the region, toward the central part of the mountain range, is a zone of extension which produced grabens, horsts, and stepped faults, represented by the Boconó fault zone.

The present uplift of the Venezuelan Andes took place in post-Eocene time. Upper Eocene sediments of the Pagüey Formation, poorly consolidated during the initial stages of the uplift, were deformed by slumping, into cascade folds (overturned to the southeast), and also slid downslope as chaotically oriented blocks which cover the Upper Eocene sediments *in situ*. Vertical uplift, probably combined with arching or tilting of the region, produced the steep thrust faults along the margin of the range, and also the zone of extension represented by the Boconó fault zone. Strike-slip movement of great magnitude probably has not taken place along this fault.

CONTENTS

Introduction . . . 444
Previous work . . . 444
Acknowledgments . . . 444
Summary of stratigraphy . . . 445
Precambrian (?) Iglesias Group . . . 445
Lower Paleozoic (?) Cerro Azul Formation . . . 446
Upper Paleozoic Palmarito Formation . . . 446
Triassic-Jurassic La Quinta Formation . . . 446
Cretaceous . . . 446
Río Negro Formation . . . 447
Apón Formation . . . 447
Aguardiente Formation . . . 447
Maraca Formation . . . 447
La Luna Formation . . . 447
Colón-Mito Juan Formation . . . 447
Tertiary . . . 447
Gobernador Formation . . . 447
Pagüey Formation . . . 448
Plio-Pleistocene . . . 448
Intrusive rocks . . . 448
La Soledad Quartz Monzonite . . . 448
Other granitic rocks . . . 448
Structural geology . . . 448
Introduction . . . 448
Structures of the basement rocks . . . 449
Faults . . . 449
Boconó fault zone . . . 449
Structures of the Cerro Azul Formation . . . 451
Structures of the non-metamorphic sedimentary cover . . . 452
Tectonic evolution . . . 453
Summary and conclusions . . . 455

Geological Society of America Bulletin, v. 80, p. 443–458, 4 figs., 2 pls., March 1969

References cited 456

Figure

1. Index map of Venezuela 445
2. Boconó fault zone and asymmetry of the Venezuelan Andes 450
3. Sketch of cascade fold in sandstones and shales of the Pagüey Formation along the Barinitas-Santo Domingo road 453
4. Experimental fracturing and folding by vertical step displacement 455

Plate

1. Geologic-tectonic map of the Barinitas-Santo Domingo region . . . . . . See Plate Section
2. Views of the Boconó fault zone and part of Cerro Gobernador . . . . See Plate Section

Table

1. Potassium-argon dating of samples of the La Soledad Quartz Monzonite and of the granitic rock of Cerro Azul 447

INTRODUCTION

This report summarizes the structural geology and tectonic evolution of a part of the Barinas mountain front, southeastern Venezuelan Andes, and is a part of a doctoral study on the geology of the Barinitas-Santo Domingo region (Fig. 1) submitted by the author to Rice University, Houston, Texas. The Barinas mountain front is considered to be typical of the southeastern Venezuelan Andes, and the area described contains a relatively well-exposed and accessible section along the Barinitas-Santo Domingo road. It is hoped that this report will stimulate interest in the Venezuelan Andes.

The Venezuelan Andes are an elongate, northeast-trending mountain range, which extends some 400 km between the border of Venezuela and Colombia in the state of Táchira, to the southwestern part of the state of Lara. The map area (Pl. 1) extends between the southeastern foothills, near the western edge of the Barinas Basin, and the high *sierras* (ranges)[1] of the Andes. Outcrops are very scarce in the southeastern and lower part (between 500 and approximately 1600 m above sea level) because of heavy forest cover, and in the northwestern and higher part (above 1600 and up to 4000 m above sea level) because of numerous river terrace deposits and glacial debris. Therefore, the study of aerial photographs is especially important as a complement to the study of stream and road sections. The best section through the map area is that along the Barinitas-Santo Domingo road.

PREVIOUS WORK

The first comprehensive report on the geology, geomorphology, and geography of the Venezuelan Andes was published by Sievers (1888), and in the latter two fields, it is still one of the most useful and complete works. Subsequently, other general reports were written by Christ (1927), Engleman (1935), Kehrer (1938), and Kündig (1938). The last two papers may be considered the starting point in the systematic study of the Venezuelan Andes. Liddle (1946) published an excellent and comprehensive reference work on Venezuelan geology, and in recent years, reports on the stratigraphy of the Andes have been written by Renz (1959), Compañía Shell and Creole (1964), and Arnold (1966).

Mackenzie (1937) and Knechtel (1938) were the first to report on the geology of the Barinas region, which covers the southeastern part of the Barinitas-Santo Domingo region. Mackenzie (1937) described the rocks which crop out in the foothills of the Andes in the vicinity of Cerro Azul, and Knechtel (1938) discussed some of the stratigraphic relationships. More recently, the stratigraphy of the Barinas region has been discussed by Pierce (1960), Kiser (1961), Alberding (1965), and Kiser and Sulek (1966).

ACKNOWLEDGMENTS

The author wishes to thank Dr. B. C. Burchfiel, of Rice University, Dr. J. S. Bell, of the University of California at Riverside, Dr. R. M. Stainforth and Dr. C. H. Graf, of Creole Petroleum Corporation, and Dr. R. Shagam, of the University of Pennsylvania, for critically reading the manuscript. G. Feo-Codecido, geologist of Compañía Shell de Venezuela, X. Picard, geologist of the Dirección de Geología, and Mr. L. Kovisars also read the manuscript. All of these persons supplied many helpful suggestions, but the author is solely responsible for the content of the article.

This report is based on work done by the author while a graduate student at Rice University, Houston, Texas, and is a part of the regional mapping program of Venezuela by the Dirección de Geología, Ministerio de Minas e

[1] Other local terms used in this report are: *río* (river), *cerro* (mountain), and *quebrada* (creek).

Hidrocarburos, Venezuela, A. Vivas R., Director, which financed the field work. The author is grateful for all the assistance received from both institutions. Dr. Burchfiel supervised the work, and his help in the field and in the laboratory is especially acknowledged. A. Sabater was of great assistance in the photogeological study of the map area, and his visit in the field is appreciated. Dr. R. Shagam, A. Bellizzia G., C. Martin Bellizzia, and L. Kovisars also visited the author in the field and their discussions of the region were most informative. D. Villalta, geologist of Compañía Anónima de Administración y Fomento Eléctrico (C.A.D.A.F.E.), accompanied the author on several geological excursions and made many helpful suggestions. Radiometric dating of several samples of granitic rocks was performed by J. F. Sutter of the K-Ar Laboratory of Rice University. The author gratefully acknowledges an Ora Arnold Fellowship of Rice University, a special assistance scholarship of Compañía Shell de Venezuela, and a scholarship of the Ministerio de Minas e Hidrocarburos.

Finally, the author wishes to thank his wife, Erika, for her help and encouragement during all phases of the work.

SUMMARY OF STRATIGRAPHY

Precambrian (?) Iglesias Group

The oldest rocks exposed in the map area (Pl. 1) belong to the Iglesias Group, defined by Kündig (1938). They consist of three lithologic units (Schubert, 1968), easily recognizable in the field (from older? to younger?): *La Mitisús Banded Gneiss* consists of alternating bands of biotite-muscovite-quartz gneisses and schists, biotite-almandine gneisses and schists, sillimanite-almandine-biotite gneisses (first described by Schürmann, 1934, p. 393, and 1939, p. 33) and schists, hornblende-plagioclase-biotite gneisses and schists, and amphibolites.

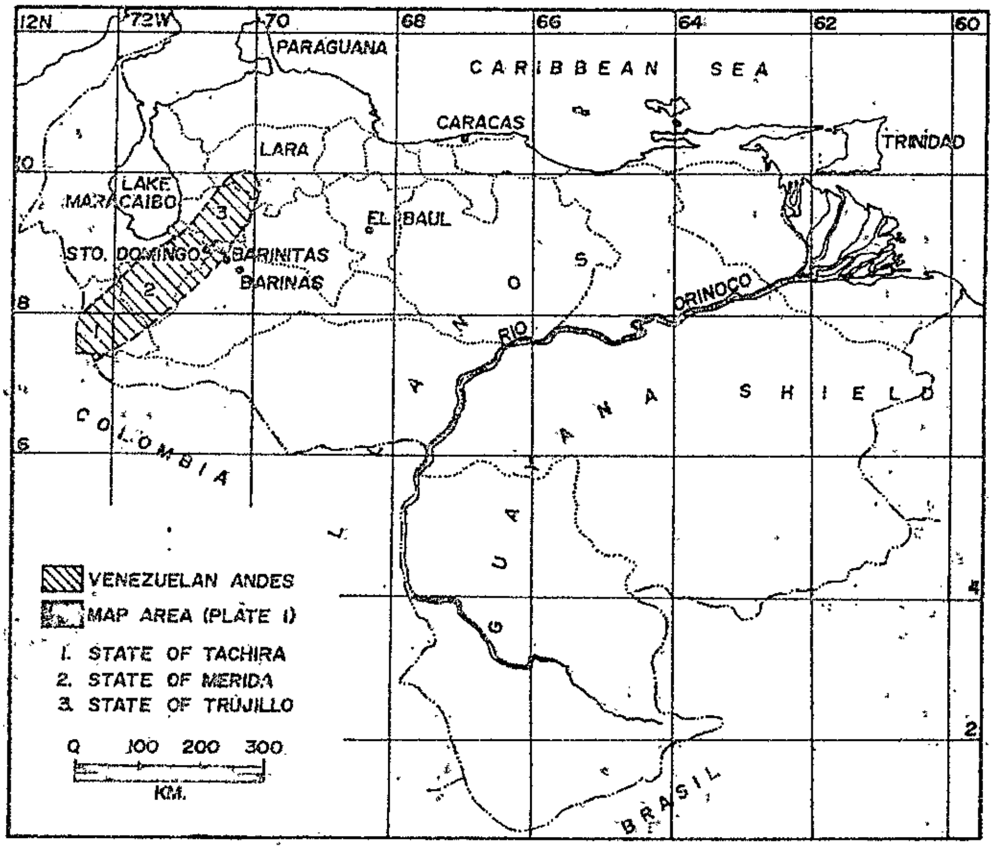

Figure 1. Index map of Venezuela.

Granitic injections and dikes and sills of pegmatite and aplite are common. This unit is probably equivalent to the Santo Domingo Gneiss of Oppenheim (1937, p. 34) and to the Sierra Nevada Formation of Bass and Shagam (1960, p. 377). The *El Alambique Schists and Quartzites* consist of alternating layers of mica schists and quartzites which occur as apparently isolated masses east of the La Raya Granitic Gneiss (Pl. 1), which is probably intrusive into both the La Mitisús Banded Gneiss and the El Alambique Schists and Quartzites. The latter are in fault contact with the Cerro Azul Formation, and may possibly be correlated with the Bellavista Formation (R. Shagam and A. Menéndez, personal commun., 1966). The *La Raya Granitic Gneiss* consists of faintly banded, at places porphyroblastic, granitic gneiss, with rare layers of amphibolite and tabular bodies of metamorphosed igneous rocks.

Lower Paleozoic (?) Cerro Azul Formation

Lower Paleozoic (?) rocks in the map area (Pl. 1) are represented by the Cerro Azul Formation, defined and described by Mackenzie (1937, p. 258–259). It crops out in a structural block in the central portion of the map area, and along the southeastern flank of Cerro Azul. Correlation between both areas of outcrop is based exclusively on similarity of lithology and stratigraphic position. It consists of two rock types, a greenish to silvery-gray phyllite with rare intercalations of light-gray quartzite, and a dark-gray, graphitic, siliceous phyllite. Locally, the Cerro Azul Formation is intruded by the La Soledad Quartz Monzonite (*see* Intrusive Rocks) and probably also by the granitic rock of Cerro Azul. Radiometric dating of these granitic rocks (Table 1) indicates that the Cerro Azul Formation is older than Middle Pennsylvanian, and probably older than Early Devonian. The Cerro Azul Formation may be equivalent to a part of the Mucuchachí Formation, as defined by Kündig (1938, p. 23) and Compañía Shell and Creole (1964, p. 76–80), but present data are insufficient to make such a correlation. Permo-Carboniferous ages obtained from fossils by Compañía Shell and Creole (1964, p. 81) for the Mucuchachí Formation, and Early Devonian and Middle Pennsylvanian radiometric minimum ages (Table 1) obtained by the author for the Cerro Azul Formation, seem to preclude a correlation between the two units. However, as pointed out by Compañía Shell and Creole (1964, p. 83 and Fig. 5), and Arnold (1966, p. 2382–2383), the possibility that the Mucuchachí Formation extends back to the Lower Paleozoic cannot be excluded.

Upper Paleozoic Palmarito Formation

The only Upper Paleozoic rocks identified in the map area are those of the Palmarito Formation, defined by Christ (1927) and reviewed by Kehrer (1938), González de Juana (1951a), and Arnold (1966). They crop out in a narrow belt (Pl. 1), about 7 km northwest of Altamira, and consist of alternating beds of dark-gray fossiliferous limestone (containing highly recrystallized pelecypods, gastropods, corals, crinoids, and *Fenestella* sp. fragments). Several veins of light-brown coarse siderite are present near the top of the formation. A probable Late Carboniferous to Early Permian age was established paleontologically by Kehrer (1938, p. 51) and Arnold (1966, p. 2378). The contact with the Cerro Azul Formation was not observed, and the contact with the La Quinta Formation appears disconformable.

Triassic-Jurassic La Quinta Formation

Triassic-Jurassic red beds in the map area, first described by Mackenzie (1937) and Knechtel (1938), and assigned to the La Quinta Formation by Pierce (1960, p. 232), crop out in a northeast-trending belt, west of Calderas (Pl. 1). It consists of brick-red, gray or greenish-gray, commonly cross-bedded conglomerates, sandstones, and shales. Near the top of the formation, there are several veins of light-brown coarse siderite. A Late Triassic to Early Jurassic age is suggested by *Lepidotus* and ostracod remains (Kündig, 1938, p. 33, and Sutton, 1946, p. 1638). The contact with the overlying Cretaceous rocks is faulted at all localities in the map area.

Cretaceous

Cretaceous rocks are exposed in a northeast-trending belt west of Altamira and Calderas, and along the southeastern flank of Cerro Azul (Pl. 1). They form a continuous depositional sequence. Lithologic units, defined by Sutton (1946) and Rod and Maync (1954), were recognized. In addition, detailed descriptions of Cretaceous rocks of western Venezuela can be found in Ministerio de Minas e Hidrocarburos (1956), Renz (1959), Rod (1959), Ford and Houbolt (1963), Pierce (1960), Kiser (1961), and Gaenslen (1962). The Apón, Aguardiente, and Maraca Formations are represented as the Cogollo Group in the map (Pl. 1).

TABLE 1. POTASSIUM-ARGON DATING OF SAMPLES OF THE LA SOLEDAD QUARTZ MONZONITE (ME 6088) AND OF THE GRANITIC ROCK OF CERRO AZUL (ME6184)[1]

Sample	Mineral	Percent K	Percent Rad. Ar^{40}	Age
ME6088	Biotite	5.77	93.9	299.2 m.y.
ME6088	Biotite	5.77	90.5	295.4 m.y.
ME6184	Biotite and hornblende	3.11	92.2	407.4 m.y.
ME6184	Biotite and hornblende	3.11	81.7	393.1 m.y.

Sample	Geologic age[2]
ME6088	Middle Pennsylvanian
ME6184	Early Devonian

[1] J. F. Sutter, analyst, K-Ar Laboratory, Rice University. Mineral separations were done in a Frantz magnetic separator and were checked with a binocular microscope.
[2] After Kulp, in Hamilton (1965, p. 224).

Río Negro Formation. The Río Negro Formation is the basal unit of the Lower Cretaceous sequence, and consists of cross-bedded conglomeratic sandstones. The age of this formation has been determined on the basis of its relative stratigraphic position, as Neocomian to Late Aptian (Maync, *in* Ministerio de Minas e Hidrocarburos, 1956, p. 499), and Barremian or older (Renz, 1959, p. 61). Some authors (*for example,* Pierce, 1960, p. 234–236) have applied the name "Calderas Formation" to this unit, following Mackenzie (1937, p. 260–261), but this term is now considered an unnecessary synonym of the Río Negro Formation.

Apón Formation. The Apón Formation consists of dark-gray, carbonaceous shale, with layers of dark-gray fossiliferous limestone, and contains limestone concretions toward the base. The age of the formation was reported as Middle Aptian to Albian by Pierce (1960, p. 237).

Aguardiente Formation. The Aguardiente Formation consists of gray to dark-gray or brown, calcareous, locally fossiliferous sandstone. It was given a provisional Cenomanian age by Pierce (1960, p. 238), and Maync (*in* Ministerio de Minas e Hidrocarburos, 1956, p. 41–42) assigns it a Middle to Late Albian age.

Maraca Formation. The Maraca Formation is the uppermost unit of the Lower Cretaceous sequence, and consists of gray to dark-gray, coarse, very fossiliferous limestone. The age of the formation is probably Late Albian (Salvador, 1961, p. 13), or Late Albian to Cenomanian (Rod and Maync, 1954, Fig. 4).

La Luna Formation. The La Luna Formation is the basal unit of the Upper Cretaceous sequence, and consists of dark-gray, dense, calcareous, in places shaly, siltstone, with large, dark-gray limestone concretions. It contains poorly preserved fish remains and ammonites. The age of the formation is Late Turonian to Early Coniacian (Sutton, 1946, p. 1649–1651), or Cenomanian to Early Coniacian (Liddle, 1946, p. 212).

Colón-Mito Juan Formation. The Colón-Mito Juan Formation is the uppermost unit of the Upper Cretaceous sequence, and consists of dark-gray siltstone with intercalations of gray to dark-gray siliceous sandstone. Dark-gray pyritic concretions are found in some layers, and the formation becomes calcareous and cherty toward the base. The age of the formation is Late Campanian to Maestrichtian (Ministerio de Minas e Hidrocarburos, 1956, p. 155 and 379), or Campanian to Late Maestrichtian (Sutton, 1946, p. 1652 and 1654).

Tertiary

No Paleocene or Lower to Middle Eocene rocks have been identified in the map area (Pl. 1). Their absence may result from erosion or from non-deposition in a stable area of low relief (Brondijk, 1967, p. 45–46). The sandstones of the Upper Eocene Gobernador Formation are unconformable (or disconformable) on the Upper Cretaceous Colón-Mito Juan Formation (Pierce, 1960, p. 256) and pass transitionally upward into the shalier Pagüey Formation, also of Late Eocene age. Elsewhere in the Barinas Basin, the non-marine Parángulo Formation, of mainly Miocene age, attains great thicknesses along the flank of the Andes, but it was not encountered in the map area.

Gobernador Formation. Pierce (1960, p. 255–257) introduced the name Gobernador Formation for the basal sandstone of the Upper Eocene section of the Barinas region. It consists of massive beds of light to dark-gray sandstone, locally conglomeratic and cross-bedded. Load casts and worm tubes are common. Fossils were not found, and the age of the formation is thought to be Middle to Late Eocene (Ministerio de Minas e Hidrocarburos, 1956, p. 192), or Late Eocene (Pierce, 1960, p. 257).

Pagüey Formation. The name, Pagüey Formation, was introduced by Pierce (1960, p. 257–261) to designate all of the Upper Eocene sedimentary rocks overlying the Gobernador Formation. The formation consists of a basal unit of dark-gray, concretionary, fossiliferous shale with intercalations of gray sandstone, and an upper unit of alternating beds of gray to pale-gray sandstone, commonly with ripple marks, load casts, and worm tubes, and dark-gray, concretionary, fossiliferous shale. Foraminifera, kindly identified by Dr. P. J. Bermúdez, indicate a Late Eocene age for the formation.

Plio-Pleistocene

Plio-Pleistocene deposits are found forming terraces along the main streams in the map area (Pl. 1). They consist of chaotic conglomerates and coarse sands derived from all of the rocks which crop out in the area.

INTRUSIVE ROCKS

Three granitic intrusive rock bodies are found in the map area (Pl. 1), of which the best-exposed is the La Soledad Quartz Monzonite. Other intrusive bodies are found west of Calderas and in Cerro Azul.

La Soledad Quartz Monzonite

The La Soledad Quartz Monzonite is an elongate body of quartz monzonite (called granite by Schubert, 1968), first reported by Sievers (1888, p. 10), which intrudes the phyllites of the Cerro Azul Formation west of La Soledad. It is also in fault contact with the Cretaceous Río Negro Formation. The rock consists of a light to dark-gray, and greenish to bluish-gray quartz monzonite, containing grains of up to 5 mm in diameter. Porphyritic feldspar grains may reach up to 2 cm in length. The features of the contact between the quartz monzonite and the Cerro Azul Formation are described in detail by Schubert (1968), and consist of several gradational zones of altered phyllites (spotted hornfels), through sheared and granitized zones, into the igneous rock. Apophyses of granitic rock intruding the altered phyllites, quartz and granitic veining, and phyllite xenoliths in the quartz monzonite are common. Potassium-argon radiometric dating yielded an age of approximately 297 m.y. for the quartz monzonite (Table 1).

Other Granitic Rocks

Two other bodies of granitic intrusive rocks crop out in the map area: (1) 7 km west of Calderas, a poorly exposed light-gray to light-brown, coarse-grained, quartz monzonite, consists principally of quartz, microcline, plagioclase, muscovite, and biotite (partly altered to chlorite); and (2) a granitic body of rock probably intrudes the Cerro Azul Formation in the Cerro Azul area, and was first reported by Knechtel (1938, p. 185). The intrusive body consists of greenish-gray, coarse-grained, hornblende granodiorite, made up of quartz, microcline, plagioclase, and hornblende. Round xenoliths of a dark-gray schistose rock, probably altered Cerro Azul phyllites, are common. Potassium-argon radiometric dating of the granodiorite yielded an age of approximately 400 m.y. (Table 1).

STRUCTURAL GEOLOGY

Introduction

The structure of the Venezuelan Andes has been studied in less detail than the stratigraphy, and consequently, less is known about it. Among others, de Cizancourt (1933), González de Juana (1952), Bucher (1952, p. 13–29), and Gerth (1955, p. 174–180, 231–249) described and reviewed the structure of the Venezuelan Andes in very general terms. The major conclusion reached by most of these authors is that the present Venezuelan Andes were uplifted vertically into large horsts, stepped faults, and grabens. Bucher (1952, p. 13–29) attributes this tectonic development to tensional stresses produced by stretching of the crust, resulting from subcrustal bulging-up of material.

More recently, Hospers and van Wijnen (1959) published a different hypothesis for the origin of the Venezuelan Andes, based on gravity data. They concluded that the mountain range has an asymmetrical mass distribution, and that this is produced by an overthrust of the southeastern part of the crust over the northwestern part (Maracaibo Basin). Compressive stress is, therefore, invoked in this hypothesis. Rod (1960) criticized this hypothesis and, correctly, pointed out that field geology data does not support the overthrust hypothesis, and that a cross section of the mountain range reveals a fan-shaped structure with thrusting along both the southeastern and northwestern edges. In addition, Hospers and van Wijnen's (1959) hypothesis does not explain the presence of the Boconó fault zone, a major fault zone which runs parallel to, and along the central part of, the Venezuelan Andes.

The following sections deal with the structures observed in the map area and its tectonic evolution. A comparison with the structurally similar Rocky Mountains of central-western United States is made in an attempt to explain the origin of the Venezuelan Andes.

Structures of the Basement Rocks

The basement rocks consist of the Precambrian (?) Iglesias Group, and occur within large fault blocks (Pl. 1). The foliation of the La Mitisús Banded Gneiss is usually uniform within each fault block, as shown by the data assembled, plotted, and contoured on Lambert Meridional Projection nets on Plate 1. Only data collected along the Barinitas-Santo Domingo road was used, because this is the only fairly well-exposed section through the map area. Nets 1 to 3 represent foliation planes and fold axes of the La Mitisús Banded Gneiss between the Boconó fault zone and the contact with the La Raya Granitic Gneiss. The regional structure inferred is a broad, asymmetrical synform, with a northeast-trending axis. Minor folds in the foliation, which are probably related to major folds, trend mostly N. 10° to 20° E. and plunge southward at varying angles, but mostly between 11 and 30 degrees. This regional structure seems to correspond to similar folds southwest of the map area (R. Shagam, personal commun., 1966). Small-scale isoclinal folds (rarely exposed), folded foliation, and endless repetition of thin layers of the rock types which constitute the La Mitisús Banded Gneiss (gneisses, schists, and amphibolites) suggest that the large-scale regional folds in this unit refolded earlier tight isoclinal folds (probably related to Paleozoic tectonic events), because later events are dominated by vertical tectonics with no apparent associated mobilization of the basement rocks.

The faults within the La Mitisús Banded Gneiss southeast of the Boconó fault zone are mostly northeast-trending fracture surfaces with no visible fault gouge in most cases, and are vertical or dip steeply to the southeast. Drag folds were observed near one fault (about 2 km southeast of La Mitisús), indicating high angle reverse faulting, with the northwestern block being thrust up relative to the southeastern block.

The only structure observed in the La Raya Granitic Gneiss is a moderately well-developed foliation defined by preferentially oriented biotite flakes which form faint bands. Foliation attitudes were plotted and contoured on a Lambert Meridional Projection net (Pl. 1, No. 4) and suggest a possible northeast direction of fold axes.

Faults

A number of major faults, poorly exposed, all striking northeast, cross the map area (Pl. 1). The fault planes, exposed in creeks which cross the Barinitas-Santo Domingo road, were described by Schubert (1968), and consist of fault zones between 1 and 2 m wide. The fault gouge consists of gray to greenish-gray clay-sized material, with abundant elongated fragments (pebble-sized to over 1 m long) of the wall rocks. No evidence of the sense of movement was found, but the older rocks are always present in the hanging wall, indicating reverse faulting. The faults strike northeast and dip between 55 degrees northwest and vertical.

Boconó fault zone. The Boconó fault zone is a major structural feature of the Venezuelan Andes, and was first named and described by Rod (1956) who, on the basis of offset drainage patterns, considered it to be a strike-slip fault with cumulative right-lateral displacement of 33 km. Alberding (1957) discussed the Boconó fault in an attempt to fit the faults of northern and western Venezuela into a broad tectonic analysis of the Caribbean region. He explains the asymmetry (Fig. 2) in the distribution of Paleozoic and Precambrian rocks in the Venezuelan Andes (first reported by Bucher, 1952, p. 23–24), by a right-lateral displacement along the Boconó fault (Alberding, 1957, Pl. 1). An extensive review of geological data concerning the Boconó fault was published by Rod and others (1958), and they arrived at the following conclusions: (1) the fault is marked by strong topographic expression and in most areas is a fault zone, rather than a single fault; (2) it extends for approximately 425 km along the central part of, and parallel to, the Venezuelan Andes; (3) movement along the fault is suggested by lithologic contrast across it, or by vertical displacement of the same formation;

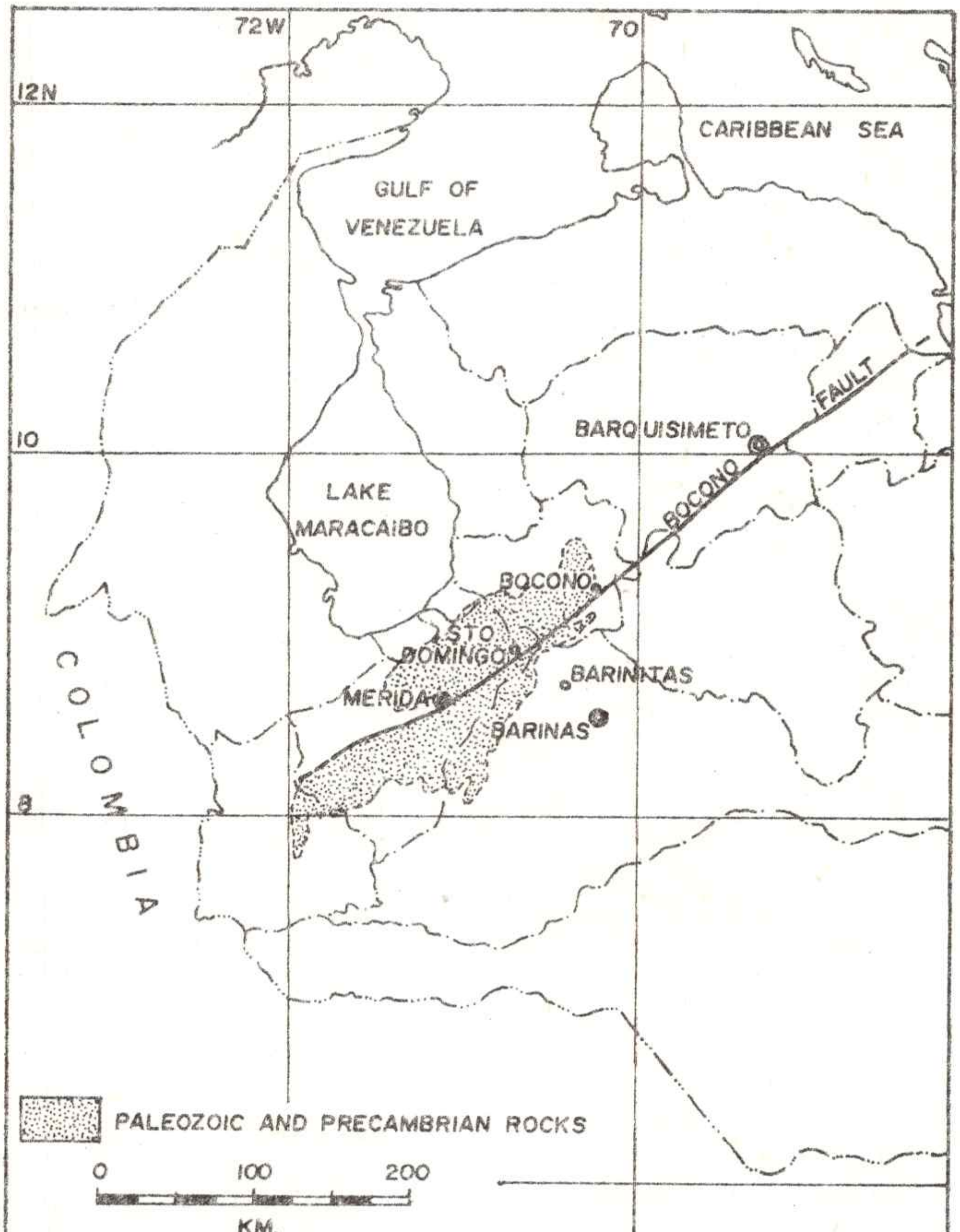

Figure 2. Boconó fault zone and asymmetry of the Venezuelan Andes (after Rod, 1956, Fig. 6, and Alberding, 1957, Pl. 1).

(4) right-lateral displacement is shown by the effects on Pleistocene features; (5) the fault trend is offset by cross faults at several places; (6) the age of the fault ranges from Late Cretaceous to Recent, although the greatest displacements are post-Eocene from evidence in the present study; (7) adjacent folding is, in general, parallel to the fault; and (8) recent earthquakes have occurred in the vicinity of the Boconó fault along most of its length. Three types of faults and movements were advocated by these authors: strike-slip, vertical or dip-slip, and a combination of both.

In the map area, the Boconó fault is exposed at several places along the upper Río Santo Domingo and Río Aracay valleys. It consists of a fault zone approximately 5 km wide (Pl. 1), between the eastern side of the Río Aracay valley and the western side of the Río Pueblo Llano valley. Rocks on both sides of the fault and in the fault zone belong to the La Mitisús Banded Gneiss, except for a small body of granitic gneiss (tentatively included within the La Raya Granitic Gneiss) north of Las Piedras. Topographically, the Boconó fault zone is characterized by a long, straight depression (Pl. 2, fig. 1), between 1 and 5 km wide, trending approximately N. 35° to 40° E. Exposures of rock are extremely poor and scarce in this area, so most of the structural interpretations are based on analyses of aerial photographs. Exposures of several faults in the Boconó fault occur just east of La Mitisús, along the Barinitas-Santo Domingo road, and at several places on the eastern bank of the Río Aracay. At these localities, the gneisses and schists of the La Mitisús Banded Gneiss pass abruptly into zones of fault breccia up to 100 m wide. The fault breccia consists of a greenish to pale-gray, extremely weathered and fragmented rock, which contains principally quartz, microcline, plagioclase, and accessory muscovite and epidote. Grain size ranges from submicroscopic to 2 mm in diameter, with a texture consisting of sheared and bent larger feldspar grains in a matrix of cataclastic, fine-grained, and recrystallized quartz and feldspar. The gneisses in the fault zone occur in large lenses (many tens of meters long and wide) of dark-gray, extremely hard, and recrystallized rock. Fault planes, where developed, are vertical or dip steeply to the northwest, usually more than 70 degrees. Approximately 6.5 km northeast of Las Piedras, on the west bank of Río Aracay, is an exposure of a normal fault within the Boconó fault zone. The fault plane strikes N. 60° E. and is vertical. Drag folding in the foliation of the gneisses and schists on both sides of the fault indicates that the northwest block moved down relative to the southeastern block. This is the only evidence of the sense of movement found within the Boconó fault zone in the map area.

Plate 1 shows structural cross sections with the author's interpretation of the data presented in the preceding paragraphs. The regional structure suggested is that of a series of large blocks, bounded by steeply dipping or vertical faults that were, and probably still are, uplifted or depressed, forming grabens, horsts, and stepped faults. East of the Boconó fault zone, high angle reverse faults are more frequent than normal faults. There is no evidence as to whether strike-slip movement took place along the faults in the map area. In the case of the Boconó fault zone, some strike-slip movements probably took place, as shown by the offset of glacial moraines west of Santo Domingo (first reported by Rod, 1956). East of Río Aracay there are peculiar, basin-like depressions with high, steep walls to the east, near the eastern edge of the Boconó zone. These depressions may be due to the opening of gaps during strike-slip movement, where the fault had small bends (D. Villalta, personal commun., 1966). The straightness of the fault zone has been used as evidence for strike-slip movement, but high angle or vertical normal faults may also produce straight fault zones. In conclusion, the evidence in the map area points to predominantly vertical or dip-slip movement, with more recent strike-slip movement, along the Boconó fault zone, and principally reverse faulting along the other faults in the region.

Structures of the Cerro Azul Formation

Structures of the Cerro Azul Formation were plotted and contoured on a Lambert Meridional net (Pl. 1, No. 5). These include attitudes of the foliation of the phyllites, fold axes, mineral lineations (probably aligned staurolite or andalusite grains, or both), and axes of kink bands. The general strike of the foliation is approximately north-south, with a moderate dip to the west. The mineral lineations appear to lie in the plane of foliation, whereas the axes of the kink bands and the small fold axes fold the foliation. This would indicate that the lineation and the foliation are the oldest structures present in the Cerro Azul Formation, and that the kink banding and the folding are younger. Paterson and Weiss (1966) produced similar kink banding experimentally at confining pressures of 5 kb and room temperature. Whether such high confining pressures are needed to produce kink banding in nature or not (especially at high temperatures) cannot be determined from these experiments. Field relations suggest that both kink banding and folding of the Cerro Azul Formation may be related to compression due to the intrusion of the La Soledad Quartz Monzonite. The outcrops are uncommon and too poor for the detailed observations needed to show if kinking followed folding, or vice-versa. The folding of the Cerro Azul Formation was inferred from changes in the dip of the foliation, especially in the western part of the area of outcrop. Available data (plotted on stereonet 5, Pl. 1) suggest folding with north-northwest to south-southeast axes on a regional scale. The attitudes of minor fold axes are variable and indicate that, locally, structural axes are sinuous.

Structures of the Non-Metamorphic Sedimentary Cover

All of the stratigraphic units between the base of the Upper Paleozoic Palmarito Formation and the top of the Upper Eocene Pagüey Formation are assigned to the sedimentary cover. All of these non-metamorphosed rocks form essentially one structural unit, displaced by faults.

Northwest of Altamira and Calderas, the basic structure is a large monocline (Pl. 2, fig. 2, Cerro Gobernador), with the upper part eroded away (cross sections on Pl. 1). All of the sedimentary units exposed in Cerro Gobernador strike northeast and dip steeply to the southeast, or are overturned and dip to the northwest, as determined from cross-bedding, graded bedding, and drag folding. This monocline is broken up into major blocks (Pl. 1). A fault of small displacement probably parallels the southeastern side of Cerro Gobernador, through the axis of the lower flexure of the monocline (cross sections on Pl. 1). Parallel northeast-trending faults northwest of Cerro Gobernador have progressively greater displacements.

Toward the base of the stratigraphic section in the Cerro Gobernador monocline, especially in the Palmarito Formation, folding and faulting is widespread. Numerous folds, overturned to the southeast, are present in the Palmarito Formation, representing either drag folds related to the folding of the monocline, or they may be folds produced by the slumping of thin layers of limestone which broke off during the uplift of the mountain range.

Between the Cerro Gobernador monocline and Cerro Azul, southeast of Altamira and Calderas, is an area of low hills and escarpments formed by rocks of the Pagüey Formation. The structure of this area (determined by A. Menéndez in 1957) consists of broad synclines and anticlines, trending northeast (Pl. 1). These folds are not reflected by the topography, because numerous blocks of rocks of the Pagüey Formation are scattered chaotically throughout the area, covering the outcrops of the rocks *in situ*. Many examples of folds overturned to the southeast and recumbent folds (cascade folds associated with slip sheets; De Sitter, 1964, p. 241) in the Pagüey Formation testify to the downhill movement of the blocks. Figure 3 illustrates one of the cascade folds, with axis trending northeast and with subhorizontal limbs, terminating at the base against a surface of slip.

The structures described so far indicate that uplift of large basement blocks along northeast-trending faults folded the sedimentary cover into a large monocline, probably in post-Eocene time, during the most recent Andean uplift. The steep eastward dip of the sedimentary cover produced instability in the weak Upper Eocene sediments of the Pagüey Formation, which slid downslope to the southeast, forming large blocks and cascade folds in the area between Cerro Gobernador and Cerro Azul. Cerro Gobernador, being made up principally of well consolidated sandstones of the Gobernador Formation, forms a steep escarpment and is an erosional remnant of the monocline.

Cerro Azul is a northeast-trending mountain situated along the southeastern edge of the map area (Pl. 1). Along its southeastern flank, a fairly complete section of Cretaceous and Upper Eocene rocks overlies the Cerro Azul Formation. Granodiorite intrudes the Cerro Azul Formation and probably forms the core of the mountain. The northwestern edge of Cerro Azul is bounded by a fault which separates the Cerro Azul Formation from the Pagüey Formation. This fault (called the Cerro Azul fault by Mackenzie, 1937, p. 257) strikes northeast, and aerial photographs suggest that it dips steeply to the southeast (A. Sabater, personal commun., 1966), but no outcrops of the fault surface were found. The Cerro Azul fault ends, or decreases greatly in

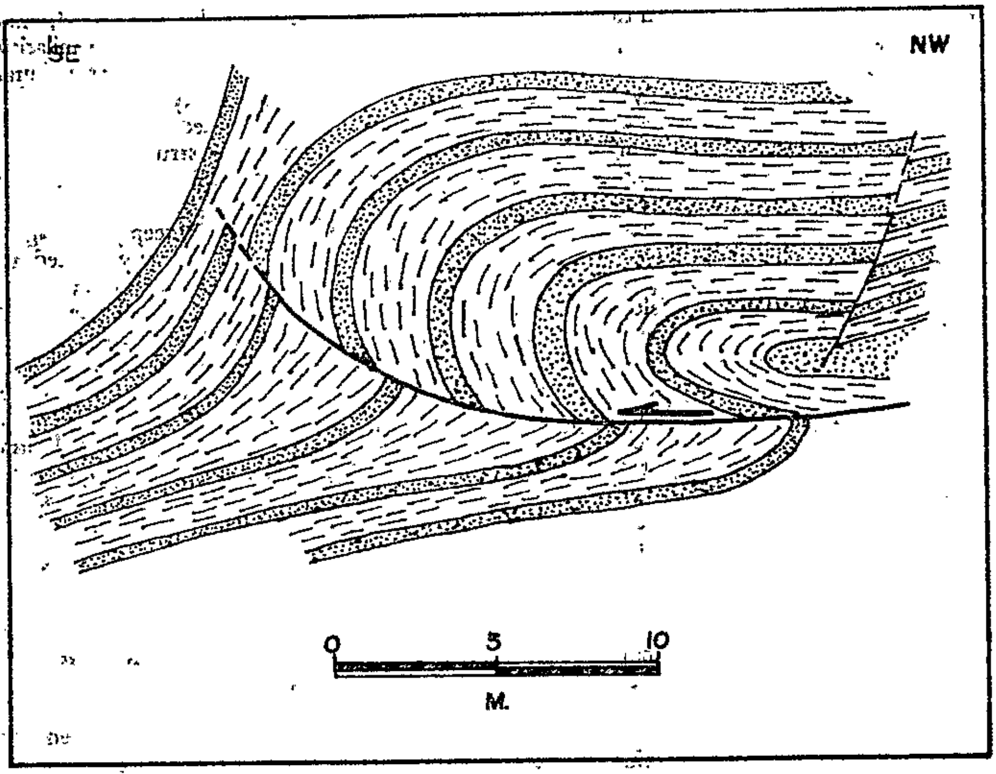

Figure 3. Sketch of cascade fold in sandstones (stippled) and shales (dashed) of the Pagüey Formation, along the Barinitas-Santo Domingo road.

displacement, to the south, because no evidence of it is found south of Río Santo Domingo. From this scant evidence, it is inferred that Cerro Azul represents a south-tilted uplifted block, produced by reverse faulting along the northwestern side of the mountain. An alternative interpretation is that Cerro Azul is a klippe which has slid southeastwards over the Pagüey Formation from the area of Cerro Gobernador, and in doing so, drag-folded the upper part of the Pagüey Formation. Field data supporting such a structural interpretation were not obtained in this study.

TECTONIC EVOLUTION

Very little is known about the tectonic environment and evolution of the Venezuelan Andes during Precambrian and Paleozoic times. The oldest rocks exposed in the map area, the Iglesias Group, represent former sediments and show higher metamorphic grade (Almadine Amphibolite Facies) than any other group of rocks in the region. The Cerro Azul Formation overlies the Iglesias Group, and is of Lower Paleozoic (?) age (probably pre-Early Devonian), and its grade of metamorphism (Chlorite Zone of Greenschist Facies) is much lower than that of the Iglesias Group. Therefore, the metamorphism of the Iglesias Group probably took place prior to the deposition of the rocks of the Cerro Azul Formation, and probably in Precambrian time, because the Precambrian Bellavista Formation overlies the Iglesias Group unconformably in other parts of the Venezuelan Andes (Compañía Shell and Creole, 1964, Fig. 5).

Granitic intrusions of Early Devonian and Middle Pennsylvanian age in the map area indicate important igneous activity perhaps related to two deformation (orogenic?) periods during the Paleozoic Era. The Upper Paleozoic deformation probably produced positive areas which, according to González de Juana (1951b, p. 196) and Bucher (1952, p. 15), were oriented perpendicularly to the present trend of the Venezuelan Andes; that is, in a northwest-southeast direction, based on the distribution of outcrops of the Triassic-Jurassic La Quinta Formation. However, the irregularity of outcrop of this formation may also be explained by the probable presence of small depositional basins between the highs, which may also explain the extremely variable thickness of the La Quinta Formation within short distances. No additional evidence for the orientation of the Late Paleozoic-Early Mesozoic highs was found. These positive areas, together with the Guayana Shield and the El Baúl-Paraguaná high (Fig. 1), were the sources from which the sediments that filled the troughs of western Venezuela were derived. No details of the regional structure present in these ancient deformational belts have been published, but intense folding must have taken place, as is shown by the deformed rocks of the Iglesias Group. Each of the movements probably strongly modified older structures and superimposed new structures.

On top of these older structures was deposited a sequence of rocks, from the marine Upper Paleozoic Palmarito Formation to the, at least partly, continental Triassic-Jurassic La Quinta Formation, and through the marine Cretaceous transgression to the Upper Cretaceous Colón-Mito Juan Formation. At the end of Cretaceous time the whole region was probably slightly uplifted, producing a disconformity, because no Paleocene and Early and Middle Eocene rocks have been recognized in this part of the Venezuelan Andes. Alternatively, part of the sands of the Gobernador Formation may be Paleocene (fossils are extremely rare), representing the end of the regression and the beginning of the Eocene transgression.

The present Andean uplift probably began in post-Eocene times. Block faulting began at that time and continued, probably intermittently, through the Quaternary. That these movements have not ended is evidenced by numerous earthquakes recorded in the Venezuelan Andes in recent years (Fiedler, 1960). River terraces at various levels above the rivers that produced them probably indicate repeated uplifts during Late Tertiary and Quaternary times. Headward erosion of rivers, originated by climatic changes, may also result in terraces, but the elevation of some of these, 200 m or more above river level, probably cannot be explained by this process.

Comparison of the structural cross sections of the Barinitas-Santo Domingo region with those of the Rocky Mountains of central-western United States (Eardley, 1963, and Howard, 1966) reveals a remarkable similarity between the two regions. The major structural features of the Central Rocky Mountains have been recently summarized by Blackstone (1963). The most common structures are those called Germanic type, which consist of very large blocks of Precambrian basement rocks uplifted and depressed along steeply dipping or vertical faults. Folding is mostly related to these vertical movements. Most of the major structures are regarded by Blackstone to be related to reactivation of older structural features with horizontally directed tangential stresses (crustal shortening) responsible for the deformation.

Eardley (1963), on the other hand, attributes the steep thrust faults along the flanks of the Rocky Mountains to the individual uplifts. An important feature in Eardley's cross sections is the presence of grabens and associated stepped faults in the area of outcrop of basement rocks (for example, in the Uinta Mountains, Eardley, 1963, Fig. 6). The main cause of uplift, according to Eardley, is the intrusion of basaltic megalaccoliths beneath the crust by differentiation from the mantle.

More recently, Howard (1966) studied the Williams Range Thrust in Colorado which bounds one of the uplifted ranges and demonstrated that the fault plane is concave downward, being almost horizontal at the surface. Cross sections presented by Howard are closely similar to those of the Barinitas-Santo Domingo region (Pl. 1). Howard (1966) explains the structures of the Williams Range Thrust in terms of a system of stresses and a method of analysis developed by Sanford (1959). The latter subjected boxes containing sand to vertical curved and step displacements (Fig. 4) and obtained all of the structures observed by Howard (1966), namely reverse faulting associated with normal faults and graben-like structures. Combining the results of Sanford's (1959) experiments with the hypothesis of Eardley (1963), it is possible that a combination of vertical uplifts with broad arching, or perhaps tilting of large parts of the crust, may produce the particular structures observed in the Rocky Mountains and in the Venezuelan Andes.

Strong similarities between the cross sections of the Central Rocky Mountains and the Barinitas-Santo Domingo region are apparent when comparing Plate 1 with cross sections of Eardley (1963, for example, Fig. 6), Howard (1966, Pls. 1 and 2), and with experimental

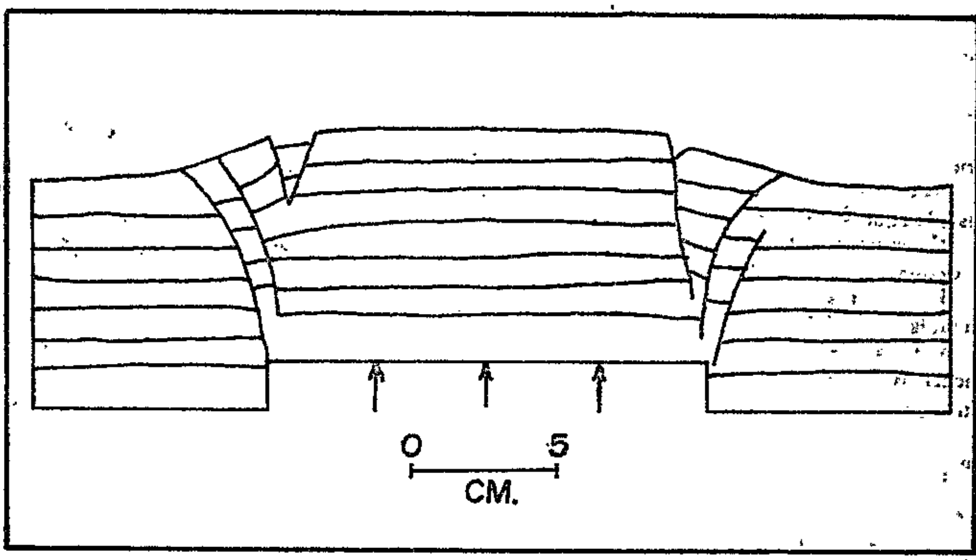

Figure 4. Experimental fracturing and folding by vertical step-displacement (from Sanford, 1959, Fig. 18).

results of Sanford (1959, Fig. 4 *this report*). Similarities include: (1) marginal thrusts, probably concave downward, (2) upwarping of the sedimentary rocks of the adjacent basins, (3) basement rocks thrust over the basin sediments, and (4) a zone of normal faulting at some distance from the margin, which in the Barinitas-Santo Domingo region is represented by the Boconó fault zone.

The Boconó fault zone is one of the most important structural features of the Venezuelan Andes, and its history is probably a key to a great part of the structural history of the mountain range. Sanford's (1959) experiments and Eardley's (1963) hypothesis for the origin of part of the Rocky Mountains shed some light on the possible origin of the Boconó fault zone and of the Venezuelan Andes. Vertical uplift (with or without additional compression; Bucher, 1952, p. 21) of blocks, combined with an arching of the whole region, probably produced the steep thrust faults seen along the southeastern margin of the Barinitas-Santo Domingo region, and at the same time, produced a zone of tension with associated normal faulting at the crest of the arch. Strike-slip movement of the magnitude advocated by Rod (1956) and Alberding (1957) is difficult to visualize in view of the present explanation of the structures of the map area, although recently minor strike-slip movement has occurred.

SUMMARY AND CONCLUSIONS

The most important structures which can be recognized in the map area (the Barinitas-Santo Domingo region), are enormous blocks of basement rocks, which consist principally of rocks of the Precambrian (?) Iglesias Group, which have been uplifted along steep or vertical reverse faults, producing monoclinal folding in the sedimentary cover along the flanks of the Andes; and grabens, horsts, and stepped faults along the Boconó fault zone in the highest parts, near the central part of the mountain range. Chaotic blocks, or rocks of the Upper Eocene Pagüey Formation, and cascade folds in the same formation, were produced by the rapid uplift and the lack of consolidation of the sediments which had been deposited just previous to the orogeny. The main period of uplift of the present Andes began in post-Eocene times, and probably still continues.

Vertical uplift, combined with arching or tilting of the region, probably produced the steep thrust faults along the margin of the mountain range, and also produced a zone of tension along the crest, represented by the Boconó fault zone. Large scale strike-slip movement along the Boconó fault zone is, therefore, not probable, although minor strike-slip movement has taken place in Recent times.

REFERENCES CITED

Alberding, H., 1957, Application of principles of wrench-fault tectonics of Moody and Hill to northern South America: Geol. Soc. America Bull., v. 68, p. 785–790.

—— 1965, Notes on the Altamira, Curito and Zapa Formations of the Barinas Basin, W. Venezuela: Bol. Inf., v. 8, p. 307–314.

Arnold, H. C., 1966, Upper Paleozoic Sabaneta-Palmarito sequence of Mérida Andes, Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 50, p. 2366–2387.

Bass, M., and Shagam, R., 1960, Edades Rb-Sr de las rocas cristalinas de los Andes merideños: Bol. Geol. (Venezuela), Pub. Esp. no. 3, tomo I, p. 377–381.

Blackstone, D. L., Jr., 1963, Development of geologic structure in central Rocky Mountains: Am. Assoc. Petroleum Geologists Mem. 2, p. 160–179.

Brondijk, J. F., 1967, "Eocene" Formations in the southwestern part of the Maracaibo Basin: Bol. Inf., v. 10, p. 35–50.

Bucher, W. H., 1952, Structure and orogenic history of Venezuela: Geol. Soc. America Mem. 49, 113 p.

Christ, P., 1927, La coupe geologique le long du chemin de Mucuchachi á Santa Bárbara dans les Andes vénézuéliennes: Eclogae Geol. Helvetiae, v. 20, p. 397–414.

Compañía Shell de Venezuela and Creole Petroleum Corporation, 1964, Paleozoic rocks of Mérida Andes, Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 48, p. 70–84.

de Cizancourt, H., 1933, Tectonic structure of northern Andes in Colombia and Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 17, p. 211–228.

De Sitter, L. U., 1964, Structural Geology (2nd ed.): New York, McGraw-Hill Book Co., 551 p.

Eardley, A. J., 1963, Relation of uplifts to thrusts in Rocky Mountains: Am. Assoc. Petroleum Geologists Mem. 2, p. 209–219.

Engleman, R., 1935, Geology of Venezuelan Andes: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 769–792.

Fiedler, G., 1960, Areas afectadas por terremotos en Venezuela: Bol. Geol. (Venezuela), Pub. Esp. no. 3, tomo IV, p. 1791–1815.

Ford, A., and Houbolt, J. J. H. C., 1963, Las microfacies del Cretáceo en Venezuela occidental: Intern. Sed. Petrographical Series, v. VI, 109 p.

Gaenslen, G., 1962, A discussion of the Cretaceous stratigraphy of the southwest Barinas mountain front: Bol. Inf., v. 5, p. 65–74.

Gerth, H., 1955, Der geologische Bau der südamerikanischen Kordillere: Berlin, Gebrüder Borntraeger, 264 p.

González de Juana, C., 1951a, Introducción al estudio de la geología de Venezuela. Primera parte. Capítulos I y II: Bol. Geol. (Venezuela), v. I, no. 1, p. 119–139.

—— 1951b, Introducción al estudio de la geología de Venezuela. Segunda parte. Capítulos III y IV: Bol. Geol. (Venezuela), v. I, no. 2, p. 195–216.

—— 1952, Introducción al estudio de la geología de Venezuela. Quinta parte. Capítulo IX: Bol. Geol. (Venezuela), v. II, no. 6, p. 407–416.

Hamilton, E. I., 1965, Applied Geochronology: New York, Academic Press, 267 p.

Hospers, J., and van Wijnen, J. C., 1959, The gravity field of the Venezuelan Andes and adjacent basins: Koninkl. Nederlandse Akad. Wetensch. Verh. Afd. Natuurk., Eerste Reeks, Deel XXIII, no. 1, 95 p.

Howard, J. H., 1966, Structural development of the Williams Range Thrust, Colorado: Geol. Soc. America Bull., v. 77, p. 1247–1264.

Kehrer, L., 1938, Some observations on the stratigraphy in the states of Táchira and Mérida, S. W. Venezuela: Bol. Geol. y Minería (Venezuela), English ed., v. 2, nos. 2, 3, 4, p. 44–56.

Kiser, G. D., 1961, Review of Cretaceous stratigraphy of the southwest Barinas mountain front: Bol. Inf., v. 4, p. 335–359.

Kiser, G. D., and Sulek, J. A., 1966, Equivalence of Río Quiú tar sands to Altamira Formation: Bol. Inf., v. 9, p. 49–54.

Knechtel, M. M., 1938, Pre-Cretaceous rocks in the state of Barinas, Venezuela: Bol. Geol. y Minería (Venezuela), English ed., v. 2, nos. 2, 3, 4, p. 182–186.

Kündig, E., 1938, The Precretaceous rocks of the central Venezuelan Andes with some remarks about the tectonics: Bol. Geol. y Minería (Venezuela), English ed., v. 2, nos. 2, 3, 4, p. 21–43.

Liddle, R. A., 1946, The geology of Venezuela and Trinidad (2d ed.): Ithaca, New York, Palaeontographica Americana, 890 p.

Mackenzie, A. N., 1937, The geologic section of the Barinas region, Districts of Barinas, Bolívar and Obispos, State of Zamora, Venezuela: Bol. Geol. y Minería (Venezuela), English ed., v. 1, nos. 2, 3, 4, p. 253–266.

Ministerio de Minas e Hidrocarburos, 1956, Stratigraphic Lexicon of Venezuela (English ed.): Bol. Geol. (Venezuela), Pub. Esp., no. 1, 664 p.

Oppenheim, V., 1937, Contribución a la geología de los Andes venezolanos: Bol. Geol. y Minería (Venezuela), v. 1, nos. 2, 3, 4, p. 25–48.

Paterson, M. S., and Weiss, L. E., 1966, Experimental deformation and folding in phyllite: Geol. Soc. America Bull., v. 77, p. 343–374.

Pierce, G. R., 1960, Geologia de la cuenca de Barinas: Bol. Geol. (Venezuela), Pub. Esp., no. 3, tomo I, p. 214–276.

Renz, O., 1959, Estratigrafía del Cretáceo en Venezuela occidental: Bol. Geol. (Venezuela), v. V, no. 10, p. 3–48.

Rod, E., 1956, Strike-slip faults of northern Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 457–476.

—— 1959, Formación Capacho en Trujillo septentrional y en Lara suroccidental: Bol. Geol. (Venezuela), v. V, no. 10, p. 49–66.

—— 1960, Comments on "The gravity field of the Venezuelan Andes and adjacent basins": Bol. Inf., v. 3, p. 170–175.

Rod, E., Jefferson, C., von der Osten, E., and Mullen, R., 1958, Roundtable discussion—the determination of the Boconó fault: Bol. Inf., v. 1, p. 69–100.

Rod, E., and Maync, W., 1954, Revision of Lower Cretaceous stratigraphy of Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 193–283.

Salvador, A., 1961, Guidebook to the geology of northeastern Trujillo: Soc. Geol. de Venezuela Occidental, Guidebook no. 3, 33 p.

Sanford, A. R., 1959, Analytical and experimental study of simple geologic structures: Geol. Soc. America Bull., v. 70, p. 19–52.

Schubert, C., 1968, Geología de la región de Barinitas-Santo Domingo, Andes venezolanos surorientales: Bol. Geol. (Venezuela), no. 19.

Schürmann, H. M. E., 1934, Massengesteine der venezolanischen Anden: Neues Jahrb. Geologie u. Paläontologie, Beil. Bd. 68, Abt. A, p. 377–400.

—— 1939, Das Alter der Massengesteine der venezolanischen Anden: Neues Jahrb. Geologie u. Paläontologie, Beil. Bd. 75, Abt. A, p. 24–53.

Sievers, W., 1888, Die Cordillere von Mérida nebst Bemerkungen über das Karibische Gebirge: Geog. Abhandl. (Penck), v. 3, no. 1, 238 p.

Sutton, F. A., 1946, Geology of Maracaibo Basin, Venezuela: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 1621–1741.

Manuscript Received by The Society January 19, 1968
Revised Manuscript Received August 19, 1968

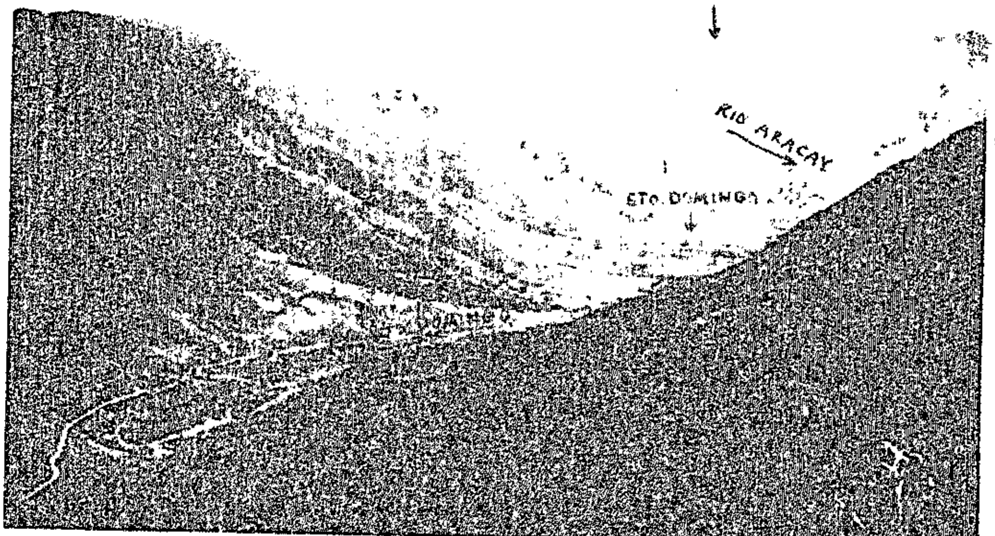

Figure 1. View of the Boconó fault zone from the western end of the Rio Santo Domingo valley (near center and left), toward the east (Río Aracay valley in far center).

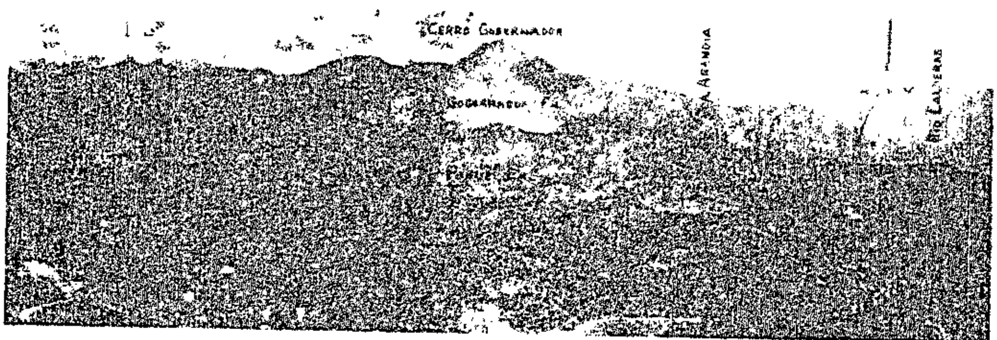

Figure 2. View of Cerro Gobernador from the Altamira-Calderas road (courtesy of G. D. Kiser).

VIEWS OF THE BOCONO FAULT ZONE AND CERRO GOBERNADOR

GEOLOGIC-TECTONIC MAP OF THE BARINITAS-SANTO DOMINGO REGION

PLATE 1, SCHUBERT
Geological Society of America Bulletin, v. 80, no. 3