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GEOLOGY OF THE EL ROSARIO QUADRANGLE,

HONDURAS, CENTRAL AMERICA

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1970

GEOLOGY OF THE EL ROSARIO QUADRANGLE, HONDURAS, CENTRAL AMERICA

by

ROBERT HARRY FAKUNDINY, B.A., M.A.

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

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of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT AUSTIN

December 1970

"The down trail from the capital was at all times a weary road to travel. A juggety-joggety journey it was; ice-cold and hot, wet and dry. The trail climbed appalling mountains, wound like a rotten string about the brows of breathless precipices, plunged through chilling snow-fed streams, and wriggled like a snake through sunless forests teeming with menacing insect and animal life. . . . Here was the flora of the tropics in its rankest and most prodigal growth. Spaces here and there had been wrested from the jungle and planted with bananas and cane and orange groves. The rest was a riot of wild vegetation, the home of monkeys, tapirs, jaguars, alligators and prodigious reptiles and insects. Where no road was cut a serpent could scarcely make its way through the tangle of vines and creepers. . . ."

O. Henry
Cabbages and Kings.

PREFACE

Honduras lies at the center of Meso-America, straddles several geologic provinces, contains the geologic record of the interaction of several lithospheric plates, and yet is geologically the least understood country in the Western Hemisphere. Now that aerial photographs are available and good quadrangle topographic maps are being made the Republica Honduras Dirección General de Minas e Hidrocarburos and Instituto Geográphico Nacional are actively working to change this situation.

In 1967 Dr. Gabriel Dengo of the Instituto Centroamericano de Investigacíon y Tecnología Industrial (ICAITI) and the Department of Geological Sciences at The University of Texas at Austin designed a quadrangle mapping program for graduate geology students. Early in 1968 John R. Everett in the Comayagua Quadrangle and I in the El Rosario Quadrangle started the mapping of central Honduras. Since then William R. Dupré has mapped the Zambrano Quadrangle and Richard C. Finch is presently mapping the San Pedro Zacapa Quadrangle (fig. 2). Marco Zuniga has started a geophysical investigation of the Ulua Valley. We have been working under the guidance and help of Reniery Elvir A., Dirección General de Minas e Hidrocarburos of Honduras. Ing. Elvir has produced preliminary quadrangle geologic maps of the San Juan de

Flores, Tegucigalpa, San Buenaventura, and Nueva Armenia quadrangles, the first quadrangle-sized geologic maps of Honduras.

I mapped the El Rosario Quadrangle during two short field seasons: March to August 1968, and February to May 1969.

This project was administered by the Instituto Centroamericano de Investigacíon y Tecnología Industrial in conjunction with the Regional Organization for Central America and Panama (ROCAP) of the United States Agency for International Development (AID). ICAITI also provided a jeep. I have also been supported by a Teaching Assistantship, the Hogg-Sharp Fellowship, and a Texaco Summer Research Grant from the Department of Geological Sciences of The University of Texas at Austin. Other financial support was given by Signal Oil Company (Jamaica) and the Companía Minería Los Angeles of Honduras. Reniery Elvir A., Dirección General de Minas e Hidrocarburos, and his staff provided office space, supplies, vehicles, field assistants, drivers, gasoline, and secretarial assistance. The Instituto Geográphico Nacional de Honduras gave a generous supply of topographic maps and aerial photographs. The Instituto will also publish the geologic map. A grant from the Owen-Coates Foundation helped pay the costs of reproducing this dissertation.

There is a free flow of ideas among students of

Central American geology. All the geologists we met unselfishly gave encouragement, comradeship, and hospitality as well as share their love for Central America. Among these are: John L. Nassiff, Kenneth Hugh, and Dr. Daniel Arden, all of Signal Oil Company of Honduras and Jamaica; Vern Garten of the New York and Honduras Rosario Mining Company; Paul Bundy of Companía Minería Los Angeles; Al Geike of the American Smelting and Refining Company. Paul Bundy showed me the Opoteca Mine at El Rosario and shared his ideas about the structural setting, time, and nature of the ore emplacement. Dr. Daniel Arden accompanied me in the field freely giving his ideas about some of the complicated structure. The New York and Honduras Rosario Mining Company gave us a tour of their mine at El Mochito. Vern Garten led us on a tour of the operations at the mine at Minas de Oro. John Svanholm shared his knowledge of mining and mineral prospects in Honduras. Ing. Ricardo Alduvin of the Banco Central de Honduras sparked us with his exhilarating spirit. Signal Oil Company (Jamaica) graceously offered to identify our fossils. Unfortunately all the fossils were lost in transit to Jamaica.

In Guatemala Dr. Gabriel Dengo and Dr. Otto Bohnenberger guided us throughout the project. Dr. Bohnenberger led us on a tour of the geology of western Guatemala. Dr. Russel Clemons and Dr. Burk Burkart showed us the areas they

are mapping in western Guatemala.

Dr. Robert L. Folk examined the sedimentary rock thin sections. Dr. Daniel S. Barker helped me with the igneous rock thin sections, and Dr. Stephen E. Clabaugh helped with the metamorphic rock thin sections. Dr. William R. Muehlberger, Dr. Gabriel Dengo, and Dr. Stephen E. Clabaugh visited the field area and set my mind "straight" on mapping philosophy and helped in the interpretations. Many of my fellow students at The University of Texas helped me through all the stages of the project, usually when they needed to devote their energy to their own problems. Among these are: J. Stuart Pittman, Jr., Anthony W. Walton, Moyad A. Shafiq, Steven E. DeLong, Edward R. Burt, Michael A. Jordon, John D. Cooper, Richard M. Cadwgan, and G. Lyman Dawe. In the field I was assisted by José Maria Gutierrez, Luis Al Fortin, Robert Ramirez-Landa, and Marco Tulio Moya. Paul W. Fakundiny spent two months with me in the field as friend, confidant, and companion.

My colleagues John R. Everett, William R. Dupré, and Richard C. Finch deserve special thanks, and possibly a few purple hearts. They nursed me when sick, straightened me out when wrong about geologic interpretation, led me through their field areas, consoled me when depressed, put up with my naiveté, and taught me a lot about living as well as geology. John R. Everett has been an inspiration, even before the project began, and has probably contributed more to this work than anyone else.

Dr. Gabriel Dengo originated the project, led us on a tour of Guatemala, El Salvador, and Honduras, introduced us to our field areas, set up and coordinated the financial support, introduced us to many of those who have helped on the project, watched our work, and advised us on the geology of Central America. He has inspired most of the scientific progress of Central America and has probably contributed more to the understanding of Central American geology than any other man.

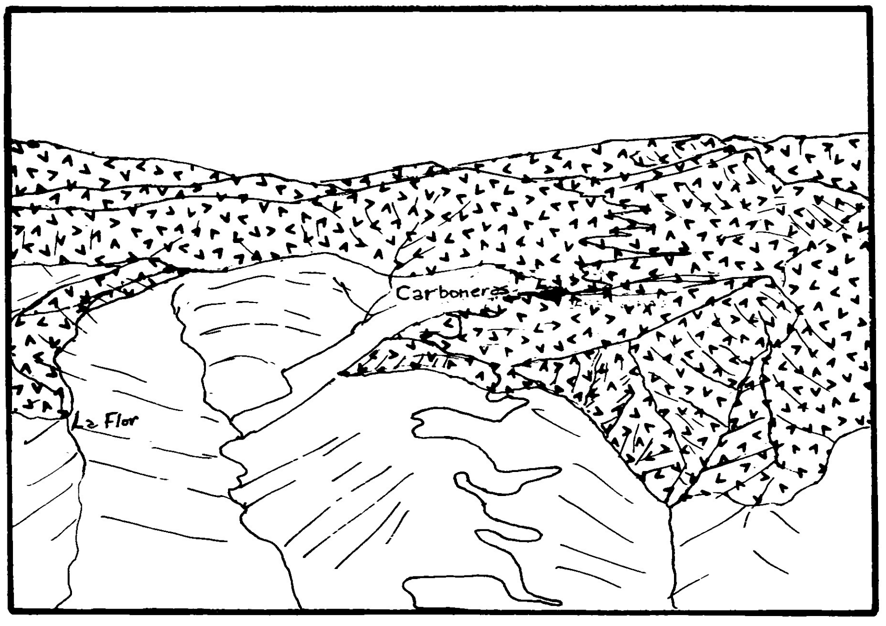
Ing. Reniery Elvir A., Dirección General de Minas e Hidrocarburos, is one of the most efficient and helpful men of Honduras. He provided us with every type of support imaginable, especially when others said it couldn't be done. Ing. J. Roberto Moncada R., Ing. Carlos Revera Cáceras, and Ing. Julio Durón of the Instituto Geográphico Nacional de Honduras were especially helpful and prompt in supplying us with maps and photographs.

Dr. William R. Muehlberger, the supervisor of this work, is a close friend and teacher who gave me inspiration, consolation, and exerted a herculean effort at guiding this work to completion comparable only to his great expertise and size. Without his patience and trust I could not have done the work. Dr. Stephen E. Clabaugh, Dr. Robert E. Boyer, and Dr. Gabriel Dengo have read and enriched the manuscript as well as giving guidance throughout my studies. John R. Everett and William R. Dupré helped with many of the illustrations.

All these people have given their time, energy, support, advice, and experience, adding greatly to this study and correcting untold errors. Those mistakes remaining are mine.

To all these people I give heartfelt thanks.

This dissertation was submitted to the Committee in July 1970.



Frontispiece. Aerial view to the west of Siguatepeque Plateau. Old Carretera del Norte climbs spur of Valle de Angeles Group redbed sandstones into Cerro La Cañada ignimbrites. Much of the ignimbrite outcrop on the right side is landslide. Quebrada de Castellanos is on left of road between the villages of La Flor and Carboneras. Skyline on right is same as skyline in plate 6G. Note Carboneras is built on back slope of block tilted back toward main cliff.

GEOLOGY OF THE EL ROSARIO QUADRANGLE,

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A B S T R A C T

The El Rosario Quadrangle, situated 100 kilometers northwest of the capital, Tegucigalpa, on the Carretera del Norte, straddles the boundary between the Volcanic Ranges and Plateaus and the Central American Cordillera morphotectonic units, and includes pre-Mesozoic metamorphic rocks, Mesozoic and Tertiary sedimentary rocks, and Tertiary intrusive and volcanic rocks.

The oldest rocks exposed are two facies of the pre-Mesozoic Cacaguapa Schist: the Humuya Member of sheared conglomerate, containing evidence of two metamorphic periods, and schist with interlayered, boudinaged meta-andesite; and the Las Marias Member of sericite-quartz schist with interlayered marble and quartzite. Nonconformably overlying the metamorphic rock are interbedded conglomerate, sandstone, and shale, with intercalated volcanic rocks of the early Mesozoic Todos Santos Formation. The early Cretaceous Yojoa Group of carbonate rock overlies the Todos Santos Formation. Two formations comprise the Yojoa Group: Cantarranas Formation of thin-bedded, marly limestone and the overlying Atima

Formation of massive limestone. The Late Cretaceous to early Tertiary(?) Valle de Angeles Group includes red sandstones and shale with minor conglomerate. Padre Miguel Group (Miocene?) siliceous ignimbrite and reworked pyroclastic rock are represented by the La Sabana and Cerro Le Cañada ignimbrite members. The La Sabana ignimbrite has an olivine basalt flow within its lower part. Intrusive igneous rocks include rhyolite with tuffaceous, devitrified-tuff, or granophyric textures, basalt and gabbro dikes, and intruded gabbro.

These rocks record three major episodes of deformation: pre-Mesozoic folding and development of schistosity; the Montaña de Comayagua structural belt, a N. 60° W. structural high with high-angle reverse faults formed during the Laramide orogeny; and Tertiary faulting that formed north-trending grabens.

The Opoteca silver mine may be the richest mineral deposit within the El Rosario Quadrangle.

CONTENTS

TEXT

Page

Page

Page

Page

ILLUSTRATIONS

FRONTISPIECE

I N T R O D U C T I O N

GENERAL STATEMENT

Honduras lies at the center of the Central American and Caribbean geologic regions. The stratigraphy and structure of Honduras must be understood before geologists can put together the history of the central part of the Western Hemisphere. This work and those of Everett (1970) and Dupré (1970) are the first detailed quadrangle studies in Honduras.

GEOGRAPHIC SETTING

Honduras is one of the largest and most mountainous countries of Central America. It is located in the northern half of Central America or that part called, by Schuchert (1935), Nuclear Central America. The entire northern side is coast line on the Caribbean Sea, whereas, the only portion of Honduras touching the Pacific Ocean is in the Gulf of Fonseca. Guatemala and El Salvador border Honduras on the west and Nicaragua borders it on the south (fig. 1).

Honduras possesses striking relief, awesome mountains and valleys, and beautiful, serene countryside. Rivers cut through mountain ranges, turn around on themselves with apparent change of heart to flow into the ocean opposite that to which they started. Thus the continental divide swings back and forth through the country in a sinuous line. Figure

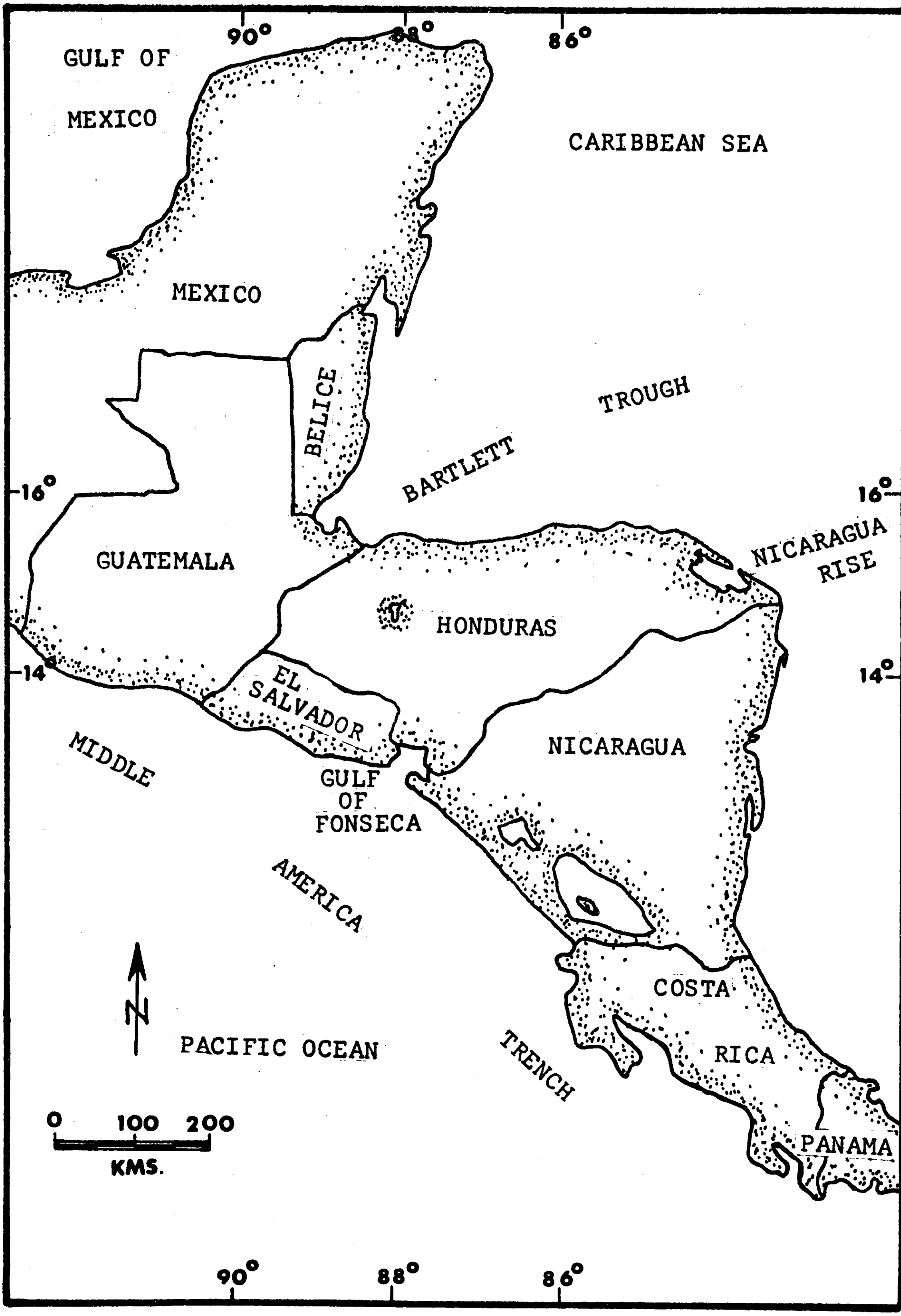


Figure 1. Map of Central America (after Dengo, 1968).

2 shows some of the major mountains, valleys, and rivers.

The El Rosario Quadrangle lies within a N. 60° W.-trending belt of mountains and valleys extending from the Montaña Santa Barbara on the northwest to Yuscarán on the southeast. This belt coincides with the boundary between the Volcanic Ranges and Plateaus and Sierras of Northern Central America morphotectonic units. Figure 3 shows the major geographic features of central Honduras. Also shown are the quadrangles bordering the El Rosario Quadrangle and other localities outside the quadrangle mentioned in the text. The quadrangles are named after their major town, shown by a dot within a circle.

Dozens of small villages spaced fairly evenly throughout the lower elevations dot the El Rosario Quadrangle. Except for the high mountains in the southeast one is always within shouting distance of a trail or field where help can be enlisted from the constantly working farmers. Streams, although polluted, are plentiful so water is always nearby. Figure 4 is a map of the drainage within the El Rosario Quadrangle. Also shown are hills and localities mentioned in the text. Montaña Los Planes ó La Choca, Montaña Rio Obscuro, and Montaña El Portillo are referred to in the text collectively as the Montaña de Comayagua of which they form the northern part. Localities are given by grid coordinates. The Universal Transverse Mercator Grid divides the quadrangle

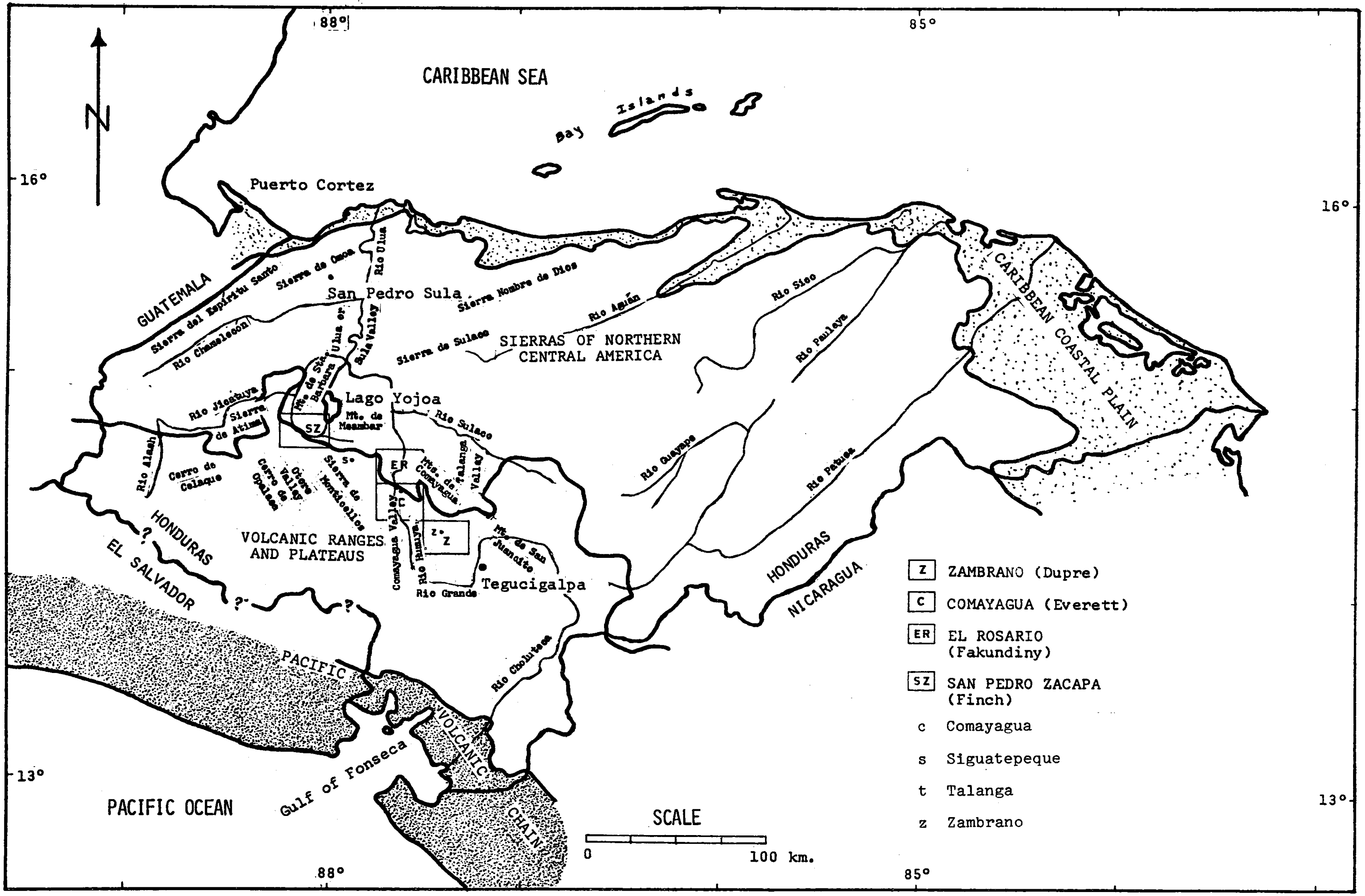


Figure 2. Location map of Honduras showing morphotectonic units (Dengo and Bohnenberger, 1969), quadrangles mapped by students from The University of Texas at Austin, and some of the major mountains and rivers.

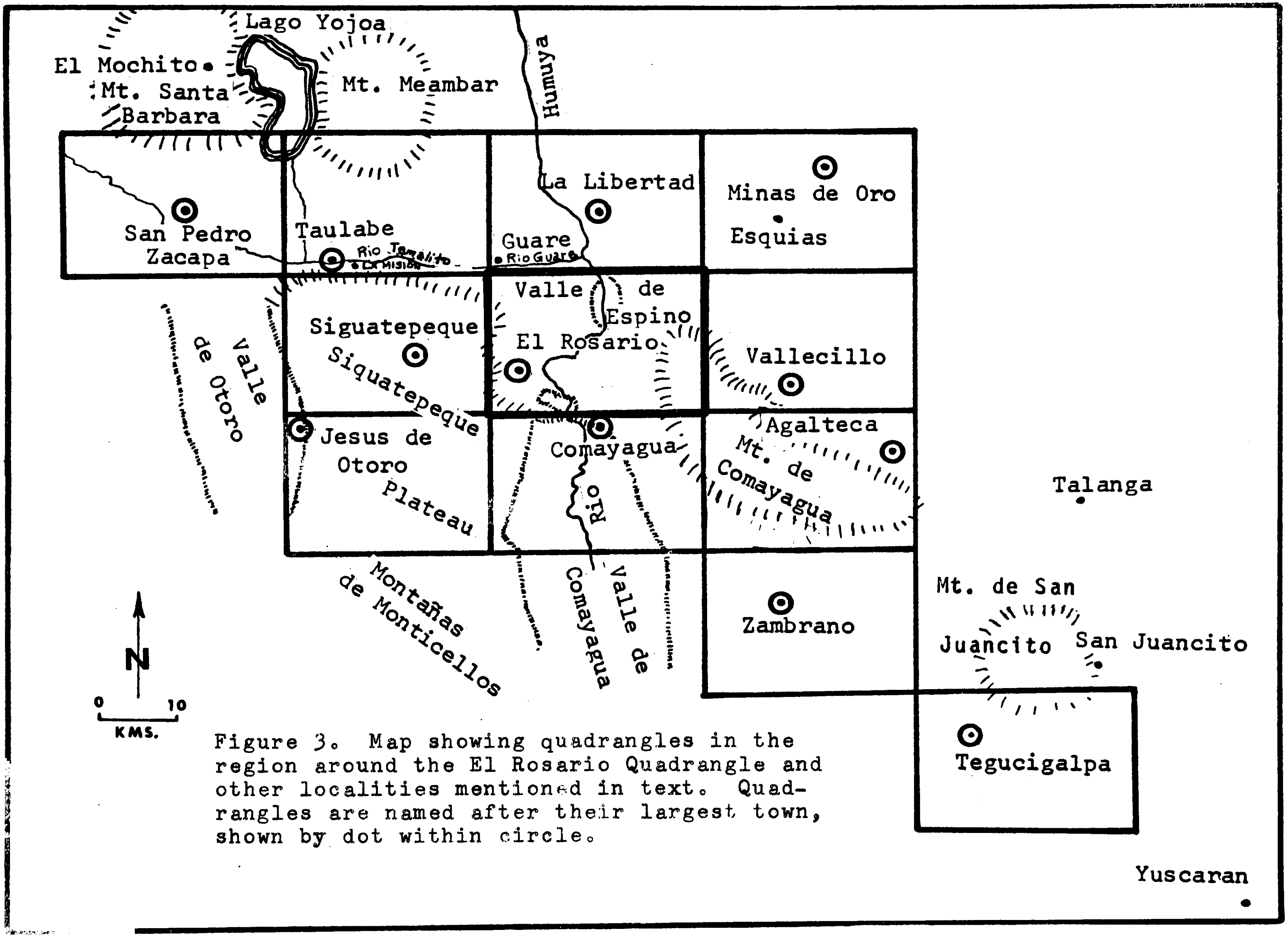


Figure 3. Map showing quadrangles in the region around the El Rosario Quadrangle and other localities mentioned in text. Quadrangles are named after their largest town, shown by dot within circle.

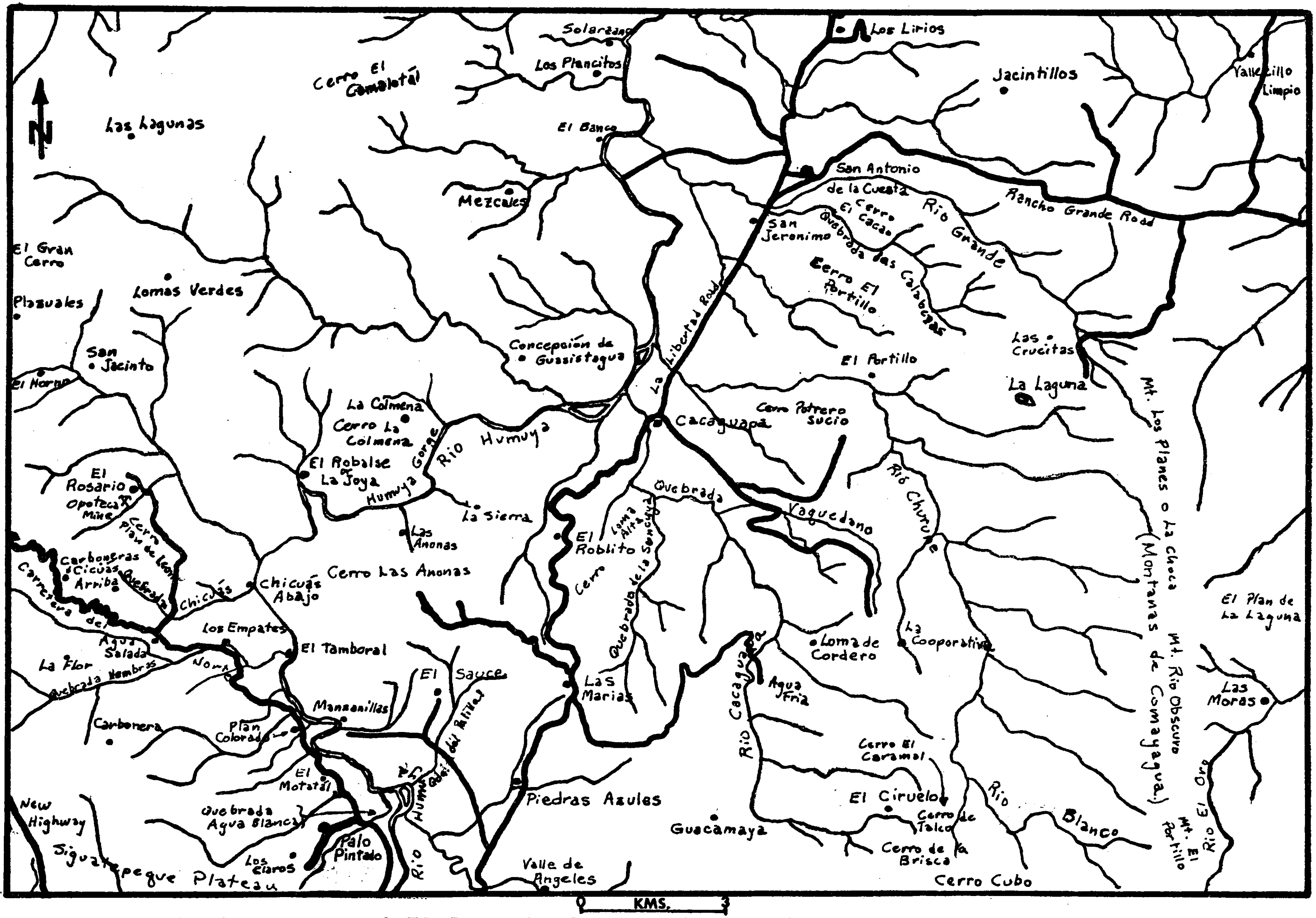


Figure 4. Drainage map of El Rosario Quadrangle showing major roads, towns, rivers, and hills mentioned in text.

into one-kilometer squares. These are identified by a four-digit number, *i.e.*, 2817. The first two digits are the ordinate, the second two, the abscissa, forming the west and south sides of the kilometer square. Where six digits are used the third digit represents decimal fractions dividing the square vertically and the sixth, decimal fractions dividing the square horizontally. The decimal fraction permits the identification of a point within 100 meters. The church in Palo Pintado is located at 256044.

The El Rosario Quadrangle has more than 2000 meters of relief. The highest point is Montaña El Portillo (grid 4303) in the southeast corner with an elevation of 2407 meters. The lowest point is 375 meters where the Rio Humuya leaves the north-central part of the quadrangle. Figure 5 is a block diagram showing the physiography and major cultural features of the El Rosario Quadrangle.

CLIMATE AND VEGETATION

Climate

Three elevation-related temperature zones exist in central Honduras: 1) hot (*Tierra Caliente*), generally up to 1000 meters elevation with a mean temperature of about 29°C; 2) temperate (*Tierra Templada*), generally between 600 and 2000 meters, with a mean temperature of about 21°C; and 3) cold (*Tierra Fria*), generally above 2000 meters with a mean

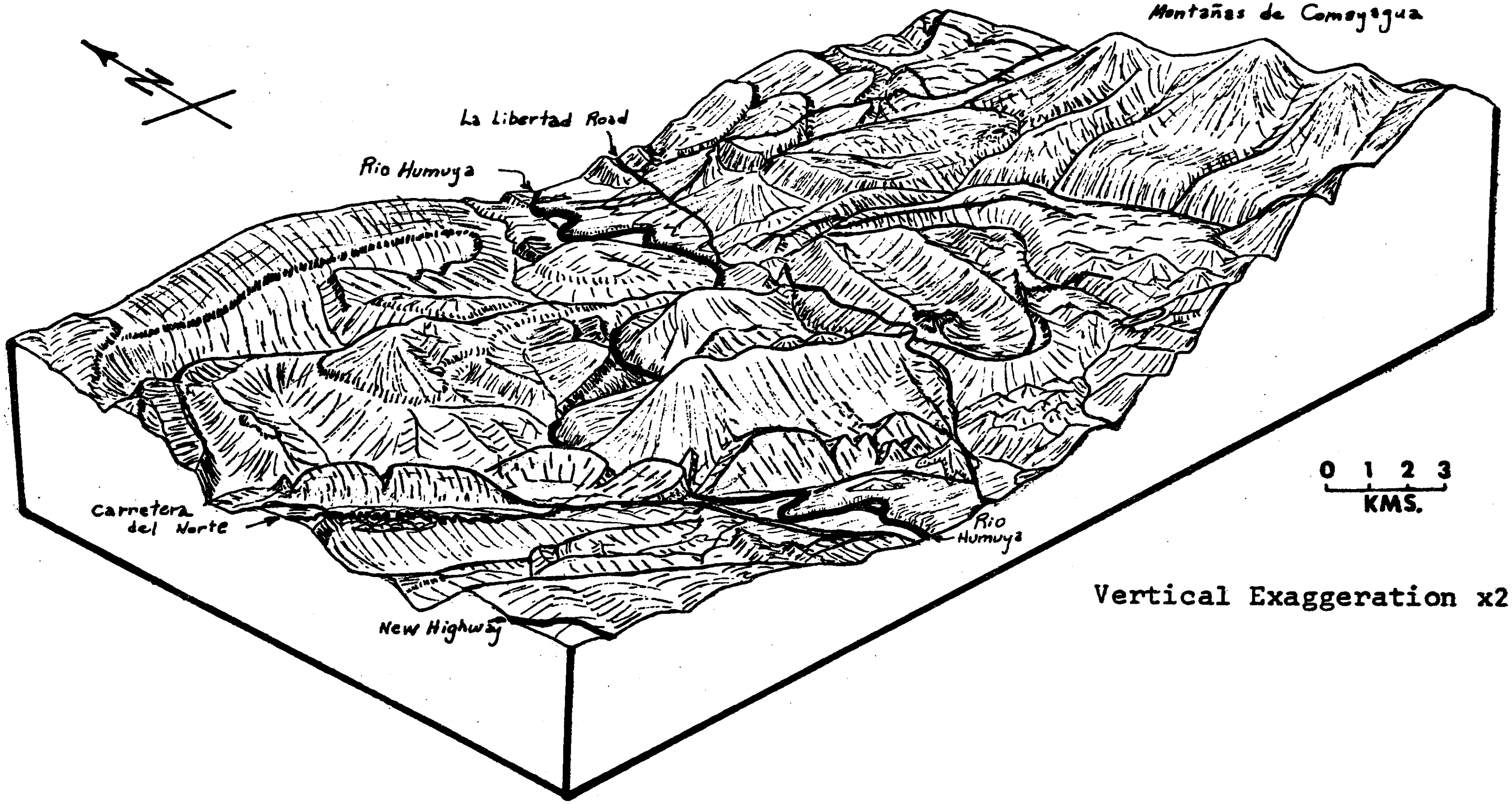


Figure 5. Sketch showing topographic features of the El Rosario Quadrangle. Heavy dark line is the Rio Humuya, dark lines are passable roads and all-weather highways.

temperature of about 15°C. There are two seasons: the warm, dry months of December through May, when dust, smoke from burning fields, and ticks hinder field work; and the wet season from June through November, the months of heaviest precipitation. During the wet season daily afternoon showers and occasional two or three day rains produce flooded rivers which hinder field work. The average yearly rainfall is 130 centimeters (Helbig, 1965, p. 220).

Vegetation

Bedrock, elevation, and amount of rainfall determine the types of vegetation and their distribution in the El Rosario Quadrangle. Thin pine forest and grass cover the volcanic plateaus and ridges as well as the flat areas of the metamorphic highland. Here grazing is extensive. Mesozoic redbed sandstones and conglomerate produce poor soil for farming; most of these areas have little vegetation. Most farming is restricted to areas underlain by carbonate rocks or valley bottom alluvium. Maize and beans are grown on limestone slopes or high on the Montaña de Comayagua scarp. At the base of the scarp some coffee plantations (*fincas*) are thriving. Sugar cane is grown on the volcanic plateau at the northwest corner of the quadrangle.

GEOLOGIC SETTING

PREVIOUS WORK

Karl Sapper (1899, 1905, 1937) was the pioneer student of Honduras geology. His contributions set up the framework of the puzzle to which later students have added pieces. Schuchert (1935) included work done by Weaver in his treatise on the Antillean-Caribbean area. Carpenter (1954) presented the first published detailed geologic mapping in Honduras. Roberts and Irving (1957) added economic studies and local mine maps to the published record. Others who have published geologic accounts concerning Honduras are Fritz-Gaertner (1891), Hoffstetter and Dengo (1960), Hugh (1965), Imlay (1944a, b), Knowlton (1918), Lloyd (1963), McBirney (1969), McBirney and Williams (1963), Mills (1959), Moody (1963), Newberry (1888), Olsen and McGrew (1941), Redfield (1923), Vaughn (1918), Vinson and Brineman (1963), Weaver (1942), Weyl (1961), and Woodring (1954). But it was not until Mills _et al_. (1967) presented their detailed stratigraphic and paleontologic study of the Mesozoic rocks in Honduras that a clear picture started to emerge. Williams and McBirney (1969) have presented an equally fine contribution concerning the volcanic history which makes a good companion piece to the work of Mills and his colleagues. Dengo (1968) and Dengo and Bohnenberger

(1969) discussed the structural and historical development of Honduras within the larger frame of all Central America. McBirney and Bass (1969) added to the metamorphic history and structural setting of northern Honduras. Elvir (1969d) gave an up-to-date accounting of the economic geology of Honduras. Everett and Fakundiny (1969) discussed structure and stratigraphy of central Honduras.

STRATIGRAPHY

Figure 6 is a chart correlating the stratigraphic units of Mills _et al_. (1967), Williams and McBirney (1969), Everett (1970), Dupré (1970), and this paper. Some of the units have been formally introduced in the literature by Carpenter (1954), Mills _et al_., and Williams and McBirney; others, given by Everett, Dupré, and myself are presented herein informally as an aid to discussing them and not with the intent to apply them elsewhere throughout Honduras.

STRUCTURE

Dengo and Bohnenberger (1969), following the lead of Guzman and de Cserna (1963), have divided Central America into areas which they call Morphotectonic Units. The map, first published by Mills _et al_. (1967), shows regions with similar internal constitution and external relief. Those morphotectonic units in Honduras are shown in figure 2.

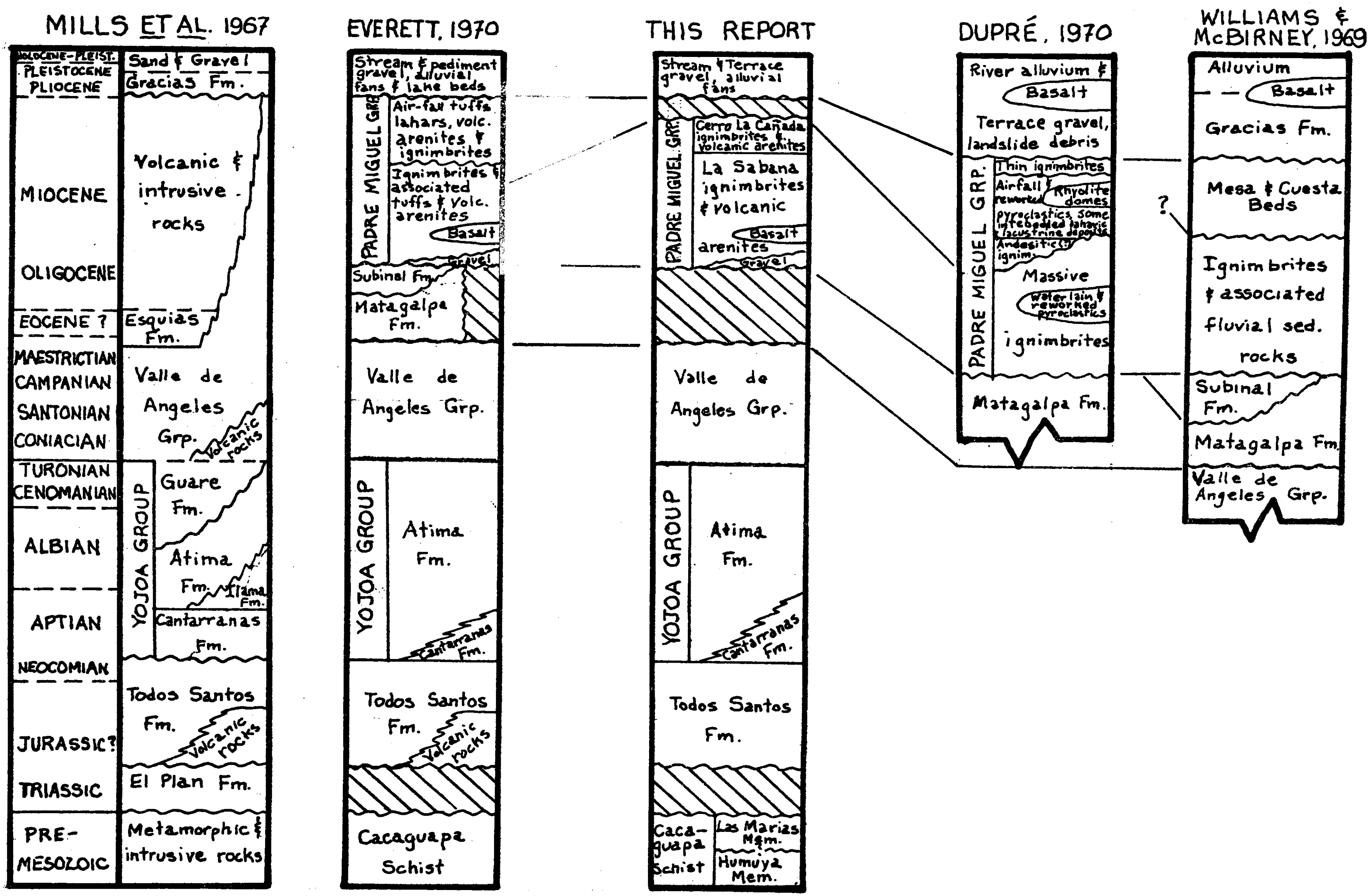


Figure 6. Stratigraphic nomenclature used in this report compared with that used by Mills et al. (1967), Everett (1970), Dupré (1970), and Williams and McBirney (1969).

Molnar and Sykes (1969) postulated three rigid lithospheric plates moving in relation to one another in the Caribbean region: the Americas, the Cocos, and the Caribbean plates (fig. 7). Their work is based on the study of first motions at sites of major seismic activity. Honduras is totally within the Caribbean plate, but structural features within Honduras may reflect the history of movement of all three.

In central Honduras two major structural trends influence the distribution of morphotectonic units and topography: the Honduras Depression and a N. 60° W.-trending structural zone, named herein the Montaña de Comayagua structural belt. The Honduras Depression is a series of *en echelon* valleys extending from the Golfo de Fonseca to the north coast. The Comayagua Valley to the south of the El Rosario Quadrangle and the Valle de Espino together form one of the grabens within the Honduras Depression system. The Ulua Valley is a graben that forms the north end of the Honduras Depression (fig. 8).

FIELD AND LABORATORY METHODS

Mapping was done on 10 by 15 degree, 1:50,000 topographic maps made by the Dirección General de Cartographia in Tegucigalpa, Honduras, and on 1:60,000 and 1:20,000 aerial photographs. Rocks were studied in hand specimen, polished

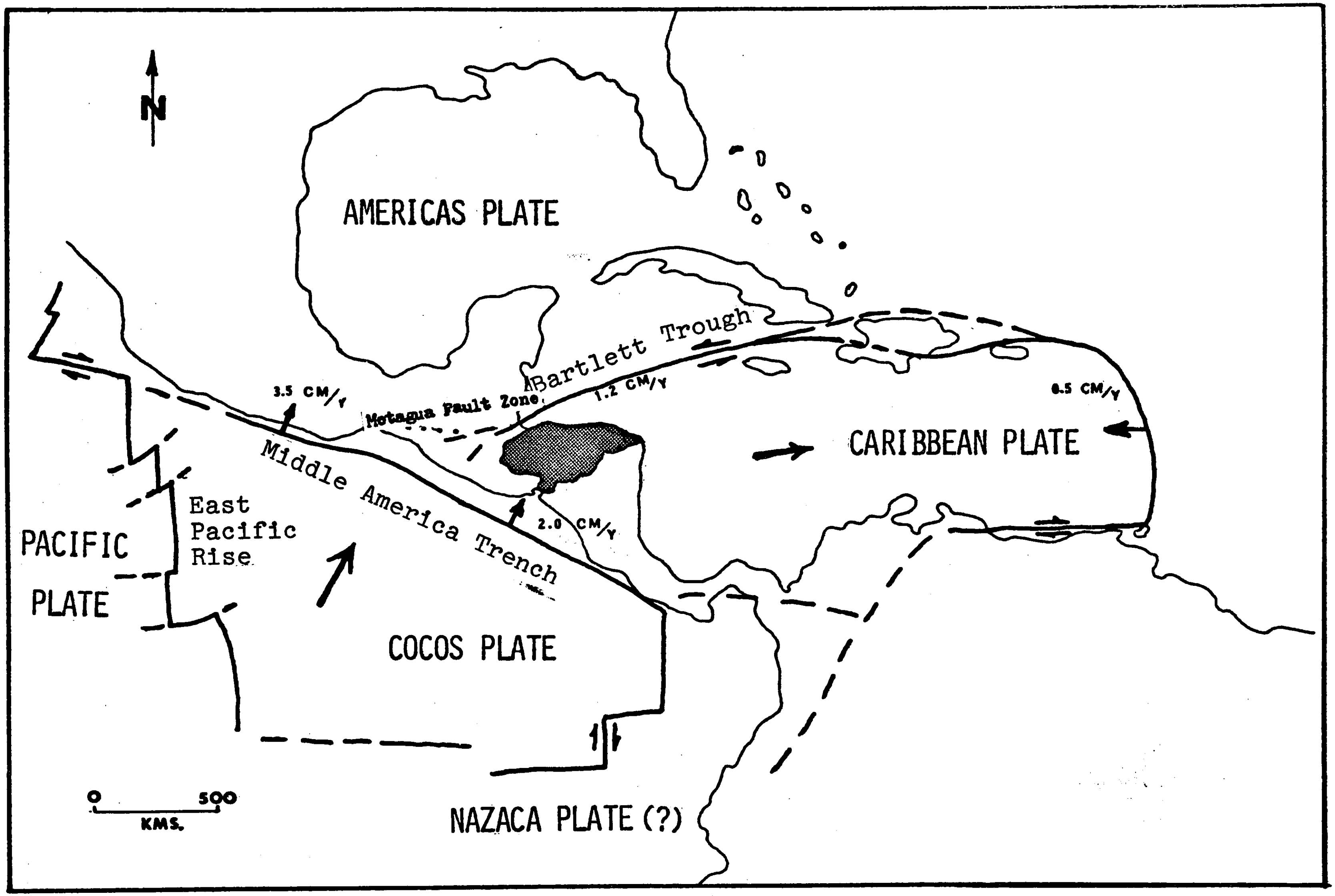


Figure 7. Middle America and Caribbean region showing plates of lithospere and relative rates of motion (slightly modified from Molnar and Sykes, 1969). Honduras is shown by stippled pattern.

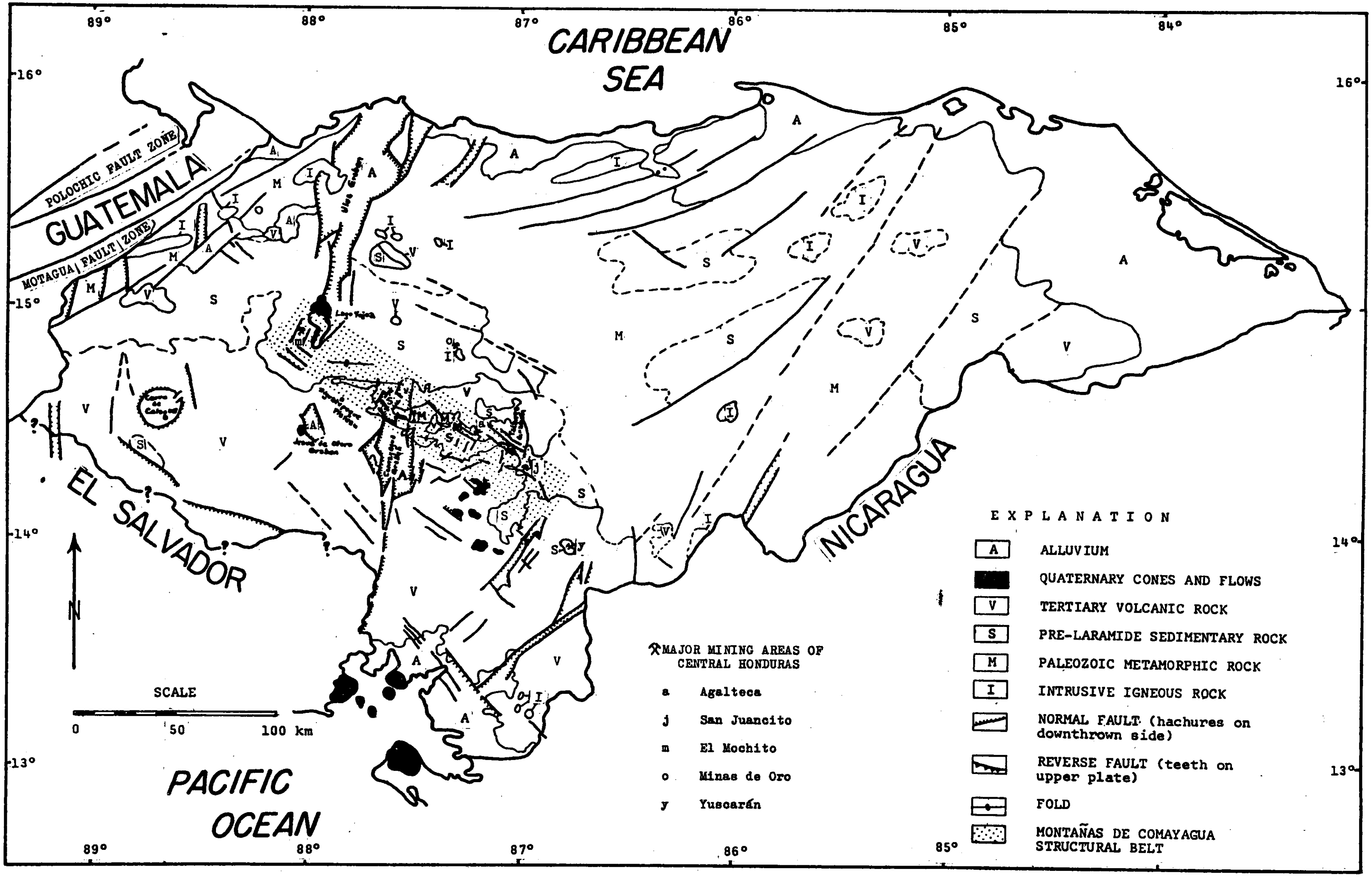


Figure 8. Simplified geologic map of Honduras (after Dengo, 1968; Mills et al., 1967; Dupré, 1970; Everett and Fakundiny, 1969; Williams and McBirney, 1969).

section, acetate peel, and thin section. Text numbers refer to the numbered descriptions in the Appendix. Approximately 180 hand specimens and thin sections are described in Appendix II.

Location names referred to in the text are taken from the map even though some have been changed since the completion of the map. Numbers in parentheses, *i.e.* (#27), refer to the numbered descriptions found in the Appendices.

Hand specimen colors were determined from the Rock-Color Chart (Goddard *et al.*, 1963) and the Munsell Soil Color Chart. Outcrop colors are my own designation.

S T R A T I G R A P H Y

GENERAL STATEMENT

This report describes six lithostratigraphic units in the El Rosario Quadrangle: 1) Cacaguapa Schist comprising the Humuya and Las Marias members; 2) Todos Santos Formation; 3) Yojoa Group which comprises the Cantarranas and Atima formations; 4) Valle de Angeles Group which here consists only of an unnamed formation of redbed sedimentary rocks; 5) Padre Miguel Group of ignimbrites, fluviatile sedimentary rocks, and a local basalt flow; and 6) alluvial deposits. Except for the Yojoa Group no fossils have been found. Therefore, ages and correlations are based on lithic similarities and stratigraphic position compared with stratigraphic sections described elsewhere in central Honduras. Several units described by others in central Honduras have not been found in the El Rosario Quadrangle: 1) El Plan Formation (Carpenter, 1954); 2) Ilama and Guare formations within the Yojoa Group (Mills *et al*., 1967); 3) Esquias Formation (Mills *et al*., 1967); 4) Matagalpa and Subinal formations (Williams and McBirney, 1969); and 5) Quaternary basalt (Elvir, 1969a, b, c, 1970; Williams and McBirney, 1969; and Dupré, 1970).

Figure 9 is a generalized stratigraphic section in the El Rosario Quadrangle. Described sections of the Todos Santos Formation and the Yojoa Group are given in Appendix I.

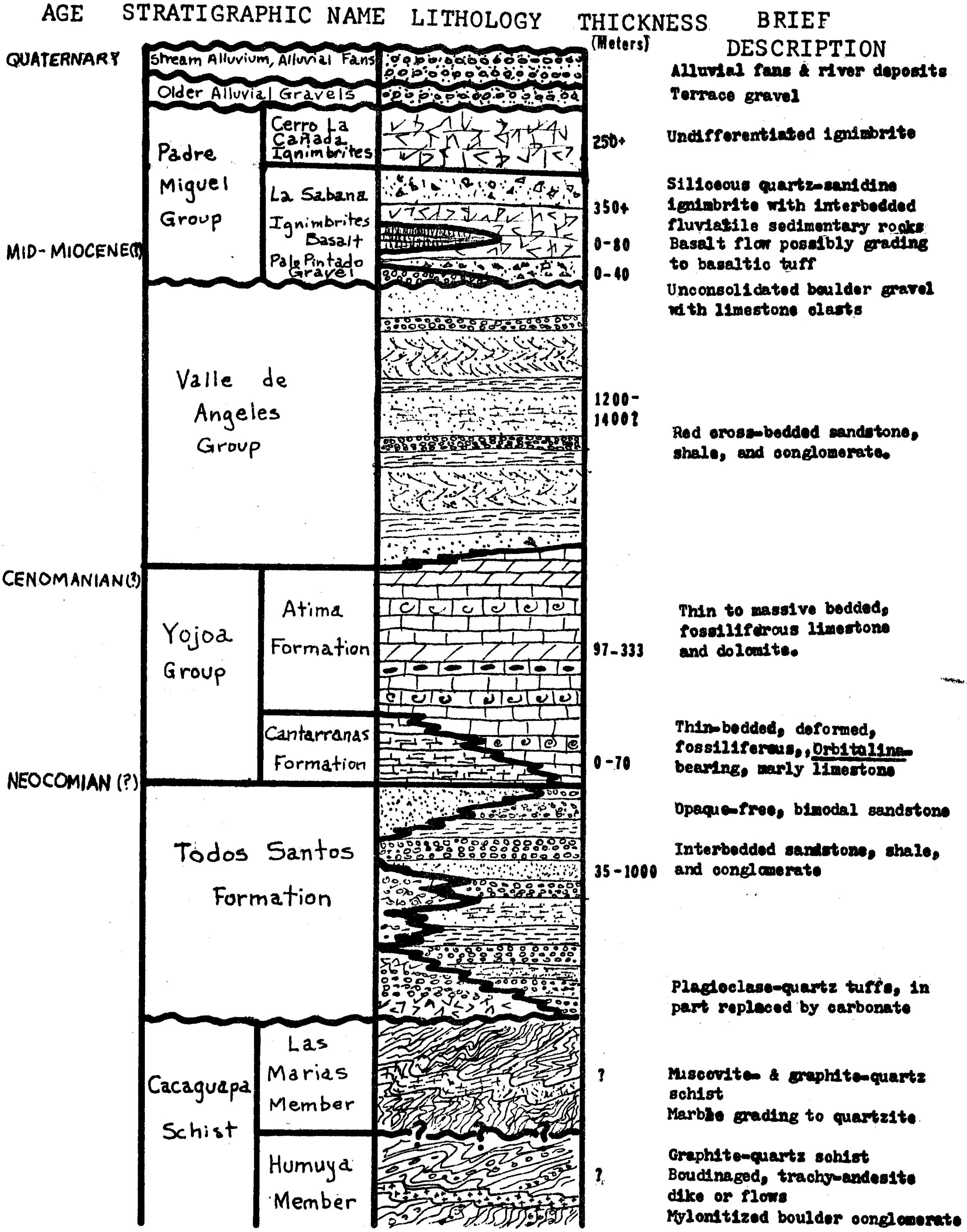


Figure 9. Generalized stratigraphic section in the El Rosario Quadrangle.

METAMORPHIC ROCKS

INTRODUCTION

The metamorphic rocks forming the continental basement of Nuclear Central America are as yet poorly understood. However, hypotheses concerning plate tectonics in Central America require careful studies of the pre-Mesozoic rocks forming the basement of Nuclear Central America. No longer can the metamorphic terranes be thought of as just "basement."

Four metamorphic provinces have so far been named and in part studied: 1) the Chuacús Series (McBirney, 1963), exposed north of the Motagua Fault zone in Guatemala, consists of amphibolite and garnet-amphibolite facies rocks, mostly garnet-biotite schist and gneiss interlayered with amphibolite, marble, and minor kyanite-staurolite gneiss; 2) the Maya Series (Dixon, 1956), forming the basement rock in Belice (British Honduras) north of the Chuacús region, consists of graywacke, quartzite, slate, phyllite, and shale with some schist and gneiss; 3) the El Tambor Formation (McBirney and Bass, 1969), forming the basement south of the Motagua Fault zone in Guatemala, consists of metadiabase and metachert associated with a thick sequence of low-grade metamorphosed sediments, mainly graywacke, but including minor amounts of glaucophane schist and eclogite; and 4) the

Palacagüina Formation (Zoppis Bracci, 1957, extended to regional use by Dengo, 1969), forming most of the basement of central and eastern Honduras and northern Nicaragua, consists mostly of phyllite, but includes limestone, marble, and quartzite.

Regional relationships of these provinces are now under study. McBirney and Bass (1969, p. 279) believed the El Tambor Formation may be a more volcanic facies of the Chuacús Series, both representing metamorphosed rocks that were originally deposited in the same eugeosyncline. Their model does not permit much strike-slip movement along the Motagua Fault zone which separates the two provinces. Dengo (1969) united the Chuacús and Maya series into a single regional and structural entity calling them parts of the Maya-Chuacús Block. He considered the metamorphic rock south of the Motagua part of the Palacagüina Formation calling this region the Chortis Block. Dengo explained the differing justaposed assemblages as the consequence of these two blocks sliding past one another along their common boundary, the Motagua Fault zone. Molnar and Sykes (1969) placed rocks north of the Motagua-Polochic zone in the Americas plate and rocks south of it in the Caribbean plate (fig. 7).

The four metamorphic provinces may not be as different as they first appear. Powers (1918) and Foye (1918) described samples collected along the northern coast of

Honduras. Judging from their brief descriptions these rocks could have come from any of the four provinces. McBirney and Bass (1969) reported both Maya-Chuacús and Chortis-type metamorphic rocks from the Bay Islands in the Gulf of Honduras. It should be remembered that the Bay Islands and the northern coast of Honduras where Powers collected his samples are thought by most students to be within the wide fault zone considered the boundary between the Americas and Caribbean plates (fig. 7). More interesting, perhaps, is the first report of meta-igneous rocks associated with Palacagüina assemblage rocks from central Honduras in the El Rosario and Comayagua quadrangles by Williams and McBirney (1969). Williams and McBirney (1969) found mica schist, quartzite, and meta-chert boulders along with the metadiabase or metabasalt in the Rio Churune and Rio Matasano in the El Rosario and Comayagua quadrangles. They felt that the Montaña de Comayagua contains rocks from an eugeosynclinal assemblage, the only ones found so far from the central highlands of Honduras. This is within the area of the Palacagüina Formation schist.

Carpenter (1954) gave the only descriptions to date of metamorphic rocks from central Honduras. These are exposed at San Juancito near Tegucigalpa. This assemblage, which he named the Peten Formation, comprises well-foliated graphitic and sericitic schist with included quartz stringers and blebs, and quartzite. The Peten Formation is nonconformably overlain by Late Triassic El Plan Formation sedimentary rocks. Thus, the Peten Formation is Late Paleozoic or older. Dengo (1969) on his map included the Peten Formation as part of his newly proposed Palacagüina Formation. So far very few isotopic age dates have been determined from the basement rocks of Central America. Pushkar (1968, p. 2707) gave a single Rb/Sr ratio indicating a maximum age of 412 m.y. for Palacagüina Schist. Long and Clemons (1969) obtained a whole-rock Rb/Sr age of 215 m.y. from a granite associated with the Chiquimula Pluton in eastern Guatemala (Clemons, 1966).

Metamorphic outcrops within the El Rosario, Vallecillo, Agalteca, Telanga, and Comayagua quadrangles are the only known exposures of basement rock well within the Volcanic Ranges and Plateaus Region of Honduras (fig. 8). The varied assemblage of rocks and the intermediate geographic position between the metamorphic regions of the Motagua and related faults and the Palacagüina-Peten metamorphic region of central and eastern Honduras make the Montaña de Comayagua an excellent place to start a study of the regional metamorphic problems.

CACAGUAPA SCHIST

Introduction

Metamorphic rocks are exposed throughout most of the southeast quarter of the El Rosario Quadrangle. Exposures extend eastward from the Rio Humuya into the Vallecillo Quadrangle and southward from the Rio Churune into the Comayagua Quadrangle. These rocks are called herein the Cacaguapa Schist for the exposures along the Rio Cacaguapa and around the village of Cacaguapa. Most of the high Montaña de Comayagua and the plateau region immediately west of the montaña are underlain by Cacaguapa Schist (pls. 1, 2, 3). Two major assemblages of the Cacaguapa Schist are present: 1) Humuya Member, composed of metamorphosed and mylonitized sedimentary rock with minor interlayered igneous rock; and 2) the Las Marias Member, comprising phyllite, schist, marble, and quartzite.

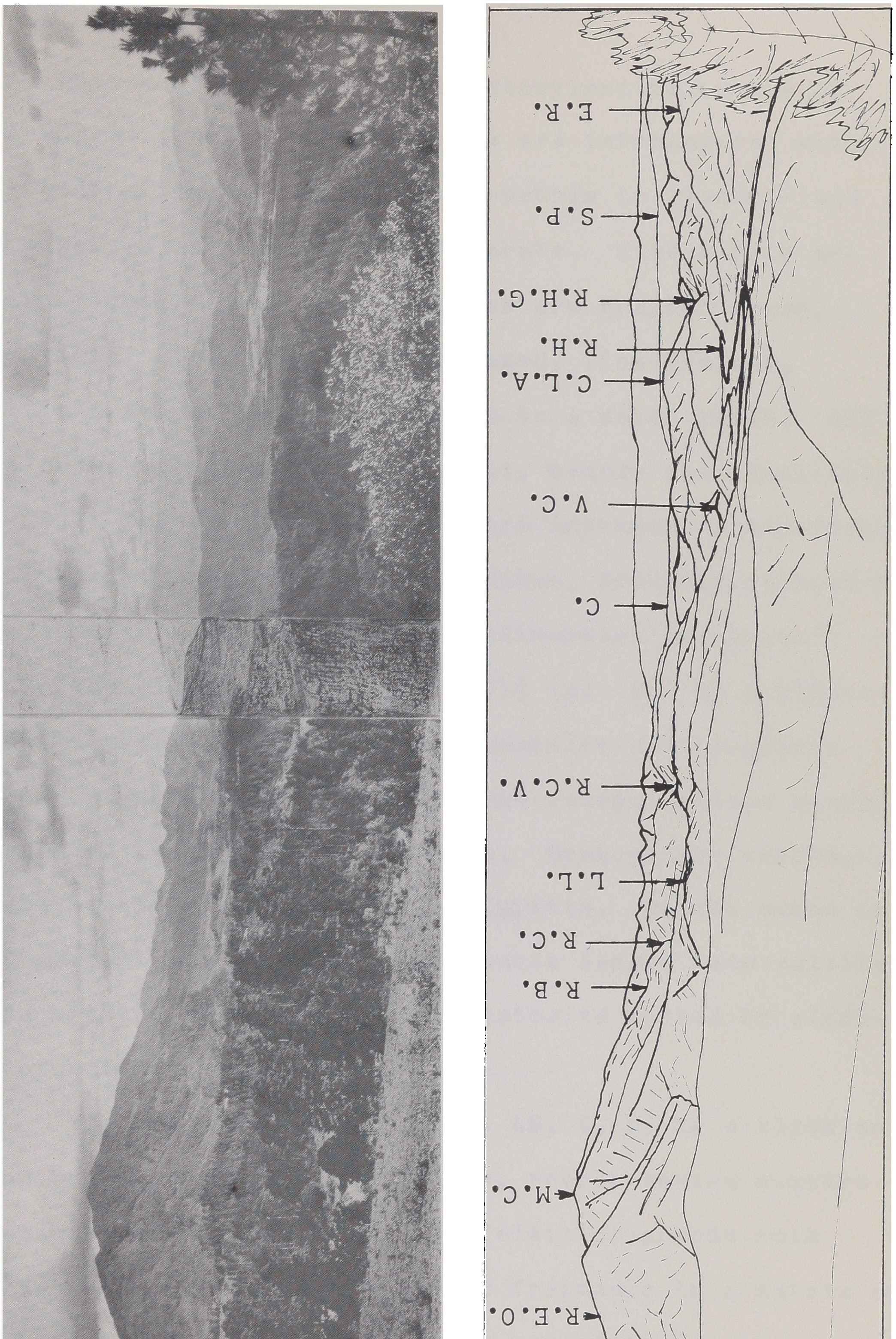
Humuya Member

Sheared, metamorphosed conglomerate and interlayered meta-igneous rock crop out in the gorge of the Rio Humuya 4 kilometers west of the village of Cacaguapa (grid 2711). Outcrops are only exposed during the dry season when the Rio Humuya is at its lowest level. They are situated on the north-south stretch of the river below the village of La Colmena (pl. 4A). Outcrops are greenish gray to black,

PLATE 3

Metamorphic highland. Photograph looking south from Jacintillos (grid 4019). The sketch spans the entire quadrangle near its southern border. R.E.O.=Rio El Oro, behing mountain on east side. M.C.=Montaña de Comayagua. R.B.=Rio Blanco. R.C.=Rio Churune. L.L.=La Laguna. R.C.V.=Rio Cacaguapa Valley. C=Comayagua, behind ridge. V.C.=Village of Cacaguapa. C.L.A.=Cerro Las Anonas. R.H.=Rio Humuya, as it leaves the R.H.G.=Rio Humuya Gorge. S.P.=Siguatepeque Plateau. E.R.=El Rosario.

PLATE 3



highly sheared, schistose and blastomylonitic rock with augen-shaped quartz lenses. These are interlayered with thick beds of less-sheared quartz-pebble to igneous- and metamorphic-clast boulder conglomerate. Within this sequence of schists and conglomerates are grayish green, mylonitized, stretched and boudinaged, fine-grained, felsitic igneous flows or sills up to a meter thick. All these rocks are deformed into tight, nearly isoclinal folds (pl. 4C). The metamorphic rocks are intruded by undeformed rhyolite and lamprophyric basalt dikes, probably related to those that intrude the Mesozoic sedimentary sequence.

The black, augen schist (#1) (pl. 4B) is a blastomylonitic graphite(?)-leucoxene-muscovite-albite-quartz schist. Augen lenses of crushed and recrystallized quartz are sheared out in a schist matrix. Opaques are carbon, probably graphite, leucoxene, and pyrite. Quartz makes up to 80 percent of the rock. The quartz lenses have calcite-filled cracks, cutting across schistosity formed by alignment of sutured quartz grains.

The conglomerate (#2) (pl. 4B, C, D) is a black to yellow brown, slightly cataclastic, poorly-sorted mixture of metamorphic quartz, hornfels (felsitic igneous rock fragments ?), and metamorphic rock fragments in a matrix of mica and opaque minerals, probably magnetite and leucoxene. Most of the metamorphic clasts are crushed and recrystallized quartz, muscotive-quartz schist, phyllite, and meta-chert. Grain sizes range from less than 1 millimeter in the finer-grained layers to more than half a meter in the coarse boulder beds. The large boulders have schistosities oriented askew to the outcrop foliation which "flows" around and conforms to the boulder outlines (pl. 4D).

The mylonitized felsite (#3) (pl. 4C) is a granulated and sheared mass of quartz and minor feldspar ranging from fine powder to 1 millimeter across. Some feldspar phenocrysts were spared total crushing and are now altered in great part to calcite. The finer grained groundmass is made mostly of wispy bands and clots of leucoxene, chlorite, sericite, and clay. Granulated calcite fills some veins that have been sheared after formation. In the outcrop the rock is a thin, hard layer that has been folded, stretched, and pulled apart to form boudins. Originally the rock was probably a thin siliceous flow or sill that was later silicified and sheared, possibly during the event that produced the mylonitization of the conglomerate.

Debris shed from the steep walls of the Humuya Gorge covers the contacts (pl. 4A). Thus, thickness and stratigraphic relationships are not evident in these few exposures.

Rocks similar to those in the Humuya Gorge crop out in the southeastern corner of the El Rosario Quadrangle. The high-standing Montaña de Comayagua is covered with a dense

PLATE 4

A. Rio Humuya Gorge looking north and downstream from center of grid 2711. Humuya Member outcrops form bed of river. Outcrops extend to where river narrows. High cliff on left is formed of Atima limestone. The village of La Colmena is just over the high ridge on the left. The vertical distance between the top of the cliff and river bottom is greater than 200 meters. Note debris slopes shedding colluvium into river, covering contacts.

B. Humuya Member. Photograph taken in Rio Humuya Gorge at boundary of grids 2711 and 2712. Mylonitized conglomerate (#2) above hammer, blastomylonitic, black, augen schist (#1) below.

C. Humuya Member. Photograph taken at same locality as plate 4B. Boudinaged, felsitic igneous rock (#3) in black, blastomylonitic schist. Note folding of felsite. Photograph taken looking down fold axis.

D. Humuya Member. Photograph taken at same locality as plate 4B. Boulder of older phyllitic schist with pre-Cacaguapa foliation included as clast in mylonitized conglomerate (#2).

E. Contorted marble unit in Las Marias Member. Photograph taken in grid 2909. Quartz layers define folding and shearing in marble. Photograph is 30 centimeters across.

F. Photomicrograph of texture within silicified marble (#14) of Las Marias Member. Width of field is .85 mm.

G. Photomicrograph of sheared meta-conglomerate (#4) showing two stages of shear development. Width of field is 2.2 mm.

H. Local, small-scale angular unconformity in Todos Santos conglomerate. Photograph taken by J. R. Everett at 313030 looking east. Section is overturned.

PLATE 4

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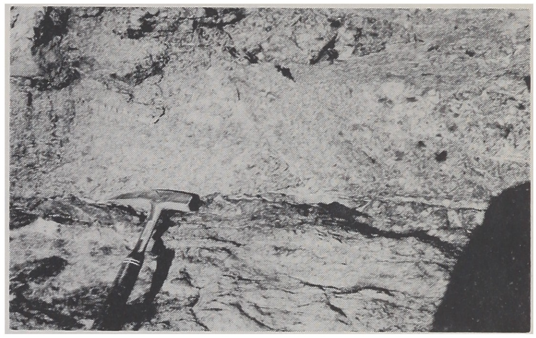

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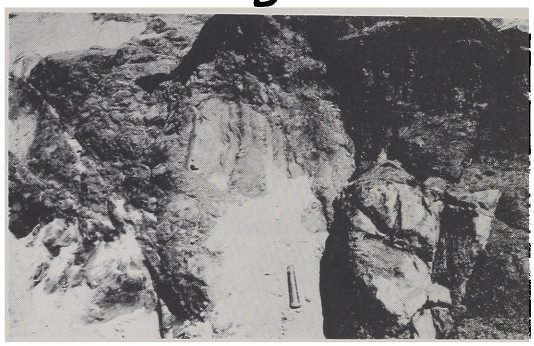

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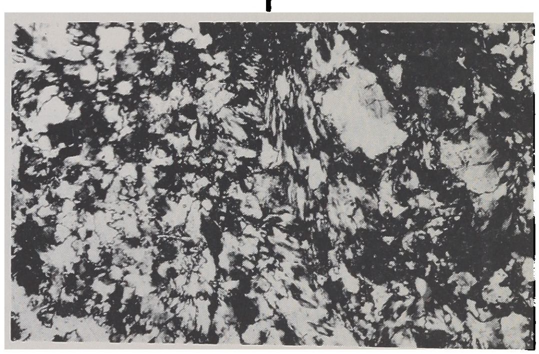

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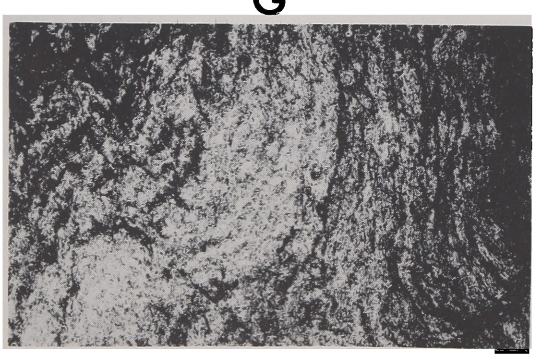

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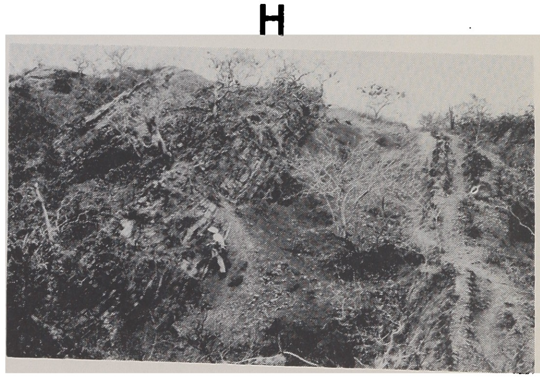

mantle of jungle. Extremely steep slopes are covered with landslide and colluvium on both the east and west sides (pl. 3). Thus, mapping the geology of the mountain is impossible within a short period and without much trail cutting. The only alternative is to collect specimens of boulders from rivers draining the steep slopes. I collected two suites of rocks from the high mountain in the southern part of the quadrangle. One is from the Rio Churune at the junction with the Rio Blanco (grid 3905). The other suite is from the Rio El Oro at Las Moras (grid 4507). The Rio Churune is accessible below the junction as well as the lower reaches of creeks draining the mountain on both sides north of these localities.

In the south along the base of the mountain boulders of black weathered, foliated, pebble conglomerate (#4) which may have undergone two episodes of shearing (pl. 4G), make up part of the Rio Blanco reverbed gravels. These are derived from the west slope of the Montaña de Comayagua. Along with the sheared metamorphosed conglomerate are boulders of epidote-rich quartzite (#5) and muscovite-quartz schist (#6). No meta-igneous rocks have been found in these boulders.

Boulders collected in the Rio El Oro on the east side of the mountain include mylonitic conglomerate of quartz and mica schist fragments (#7), spotted talc schist, with calcite nodules (#8), and highly foliated quartzite (#9).

Cliff-forming, yellow-weathered foliated rock (#10) crops out north of El Plan de La Laguna. The rock is a pale olive, sheared quartz-feldspar blastomylonite of about equal amounts of crushed and recrystallized plagioclase, probably albite, K-feldspar, and quartz. This could be either a mylonitized arkosic conglomerate or a sheared granite intrusion.

Many questions remain unanswered. One of these is whether the mylonitization is a regional feature related to the metamorphic events or a result of large-scale, post-metamorphic faulting. It is evident, from the metamorphic clasts in the conglomerate, these rocks were derived from an older metamorphic terrain. The large size of the metamorphic and igneous clasts indicates that they were derived from a nearby source, and that volcanism accompanied their deposition or followed soon after. The sedimentary and igneous rocks underwent one and possibly two metamorphic events that formed the schistosity, formed isoclinal folds, and may have also imposed the cataclastic texture. No diagnostic minerals have been found that indicate the metamorphic facies of these rocks.

Las Marias Member

Phyllite, muscovite-quartz schist, and chlorite-quartz schist containing stringers and lense-shaped blebs of quartz interlayered with one or more marble and quartzite beds underlie most of the metamorphic area from the Rio Humuya eastward to the west side of the Montaña de Comayagua. Good exposures form the road cuts of the La Libertad Road from Piedras Azules to Cacaguapa and crop out in the canyon bottoms of the Rio Cacaguapa and Rio Churune. These schists, marbles, and quartzites are herein called the Las Marias Member for the excellent exposures along the La Libertad Road in the Las Marias area. West of the La Libertad Road numerous small rhyolite and mafic bodies intrude the Las Marias Member; east of the road the only intrusive rocks found in the Las Marias Member are lamprophyric and dioritic dikes.

Las Marias schist holds up rolling hills with incised, V-shaped canyons covered mostly with pine trees. Soil and colluvium cover hillsides obscuring structural features in the rock. Marble and quartzite form steep-faced ledges.

Most of the Las Marias schist is a well-foliated and crenulated, yellow brown muscovite-quartz schist (#11) that weathers brownish olive. Sheared quartz stringers and blebs lie within the foliation. Limonite stains, the alteration product from pyrite, give the brown colors.

Chloritic and graphitic schists, interlayered with muscovite-quartz schist, are exposed in canyon bottoms where outcrops are less weathered. These may not make up a significant proportion of the Las Marias schist. They cannot be traced across country, because they weather to the same color of soil as the rest of the unit. The schist near the marble-quartzite layer just east of the La Libertad Road has lenses of muscovite, quartz schist with zoisite and vesuvianite(?) (#12). The majority of boulders in the Rio Cacaguapa where the Agua Fria timber road crosses it at grid locality 346079 are composed of chlorite-quartz schist (#17B).

Cliffs of a gray weathered, siliceous marble (#13) and quartzite layer (#14) form a prominent marker horizon within the Las Marias Member. The layer varies from a few meters to greater than 60 meters thick. The unit crops out in an arcuate band from near Cacaguapa on Cerro Loma Alta southward to Las Marias where it is thickest and forms the cliff high above the east side of the La Libertad Road. From Las Marias it trends eastward and then northwest to near the village of Loma de Cordero. Here it is terminated against a fault. Three isolated areas have outcrops separated from the main trend. One is the marble forming the high cliff above the village of Cacaguapa. Another is on the north side of Quebrada Vaquedano 4 kilometers east of

Cacaguapa. Here the marble may be the faulted extension of the unit at Loma de Cordero. The other outcrops form the ridge west of the La Libertad Road south of El Roblito. These may be another separate lens of marble at a different stratigraphic horizon than the main ledge former, because the marble layer is much thinner and more deformed than the marble in the main belt (pl. 4E).

The rock is a dusky grayish blue, siliceous marble that weathers gray and grades along strike into a bluish gray and dusky red quartzite. From a distance the two units look identical. The compositional change probably reflects a facies change in the original sedimentary rock from silty limestone to sandstone. Outcrops of the quartzite do not show small-scale deformation features, even though thin sections show the quartzite is highly deformed. Strongly undulose quartz with equant and irregular shapes and sutured borders combined with elongate, plumose and radiating, undulose grains make up most of the rock and give it a "snowflake" texture (pl. 4F). Swirling bands of hematite, limonite, and leucoxene associated with patches of calcite make up less than 10 percent of the rock and define foliation and folding.

Weathered marble surfaces, unlike the quartzite, show in great detail the highly contorted state of the Las Marias Member. Folded and sheared layers of quartz stand out in relief against the more calcite-rich areas (pl. 4E).

The northern end of the Montaña de Comayagua above the Rio Churune has outcrops of muscovite-quartz and graphite(?)-muscovite-quartz schist (pl. 3). Here associated with the schists are boulders of highly foliated amphibolite schist with interstitial quartz (#15 and #16). These are probably the same rocks Williams and McBirney (1969) report from the river bed farther downstream where the La Libertad Road crosses the Rio Chúrune. Boulders of amphibolite-rich rock from the side of the mountain high above La Laguna and Rio Churune and in the river at the base show all degrees of foliation development from good poikilitic, dioritic igneous texture to highly sheared, schistose and gneissic texture. The schistosity may be the result of shearing accompanying emplacement of dikes along faults and not necessarily the metamorphic event that produced the mica schists; although unlikely, these rocks may be sheared and altered post-metamorphic basalt and gabbro dikes and not metamorphosed volcanic rocks emplaced prior to the metamorphic event.

Some copper mineralization, mostly malachite and azurite, stain the marble in one outcrop on the ridge west of the La Libertad Road (#17B).

Metamorphic Facies and Correlation

Assemblages collected from the southern part of the mountain within the El Rosario Quadrangle are similar to the metamorphosed conglomerate found in the Rio Humuya. The Rio Humuya and the rivers draining the high mountain cut deeper into the metamorphic block than the Rio Cacaguapa (fig. 16). Thus, the Humuya Member may be a stratigraphically and structurally lower unit than the finer-grained Las Marias Member.

The mineral assemblages of the Las Marias Member, although not very indicative of metamorphic grade, show the rocks reached greenschist facies and some possibly reached the conditions of the lower grades of the amphibolite facies. The amphibolite facies rocks were collected from the lower slopes of the Montaña de Comayagua where the structurally deepest rocks of the Las Marias Member are exposed (fig. 16). Thus, the metamorphic grade may, in part, reflect depth of burial.

The Humuya Member mylonitic rocks have not been described from any other metamorphic areas near central Honduras. The Las Marias Member is similar, if not identical, to the Peten Formation (Carpenter, 1954) near San Juancito and the Palacagüina Schist (Zoppis Bracci, 1957; Dengo, 1969). Therefore, the Cacaguapa Schist is probably related to the Palacagüina Schist, but consists in part of structurally deeper facies, both compositionally and in metamorphic grades. The meta-igneous rocks described by Williams and McBirney (1969) from central Honduras can be interpreted as post-metamorphic, sheared lamprophyres or as metamorphosed mafic igneous rocks. However, the amounts and types of rock exposed and their structures do not compare with the published descriptions of the Chuacús or El Tambor eugeosynclinal suites.

TODOS SANTOS FORMATION

INTRODUCTION

The Todos Santos Formation is a redbed sequence of sandstone, shale, conglomerate, and volcanic beds that are in places over 1000 meters thick. The conglomerate beds usually make up less than half the sequence. However, they form more resistant outcrops and have greater variance in color than the sandstone and shale beds and thus, being the most prominent, they give the formation the appearance of being mostly conglomerate (pls. 4H, 5A, 5B, 5H). The volcanic beds are devitrified crystal-poor vitric tuffs interbedded with the clastic units. The conglomerates have clasts of mostly metamorphic or mostly volcanic origin. Near or at the top of the formation is an opaque-rare, bimodal arkose. These pre-Albian rocks probably formed from erosional products shed off faulted metamorphic blocks into

PLATE 5

A. Stair-step topography developed on flat lying Todos Santos Formation. Photograph taken at 452210 looking southwest. The main step over the falls is about 2 meters high.

B. Todos Santos Formation outcrops. Photograph taken at 318030 looking west. Photograph plate 4H taken on back side of main ridge in center ground at whitest bed. Beds dipping north are overturned. Village of Valle de Angeles is at bottom of slope.

C. Photomicrograph of Todos Santos Formation volcanic-clast conglomerate. Specimen #23, width of field is 2.2 mm, crossed nicols. Trachytic plagioclase tuff fragment on left, crystal-poor plagioclase vitric tuff fragment in center (dark), metaquartzite fragment in upper right (light).

D. Photomicrograph of Todos Santos Formation calichified volcanic rock. Specimen #27, width of field is .85 mm, plane light. Crystal-poor quartz vitric tuff (left) being replaced by coarse sparry calcite (right).

E. Photomicrograph of Todos Santos Formation sheared clay-rich conglomerate. Specimen #47, width of field is 2.2 mm, plane light. Metamorphic-clast conglomerate with clay matrix. Note shearing on left.

F. Photomicrograph of Todos Santos Formation volcanic rock. Specimen #53, width of field is 2.2 mm, plane light. Crystal-poor, argillized feldspar, quartz tuff from base of formation. Note embayed quartz border at upper left.

G. Photomicrograph of Todos Santos Formation volcanic clast from conglomerate. Specimen #69, width of field is 2.2 mm, crossed nicols. Devitrified crystal-poor quartz, K-feldspar, plagioclase tuff.

H. Large-scale crossbedding in Todos Santos Formation conglomerate. Photograph taken in Humuya Gorge at 284128 on the northwest side of the Rio Humuya looking northeast.

PLATE 5

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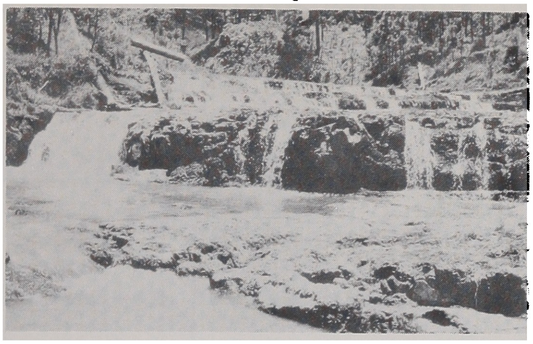

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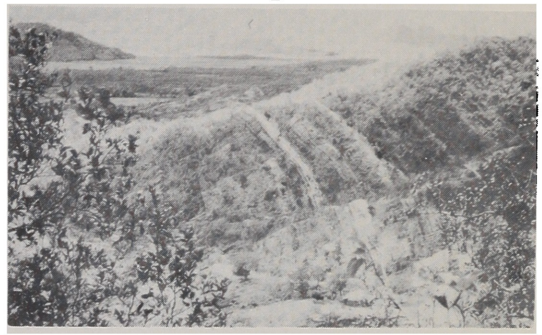

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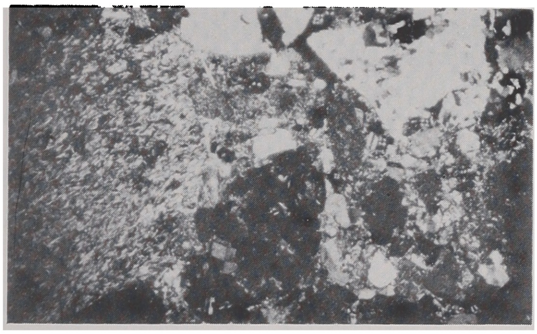

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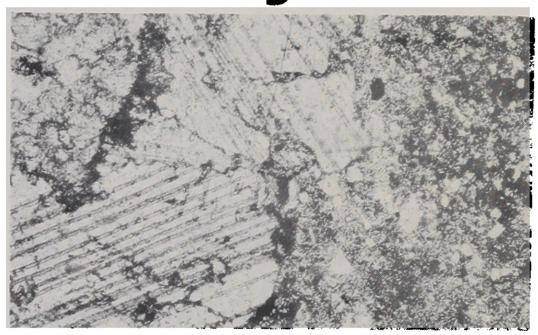

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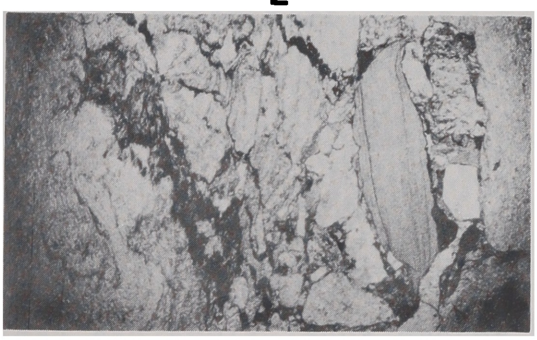

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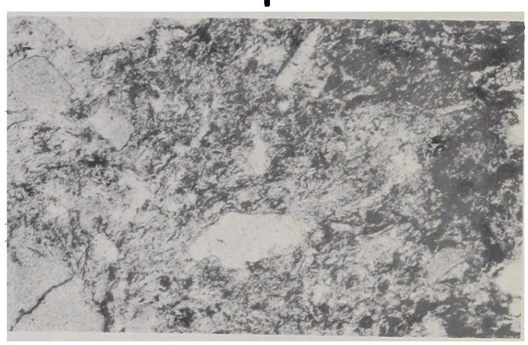

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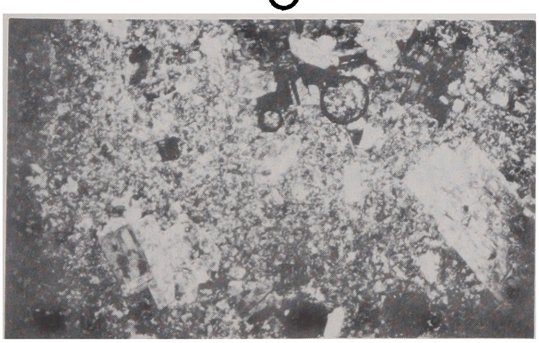


H

intermontane basins as coalescing fanglomerates and associated flood plain deposits in part concomitant with volcanic flow deposition.

Stratigraphic Nomenclature

Sapper (1937) first applied the name Todos Santos Formation to the oldest Mesozoic sedimentary complex exposed in Chiapas, Mexico, and Guatemala. These "sandstones, marls, shales and sandy slates, puddingstones, and conglomerates" (quoted from a translation by Walper, 1960) are named after a village in a deep valley within the Altos Cuchumatanes Mountains of northwestern Guatemala.

Dollfus and Mont-Serrat (1868) included these rocks within their Santa Rosa Series. Weaver (1942) correlated them with his section of Metapán Formation in El Salvador and the upper part of the Tegucigalpa Formation in central Honduras. Carpenter (1954) called weaver's lower part of the Tegucigalpa Formation the El Plan Formation and left the upper part (Todos Santos ?) unnamed.

Most students in Guatemala generally follow Sapper's lead and apply Todos Santos Formation to all clastic sedimentary packages with minor interbedded limestone and volcanic rocks that lie above the Permian Chochal Formation and below thick Cretaceous limestone. Richards (1963) divided Sapper's Todos Santos into two formations: 1) a lower formation with a lower conglomerate member and an upper siltstone-shale member, calling these the Todos Santos Formation, and 2) an upper formation, the San Ricardo Formation, of siltstone with a distinct limestone member. Anderson (1969) recognized the same grain size decrease upward in his sections, but resurrected Sapper's original definition, discarding San Ricardo Formation.

In Honduras at San Juancito Carpenter (1954) did not recognize the usual intermontane basin-type clastic sedimentary rocks predominant in the Todos Santos Formation, but mapped unnamed clastic rocks above the Triassic El Plan Formation and below Cretaceous limestone. Mills *et al*. (1967) applied Todos Santos Formation to all clastic sedimentary rocks above metamorphic basement rocks or El Plan Formation and below Cretaceous limestone.

Good accounts of the development of the nomenclature of these rocks are given by Anderson (1969) for Guatemala and Mills *et al*. (1967) for Central America in general.

Local Stratigraphy

In keeping with the tradition set by Sapper (1937), resurrected by Anderson (1969), and reinforced by Mills *et al*. (1967), I also include in the Todos Santos Formation all exposed sedimentary and interbedded volcanic rocks lying under Cretaceous limestone; the El Plan Formation has not been found in the El Rosario Quadrangle.

GENERAL APPEARANCE

Outcrops

Todos Santos exposures may consist of more than 1000 meters of stratigraphic section. Beds are generally continuous and regular along strike. Locally the beds are lenticular, usually lenses of sandstone in shale or lenses in sandstone and shale in conglomerate. In most places faulting makes it difficult to trace the beds along their strike. However, at El Sauce individual beds can be followed for more than a kilometer. Beds range in thickness from 10 centimeters to 2 meters. Lithologically similar packages of beds, *e.g.* a sandstone bed with some intercalated conglomerate beds or a conglomerate bed with intercalated thin sandstone and shale lenses, range from .3 meters to over 60 meters thick and can be traced throughout an unfaulted block. There is no apparent relationship between thickness and rock type. Sandstone and shale comprise possibly 60 percent of the section, but conglomerate is present everywhere. Because the conglomerate is ubiquitous and forms the resistant beds, it is the most obvious and striking rock type within the Todos Santos Formation, even though it makes up less than half the stratigraphic section.

The colors of Todos Santos outcrops are extremely variable with: 1) white, red, and green conglomerate beds containing clasts of many colors; 2) reddish brown to maroon shale and siltstone; 3) reddish brown volcanic beds with gray patches where carbonate has replaced the volcanic rock; and 4) greenish gray sandstone. The many colors of bedding help distinguish the Todos Santos Formation from the monotonous reddish brown outcrops of the Valle de Angeles Group.

Bedding is shown by layers of different grain sizes, grain composition, color, and internal sedimentary structures. Some beds have grain sizes that grade upward from coarse to fine; others have fairly uniform grain size throughout; but most beds are very poorly sorted from top to bottom. Many sandstone and conglomerate beds have large-scale crossbedding (fluvial?) up to half a meter thick (pl. 5H). Some shale beds have small-scale ripple cross beds. Locally the units have channel scour, cut and fill structures, and small-scale angular unconformities (pl. 4H).

Most of the carbonate in the Todos Santos Formation is secondary. A few shale beds have calcite nodules, 2 to 3 centimeters in diameter, with cracks filled by celestite or barite(?) (#33). Calichefication is common in the volcanic beds and may be the main agent of carbonate formation. Caliche balls and pisolites are a common form of carbonate and may represent old soil horizons. Locally some shale layers have large carbonate nodules up to .3 meters in diameter which appear to be aggregates of carbonate breccia possibly collected and held together by carbonate-secreting algae. Some of the smaller nodules may be remains of fresh water(?) coral.

Most Todos Santos outcrops weather to hard, resistant beds that form "stair-step" topography (pl. 5A), but some sandstone layers produce spheroidally weathered boulders, whereas, other sandstones, particularly the spotted arkosic sandstone, are extremely friable in most places.

The only uninterrupted sections of Todos Santos Formation exposed in the El Rosario Quadrangle are the thin edges of the unit around the metamorphic highland. Here the section, although thin, is complete from the underlying metamorphic basement to the overlying Yojoa Group carbonate rocks. The thickest sections are the southward-dipping section at El Sauce (fig. 12B and Appendix I), the westward-dipping section in the northeast corner, and the section exposed on the south limb of the Taulabé anticline in the northwest. Probably the best exposures I have visited and seen on photographs or topographic maps for a detailed study of the Todos Santos Formation in this vicinity are in the western part of the Vallecillo Quadrangle east of the El Rosario Quadrangle.

Contacts

The lower surface of the Todos Santos Formation is exposed only around the perimeter of the metamorphic highland. Elsewhere the lowest exposed parts of the formation are in fault contact with metamorphic rocks or younger sedimentary and intruded rocks.

The upper contact with overlying Yojoa Group carbonate rocks is not well exposed. The easily eroded marls of the Cantarranas Formation combined with overlying massive Atima limestone form mass-wasting cliffs that contribute colluvium covering much of the upper contact of the Todos Santos Formation. Also, the Cantarranas marls in many places are sheared and contorted, thus, obscuring or obliterating contact features that might show the nature of the original sedimentary contact. Where the Cantarranas is not disturbed by shearing the contact between the Todos Santos and the Cantarranas appears conformable. Bedding in the Todos Santos Formation is parallel or subparallel to the Yojoa Group bedding. This can be seen at El Sauce (grid 2707) and Cacaguapa (grid 3112). Therefore, I believe most Todos Santos rocks are conformable under the Yojoa Group.

Geomorphic Expression

The Todos Santos Formation is fairly easy to recognize in the field, on aerial photographs, and less so on topographic maps. Shallow dipping blocks form stair-step topography with coarse, well-cemented conglomerates forming ledges between units of more easily eroded shales and mudstones (pl. 4H). Steeply dipping beds form local flatiron-shaped slopes with V-shaped valleys and ridges and consequent rectangular drainage. On aerial photographs the Todos Santos Formation is easily distinguished by its well-bedded appearance, banded light and dark shades, and the usual sparse vegetation (pl. 5B). On topographic maps the cuesta forms of dipping Todos Santos beds are prominent, but flat-lying beds look similar to Tertiary volcanic rocks.

LITHOLOGY

Four genetically different lithologies and their combinations form the Todos Santos Formation: 1) clay-rich or clay-poor predominant metamorphic-clast conglomerate with interbedded reddish-brown sandstone, shale, and spotted arkose; 2) volcanic-clast conglomerate and spotted arkose; 3) devitrified crystal-poor vitric tuff; and 4) light colored, bimodal arkose. No syngenetic fossils that are useful for time-rock placement have yet been found in this formation.

Metamorphic-clast Conglomerate

Clay-poor conglomerate.--Metamorphic-clast conglomerate and associated finer-grained clastic rocks make up most of the Todos Santos Formation (#24, 28, 29, 30, 31, 50, 54, 56, 57, 59). Fresh specimens are dusky red, reddish brown, yellowish orange, gray or white, and usually show no bedding, even though outcrops are bedded by grain size. The rock has little porosity, low permeability, and is very poorly sorted. All clasts are angular to round and usually cemented by quartz, lesser hematite, limonite, chlorite, clay, or rare calcite. The rock consists of 20 to 90 percent common, unstrained quartz, vein quartz, and composite quartz. Other clasts are mostly quartz-sericite schist, quartzite, muscovite schist, phyllite, sandstone, chert (some with radiolaria), and shale (pl. 5E). Plagioclase and K-feldspar are rarer than in the volcanic-clast sedimentary rocks. Opaque minerals are mostly hematite with associated hematitized magnetite and some leucoxene.

Clay-rich conglomerate.--A clay-rich variety of the metamorphic-clast conglomerate (#43, 44, 45, 46, 47, 48, 49, 51, 52) forms much of the Todos Santos Formation in the area east of El Ciruelo in the southeastern part of the quadrangle. Here the outcrops are extremely weathered and, therefore, difficult to distinguish from weathered ignimbrite outcrops found elsewhere. It is possible that some of the area mapped as Todos Santos Formation may be, in fact, weathered ignimbrite. Thick soil horizons and dense brush hinder detailed mapping of the area. The outcrops weather to light colors of brown, orange, and yellow. The rock is composed of mica schist fragments in a clay matrix. Many of the specimens show varying degrees of shearing (pl. 5E). The deformation is probably very local adjustment to the stresses which produced major graben faults near the localities from which these specimens were collected.

Distribution of clay.--Besides the clay differences in the matrix the major difference between the clay-poor and clay-rich varieties of metamorphic-clast conglomerate is that the clay-rich variety comprises mostly mica schist fragments, whereas, the clay-poor variety is made mostly of quartzite clasts. This difference is probably the direct result of distance from source area and the type of source rock. These conglomerates were deposited as alluvial fans and their composition, in part, should be controlled by their position in the fan. As an alluvial fan grows it encroaches upon the highland source area. Only the head of the fan is adjacent to bed rock. Thus, the head of the fan will have the least winnowed and least abraded sediments. If a source area is predominantly mica schist with minor quartz, the situation at El Ciruelo, the head of the fan will have a much higher proportion of schist to quartz fragments than sediments down the fan slope. On the lower slopes the quartz is deposited while schist fragments are disaggregated to mica and clay and washed away. The clay in the conglomerate deposit at the head is derived from the breakdown of schist during and after diagenesis. Thus, the lowest units of a sedimentary package made of alluvial fan sediment, such as the Todos Santos, would have clay-rich, mica schist fragment conglomerate. At Las Marias the basal conglomerate, even though adjacent to the source area, has little mica schist and clay because the source rock is made of a higher proportion of quartzite and quartz veins than the metamorphic rock at El Ciruelo. One anomalous specimen (#73B), because of its high organic content, appears to have formed in a swampy environment. This is possibly a mud flow rock.

Volcanic-clast Conglomerate

The next most voluminous rock type is volcanic-clast conglomerate (#18, 23, 26, 38, 69), with associated sandstone and shale. These rocks are usually reddish brown to pale pink or greenish yellow. Hand specimens usually show bedding by grain size. Porosity and permeability are very low. Clasts are always poorly to very poorly sorted and angular to subangular, ranging from very fine sandstone to pebble conglomerate grain size. These are cemented by quartz, chalcedony, hematite, chlorite, or clay. Clast composition is usually 15 to 30 percent common quartz, lesser embayed, volcanic quartz, plagioclase, metamorphic quartzite, phyllite, schist, sedimentary grains of chert, sandstone, and mudstone, and minor volcanic grains (pl. 5C, G).

Spotted Arkose

Interbedded with metamorphic-clast and volcanic-clast conglomerates are beds of white-spotted, dusky red to reddish brown arkose that weathers maroon (#19, 36, 60, 70, 72). Most specimens are friable; quartz and hematite only partly cementing grains. Porosity and permeability are higher than in any other Todos Santos facies. As usual sorting is very poor. Grain size ranges from silty to granule sandstone. Clasts may comprise up to 65 percent embayed volcanic, vein, or common quartz. The white spots are vacuoled palgioclase or K-feldspar altered in part to clay. Metamorphic clasts are common and may be more prevalent than volcanic clasts. They include quartzite, mica schist, phyllite, and muscovite grains. Chert is abundant. Sand to granule sized volcanic clasts are trachytic, decussate plagioclase tuff, devitrified glass and crystal-poor, bent glass shard tuff. Magnetite, hematite and lesser leucoxene and limonite form the opaque minerals.

Poly-clast Conglomerate

Many beds are composed of conglomerate with about equal amounts of metamorphic and volcanic rock fragments (#22, 35, 40, 42, 55, 62, 71). Some have sedimentary clasts, probably reworked from older Todos Santos units (#28, 35, 38, 55, 64). It is difficult, if not impossible, to distinguish between metamorphic-clast, volcanic-clast, and poly-clast conglomerates in the field.

Sandstone

Very dusky red and gray sandstone (#58, 64, 68) beds are intercalated with conglomerate throughout the Todos Santos Formation and comprise most of the section. They contain mostly clasts of common quartz with varying amounts of clay. They are usually graded and crossbedded.

Shale

The least prevalent rock type within the Todos Santos Formation is shale (#34, 52). Recognizable silt to sand-sized particles include schist fragments, mudballs, chert, and anomalous blue chlorite. Secondary calcite nodules (#33) are common in some shale layers. Some of the nodules may be organic, however, no recognizable organic forms have been found.

Devitrified, crystal-poor, vitric tuff

At Las Marias, El Sauce, and the canyons of the Rio Humuya the Todos Santos contains thin, 1 to 5 meters thick, beds of crystal-poor plagioclase, quartz vitric tuffs (#20, 25, 27, 32, 37, 53, 65, 66, 67, 69). The groundmass of these tuffs is totally devitrified. Many of the tuff beds are replaced, in part to nearly completely, by fine to coarse calcite (pl. 5D). Some are pisolitic caliche ball beds, probably old surface weathering zones. The calcite and caliche-rich beds look like limestone and calclithite in the outcrop. The calcite-poor tuffs look like reddish-brown mudstone. The tuff units are usually interbedded with volcanic-clast conglomerate.

Generally they contain from 1 to 30 percent phenocrysts of embayed quartz, quartz-illite grains, and magnetite altered in part of hematite. Some have minor amounts of lithic fragments; trachytic decussate plagioclase tuff fragments and illite clumps are the most prevalent. Groundmass ranges from minor glass to devitrified glass of very fine quartz-illite-hematite-chlorite to lath-shaped plagioclase-quartz-illite microcrystals (pl. 5F, G). Leucoxene is rare and seems to be present only where there is chlorite.

Coarse, sparry calcite either totally replaces volcanic material or selectively replaces the matrix, leaving patches of tuff or volcanic grains and phenocrysts floating in calcite. Hematite concentrations in the calcite retain the wispy flow structure originally present in the tuffs. The caliche balls or pisolites retain, in part, the wispy flow structure, but calichefication does, in places, completely remove the original tuff texture.

In many places near the top of the section lie one or two discontinuous, thin layers of hard, yellow or purple-spotted, greenish-gray, fine-grained, porphyritic volcanic rock. In the outcrop these look like altered rhyolite sills. Thin sections show a crystal-poor tuff texture, similar to some of the textures of the intruded rhyolite discussed below. Compositionally these are very similar to the calcite-replaced tuffs except they have a more prominent foliation parallel to bedding in hand specimen and are greenish gray. Pumice fragments in some contain enough hematite staining to give the rock a purple-spotted appearance. Yellow spots are probably weathered feldspars. Everett (1970) believes that similar layers in the Comayagua Quadrangle were, at least in part, deposited during the deposition of Todos Santos sediments as air-fall tuffs. In the El Rosario Quadrangle I cannot tell whether they are syndepositional with Todos Santos sediments or intruded later because: 1) these layers are identical in thin section to rhyolite dikes that intrude Yojoa Group carbonate rocks, and 2) they do not bake the surrounding sedimentary rocks and Valle de Angeles red-beds along fault zones, but, on the other hand, I have not found any of these thin layers, which cut sedimentary section along strike. Therefore, there may be two periods of fine-grained tuff or rhyolite emplacement recorded within Todos Santos sedimentary rocks: 1) Todos Santos air-fall tuff deposition, and 2) post-Mesozoic dike or sill intrusion.

<u>Light-colored Arkose</u>

Up to over 30 meters of discontinuous, light-colored, opaque-poor, bimodal arkose or subarkose (#21, 39, 61, 73A) crop out at or near the top of the section. In places it grades into overlying carbonate rock. At a few localities it is overlain by a few meters of conglomerate. The rock is brownish olive, hard, usually poorly bedded, and has low porosity and permeability. The grains are bimodal granule sands and clayey sands cemented primarily by quartz. Clasts are mostly quartz and altered feldspars, probably K-feldspar, producing kaolinite. Some mica schist and vein quartz clasts are present. Rare hematite is about the only opaque mineral. These rocks have bimodality, lack of heavy minerals, and grain size common in aeolian dune sands. Some reworking of these rocks is required to disturb the good bedding features common to dune deposits. The discontinuity of these sands along strike over the whole area also seems likely, if they are reworked dune sand.

DISTRIBUTION

The Todos Santos Formation crops out in the northwest corner of the quadrangle in fault-bounded blocks and the faulted Taulabé anticlinorium. Here the lower surface is not exposed. The formation is overlain conformably by Atima limestone or unconformably by a blanket of Tertiary ignimbrite.

In the northeast the Todos Santos is exposed as inliers where the overlying Atima limestone and Tertiary ignimbrite has been eroded. Here the rock is relatively unfaulted. Most contacts are sedimentary and are the upper surface of the Todos Santos conglomerates. The lower surface is not exposed.

In the center of the quadrangle Todos Santos rocks lie nonconformably on metamorphic and igneous rocks. East of Cacaguapa they dip northward under ignimbrite. At Las Marias and El Sauce they dip southward under Yojoa Group limestones. West from Cerro El Cubo they generally dip west off the metamorphic rocks under a limestone cap. Thus, they generally ring the metamorphic high and dip away from it in all directions.

The contact with limestone in the south near Valle de Angeles is in part a fault: overturned Todos Santos beds lie adjacent to and below Cretaceous limestone. Here the Todos Santos is exposed in a broad overturned syncline that is highly faulted. Numerous faults bound small blocks tilted in almost any possible direction so that measuring section is nearly impossible (fig. 12A).

Todos Santos rocks are also exposed in the canyons of the Rio Humuya from El Tamboral, near the Carretera de Norte, to Cacaguapa on the La Libertad Road. Near El Rosario Todos

Santos conglomerates are displaced by high-angle reverse faults against limestone or by normal faults against younger rocks.

THICKNESS

Figure 10 shows the variation of thickness of the Todos Santos Formation in the El Rosario Quadrangle. The thinnest section of Todos Santos crops out around the metamorphic high. At Las Marias (Appendix I) 35 meters of Todos Santos lie between the nonconformity on metamorphic rock up to the overlying Cantarranas Formation. At Cacaguapa (Appendix I) the Todos Santos Formation is 155.7 meters thick. In the northwest corner, farthest from the metamorphic high, the section that is exposed is at least 500 meters thick. In the northeast possibly more than 1000 meters of conglomerates are exposed within the quadrangle. The northeast section may be much thicker, for it continues toward the east into the Minas de Oro and Vallecillo quadrangles, each of which has a very thick exposed section of steeply-dipping Todos Santos rocks.

The presently exposed metamorphic rocks stood as a high, possibly bounded by faults, during Todos Santos deposition. The Todos Santos Formation is thickest in the central portions of basin lows and thinned toward the high-standing blocks, probably lapping onto, but never completely covering it. This would produce an on-lapping sequence with the

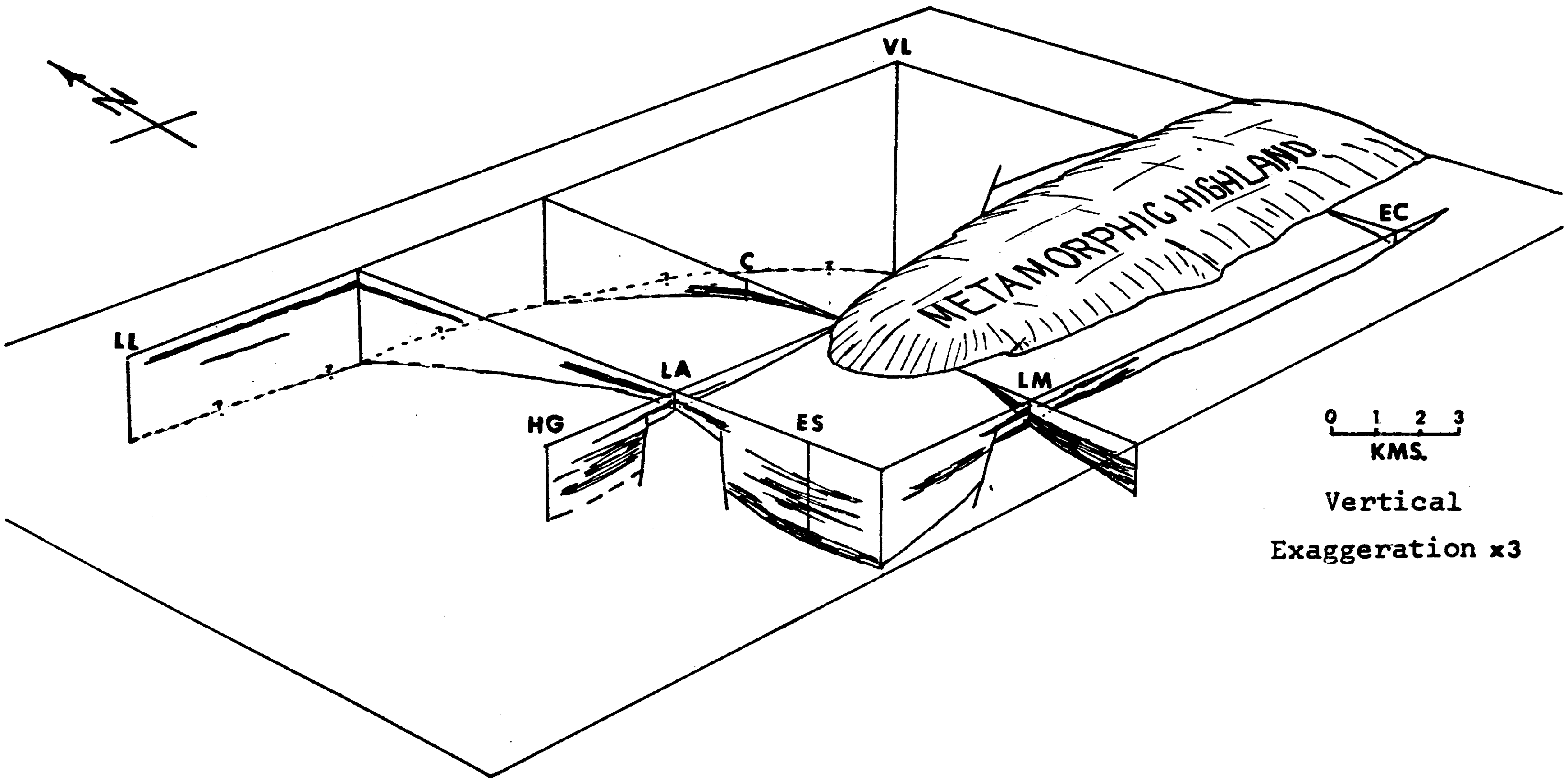


Figure 10. Block diagram showing thickness of Todos Santos Formation in the El Rosario Quadrangle. Dark areas are volcanic rock or volcanic-clast conglomerate. Faults are hypothetical. C = Cacaguapa described section 2, Appendix I; E.S. = El Sauce described section 3, Appendix I; L.M. = Las Marias described section 1, Appendix I; L.L. = Las Lagunas; V.L. = Vallecillo Limpio; H.G. = Humuya Gorge; L.A. = Cerro Las Anonas. Sections hung on bottom of Yojoa Group. Vertical Exaggeration x 3.

facies exposed in the sections adjacent to the high being the uppermost portions of the formation.

AGE AND STRATIGRAPHIC RELATIONSHIPS

Age

No syngenetic fossils have been found in Todos Santos rocks of the El Rosario Quadrangle. A younger limit to the age of these rocks can be guessed from the age of fossils found in the overlying Yojoa Group (See Yojoa Group below.). The overlying limestones are Late Neocomian or younger. Thus the Todos Santos Formation is Late Neocomian or older.

The older limit of Todos Santos age is more difficult to derive. The metamorphic rocks may be as old as 215 m.y., if they were altered during the same events that metamorphosed rocks in eastern Guatemala (Long and Clemons, 1969). Mills *et al*. (1967) believed the Todos Santos in the Comayagua region is younger than the Late Triassic or Jurassic El Plan Formation. I feel the transitional nature of facies from the upper Todos Santos Formation into the overlying Cantarranas Formation favors an age closer to or within the Early Cretaceous.

Stratigraphic Relationships

Todos Santos conglomerates lying directly under the Yojoa Group crop out from Comayagua westward to at least San

Pedro Zacapa near Lago Yojoa. Todos Santos-type conglomerates are exposed from around San Juancito, near Tegucigalpa and discontinuously to Olancho in east-central Honduras. Mills *et al*. (1967) felt that the conglomerates underlying Yojoa Group limestones are Todos Santos Formation to the western border of Honduras. Crane (1965) had shale, sandstone, and conglomerate underneath Cretaceous limestone in eastern Guatemala which he called Todos Santos. In western Guatemala at the type locality for Todos Santos Clemons (personal communication, 1969) mapped several thousand meters of Todos Santos conglomerate that he felt is correlative with Crane's clastic rocks in eastern Guatemala. Therefore, conglomerates have been mapped from western Guatemala to east-central Honduras as Todos Santos Formation. Whether all these outcrops represent exposures of one continuous rock body is not possible to determine at present, and is probably unlikely, if they are deposited in disconnected intermontane basins. Regardless, because 1) they were all deposited in similar environments (intermontane basins), 2) they all appear to be similar in age (Triassic to Early Cretaceous) and deposited during the taphrogenic phase of the Jaliscoan cycle (Mills *et al*., 1967), and 3) no other types of rock were deposited during this time, it is easiest, although not safest, to assume they are the depositional evidence for one tectonic period of Central American geologic history and, thus, may all rightfully be called Todos Santos Formation, even if they do not represent one originally continuous rock body.

In the Todos Santos Formation in the El Rosario Quadrangle volcanic-clast conglomerate predominates in the lower part. Tuffs are prevalent just south of the high at El Sauce and in the Humuya Gorge (fig. 10), but elsewhere they are represented only by the spotted, greenish-gray tuff. Around the metamorphic highland metamorphic-clast conglomerate dominates the section. These clasts were most probably derived locally from this high. At the top reworked dune sands are discontinuous and locally overlain by a thin metamorphic-clast conglomerate just below carbonate rock.

ENVIRONMENT OF DEPOSITION

Most students who have studied the Todos Santos Formation believe that it was deposited in intermontane basins as fanglomerates and associated fluvial sands. This model will also hold in central Honduras, but must be expanded to include volcanism. As faulting started debris was eroded off highland blocks and washed as conglomerates of coalescing alluvial fans into the basin lows accompanied by deposition of tuffs. Some of the resulting deposits may be the age equivalents of andesite and volcanic conglomerate that Mills *et al*. (1967, p. 1765) reported in Olancho, eastern Honduras. The tuffs may have fallen into saline lakes, allowing immediate alteration and diagenetic processes to cement and replace the tuff with carbonate well enough for the tuff layers to hold up under later deposition of conglomerate. Those deposits that were torn up provided in part the clasts that form the volcanic-clast conglomerates. All the while metamorphic debris was feeding the fans, especially near the highland. When the tuffs were exposed for any length of time caliche-forming processes produced caliche-ball soils. Near the close of Todos Santos deposition as tectonic activity subsided sand dunes wandered across the region. A few floods eroded some of the dune sand and deposited patches of alluvial fan material on the rest. At this point the area was inundated by a rather quiet sea, setting the stage for carbonate deposition. Thick deposits of conglomerate with detrital feldspar, included sand dunes, lack of plant or animal fossils, and caliche formation all indicate an arid or semiarid climate during deposition. The paucity of sedimentary structures within the dune sand may be the result of the encroaching Cretaceous sea reworking the sands as it lapped onto the highland.

YOJOA GROUP

INTRODUCTION

The Yojoa Group is a carbonate sequence with thin marly limestone locally present at the base and a thick well-bedded to massive, cliff-forming, fossiliferous limestone comprising the rest. These limestones range in age from Neocomian (?) to Cenomanian (?), but have mostly Albian and Aptian faunas. The marly limestone is probably a back-reef facies deposited on the landward side of oyster bank reefs growing on the flanks of a highland of Todos Santos rocks.

Stratigraphic Nomenclature

The Yojoa Group, named after Lago (lake) Yojoa in Honduras, is the name Mills *et al*. (1967) gave to the Lower Cretaceous carbonate rocks of Honduras to extricate students in Honduras from the names and stratigraphic usage in Guatemala and early work in Honduras. Discussions of stratigraphic nomenclature of carbonate rock in Honduras are in Mills *et al*. (1967) and for Lower Cretaceous carbonate rocks of Guatemala in Anderson (1969). Mills and his colleagues assigned four formations to the Yojoa Group: 1) Cantarranas Formation, a basal carbonate sequence containing thin-bedded, dark limestone and shale of Neocomian to Albian age; 2) Atima Formation, massive cliff-forming Albian to Late Cretaceous limestone; 3) Ilama Formation, limestone conglomerate interbedded with Atima and Cantarranas limestones; and 4) Guare Formation, thin-bedded, black shale and limestone younger than the Atima Formation.

Carpenter (1954) first used the name Cantarranas for all Cretaceous limestone cropping out at San Juancito near Tegucigalpa. Mills _et al_. (1967) applied Cantarranas Formation to the basal part of the carbonate sequence throughout Honduras that commonly contains thin-bedded, dark limestone and shale of Neocomian to early Albian age. They considered it to be equivalent to Carpenter's Cantarranas Formation.

The Atima Formation was named by Mills _et al_. (1967) for the massive, cliff-forming, gray to dark gray rudistid-rich limestone exposed at Atima Pueblo and in the Atima River Gorge in the western part of Departamento Santa Barabara in Honduras. They correlated it to the massive Lower Cretaceous Ixcoy and Cobán limestones in Guatemala and possibly in part to Carpenter's (1954) Cantarranas Formation at San Juancito in Honduras. It is also probably equivalent to the limestone exposed at Esquias which Weaver (_in_ Schuchert, 1935) called the Esquias Formation.

Local Stratigraphy

In the El Rosario Quadrangle I recognize only two formations of the Yojoa Group: 1) Cantarranas, light gray-weathered, marly facies found at the base of the carbonate sequence; and 2) Atima, massive, cliff-forming, gray to dark gray limestone and dolomite.

CANTARRANAS FORMATION

General Appearance

Outcrops.--The Cantarranas Formation is thin, laminar- to lenticular-bedded, light gray, clay-rich limestone. Outcrop areas are usually shallow sloping, light gray caliche and yellowish gray soil-rich hillsides with small, flat, disc-like boulders of shaly limestone up to 3 centimenters thick that from a distance look like cow paddies. During the dry season a red grass grown on Cantarranas hillsides giving the surface the same color as Valle de Angeles Group hillsides. Exposures are rare where the Cantarranas is protected from erosion by overlying massive Atima limestone because the debris from the cliffs above cover the hillside. Where Cantarranas is exposed under these massive cliffs erosion has cut into the marly limestone forming a recess in the slope. Thin, lenticular, harder blocks, usually fossil-rich, break out easily from the neighboring intercalated clay-rich zones. Thus, the outcrop has a flaggy-bed texture and produces disc-like boulders. Toward the top of the formation the outcropping rock is more cohesive and forms more resistant slopes.

Discontinuous lenses, usually 6 centimeters or less thick and a few meters long, of hard, fine-grained limestone form bedding within more prevalent shaly marls. The shaly marls have very little structure probably due to both burrowing of marine organisms during deposition and to cleavage imposed upon them after diagenesis.

Internal structures.--In the Comayagua Quadrangle adjacent to the south much of the Cantarranas Formation is highly sheared into kink-banded, slaty layers with the original bedding in places totally obscured by these later deformational features (pl. 6D), discussed by Everett (1970). Fossils have much higher shear viscosities than the host marly limestone allowing some to remain intact. In the El Rosario Quadrangle, however, only the outcrop of Cantarranas Formation in the fault slice 1 kilometer north of Las Marias (305080) displays this type of shearing. Here, similar to the Cantarranas near Comayagua, the bedding is obscured by cleavage, fossils are intact, but no kink-banding is developed. The cleavage is probably produced by shearing imposed during movement along the fault.

Contacts.--Generally contacts of the Cantarranas Formation are covered by scree slope debris. Strikes and dips within the Cantarranas are parallel to those of the underlying Todos Santos Formation and to those that can be measured in the overlying Atima Formation. Thus, the formation is believed to be conformable from Todos Santos into Cantarranas and from Cantarranas into Atima. The boundary between Cantarranas and Atima formations is gradational from clay-rich

PLATE 6

A. Atima limestone cliff and landslide of limestone blocks over Todos Santos Formation. Photograph looking west at 264110 in Rio Humuya Gorge. Top of hill is 250 meters above Rio Humuya bed. Trees just below limestone cliff are growing on Atima boulder landslide which covers the Atima-Todos Santos contact.

B. Atima limestone cliff. Photograph looking north at 197139. Limestone is 360 meters thick from bottom of photograph to top of hill. Cliff is scarp along San Jacinto Fault.

C. Basalt flow in La Sabana ignimbrites. Photograph looking south in grid 2603. Maguey plants are growing on basalt. Light colored plants on ignimbrites above are cactus. Photograph taken from ridge in middle of photograph in plate 7 looking to the right.

D. Kink-banding in sheared Cantarranas Formation. Photograph looking west at 292012 on La Libertad Road in Comayagua Quadrangle 2 kilometers south of the El Rosario Quadrangle. Photograph taken by John R. Everett.

E. Atima limestone and colluvium over Todos Santos Formation. Photograph looking northwest at 252086 in Rio Humuya Gorge. Near slope on left side of river is colluvium from Atima limestone cliffs not in picture.

F. Valle de Angeles Group redbeds exposed in Quebrada Hembras at 226079. Photograph looking west. Minor faulting is abundant. A large fault is recognizable at left edge of picture behind Paul Fakundiny; another is just to right of field of view.

G. Cliff of Cerro la Cañada ignimbrites forming skyline rim. Photograph looking northwest at village of El Rosario. Skyline is the Siguatepeque Plateau in the Siguatepeque Quadrangle.

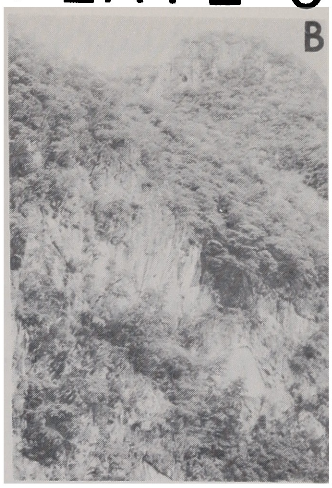
H. Photomicrograph of silicified basal glass of La Sabana ignimbrites. Appendix number 132. Width of field is .85 mm. Crossed nicols. Note "rice"-shaped quartz grains.

I. Photomicrograph of dolomite rhombs replacing micrite limestone matrix. Specimen #80. Width of field is .85 mm. Plane light.

PLATE 6

A

B



C

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E

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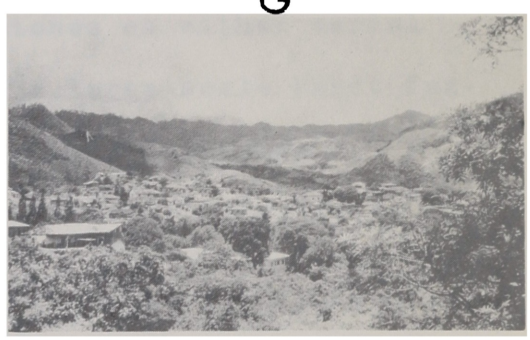

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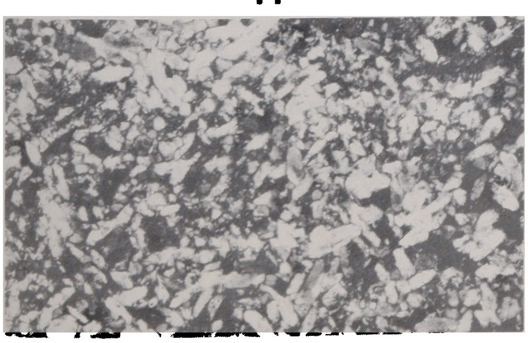

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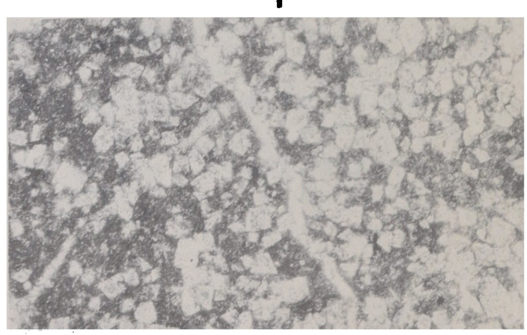


to clay-poor, Orbitolina-bearing limestone. This contact is arbitrarily mapped at the base of beds where the fossil-clay ratio is high enough to produce erosionally resistant outcrops similar to the overlying massive units within the Atima Formation.

Geomorphic expression.--Because it is easily eroded, the Cantarranas Formation forms topographic indentations at the base of the Yojoa Group carbonate sequence. Except for the small outcrop caught in the fault slice north of Las Marias the Cantarranas Formation only remains where it has a shielding cap of Atima limestone. Once the Atima Formation limestones are removed erosion rapidly strips the Cantarranas marls to form shallow-sloped hillsides and eventually exhumes the underlying resistant clastic rocks of the Todos Santos Formation. I cannot distinguish between thin-bedded Atima and Cantarranas limestones on either aerial photographs or topographic maps. No large-scale karst features have been found in the Cantarranas Formation.

Lithology

The Cantarranas is generally a fine calcilutite to medium calcarenite: clay-rich fossiliferous disturbed biomicrite with abundant organic material (#74, 75, 76). Fresh rock is very dark grayish brown to yellowish brown and weathers brownish olive to light gray. Fossils are predominantly Orbitolina and miliolids, usually aligned parallel to and enhancing the bedding. Much of the rock is disturbed or bioturbated probably by burrowing marine organisms. Sparry calcite is common in the disturbed parts. The rock has sparse, angular, silt-sized quartz grains, probably blown into the depositional area from the exposed highland. Clay is usually illite and probably detrital. There is some magnetite altering to hematite, but most of the opaque minerals are pyrite altering to limonite, which produces the yellowish colors. A dendritic, opaque mineral, possibly manganese oxide, is present in some clay-rich samples. Broken pelecypod shell fragments are common. Echinoid spines are also present. Rarely whole echinoid shells weather out of the rock. Organic material, usually tar stringers in cracks, is common.

ATIMA FORMATION

General Appearance

Outcrops.--Atima Formation is a massive, cliff-forming, light gray to bluish gray-weathered limestone and dolomite comprising most of the Yojoa Group carbonate sequence (pl. 6A, B, E, 12C). Locally it is shaly Orbitolina-rich rock, massive, over 10 meters thick, oyster beds, or rare rudistid reefs. Bedding ranges from 6 centimeters or more thick shales to more than 15 meters thick, massive, unbedded layers (pl. 6B). Fresh rock ranges from bluish black and very dark grayish brown to light gray and white. The weathered rock is light gray to bluish gray. The village of Piedras Azules is named after the striking bluish gray boulders it is built upon. Fresh bluish black rock usually gives off a petroliferous odor when broken. Locally the Atima limestone contains black chert nodules and lenses up to 15 centimeters thick. In places white calcite veins cut the rock along joints or gash fractures (pl. 11D). Karren erosion features are common and sink hole karst forms irregular erosion surfaces. Usually bedding is not evident in the eroded outcrops, but is reflected in rows of aligned, large, round boulders with terra rosa soil in between. The terra rosa soil between massive limestone boulders is the Honduras farmer's favorite site for growing corn. Where expressed, bedding is usually formed of layers and lenses, some over 10 meters thick, of broken shells which Mills *et al*. (1967) called patch reefs.

Contacts.--The lower contact of the Atima where it is underlain by the Cantarranas Formation is arbitrarily placed where the clay content of the limestone is low enough to make the erosion character similar to the main mass of Atima limestone above. Where Cantarranas is absent the Atima lies directly on Todos Santos clastic rocks. The Atima-Todos Santos contact is usually covered by Atima erosion debris and soil, but is believed to be conformable (pl. 6A, E).

The upper contact with Valle de Angeles Group clastic rocks is usually sharp and conformable. At Mezcales, 7 kilometers west of San Antonio de la Cuesta (2917, 2918), the Atima limestone interfingers with Valle de Angeles redbeds. Here the limestone is calichefied.

Geomorphic expression.---On dip slopes Atima outcrops form distinctive hummocky surfaces with karst holes and large round boulders. Most striking, however, are the high cliffs formed where Atima limestone is being stripped off the underlying Todos Santos Formation (pl. 6A, B, E). Below the cliffs limestone scree slopes and landslides spread jumbled boulders into the canyon bottoms. Thick brush grows over much of the exposed Atima Formation adding, along with karst features, to the difficulty of moving around over the surface. The geomorphic expression of Atima is very distinctive on both aerial photographs and topographic maps. Steep slopes are almost always capped by Atima limestone, except for the cliffs formed by ignimbrite layers in the southwest and northeast. Depressions form on both Atima and ignimbrite, but the ignimbrite is usually much lighter in color and devoid of thick brush, and some ignimbrite depressions are filled with water.

Lithology

The Atima Formation has within it many of the common lithologies usually associated with massive limestone including: 1) calcarenite: sparse to packed foram biomicrite to biosparite (#88), 2) calcirudite: sparse to packed fragmental pelecypod dismicrite, pelmicrite, biosparite, and intrasparite (#78, 81 to 89, 91, 92, 94, 95, 97 to 99, 102, 104 to 107), 3) calcilutite (#79), and 4) medium to coarsely crystalline saccharoidal replacement dolomite (#77, 80, 93, 96, 103, 108, 110, 112). Micrite-coated, round intraclastic sparite probably formed by high energy wave action.

Generally fresh rock is dark gray, very dark grayish brown, or bluish black; dolomitized specimens are usually lighter colored.

The rock may have included illite clay, angular (detrital) or euhedral (authigenic) silt-sized quartz, also magnetite altering to hematite, pyrite altering to limonite or hematite, and rare leucoxene.

Pelletiferous micrite is common as matrix. In many specimens the pellet outlines are blurred, probably reflecting bioturbation or other disturbing action. Neomorphic sparry calcite is most commonly associated with micrite that does not have pellet shapes (#79, 83, 90, 96 to 99). Organic material, mostly in the form of tar, is abundant and usually concentrated along stylolitic cracks (#80, 82, 87, 90, 91, 94, 95, 96, 98 to 102, 104, 195).

Replacement dolomite is common, especially in the outcrops forming the north-northwest-trending hills south of El Sauce and in parts of the section on Cerro Las Anonas (#80), (pl. 6I). Fossils are usually destroyed in the dolomitizing process, but rare miliolids remain in some specimens.

Black chert is concentrated along some layers. In one specimen (#101) it formed as replacement silica in an intrasparite. Also found in chert-rich limestone layers are silicified pelecypod fragments and chalcedony replacing a matrix of pellets (#80, 82, 96, 100, 101, 111, 112). Dolomite rhombs are commonly included in the replacement silica. Authigenic quartz (hexagonal crystal forms) have grown in some rocks with pelletiferous matrix (#94, 108) or in dolomitized rock (#110).

Limonite and clay are concentrated along stylolitic cracks and may be residuum after calcite dissolved.

Common fossils include: miliolids, Orbitolina, bryozoans, Gryphaea-like pelecypods, oysters, ostracods, echinoid fragments and spines, spiral gastropods, caprinid rudistids, spiral and Globigerina-like foraminifera, and algae(?). Mills et al. (1967) reported the only list compiled so far of fossils found in the Atima limestone in the Comayagua region. The fossils I collected were lost in transit to the paleontologist.

DISTRIBUTION

Cantarranas Formation

The Cantarranas Formation is only exposed near the metamorphic highland at: 1) Cacaguapa, 2) El Sauce to Piedras Azules, and 3) Valle de Angeles. Elsewhere it is either covered by scree, sheared out along décollement zones or was never deposited.

Mills et al. (1967, p. 1748, cross section D-D') show three outcrops of Cantarranas along the La Libertad Road, the middle one is shown with a question mark. The southern exposure at 295059 is as they represent it. The middle exposure at 305080 is a sliver of Cantarranas caught in a fault zone with Todos Santos clastic rocks on both sides. The marly facies of the carbonate sequence has not been found on the north side of Cerro Las Anonas as they show it with a question mark. Here an Orbitolina-rich rock crops out, but forms resistant cliffs. At the northernmost locality they show the Cantarranas at the base of the carbonate sequence, which it is, but the block tilts southward, not northward as they interpreted from aerial photographs (Kenneth E. Hugh, personal communication, 1968). Therefore, the Cantarranas Formation is exposed in that fault block at Cacaguapa.

Atima Formation

Atima limestone crops out all around the metamorphic highland. It forms west-dipping slopes at Cerro El Cubo in the southeast, floors the Cacaguapa Valley at Guacamaya, holds up the ridge extending from Valle de Angeles to El Rosario, holds up Cerro Las Anonas (pl. 7), forms cliffs north of the metamorphic highland from El Robalse to Cacaguapa, crops out as an inlier through volcanic rocks at El Portillo on the Rio Churune, forms dip slopes at Jacintillos in the northeast, crops out in fault blocks on the south limb of the Taulabé anticline in the northwest, and forms massive cliffs in the extreme west at Plazualas (pl. 6B, 12C) and Lomas Verdes.

It is not certain whether the Atima Formation ever totally covered the metamorphic highland. No outcrops have been found either as erosional outliers or in downfaulted blocks within the exposed metamorphic region east of the La Libertad Road. Some onlapping, farther on to the highland than now exposed, must have existed, because thick sections of Atima are faulted against metamorphic rock along the northern border of the highland. There is no evidence for older rocks being exposed during the formation of Atima limestone, except the minor amount of angular silt-sized quartz, postulated to have been blown into the area of limestone deposition.

THICKNESS

Cantarranas Formation

The thickest section of exposed Cantarranas Formation is at El Sauce (Measured Section III, Appendix I). Here the thin-bedded, marly limestone is about 70 meters thick. It rapidly pinches out to the west and is terminated along strike to the east against the Las Marias Fault zone. Near the village of Valle de Angeles it is never more than 20 meters thick. At Cacaguapa it is patchy and never more than 10 meters thick.

Atima Formation

The Atima Formation varies in thickness throughout the El Rosario Quadrangle ranging from about 97 meters at Cacaguapa to at least 333 meters at Cèrro Las Anonas (Measured Sections II and IV, Appendix I). Near Plazualas 4 kilometers northwest of El Rosario a very thick section of Atima forms the cliffs at El Horno and Gran Cerro (pl. 6B, 12C). Here, however, the section may be repeated by faulting. In the north wall of the canyon just north of El Horno unbedded limestone forms a vertical cliff at least 250 meters high (pl. 6B).

AGE AND STRATIGRAPHIC RELATIONSHIPS

Age

Cantarranas Formation.--Mills et al. (1967) placed the age of the Cantarranas Formation as Neocomian to Aptian on the basis of fossils collected along the Rio Guare at Anderson's Sawmill 2 kilometers north of the northwestern part of the El Rosario Quadrangle. The fossils were identified by Brönniman and Bonet (in Mills et al., 1967, p. 1781) who gave an age assignment of Early Albian.

Atima Formation.--Mills et al. (1967, p. 1782, localities 128, 129, 130) collected fossils from 3 localities in the Atima Formation within the El Rosario Quadrangle. These specimens were studied by Federico Bonet, C. Teller, and M. Trejo. Near the base of the Atima they found abundant *Orbitolina texana* and possibly *Orbitolina minuta*? (benthonic facies) which they believed to be Early Albian. A little higher in the section they found abundant *Orbitolina* sp. (benthonic facies) supposedly Middle to Early Albian. In the upper part of the Atima limestone they found *Nummoloculina* sp. and *Cuneolina* sp. (benthonic facies) which they concluded to be probably Albian, but Late Cretaceous was not excluded. Thus the Atima Formation within the El Rosario Quadrangle spans nearly the entire Albian Stage.

Stratigraphic Relationships

Contarranas Formation.--The Cantarranas Formation lies above the Todos Santos Formation and below the Atima Formation wherever it is exposed. Because it is believed to be a lagoon deposit behind Atima reefs (see section on Environment of Deposition below), it was probably deposited at the same time parts of the basal Atima reefs were building directly on Todos Santos clastic rocks farther from the highland. Whether the marly limestone grades laterally into basal Atima reefs, as this hypothesis requires, is not known.

Atima Formation.--The Atima Formation at most localities overlies the Todos Santos Formation except around the old highland where it lies on the Cantarranas Formation. In some places the top of the Atima Formation interfingers with basal Valle de Angeles clastic rocks. According to Mills *et al.* (1967) the Atima Formation is a patch reef facies with a back reef facies, the Cantarranas Formation, on the landward side. They also believed that the Cantarranas Formation is older than the Atima. However, mapping in the El Rosario Quadrangle has not excluded the possibility that the lower part of the Atima Formation may be the time equivalent of the Cantarranas Formation, the oyster beds (patch reef?) acting as a dam for mud deposition on the landward side and as a protecting barrier from seaward high energy action. As the sea transgressed the highland so did the Atima reefs.

Therefore, the base of the Atima is probably younger closer to the highland than the basal Atima rock farther away.

ENVIRONMENT OF DEPOSITION

During the Early Cretaceous a quiet sea transgressed across the Todos Santos clastic deposits. In this area Atima reefs or oyster banks started to grow on the submerged fringe of the highland area in the central and southeastern part of the El Rosario Quadrangle. Within the lagoons behind these banks the Cantarranas muds and skeletal debris collected. As the sea continued to transgress the highland area the banks grew landward following the shoreward-migrating marly facies and covering the mud's seaward extensions. Unbroken fossils, especially fragile echinoderm shells, within the Cantarranas attest to a quiet environment of deposition. Pelecypod shell debris was probably washed in from the seaward banks during storms. These storms may have been one of the agents that disturbed the Cantarranas muds along with burrowing organisms.

I believe that the Atima reefs may have grown in a fairly high energy environment and later limy mud filled in the reef framework. The thickest sections of Atima limestone are mostly oyster beds and some rudistids banks. *Orbitolinas* are closely associated with micrite, their preservation as fossils possibly indicating quiet water deposition. Thus, on the fringe of the quiet sea oysters grew in banks. Behind these banks mud and foram tests collected and were protected by the oyster banks. Later reefs grew over the back reef marly facies forming the bulk of Atima limestone. At the close of Yojoa Group deposition a flood of clastic sediments (Valle de Angeles Group) buried the limestone choking off carbonate deposition.

ILAMA FORMATION

Mills _et al_. (1967) proposed the name Ilama for limestone conglomerates deposited within the Yojoa Group (fig. 6). They believed these conglomerates are the result of some tectonic event, possibly the "anatexitic phase" of the early Laramide orogeny, occurring during Yojoa Group deposition (p. 1775). No Ilama conglomerates are exposed in the El Rosario Quadrangle. Thus there is no evidence for postulating the beginning of Laramide deformation during Yojoa deposition in the El Rosario Quadrangle. Similar conglomerates lie at the base of the Valle de Angeles Group in the San Pedro Zacapa Quadrangle (Richard C. Finch, personal communication, 1970).

GUARE FORMATION

Mills _et al_. (1967) described a thin-bedded, black shale and limestone, which they termed the Guare Formation, at the top of the Yojoa Group in the El Rosario Quadrangle (fig. 6). The type area is the Rio Guare which flows west to east into the Rio Humuya in the La Libertad Quadrangle within a few kilometers of the northern edge of the El Rosario Quadrangle. I have seen outcrops of black shaly limestone in the headwaters of the Rio Guare in the southeast corner of the Taulabé Quadrangle adjacent to the northwest of the El Rosario Quadrangle and similar rocks exposed in a road cut between La Misión and Taulabé to the west on the southern slopes of the Rio Tamalito Valley. But I have not found this facies in the El Rosario Quadrangle. I do not believe it is present at depth where Mills _et al_. (1967) on their cross sections showed it buried beneath alluvium.

VALLE DE ANGELES GROUP

INTRODUCTION

Above the Yojoa Group lies a thick sequence of terrigenous redbed sandstone, shale, and minor conglomerate named the Valle de Angeles Group. The redbeds were probably deposited in a deltaic or nearshore environment. In many other places in Honduras it is difficult to tell the Valle de Angeles Group apart from the Todos Santos Formation, but in the El Rosario Quadrangle the Valle de Angeles Group has a monotonous reddish brown color contrasted with the variegated colors of the Todos Santos Formation and lacks the large volume of conglomerate, so prevalent in the Todos Santos Formation. The two packages of redbed clastic rocks are easy to differentiate where they are separated by the Yojoa Group carbonate rocks.

Stratigraphic Nomenclature

Mills et al. (1967) designated the package of redbed clastic rocks and interbedded thin limestone layers above the Yojoa Group as the Valle de Angeles Group. Carpenter (1954) first used Valle de Angeles as a name for a formation near San Juancito; his usage is no longer followed. A detailed discussion of the history of nomenclature of these redbed clastic rocks was given by Mills et al. (1967). The name Valle de Angeles is in no way associated with the village of Valle de Angeles at the southern border of the El Rosario Quadrangle. In fact, the village is built on the Todos Santos Formation.

Mills et al. (1967) used the name Valle de Angeles Group in constructing a new stratigraphic scheme in Honduras. Theirs is a good start, but they only designated one formation within the group, the Esquias Formation (fig. 6); later workers can assign formation names to the Valle de Angeles Group where they are appropriate. Williams and McBirney (1969) recognized the Esquias Formation within the Valle de

Angeles Group and added the name Subinal Formation to designate the redbed clastic rocks with abundant volcanic detritus that lie above the Esquias and Matagalpa formations (fig. 6). I do not know if they intended the Matagalpa and Subinal formations to be part of the Valle de Angeles Group or to stand as separate formations above the Valle de Angeles Group.

No one using the newer stratigraphic schemes has applied a formation name to the thick redbed sequence of the Valle de Angeles Group below the Esquias Formation (fig. 6).

Local Stratigraphy

Only the thick sequence of redbed sandstones that form the lowest unit (unnamed by Mills *et al*., 1967) of the Valle de Angeles Group resting directly on the Yojoa Group crops out in the El Rosario Quadrangle. No new formation name is proposed here for the redbed sandstones of the Valle de Angeles Group in the El Rosario Quadrangle because: 1) the top of the formation is eroded; sections should be measured where there is an undisturbed sequence from the Yojoa Group to the Esquias Formation, and 2) the Valle de Angeles Group is so extremely faulted here that no section can be measured and described with confidence that it would be complete.

In their discussion of the Valle de Angeles Group exposed in the El Rosario Quadrangle Mills *et al*. (1967, p.

1749) stated:

> Unconformably above the Guare beds is 2,100 ft of red clastic sedimentary rocks of the Valle de Angeles Group. They can be examined in the Guare Valley, but the best exposures are on the national highway between Comayagua and Siguatepeque where the redbeds overlie the south-dipping Atima fault blocks. At the base is 700 ft of thin-bedded, poorly indurated red shale, siltstone, and a few fine-grained sandstone beds interbedded with 200 ft of brown, massive, lithographic limestone which is probably Late Cretaceous and part of the Esquias Formation. In addition, the Esquias consists of red shale which contains thin beds of shaly limestone with abundant pelecypod fragments that were impossible to identify. Above the pelecypod-bearing bed is 600 ft of cross-bedded indurated shale, siltstone, and fine-grained sandstone. Gypsum is common along bedding and fracture planes. At the top of the group, and separated from it by a slight unconformity, is 400 ft of massive, red quartz conglomerate and coarse-grained sandstone containing volcanic tuffs and thin flows. This last unit may be equivalent to the Subinal Formation.

I found no limestones between the Carretera del Norte (national highway) and the volcanic rocks to the south, as Mills et al. (1967) show on their cross section D-D'. Nor did I find 400 feet of massive, red quartz conglomerate and coarse-grained sandstone containing volcanic tuffs and thin flows. Mills and his colleagues may have interpreted the folded and reverse-faulted Todos Santos, Cantarranas, and Atima formations exposed along the La Libertad Road just north of Comayagua (Everett, 1970) as part of the Valle de Angeles Group (fig. 12A). It is understandable that Mills et al. (1967) arrived at an interpretation such as the one quoted above after a quick reconnaissance of the area, because the rocks exposed along the La Libertad Road between Comayagua and the faulted blocks of Atima limestone at Piedras Azules are complexly deformed. Also, here the complex structure at Valle de Angeles is juxtaposed to rather simple structure (fig. 12B) to the west on the other side of the Las Marias Fault that extends through Piedras Azules. By projecting both sections into one line one would derive a composite section similar to the one quoted above. The interpretation of Mills _et al_. (1967) was probably the most reasonable not knowing about the complex structure along the whole region just north of the Carretera del Norte between Comayagua and Siguatepeque (see Montaña de Comayagua structural belt below). The volcanic tuffs and thin flows they thought might be Subinal Formation are probably the Padre Miguel Group exposed just west of the Carretera del Norte where it enters the quadrangle at grid 2603.

REDBED SANDSTONE

General Appearance

Outcrops.--The Valle de Angeles Group in the El Rosario Quadrangle is a dark reddish brown, well-bedded sequence of redbed quartz sandstone and subarkose interbedded with shale and a few conglomerate beds. The weathered color is constant vertically and along strike. The uniform color is the most noticeable and easiest feature of the outcrop to recognize. Bedding ranges from 2 to more than 50 centimeters thick and is usually shown by differences in grain size. Alternating sandstone and shale layers have small-scale current cross-bedding, ripple marks, some soft-sediment deformation features, and are usually burrowed. The bedding is continuous where it can be followed (pl. 6F), but the formation is so highly faulted that it is not possible to follow a single bed for any distance. Outcrops are usually jointed. Many joint sets are filled with gypsum veins from 2 to 6 centimeters thick.

Contacts.--The lower contact has been described under the section on Atima Formation. The upper contact of the Valle de Angeles Group is an angular unconformity with the basal units of the Padre Miguel Group; shallow-dipping lag gravel, tuff and ignimbrite, or basaltic lapilli tuff cover the more steeply-dipping redbeds. In most places slump blocks and landslide of volcanic rock cover the contact.

Geomorphic expression.--The Valle de Angeles redbed clastic rock is usually weakly resistant to erosion and generally underlies flat, low areas and only forms hillslopes where it has a protective cap of volcanic rock. It forms much smoother surface features than either the Atima or Todos Santos formations, similar to the surface developed on the Tertiary volcanic rocks. On aerial photographs the Valle de Angeles is easy to distinguish because usually only brush grows on it. The presence of trees and the lighter shades of gray on the photographs make the volcanic rocks easy to distinguish from Valle de Angeles outcrops.

Lithology

Most of the rocks of the Valle de Angeles Group in the El Rosario Quadrangle are mudstone (#113, 114, 116 to 119) or fine- to coarse-grained sandstone (#115, 120, 122, 123, 124) with minor intercalated quartz-pebble conglomerate (#121). They are almost everywhere cemented with calcite, quartz, and hematite. The fresh rock ranges from yellow brown to dark reddish brown. Almost all specimens have plagioclase, chert (some radiolarian-bearing), limestone, metamorphic rock fragments, volcanic rock fragments, and magnetite altering to hematite. The hematite gives the distinctive reddish brown color. Some of the samples have a high percentage of epidote (#123, 124) and a few contain glauconite (#122, 123, 124).

Distribution

The Valle de Angeles Group crops out south of the southernmost line of Atima limestone-capped hills from Piedras Azules to El Rosario and in a structural basin just north of El Rosario and west of the Rio Humuya. There may be Valle de Angeles rocks buried beneath Tertiary rocks in the Valle de Espino. Elsewhere in the El Rosario Quadrangle where Valle de Angeles rocks might have been deposited, they have been eroded away.

Thickness

Because of intense faulting in regions where Valle de Angeles clastic rocks are exposed, it is difficult to estimate thicknesses. Within the structural basin north of El Rosario erosion has left possibly no more than 600 to 700 meters of redbeds (pl. 2). South of the Atima limestone-capped hills the formation generally dips to the south and, discounting minor faulting, there may be as much as 1200 to 1400 meters of Valle de Angeles redbeds below the Tertiary volcanic tuffs and ignimbrites.

Age and Stratigraphic Relationships

Age.--The Valle de Angeles Group in the El Rosario Quadrangle lies above the Atima Formation. The inception of clastic deposition marked the end of carbonate reef building. Deposition of clastic redbed sands and muds continued probably intermittently until they were folded, partially eroded and covered by Tertiary volcanic ignimbrite. This limits the age of the redbed sequence from Late Cretaceous to Middle Miocene. If the redbed sandstone unit is everywhere older than the Esquias limestone (Mills *et al.*, 1967), the younger limit is Eocene.

Stratigraphic relationships.--The Valle de Angeles Group lies between the underlying Yojoa carbonate rocks with probable conformity and the unconformably overlying volcanic rocks of the Padre Miguel Group. In the El Rosario Quadrangle no volcanic rocks are seen interfingering with Valle de Angeles Group clastic redbeds either at the base or at the top as Mills *et al*. (1967, p. 1719, fig. 3) show in their Stratigraphic Summary.

Environment of Deposition

The end of Yojoa Group carbonate deposition coincided with the beginning of fine- to medium-grained clastic sediment influx at the edge of a regressive sea. Lack of fossils, type of sedimentary structures, and worm (?) burrows found within the Valle de Angeles redbeds are common in fluvial or deltaic environments. If the redbeds are deltaic, the basal mudstones (#113, 117, 118) may have been pro-delta muds that buried organic reefs, stranded by the regressing sea. As the delta system built seaward sands and minor conglomerate beds were deposited over the basal mud.

ESQUIAS FORMATION

The Esquias Formation was applied by Charles E. Weaver (*in* Schuchert, 1935) to limestones exposed at the village of Esquias in the Minas de Oro Quadrangle adjacent on the northeast to the El Rosario Quadrangle. Mills *et al.* (1967) and Williams and McBirney (1969) perpetuated the name and concept, using it as a name for Upper Cretaceous to Eocene limestone within the Valle de Angeles Group. Mills *et al.* (1967) and Williams and McBirney (1969) recognized Esquias limestone in the La Libertad Quadrangle to the north of the El Rosario Quadrangle.

Weaver is apparently the only worker in print who has actually studied the limestone exposed at Esquias (Kenneth E. Hugh, personal communication, 1968) and according to Schuchert (1935, p. 354) correlated them with the massive limestones elsewhere in central Honduras (Upper Cretaceous of Sapper, 1905, and Yojoa Group of Mills *et al.*, 1967). After a brief examination of the limestone at Esquias it is my belief that the limestone belongs to the Atima Formation.

No limestone beds were found within the Valle de Angeles Group in the El Rosario Quadrangle.

MATAGALPA FORMATION

The Matagalpa Formation defined by McBirney and Williams (1965) is andesite, basalt, and pyroclastic ejecta underlying extensive siliceous Miocene ignimbrite packages. To the south of the El Rosario Quadrangle it overlies Valle de Angeles redbeds and is older than the Padre Miguel Group

(Williams and McBirney, 1969; Dupré, 1970; Everett, 1970). I have not recognized Matagalpa Formation rocks in the El Rosario Quadrangle. However, some of the altered hypabyssal igneous rocks exposed on Cerro Las Anonas may be related to Matagalpa extruded rocks.

SUBINAL FORMATION

Williams and McBirney (1969) applied the name Subinal Formation to Middle Tertiary redbed clastic rocks deposited in central Honduras later than the Matagalpa Formation. Hirschmann (1963) first proposed the name for redbed clastic rocks that crop out in a fault block within the Motagua River Valley in Guatemala. These lie unconformably on Permian or older rocks and are overlain unconformably by Tertiary basalt and Quaternary pumice. Hirschmann believed it is no older than Cenomanian.

If Subinal redbeds, as used by Williams and McBirney (1969), are exposed in the El Rosario Quadrangle, they will be difficult to recognize, because the marker beds underlying the formation in central Honduras, either the Esquias or Matagalpa formations, are not recognized.

PADRE MIGUEL GROUP

INTRODUCTION

Tertiary siliceous ignimbrite with associated water-laid and pyroclastic sedimentary rock and a basalt flow form steep cliffs, underlie high plateaus, and cap ridges in the El Rosario Quadrangle. This volcanic package is part of the ignimbrite sequence called the Padre Miguel Group that extends over much of southeastern Guatemala, western Honduras, and northwestern El Salvador (McBirney and Williams, 1965).

Stratigraphic Nomenclature

The name Padre Miguel Group was given by Burkart (1965) to siliceous volcanic rocks and associated sedimentary rocks in the Esquipulas region of southeastern Guatemala. Williams and McBirney (1969) correlated Burkart's Padre Miguel Group with siliceous volcanic rocks exposed throughout the Volcanic Ranges and Plateaus. Dupré (1970) described the Padre Miguel Group in the Zambrano Quadrangle near Tegucigalpa. Everett (1970) extended Dupré's study northwestward into the Comayagua Quadrangle adjacent to the south of the El Rosario (figs. 6, 11).

Local Stratigraphy

In the El Rosario and Comayagua quadrangles the Padre Miguel Group has two recognizable units that are informally designated the La Sabana ignimbrites and Cerro La Cañada ignimbrites by Everett (1970, fig. 6, p. 55) for the ignimbrites that are exposed just north of Comayagua at the

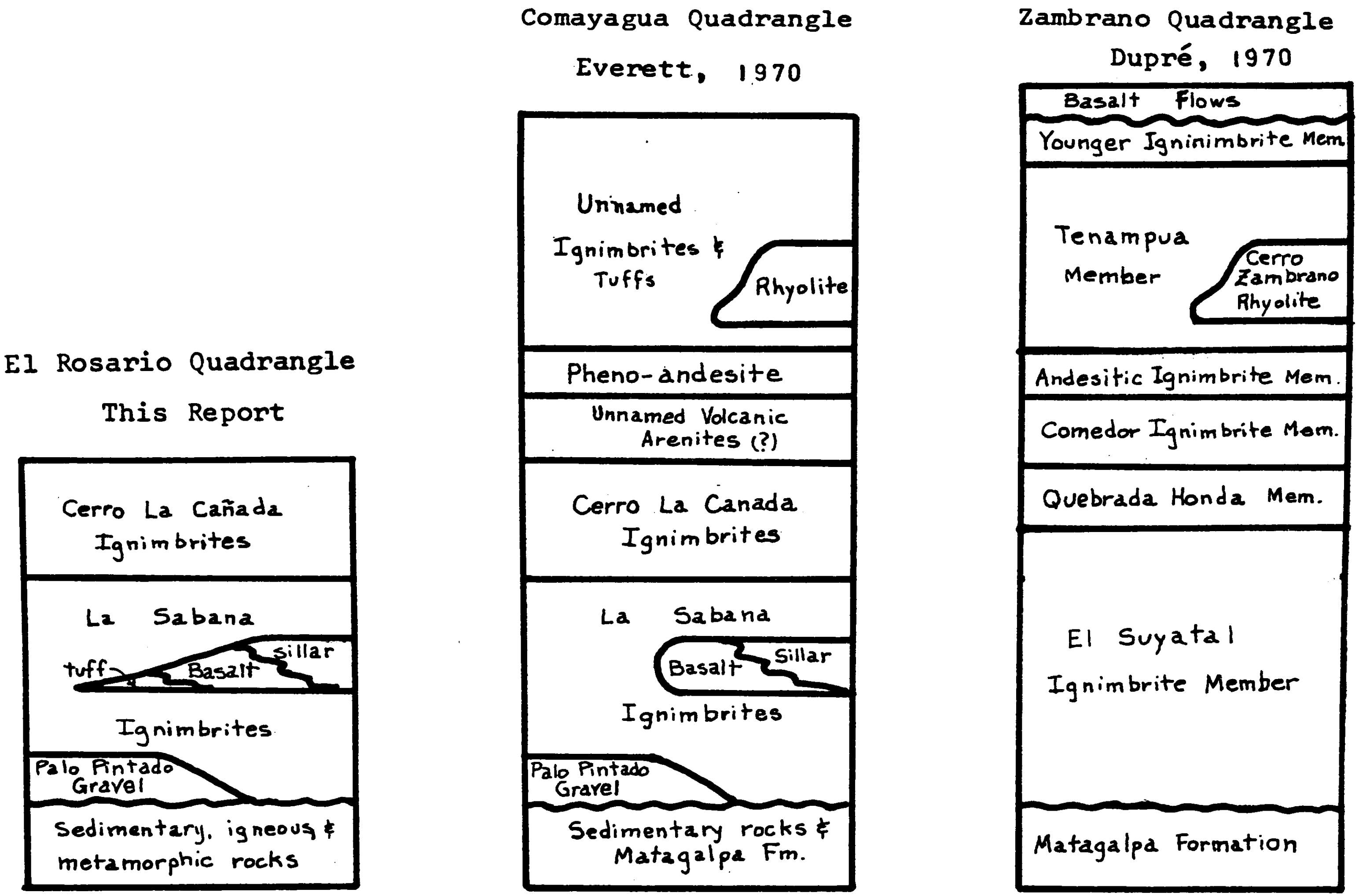


Figure 11. Stratigraphy of Padre Miguel Group in the El Rosario, Comayagua, and Zambrano quadrangles showing Everett's (1970) and Dupré's (1970) terms.

village of La Sabana 4 kilometers south of the El Rosario Quadrangle and Cerro La Cañada 10 kilometers south. I use Everett's nomenclature. Ignimbrite and possibly air-fall tuffs and pyroclastic rock cap the Montaña de Comayagua. These are probably younger than the La Sabana ignimbrites (Everett, 1970). I include them in the Padre Miguel Group, but do not know with which unit they are correlative.

Terminology

The problem of naming pyroclastic volcanic rocks has a varied history. As students learn more about origin, depositional conditions, lithification, and alteration the names will probably be revised. Mackin (1960), Cook (1965), Smith (1960), and Ross and Smith (1961) discussed the present state of knowledge and presented naming schemes that attempt to keep these factors separate.

An ignimbrite (Cook, 1965, p. 3) is a "sheet-like deposit of relatively nonsorted and nonstratified pyroclastic material." "Ignimbrite" is synonymous with "ash flow tuff" as used by Ross and Smith (1961, p. 3). "Ignimbrite" is used herein (suggested by Rowley, 1968) as a term for the rock type comprising a sheet-like deposit of relatively nonsorted and nonstratified pyroclastic material and does not imply the degree of welding or crystal:vitric:lithic compositional ratio.

LA SABANA IGNIMBRITES

Introduction

La Sabana ignimbrites are mostly siliceous, crystal-vitric to vitric-crystal, variously welded ignimbrites with discontinuous vitrophyre, silicified vitrophyre (#132, 133, 134), and a basal gravel unit, herein called the Palo Pintado gravel. The ignimbrites locally have an included discontinuous olivine basalt flow in the lower part (pl. 8).

Palo Pintado Gravel

A gravel composed of metamorphic quartz pebbles, red-bed cobbles, and distinctive light brown chert-bearing limestone clasts (#131), cemented by calichefication, held together by clayey soil, or in part unconsolidated form part of the base of the Padre Miguel Group. The Palo Pintado gravel is named for the gravel beds that form the lowest rock unit of the La Sabana ignimbrites exposed in the frontal hills of the Tertiary volcanic plateau 1 kilometer south of the village of Palo Pintado (pl. 7). Boulders in the unit range up to 2 meters in diameter. The thickness of the unit varies from a few up to 40 meters. Map distribution probably includes not only the outcrop width, but also much of the eroded product shed downslope from the outcrop as a lag deposit mantling the underlying Valle de Angeles redbed spurs. Basalt and ignimbrite boulders associated with the gravels, although not found in the outcrop, are probably washed onto and mixed with the lag gravel by flood waters eroding ignimbrite outcrops higher in the canyons. The Palo Pintado gravel distribution is mapped where outcrops and associated lag gravel contain metamorphic clasts and the distinctive light brown chert-bearing limestone cobbles.

Olivine Basalt Flow

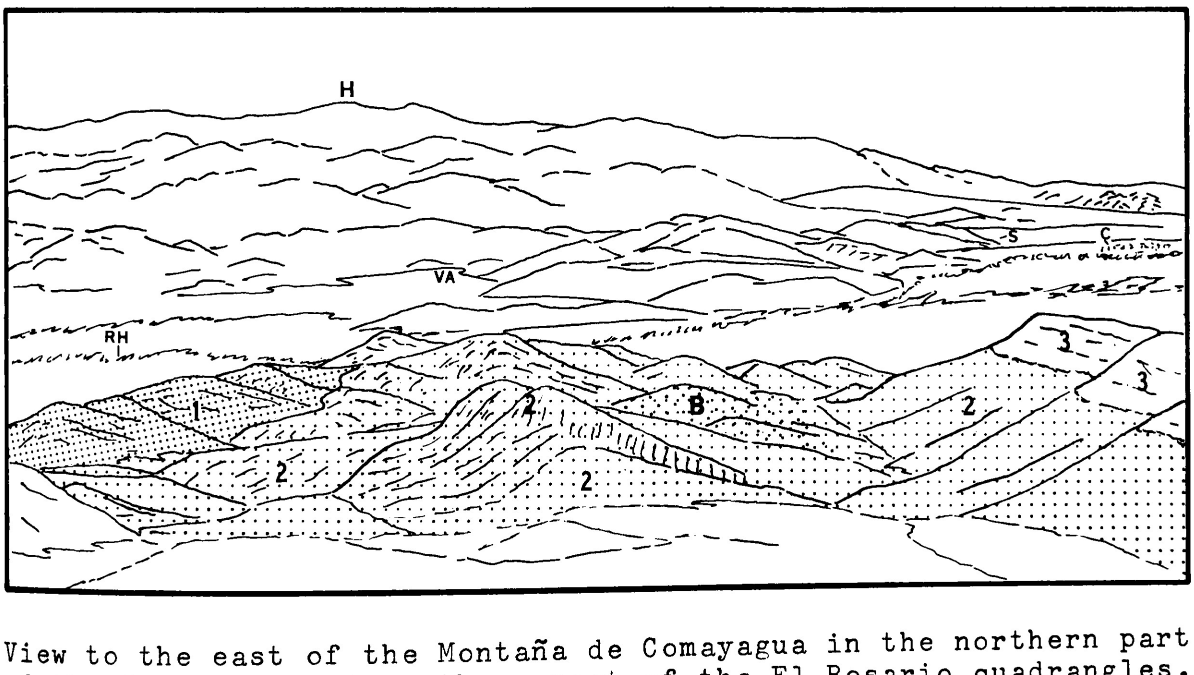
At Palo Pintado an olivine basalt flow is interlayered with the La Sabana ignimbrites (pls. 6C, 7, 8). The flow is brownish black, dark gray, or reddish brown in the outcrop. Maguey plants favor growing on basalt outcrops. Pits, once the site of olivine crystals, and vesicles are common. The flow varies in thickness up to 80 meters along its exposure. At the east end of La Sabana outcrops near Palo Pintado the basalt pinches out and the ignimbrite at that horizon contains large boulders of the basalt (pl. 7).

Olivine basalt flow rock (#125, 126) is composed of 70 percent zoned plagioclase laths and 30 percent interstitial pyroxene and olivine, in part altered to brown iron-bearing mineral, probably not iddingsite, forming a trachytic texture. Opaques are hematite.

Ignimbrite

Except for the basal gravel and thin basalt flow at Palo Pintado the La Sabana ignimbrites are composed of

PLATE 7



View to the east of the Montaña de Comayagua in the northern part of the Comayagua and southern part of the El Rosario quadrangles. Photograph, taken from Los Claros at grid locality 240035, shows the Palo Pintado section of the Padre Miguel Group ignimbrites. The highest point in the region (H) is 2400+ meters. Geographic and geologic localities are: Comayagua (C), La Sabana (S), Valle de Angeles (VA), Rio Humuya at the 540 meter elevation (RH), Palo Pintado gravel (1), La Sabana ignimbrites (2), with basalt flow (B), and basal part of the Cerro La Cañada ignimbrites (3).

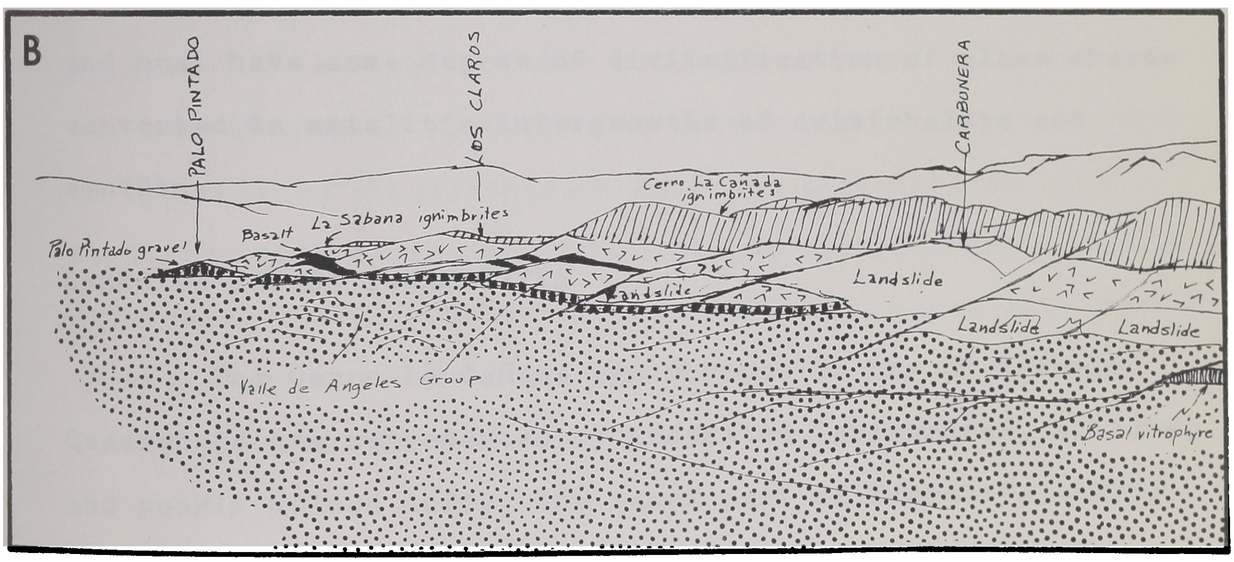
PLATE 8

A. View of Padre Miguel Group ignimbrite section exposed from Palo Pintado to Carbonera in the cliffs bounding the northeast side of the Siguatepeque Plateau. Photograph is looking southeast from old Carretera del Norte on Cerro de las Pilas (grid 1910).

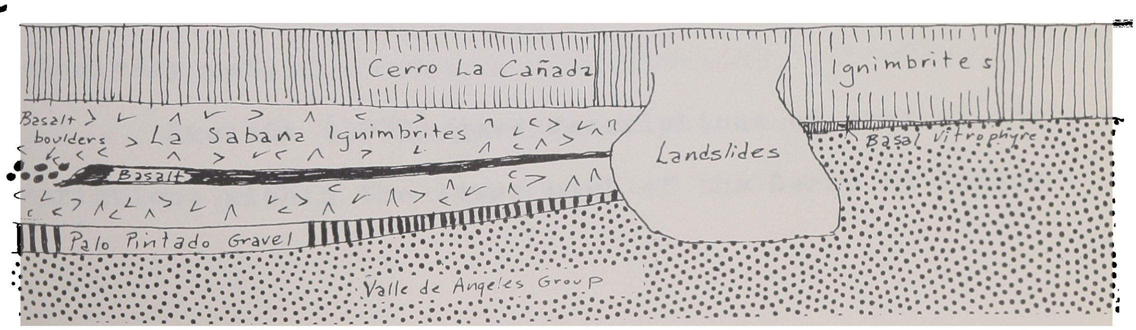
B. Sketch of the photograph showing the distribution of various units within the Padre Miguel Group.

C. Diagrammatic section showing lateral variations within the Padre Miguel Group. Vertical scale greatly exaggerated.

PLATE 8


B
PALO PINTADO
LOS CLAROS
CARBONERA
Cerro La Cañada ignimbrites
La Sabana ignimbrites
Basalt
Palo Pintado gravel
Landslide
Landslide
Landslide
Landslide
Valle de Angeles Group
Basal vitrophyre

C


Cerro La Cañada
Ignimbrites
Basalt boulders
La Sabana Ignimbrites
Basalt
Landslides
Basal vitrophyre
Palo Pintado Gravel
Valle de Angeles Group

variously welded crystal-poor ignimbrites.

Everett (1970) described the La Sabana ignimbrites in detail. These ignimbrites include: pinkish-gray, biotite-quartz-sanidine, crystal-vitric ignimbrite with 5 percent rock fragments; pale red, biotite-quartz-sanidine, vitric ignimbrite with 2 percent rock fragments; very pale orange, pumice-rich, quartz-sanidine, vitric-crystal sillar; and interbedded thin-bedded fluviatile volcanic arenites and poorly indurated tuffs. Most of these units have broken crystals of sanidine, sodic plagioclase, embayed quartz, biotite, hornblende, and rare anorthoclase. Most units are welded with eutaxitic structure of flattened pumice shards and most have some degree of divitrification of glass shards converted to axiolitic intergrowths of cristobalite and sanidine.

CERRO LA CAÑADA IGNIMBRITES

The Cerro La Cañada ignimbrites in the El Rosario Quadrangle are represented by indurated ignimbrites, sillars, and poorly welded tuffs, the basal part of Everett's (1970) section. These may possibly lie unconformably on the La Sabana ignimbrites, but this hasn't been demonstrated conclusively yet.

Everett (1970) gave descriptions of some of the variations within the lower part of the Cerro La Cañada ignimbrites. These ignimbrites include: well-welded, grayish-pink, quartz-sanidine, crystal-vitric ignimbrite; light gray, quartz-sanidine, vitric, probably air-fall, poorly bedded tuff; welded, grayish-pink, quartz-sanidine, crystal-vitric ignimbrite with 10 percent flattened pumice fragments. These are interbedded with fine-grained volcanic arenites and fluffy air-fall tuffs.

GENERAL APPEARANCE

Outcrops

The ignimbrites erode to pastel greenish gray, pink, and purple outcrops forming rolling hills with round valley bottoms. This less incisive cutting, compared with erosion of older rocks, is probably due to the high porosity of much of the rock which allows rain water to sink into and not wash over much of the outcrop. At the top of some units are thin, dark (usually brown or brownish red), hard, mottled, surficial crusts that are probably old weathered surfaces. In the outcrop the rock weathers to clay, so that it becomes soft and mushy to a geologic pick. Alteration has softened the rock in roadcuts made within the last few years. Mule trails become slots from continual abrasion of hooves on the soft, altered glass-shard rock (pl. 10E). Sheetwash down a timber road at Los Lirios has cut a sinuous slot along a bulldozer gouge. This slot, formed within the last few years, is up to 20 centimeters wide and 15 centimeters deep with overhanging walls (pl. 10B).

Outcrops may be layered, from a few millimeters up to a few centimeters thick, in the well-bedded air-fall tuffs, water-laid tuffs and volcanic sandstones, and up to 20 meters thick in the sheets of sillar and indurated ignimbrites. The sillars and indurated ignimbrites form thick massive cliffs, some with poorly developed columnar joints. Many of these thick sheets are separated by thin tuff units that form recesses in the cliff walls.

At Los Lirios in the basal part of the La Sabana ignimbrites spheres up to a meter in diameter form in the weathered outcrop (pl. 10G). There appears to be no compositional difference between the material in the spheres and the host rock. Also, they do not appear to be exfoliation features related to a joint system, for they are situated in the outcrop in such positions that no nearly flat plane could be passed between them. Robert L. Smith, as quoted by Stirling (1969, p. 299), presented a hypothesis for the formation of similar, though larger, balls in an ash-flow tuff in Mexico. Smith believed they are crystallization (devitrification?) spheres at the edge and bottom of a flow. Expansion of the sphere of crystallization started from cooling nucleii. The sphere boundaries could not coalesce before the unit cooled, and are, thus, caught in a host matrix of uncrystallized glass.

Geomorphic Expression

Palo Pintado gravel forms a resistant layer at the break in slope between steep ignimbrite hills and shallow sloping spurs of Valle de Angeles redbeds.

The basalt flow is less resistant to erosion than the ignimbrites and forms a recess in the ignimbrite slope (pl. 7).

The ignimbrites form rolling hills and flat uplands. They are more resistant to erosion than Valle de Angeles redbeds; all hills of Valle de Angeles redbeds are capped by a protective blanket of Padre Miguel ignimbrites.

Lithology

Specimens of Padre Miguel ignimbrites (#122, 128, 129) are up to 55 percent crystals of resorbed quartz (after beta-quartz), sanidine (some with Carlsbad twins), plagioclase, and biotite. The crystals are in a devitrified matrix which retains some glass shard texture, showing varying degrees of welding.

In the region east of Guacamaya around cerros de La Brisca, El Caramal, and de Talco the Todos Santos Formation is extremely weathered and looks similar to reddish brown-weathered ignimbrite in the outcrop. Tuffaceous rocks (#351) have been collected from there, but these may be extensions of frothy rhyolitic dikes that crop out nearby to the west. Still, it is possible that Padre Miguel ignimbrites do underlie some of the area just east of Guacamaya. Everett (1970) described the petrography of the Padre Miguel ignimbrites in detail.

Silicified basal glass.--At Jacintillos 4 kilometers east of San Antonio de la Cuesta where ignimbrite lies on Atima limestone and on the top of Cerro El Camalotal 5 kilometers west of Los Plancitos where ignimbrite is presumed to have once been deposited and now stripped away by erosion, hard, silica-rich rocks (#132, 133, 134) crop out. The contacts are covered by soil. The rock is almost totally rice-shaped grains of quartz (pl. 6H). Rare calcite grains are included within some of the quartz. The rock is compositionally a quartzite, but its origin is unclear. Some interpretations are that it is 1) silicified basal glass of the ignimbrite, 2) silicified limestone, and 3) a silicified limestone soil.

BASAL CONTACT

Almost everywhere rubble eroded from the volcanic rock and colluvium cover the contact between the ignimbrite and older rock. The wall of a road metal quarry cut out of a road cut on a hairpin turn of the Carretera del Norte 1 kilometer west of Agua Salada shows a contact of ignimbrite on Valle de Angeles redbeds. The ignimbrite, however, is probably landslide material slumped off the cliff (Frontispiece). The only definitely undisturbed contact so far found is in a road cut of a timber road at Los Lirios off the La Libertad Road at the northern border of the quadrangle and on the hill just south of the road. Here ignimbrite is deposited upon Todos Santos redbed conglomerate. The redbeds have a thin soil horizon with an irregular upper surface of 2 to 3 meters relief. Ignimbrite fills in the topography (pl. 10A).

BASAL RELIEF

As much as 350 meters of relief existed on the surface over which the Padre Miguel Group volcanic rocks were deposited; Dupré (1970) estimated up to 800 meters relief; Everett (1970) estimated 500 meters. The rocks of the metamorphic highland were exposed. Hills of folded and faulted Atima limestone stood high with lower, flatter plains underlain by Valle de Angeles redbeds in between. Williams and McBirney (1969) believed the Padre Miguel was deposited on a surface that was near sea level. Since deposition, faulting and broad upwarping have lifted the contact to elevations ranging to over 2000 meters on the top of the Montaña de Comayagua (fig. 16).

DISTRIBUTION

The most impressive outcrops in the El Rosario Quadrangle are the high cliffs south of the old Carretera del Norte between Palo Pintado and the west edge of the area formed by the Cerro La Cañada ignimbrites. The unit can be followed along the cliff northwest into the Siguatepeque Quadrangle and then back into the El Rosario Quadrangle in the northwest corner (pls. 6G, 8, Frontispiece). East from the corner scattered, separated patches of poorly welded La Sabana ? ignimbrites cap ridges and form cuestas to the Valle de Espino where the ignimbrites form some of the valley bedrock. The west side of the valley is marked by high cliffs of La Sabana ignimbrites that cover much of the high plateau country north of the Montaña de Comayagua (fig. 17).

THICKNESS

There are no complete unfaulted sections of Padre Miguel ignimbrites exposed in the El Rosario Quadrangle; all have eroded tops. The thickest sections remaining after erosion are in the high cliffs south of the old Carretera del Norte in the southwest corner of the quadrangle where the ignimbrites are at least 350 meters thick and in the cliffs forming the eastern side of the Valle de Espino where the section is at least 250 meters thick. The section exposed at Palo Pintado (pl. 7) is described by Everett (1970). Here the section, extending into the Comayagua Quadrangle, is over 400 meters thick.

AGE AND STRATIGRAPHIC RELATIONSHIPS

Age

Williams and McBirney (1969) reported mid-Miocene K/Ar isotopic dates of 16.8 million years (plagioclase) and 18.9 million years (biotite) from an ignimbrite specimen collected east of Comayagua. The exact location of the outcrop is not clear, but Everett (1970) believed the locality would have to be at the base of the La Sabana ignimbrites near Capiro (grid 3497) 3 kilometers east of Comayagua.

Stratigraphic Relationships

Padre Miguel ignimbrites overlie Valle de Angeles redbeds with angular unconformity. They are in turn overlain by Quaternary alluvial deposits of the Rio Humuya drainage system. They are relatively flat lying and have only Miocene and younger deformational structures within them. Thus, they contain a meaningful record of Late Tertiary and Quaternary deformational events.

VOLCANIC SEDIMENTARY ROCKS

Reworked, water-laid pyroclastic sedimentary rocks interbedded with cross-bedded mudstone, sandstone, and conglomerate crop out just west of the cliffs bounding the eastern side of Valle de Espino. These white, pink, and orange beds are made of mostly unconsolidated sands of volcanic glass fragments and conglomerate of volcanic rock fragments. The top of the exposures is mantled by alluvial fan gravels.

A similar layered and cross-bedded unit is exposed on the east side of the Rio Humuya where it leaves the quadrangle. Here the outcrops are capped by older alluvial gravels of the Rio Humuya. In both localities the bedding dips about 15 degrees to the north.

These beds may be part of Tertiary volcanic units younger than the La Sabana ignimbrites that have extensive reworked waterlaid volcanic sediments reported by Everett (1970) and Dupré (1970) farther south and may be equivalent to the ignimbrites and associated rocks that cap the Montaña de Comayagua (Everett, 1970).

ALLUVIAL DEPOSITS

INTRODUCTION

Among the alluvial deposits in the El Rosario Quadrangle are: 1) older alluvial gravels, 2) alluvial fans, 3) landslides, 4) colluvium, 5) pediment lag gravel, and 6) modern stream alluvium. Their form and composition provide some of the main evidence for Quaternary geomorphic history.

OLDER ALLUVIAL GRAVEL

Older alluvial gravel is poorly consolidated or unconsolidated alluvium now being dissected. Terrace deposits at El Rosario, La Joya, around Cacaguapa at the head of Valle de Espino, and at Los Plancitos are probably old Rio Humuya alluvium now being dissected after a change of base level.

Sediments comprising the older gravel deposits that ring the Valle de Comayagua from El Tamboral to Palo Pintado are locally derived. An example is the boulders of alluvial material in Quebrada Agua Blanca at Palo Pintado. These round boulders are olivine basalt almost certainly derived from the flows within the La Sabana ignimbrite exposed 1 kilometer to the south and west. Across the Rio Humuya in the river banks being dissected by the waters in the Quebrada del Palillal disc-shaped cobbles of limestone and redbed conglomerate are stacked edgewise at angles of 60 to 70 degrees, typical of high flow regime deposition. Gravel composed of Valle de Angeles redbed clasts and volcanic rock is exposed high on the side of the hill south of the old Carretera del Norte at Los Empates. This exposure may represent a higher segment of the depositional system that includes the older gravels at Plan Colorado.

Gravel on Ignimbrite

Gravel deposits of redbed conglomerate and metamorphic rock, mostly schist, cap the volcanic plateau at Cerro El Cacao and Cerro El Portillo east and southeast of San Jeronimo. It is not certain whether these are gravel lag deposits of an old erosion surface that truncates the structure within the volcanic rock or are sediments deposited with the volcanic rock during ignimbrite extrusion. They do indicate that at least portions of the metamorphic highland were exposed prior to the formation of the Valle de Espino or else during the early stages of Padre Miguel Group deposition.

Guacamaya Valley Alluvium

The sediments that floor the valley high above Valle de Angeles at Guacamaya pose a special problem. These are gravels and soil with boulders of limestone derived from the head of the valley. Except for a ridge of limestone that crosses the valley the drainage surface of the valley slopes west and southwest from El Ciruelo to the Valle de Comayagua. The alluvial sediments are trapped high in the valley behind the ridge, possibly in karst sink holes developed in the limestone bedrock. Modern drainage of the basin is north through a gap cut by the Rio Cacaguapa.

ALLUVIAL FANS

Alluvial fans flank the west side of both the Valle de Comayagua and Valle de Espino. In the Valle de Comayagua two separate fans are formed by detritus from the canyons at Valle de Angeles and four canyons near Piedras Azules. The fan at Piedras Azules has three lobes forming hummocky hills. In the Valle de Espino a coalescing alluvial fan system or bahada flanks the entire east side of the valley and is formed of sediment deposited by all the streams flowing into the valley north of the Rio Churune. All the fans in the El Rosario Quadrangle comprise poorly sorted clasts up to boulder size, some more than 2 meters in diameter. The fans in the Valle de Comayagua are younger than the older gravel alluvium because they are deposited on pediment surfaces cut on the older gravel alluvium.

LANDSLIDES

The distinction between landslide debris and colluvium is difficult to make in the field. Material that has broken away from its outcrop as a distinct mass, moved downslope, and come to rest in a short time are mapped as landslide. They are recognized by their hummocky, lobate forms, poor drainage, with local ponding of water, chaotic structural features, and appear to originate from arcuate concave-outward breaks in the cliffs above.

The most massive landslide deposits lie at the break in slope below the ignimbrite cliffs in the southwest corner of the quadrangle. Here they are actively forming today. Material broke loose from the cliff south of Carbonera in late July 1968, exposing fresh white ignimbrite in the newly formed scar. Most of the material on which the old Carretera del Norte is built from near Chicuás Arriba to near the top of the grade is mostly landslide debris. Carboneras is built upon the backslope of a large tilted block dipping toward the volcanic plateau (Frontispiece).

Cliffs of Atima limestone also produce landslide material. The village of Las Anonas is built on debris derived from the north side of Cerro Las Anonas (pl. 4).

COLLUVIUM

Colluvium consists of slopewash and crept soil. It is not mapped as a separate alluvial body on the map. Usually where contact lines are dashed on the map in areas with steep slopes it is because colluvium covers the contact. The Cantarranas Formation is poorly exposed throughout the area because it is usually covered by colluvium from the cliffs of Atima limestone above.

PEDIMENT GRAVEL

Quaternary pediment deposits consist of thin unconsolidated sand and gravel lag lying on well-defined erosion surfaces that truncate structure. These are not shown as a separate unit on the map. Gravels lying on a pediment surface cut in Valle de Angeles redbeds west of El Tamboral just east of the old Carretera del Norte are rich in chalcedony and chert concretions.

COMAYAGUA AND ESPINO VALLEY ALLUVIUM

Quaternary alluvium of unconsolidated sediment covers much of the flat bottoms of the Valle de Comayagua and Valle de Espino. Much of these deposits are covered during high floods. In the Valle de Espino Quaternary alluvium is extremely thin because the present channel of the Rio Humuya from El Banco north to Solorzano and a tributary in Quebrada Suncuya at the north edge of the quadrangle are cut in Tertiary ignimbrite underlying alluvium. Most of the sediment in the Humuya Gorge is moved downstream during each flood, scouring bedrock for most of the river from El Tamoral to west of Cacaguapa. The only exception is the flat flood plain deposit ½ kilometer downstream from La Joya on the south side of the gorge. Here the sediment is covered by water during floods, but is probably not all removed during each flood season. This is shown by shrubbery older than one season growing on the levee between the channel and the flood-plain.

I N T R U S I V E   I G N E O U S   R O C K S

INTRODUCTION

At least four episodes of igneous rock emplacement are evident in the El Rosario Quadrangle: 1) pre-metamorphic emplacement of felsitic igneous flows or sills, discussed under Metamorphic Rocks; 2) extrusion of flows and possibly tuffs that formed the Todos Santos crystal-poor, vitric tuffs, discussed under Todos Santos Formation; 3) Late Cretaceous or early Tertiary emplacement of hypabyssal rhyolite and basalt; and 4) extrusion of Tertiary ignimbrite with associated basalt flows of the Padre Miguel Group. A fifth period of igneous rock emplacement might be indicated by a large body of gabbro. Post-metamorphic hypabyssal igneous rocks are: 1) El Rosario rhyolite, 2) basalt dikes, and 3) gabbro.

CLASSIFICATION

The compositional classifications used herein are those of Streckeisen (1965) and also Cook (1965) for tuffs. Streckeisen suggests that the prefix "pheno-" be placed before the general rock name of tuffs and aphanitic porphyritic rocks to insure that it is understood that only the composition of the phenocrysts has been considered in giving the name.

EL ROSARIO RHYOLITE

INTRODUCTION

White to greenish gray pheno-rhyolite tuff to granophyric granite intrude Mesozoic and early Tertiary sedimentary rocks in the El Rosario Quadrangle. These siliceous bodies are sills, dikes, or irregularly-shaped plugs. They are usually emplaced along fault zones, mostly high-angle reverse faults and, therefore, intruded during or after Laramide deformation. Lead and silver mineralization in the Opoteca Mine at El Rosario is related to the emplacement of these rhyolitic dikes in high-angle, reverse fault zones.

Nomenclature

The El Rosario rhyolite includes not only rocks of granite composition, but also siliceous rocks containing plagioclase, called herein pheno-quartz andesite, that are related to the rhyolite dikes.

GENERAL APPEARANCE

Outcrops

Outcrops are usually only exposed in creek or river bottoms where they are rounded by river sediment abrasion. They are greenish gray to light yellowish gray and extremely hard where fresh. In the walls of the Humuya Gorge they form steep banks or cliffs (pl. 10F, H). At El Rosario the largest body (grid 2011) has thick brush growing on it.

Form.--El Rosario rhyolite is mostly discontinuous dikes less than 10 meters thick in fault zones. But at El Rosario and in the Humuya Gorge east of Cerro La Colmena larger irregularly-shaped bodies are exposed (pl. 1). These are probably also related to faults.

Contacts

Where rhyolite intrudes exposed mica schist on Cerro Las Anonas (pl. 9) the contacts have lit-par-lit injection features. Most of the rhyolite cutting Mesozoic sedimentary rocks intrude along faults. No baking has been seen in the host rock at any of the contacts.

Geomorphic Expression

El Rosario rhyolite weathers more readily than any of its host rock. Consequently, rhyolite outcrops usually occupy river bottoms (pl. 10F, H). At El Rosario the rhyolite holds up a hill, but here it may be partially hydrothermally altered to give it more resistance to erosion (pl. 12A, B).

Lithology

The rock varies from light yellow green, crystal-poor, quartz-sanidine tuff with devitrified groundmass to greenish yellow granophyric, albite and K-feldspar granite to orangy yellow aphanitic porphyritic altered rhyolite with resorbed quartz and altered feldspars in a clay-rich devitrified groundmass (#135 to 150) (pl. 11A, B, C).

Thin rhyolite dikes replaced in part by calcite intrude the Todos Santos and Atima formations. Northeast of Valle de Angeles they are greenish gray. Near Cacaguapa they have purple inclusions with hematite concentrations which I believe may be fine-grained, altered fragments of Valle de Angeles shale. The dike south of Guacamaya in grids 3304 and 3404 grades from aphanitic porphyritic rhyolite eastward into soft crystal-poor tuff (#351).

The tuffaceous and aphanitic porphyritic varieties may be feeder dikes for the Tertiary extrusive sequence, because of their textural and compositional similarity to the Padre Miguel Group tuff and ignimbrite.

Compositional variation.--Although the El Rosario rhyolite has a variety of textures and compositions, no compositional variation has been seen within one continuous outcrop. Some dikes grade from aphanitic porphyritic to tuffaceous texture along their length.

DISTRIBUTION

El Rosario rhyolite has only been found exposed within the metamorphic highland west of the Las Marias fault, mostly on Cerro Las Anonas and in the Humuya Gorge, and in the zone of high-angle reverse faults from east of Valle de Angeles to west of El Rosario (pls. 2, 9; figs. 12B, 15C).

AGE

The El Rosario rhyolite intrudes Valle de Angeles redbeds and older rocks along high-angle reverse faults (Laramide) from El Rosario to Valle de Angeles. Nowhere in the El Rosario Quadrangle has the rhyolite been seen intruded into the Padre Miguel Group; dikes may, however, be feeders for ignimbrites. Therefore, the rhyolite is no older than the beginning of Laramide deformation and possibly no younger than mid- and late Tertiary.

BASALT (DIORITE) DIKES

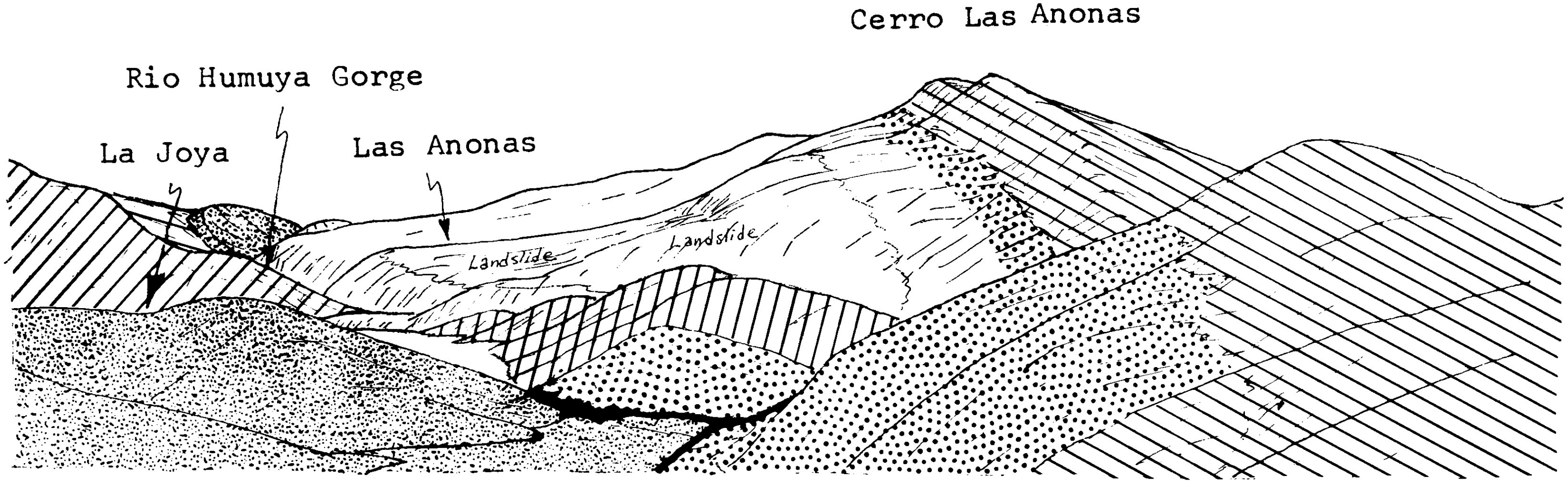
INTRODUCTION

Dark-colored, mafic-rich dikes intrude Todos Santos and older rocks and El Rosario rhyolite, along joints within the rhyolite and along north-trending faults in older rocks.

<u>Nomenclature</u>

Mafic dikes composed of plagioclase and mafic minerals are classified as andesite or basalt and diorite or gabbro by Streckeisen (1965) according to texture and percentage of mafic minerals. In the El Rosario Quadrangle the

PLATE 9



Photograph and sketch of Cerro Las Anonas and Rio Humuya Gorge. Photograph looking east from the west end of Cerro Grande in grid 2310. Lined areas are Atima limestone, large dots are Todos Santos Formation, and stippled areas are Valle de Angeles Group. Unpatterned area in middle is Cacaguapa Schist and intruded igneous rocks. Elevation difference from Rio Humuya to top of Cerro Las Anonas is 700 meters.

textures of mafic dikes range from very fine grained (microcrystalline) to very coarse grained. Compositions straddle Streckeisen's diorite-gabbro, andesite-basalt line. "Basalt" is used herein to include the variations of texture and composition of mafic dikes within the El Rosario Quadrangle and include both diorite and basalt.

GENERAL APPEARANCE

Thin, grayish green basalt dikes, usually less than 5 meters wide, weather yellow brown and form rounded boulder outcrops. In the Rio Humuya Gorge they form both sides of the canyon bottom (pl. 10H).

Where basalt dike contacts are exposed intruding Todos Santos clastic rocks the host rock may have a baked zone up to 12 or 15 centimeters thick. Other than a decrease in grain size within the basalt dikes at their bordors there is no apparent contact alteration where they intrude rhyolite.

Outcrops are usually less resistant to erosion than the surrounding host rock and are, therefore, only found in canyon bottoms or on the side of Cerro Las Anonas where the hill is help up by Atima limestone.

Lithology

Some of the rock is highly altered and, although finer grained, looks in thin section similar to the gabbro described below. Hornblende, up to 50 percent of the rock, replaced in part by chlorite (penninnite?) poikilitically encloses plagioclase laths producing in some specimens a lamprophyric texture. Pyroxene and some minor quartz are present as interstitial grains in the poikilitic crystal network. Highly altered basalt has feldspars heavily charged with vacuoles. Less altered basalt is replaced in part by epidote.

Highly altered, aphanitic to tuffaceous textured mafic-rich rock crops out on Cerro Las Anonas. These rocks have altered plagioclase and large amounts of chlorite, up to 40 percent, associated with calcite. No hornblende has been seen in thin section. Possibly these fine-grained, basaltic rocks are chemically similar to hornblende basalt but with chlorite and calcite instead of hornblende.

DISTRIBUTION

Basalt dikes are emplaced in rocks around the metamorphic highland. No basalt dikes have been found intruding the Padre Miguel Group, although Everett (1970) reported that diorite dikes intrude the Padre Miguel Group in the Comayagua Quadrangle.

AGE

The age of emplacement of basalt dikes is not certain. Some are younger than the El Rosario rhyolite (pl. 10C). Basalt dikes are associated with, and probably injected along, normal faults that bound the Comayagua graben. If these dikes were feeders to Quaternary basalt flows, the flows should still be preserved nearby, because Dupré (1970) reported very little erosion of Quaternary basalt near Tegucigalpa. Therefore, the basalt dikes in the El Rosario Quadrangle are probably related to one or both of the early or middle Tertiary basaltic volcanic events, the extrusion of Matagalpa basalt (Williams and McBirney, 1969) or the extrusion of Padre Miguel Group basalt flows.

GABBRO

INTRODUCTION

In the southeastern corner of the El Rosario Quadrangle a high, wide ridge covered by nearly impenetrable jungle extends eastward well into the Vallecillo Quadrangle. On aerial photographs the ridge looks identical to the east-trending ridge of gabbro in the Comayagua Quadrangle (Everett, 1970). Weathered, light olive gray boulders of hornblende gabbro are part of the specimen suite found in the Rio El Oro that drains the north side of the ridge. For these reasons the ridge is shown on the map as gabbro. Boulders of similar gabbro sit high on the northwest side of the Montaña de Comayagua above La Laguna. The mountain may be made of more gabbro than is shown on the map (pl. 1).

LITHOLOGY

Fresh rock is greenish black with a coarse holocrystalline texture. Hornblende rimmed by pyroxene poikilitically enclose plagioclase laths. Chlorite (peninnite?) in part replaces hornblende. The plagioclase is clouded with vacuoles and partially replaced by calcite, quartz, and sericite. Opaques are magnetite.

AGE

The relative age of these gabbro bodies is not known. Compositionally they are very similar to the basalt dikes. If they are part of the same igneous event as the basalt dikes, they are younger than the El Rosario rhyolite and young enough to be injected into the graben-forming faults.

PLATE 10

A. Contact of La Sabana ignimbrites on Todos Santos redbed conglomerate. Photograph looking east on timber road in grid 3620. John R. Everett's left hand is just above contact. Soil horizon can be seen between left knee and contact.

B. Sinuous grooves cut by sheetwash along bulldozer blade scratch. Photograph looking north on timber road in grid 3520. Hammer in groove at center gives scale.

C. Basalt dike intruded into rhyolite. Near vertical photograph taken at border of grids 2610 and 2511 in Humuya Gorge.

D. Basalt dike intruded into Humuya Member of the Cacaguapa Schist. Photograph looking east in grid 2711. Hammer in center of photograph gives scale.

E. Trail cut by mules in La Sabana ignimbrite. Photograph looking north along trail in grid 3099 at La Sabana in the Comayagua Quadrangle 4 kilometers south of the El Rosario Quadrangle. Dr. D. D. Arden, Jr. stidies the trail.

F. Rhyolite in Humuya Gorge. Photograph looking west at border of grids 2611 and 2711. Cliff on left side is approximately 8 meters high.

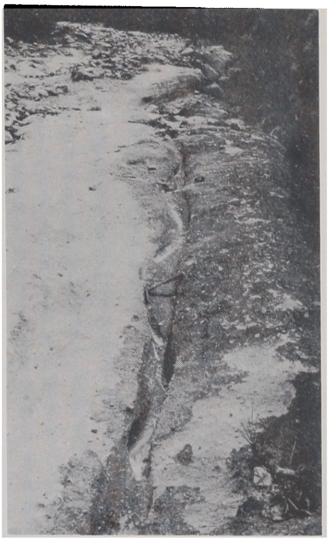
G. Spheres weathering out of La Sabana ignimbrites. Photograph taken at same locality as D above.

H. Rhyolite cliff in Humuya Gorge. Photograph looking west in grid 2711. Cliff on far side is rhyolite. Outcrops in foreground are basalt dikes.

PLATE 10

A

B



C

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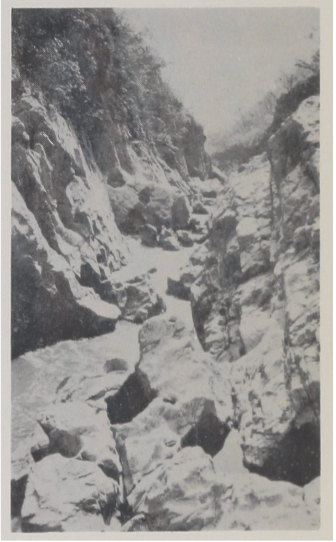


G

H

PLATE 11

A. Photomicrograph of sample #138A showing "snowflake" texture. Crossed nicols. Width of field is .85 mm.

B. Photomicrograph of sample #144 showing devitrified texture intermediate between "snowflake" and granophyric rock. Crossed nicols. Width of field is .85 mm.

C. Photomicrograph of sample #142 showing granophyric texture. Crossed nicols. Width of field .40 mm.

D. Gash fractures in Atima limestone boulder. Calcite fills fractures. S. E. Clabaugh studies the fractures in Rio Humuya in grid 2912.

E. End view of El Rosario high-angle reverse fault zone. Photograph looking northwest from grid 2308. This is the same hill shown in plate 12B and B' but from the ground.

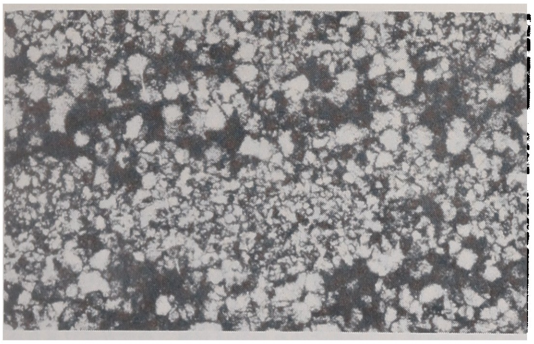
E'. Sketch of E showing position of high-angle reverse faults.

F. View of high-angle reverse fault near El Rosario. Photograph looking southeast from grid 2110. View shows opposite side of hills shown in photograph E.

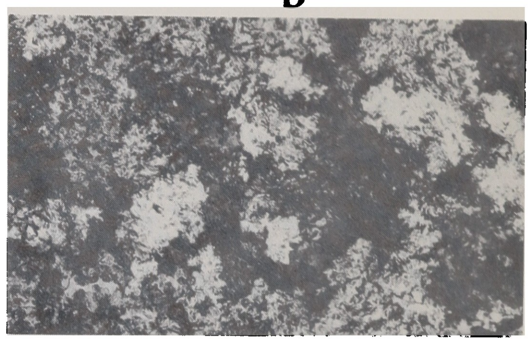
F'. Sketch of F showing high-angle reverse fault where it starts to flatten out. This is the same hill shown in plate 8A and A'. Fault line is close to horizontal here because this is a front view.

PLATE 11

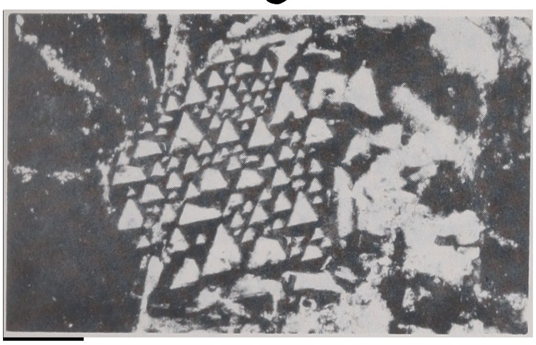
A



B

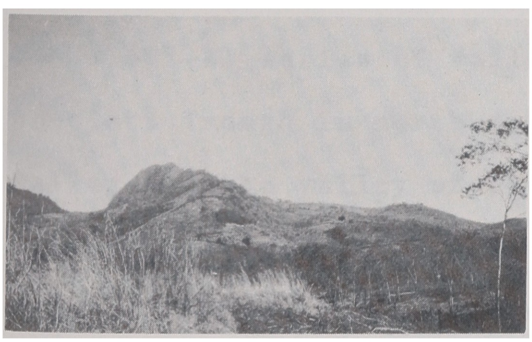


C



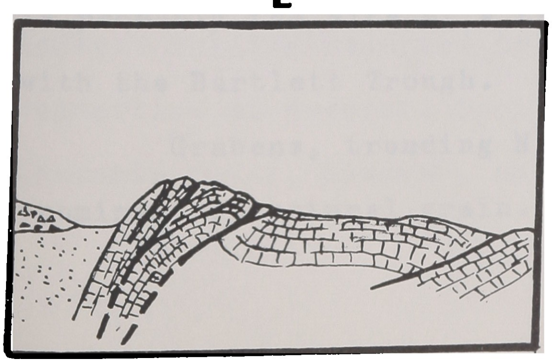
D

E



F

E′



F′

S T R U C T U R A L   G E O L O G Y

REGIONAL STRUCTURAL SETTING

Honduras occupies most of the exposed Caribbean lithospheric plate (Molnar and Sykes, 1969). The plate is bounded on the west by the Middle America Trench, a zone of eastward subduction ("subduction" is proposed by Nelson and Temple, 1969, as "areas where crust is being reincorporated into the mantle."), on the east by the Antillean zone of westward subduction, on the north by the Bartlett (Cayman) Trough of left-lateral transcurrent faulting, and on the south by a poorly-understood zone of right-lateral displacements along a line connecting the Antillean arc with Panama.

Several prominent structural directions are recognized in Honduras (fig. 8). The most obvious are a N. 30°- to N. 60° E. series of valleys that are parallel to the Bartlett Trough in northwestern Honduras and the Chamelecón Valley and the valley of the Rio Aguán in northern Honduras. Farther east the Rio Patuca flows in N. 30° E. valleys. These directions probably represent major structural breaks in the Caribbean plate. The Chamelecón Valley, for instance, is probably the site of a transcurrent fault zone associated with the Bartlett Trough.

Grabens, trending N.- to N. 15° E., form a second prominent structural grain. The Comayagua Valley is part of a system of <u>en echelon</u> grabens called the Honduras Depression.

A third grain, although not as prominent geographically as the first two, but possibly as significant, shows clearly on the newly published topographic quadrangles maps. This is a series of wide belts trending N. 60° W., parallel to the Middle America Trench. One of these belts crosses through the El Rosario Quadrangle. The internal structural elements of this belt form much of the local structure in the El Rosario Quadrangle.

Mills <u>et al</u>. (1967) described east-trending fold systems in central Honduras, the Atima anticlinorium in the Santa Barbara Mountains near Lago Yojoa and the Taulabé anticlinorium, trending from Taulabé into the La Libertad and El Rosario quadrangles. These are probably structural features associated with the N. 60° W.-trending structural belt.

LOCAL STRUCTURE

INTRODUCTION

The complex patterns of the geologic map (pl. 1) are formed mostly by faulting during at least two tectonic episodes. Folding occurred in the metamorphic rocks before deposition of Mesozoic rock, and again during the Laramide. Laramide folds, however, are secondary structural features related to basement deformation within a 130 kilometer long, N. 60° W.-trending structural belt. Cenozoic grabens formed in response to a different stress field. Renewed uplift may have occurred along the earlier structural belt.

FOLDS

Introduction

Folds are rare in the El Rosario Quadrangle. The two largest, the Cacaguapa anticline and the Taulabé anticline, indicate at least two periods of deformation with different stress orientations. The S. 15° W.-plunging Cacaguapa anticline was formed before the deposition of Mesozoic sediments with direction of maximum shortening oriented WNW-ESE. The Taulabé anticline formed after the deposition of Mesozoic sediments. It trends east with the direction of maximum shortening oriented N-S.

Metamorphic Folds

Folding in the Cacaguapa Schist is revealed on a large scale by a convenient marker bed, a marble-quartzite layer. The marble, and possibly the quartzite, has small-scale structural elements that will have to be studied before the deformation of the metamorphic rocks is clearly understood. This is beyond the scope of this mapping project.

Generally the marble-quartzite unit forms a large, open asymmetrical antiform plunging south-southwest. This fold is herein referred to as the Cacaguapa anticline. Cleavage planes near the marker layer are parallel to the layering. Elsewhere they are parallel to the axial plane of the large fold. Axes of small-scale crenulations within the schist and marble are parallel to the plunge of the major fold. More small-scale structural elements must be collected before a reasonable analysis can be made.

This deformation was imposed probably during the event that metamorphosed the pelitic sequence, because this sense of folding is not reflected in the deformation of younger rocks.

Laramide Folds

A large, open anticline trends and plunges eastward along the eastern slope of Cerro El Comalotál in the north-western quarter of the El Rosario Quadrangle. It is part of the fold system named the Taulabé anticlinorium by Mills *et al*. (1967); herein it is called the Taulabé anticline to distinguish it from other folds of the anticlinorium farther west. The fold is not part of the structure in the hills west of the La Libertad Road around Las Marias.

At Cerro El Comalotál the Taulabé anticline has folded Todos Santos conglomerate, Atima limestone, and Valle de Angeles redbeds. Erosion truncated the folded structure forming the surface on which the La Sabana ignimbrites were later deposited. Here the ignimbrites are not deformed by folding as much as the underlying sedimentary rock. Thus, folding began after deposition of Valle de Angeles redbeds (Late Cretaceous or early Tertiary), and mainly before extrusion of the ignimbrite (mid-Miocene). The folding is, therefore, mainly a Laramide feature with minor reactivation after Padre Miguel deposition.

Other Folds

Folds other than the Cacaguapa and Taulabé anticlines in the quadrangle are related to faulting, either reverse or normal block faults, and will be considered along with the analysis of faulting.

FAULTS

Introduction

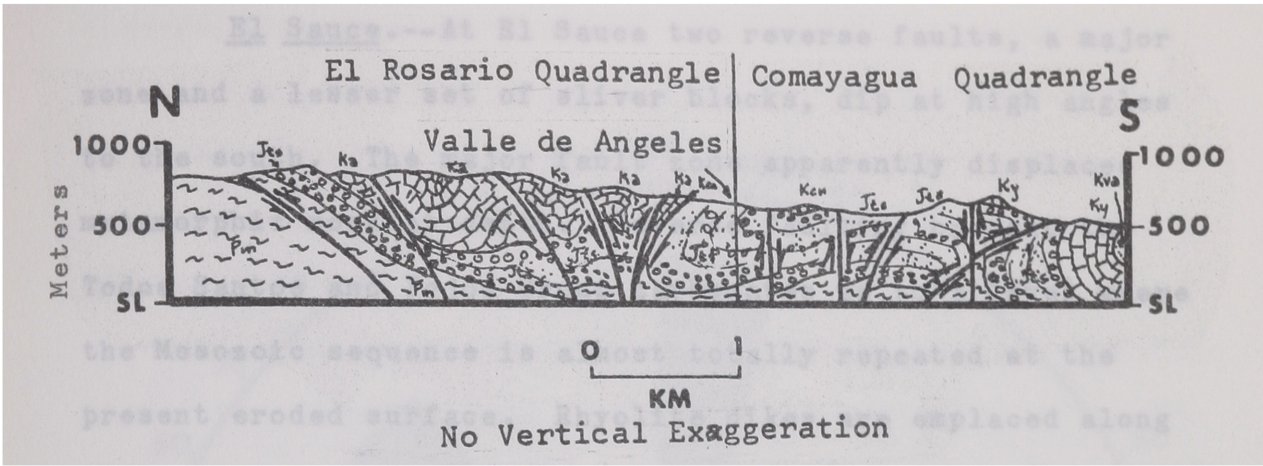
Several periods of faulting took place in central Honduras: 1) before and during deposition of the Todos Santos Formation, 2) during Laramide deformation, and 3) after Laramide deformation, possibly continuing nearly to the present. These show as reverse faults, probably secondary features above a major basement deformational feature, and a series of normal fault sets trending N. 45° W., N.

0-15° E., N. 30° E., and N. 60° E. Faulting before and during Todos Santos deposition is inferred from the wedge of clastic sediments thickening away from the metamorphic highland source.

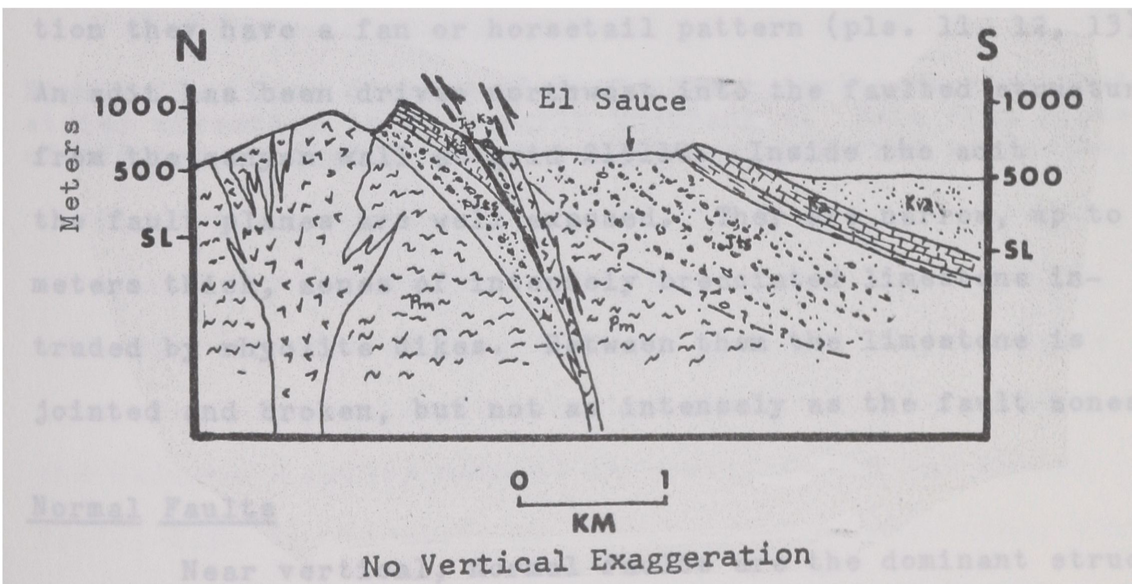
Reverse Faults

High-angle reverse faults displace Todos Santos Formation and Yojoa Group rocks along a N. 60° W. line from Valle de Angeles to El Rosario. Everett (1970) mapped this same zone to the southeast across the Comayagua Quadrangle. Three areas have well-displayed high-angle reverse faults or outcrops that require high-angle reverse faults to explain their distribution: 1) Valle de Angeles, 2) El Sauce, and 3) El Rosario. Rhyolite dikes are present along parts of all the reverse fault zones.

Valle de Angeles.--At Valle de Angeles reverse faults displace Atima limestone, Cantarranas marly shales, and Todos Santos conglomerate at the surface. Imbricate fault planes dip both north and south toward a common zone at depth. Rhyolite intrudes the fault planes in many places. Away from the main area of faulting 3 or 4 small reverse faults, some with up to 20 meters throw, repeat metamorphic rock and Todos Santos conglomerate to the north. Toward the south at the southern border of the quadrangle Todos Santos conglomerate beds are overturned to the south (fig. 12A).



A. Cross section along longitudinal grid 31 straddling the El Rosario-Comayagua quadrangle boundary. This is the same section shown in figure 14 with normal faults included.



B. Cross section along longitudinal line just east of grid line 28 at El Sauce. This section is the central portion of the cross section shown by Mills <u>et al</u>. (1967, p. 1748, Section D-D').

Figure 12. Cross sections through Montaña de Comayagua structural belt features.

El Sauce.--At El Sauce two reverse faults, a major zone and a lesser set of sliver blocks, dip at high angles to the south. The major fault zone apparently displaces metamorphic rock at depth. Reverse faulting brought the Todos Santos and Yojoa Group carbonates up to a level where the Mesozoic sequence is almost totally repeated at the present eroded surface. Rhyolite dikes are emplaced along these zones as at Valle de Angeles and El Rosario (fig. 12B).

El Rosario.--High-angle reverse faults at El Rosario are a series of southwest-dipping, curved (convex downward) planes that displace Yojoa Group carbonates and Todos Santos conglomerate. The system has imbricate planes that splay upward and out flattening to the northeast. In cross section they have a fan or horsetail pattern (pls. 11, 12, 13). An adit has been driven northwest into the faulted structure from the canyon wall at grid 215110. Inside the adit the fault planes are well exposed. They are narrow, up to 5 meters thick, zones of intensely brecciated limestone intruded by rhyolite dikes. Between them the limestone is jointed and broken, but not as intensely as the fault zones.

Normal Faults

Near vertical, normal faults are the dominant structures exposed in central Honduras. Figure 13 is a rose diagram plot showing the plot of 175 normal faults and photo

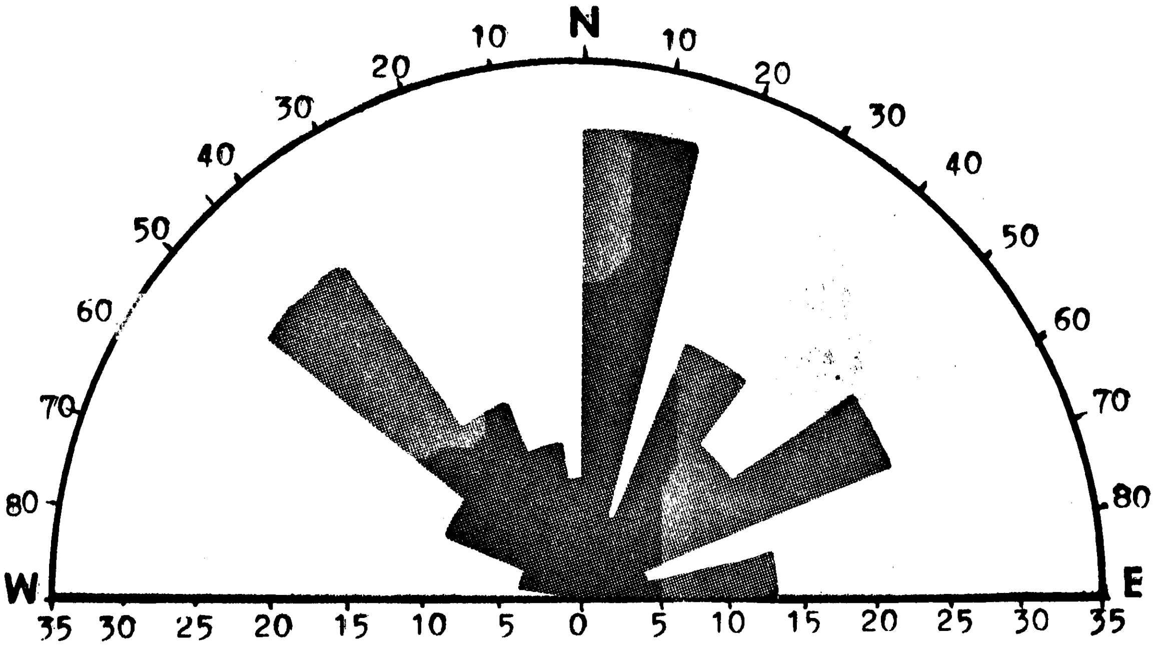


Figure 13. Rose diagram plot of normal faults showing their strike direction in El Rosario Quadrangle. Data from plots of 175 mapped faults and photo linears, inferred as faults.

linears, most probably faults, that occur in various directions in the El Rosario Quadrangle. This plot is not weighted for magnitude of displacement or fault length. It shows four dominant directions of faulting, N. 45° W., N. 0-15° E., N. 30° E., and N. 60° E., that are probably related to various times of formation and types of basement deformation. For instance, the N. 0-15° E. direction shows faults that formed the Comayagua graben, one of the youngest major structures. Other fault systems are: 1) tear faults bounding high-angle reverse fault zones, 2) other faults associated with the formation of the structural belt, and 3) faults bounding randomly oriented blocks, probably associated with graben formation and region uplift.

North-trending normal faults are associated with graben faulting that produced the Honduras Depression in the Comayagua region. In the El Rosario Quadrangle these are: 1) the Montaña Rio Obscuro fault, inferred from geomorphic form, and the Espino graben faults, the eastern one along with the Montaña Rio Obscuro fault produce the Montaña de Comayagua scarp which is the east side of the depression; 2) the Cacaguapa fault, down to the east; 3) the Las Marias fault, down to the west; 4) the Rio Humuya fault zone, down to the west; and 5) the San Jacinto fault, down to the east, that bounds the west side of the Honduras Depression in the El Rosario Quadrangle (fig. 18).

The two major times of normal fault formation are during the Laramide development of the structural belt and post-Laramide formation of the Comayagua graben. Normal faults are discussed below as they relate to these two major deformations.

Joints

The only rock with a consistent, well-developed joint system is the granophyric granite facies of the Rio Humuya rhyolite in the Rio Humuya Gorge at grids 2610, 2611, 2710, and 2711 (pl. 10F). Here joints are vertical and trend N. 75° W., parallel to the river. The path of the river in this part of the gorge is probably determined by easy breaking of the rock along this joint system.

The only other sets of well-developed tensional cracks are developed as calcite-filled, en echelon gash fractures in Atima limestone (pl. 11D). If enough of these fractures could be plotted from limestone outcrops still in place, they might offer solutions to the stresses placed upon the limestone.

MONTAÑA DE COMAYAGUA STRUCTURAL BELT

Topographic maps, aerial photographs and scattered areas of geologic mapping of central Honduras show a dominant N. 60° W.-trending zone of topographic and geologic grain.

The zone trends from San Juancito near Tegucigalpa northwest into the Montañas de Santa Barbara west of Lake Yojoa, a distance of about 130 kilometers. The zone may extend even farther southeast to Yuscarán. The width varies from 20 to 30 kilometers. Everett (1970) and I suggest that this zone be called the Montaña de Comayagua structural belt for the Montañas de Comayagua, the major topographic feature along the belt.

Zones of deformation of this magnitude in central America are probably related to large-scale displacements in the basement rock that are related to the deformational history of the Caribbean plate. Therefore, it is expected that deformational features in the thin sequence of sedimentary and volcanic rock overlying the basement will have a confused configuration not easily satisfied by models explaining small-scale structural regimes. A first glance of the geologic maps of the El Rosario and Comayagua quadrangles shows faulting in the Montaña de Comayagua structural belt that looks similar to the breakage pattern of a shattered automobile windshield. Yet there is some order within the melange.

Structural features that characterize the Montaña de Comayagua structural belt include: 1) large, open east-trending folds, the Taulabé and Atima anticlinoria and possibly the metamorphic highland; 2) tight, asymmetrical or overturned folds, usually overturned to the south; 3) a zone of high-angle reverse faults; 4) intrusions of silicic, igneous rock as dikes, plugs, and stocks; and 5) hydrothermal alteration and base metal mineralization.

Lowell (1969) presented a type of model that includes these trends of folding and reverse faulting. The model requires left-lateral, strike-slip motion at the boundaries of two crustal plates which are also being driven toward one another at a small angle (fig. 14A) producing a compressional component normal to the trend. Lowell photographed clay cake experiments in which this situation was reproduced. Material from the plate boundaries must move upward and, near the surface, outward away from the trend to accommodate the resulting reduction in volume at depth (fig. 14B). Features at the upper surface of the clay cake include: 1) folds, both open and tight, trending obliquely to the main strike-slip motion trend; 2) high-angle reverse faults; and 3) normal faults with small displacements striking perpendicular or subperpendicular to the trends of the folds (fig. 14B). All these features are present in the El Rosario Quadrangle on a large scale. North-trending normal faults, a feature of the model, have directions coincident with Comayagua graben faults, features of a later deformational event. Normal faults produced by both events cannot be distinguished. Possibly normal faults, predicted from the model, may have been produced during the formation of the Montaña de Comayagua structural belt

PLATE 12

A. Aerial view of El Rosario structure along the Montaña de Comayagua structural belt. View is from the northwest.

A'. Sketch of A showing high-angle reverse faults. R is rhyolite.

B. Aerial view of El Rosario structure along the Montaña de Comayagua structural belt. View is from the southeast.

B'. Sketch of B showing high-angle reverse faults. R is rhyolite.

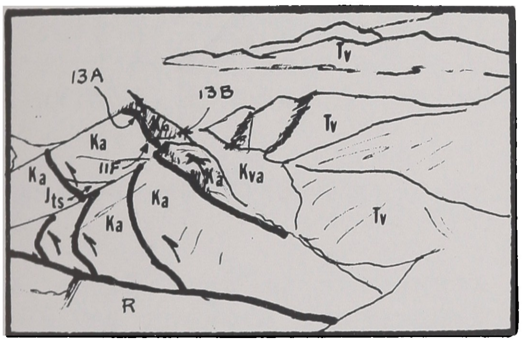
C. Aerial view of San Jacinto fault looking north. Cliffs on left are Atima limestone. Stratigraphically higher Valle de Angeles Group sandstones are topographically and structurally lower on the right of the fault. Plate 6B is photograph of cliff at lower left from about the same direction. El Horno is beneath airplane.

PLATE 12

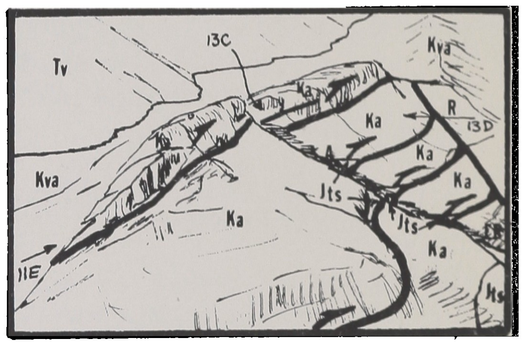
A

B

A´



B´



C

PLATE 13

A. View of El Rosario structure in Montaña de Comayagua structural belt at El Rosario showing drag folds above fault plane. Photograph taken from adit entrance at grid 2110.

A'. Sketch of A.

B. View of drag fold of El Rosario structure in Montaña de Comayagua structural belt at El Rosario. Photograph taken in grid 2110.

B'. Sketch of B.

C. View of high-angle reverse faults in Montaña de Comayagua structural belt at El Rosario. Photograph looking northwest from canyon above village of El Rosario in grid 2110.

C'. Sketch of C showing Atima limestone folded and repeated by faulting.

D. View of front of El Rosario structure in Montaña de Comayagua structural belt. Photograph looking southwest from village of El Rosario. Lines on hillside are prospect trenches over Opoteca Mine.

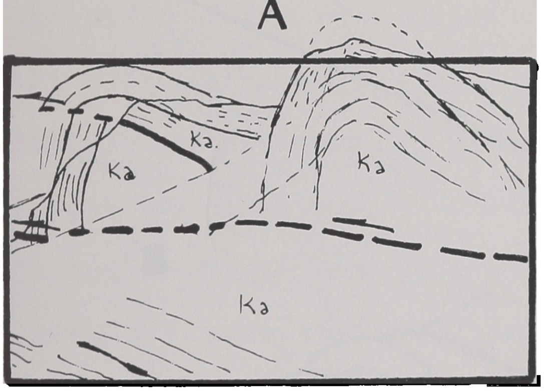
D'. Sketch of D showing Atima limestone moved up and toward viewer along high-angle reverse faults. Dashed lines are approximate locations of faults. Canyon at left is location of photographs plates 11F, 13A, B, C.

PLATE 13

A

B

A′

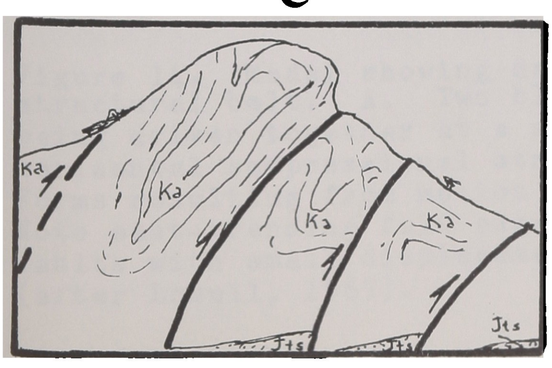


B′

C

D

C′



D′

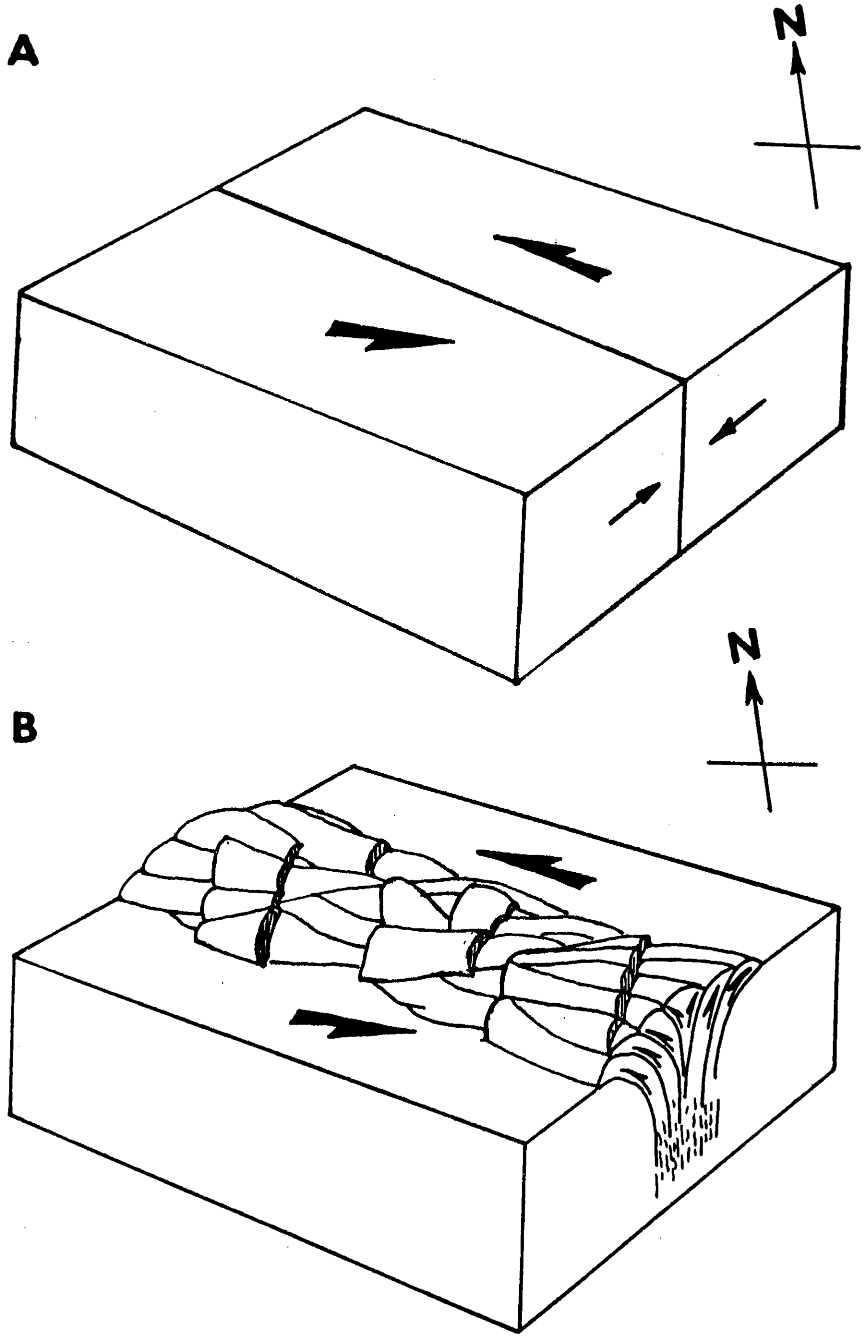


Figure 14. Model showing development of Montaña de Comayagua structural belt. A. Two blocks moving past each other and being driven together at a small angle. Note component of horizontal compressional stress normal to fault zone. B. Forms resulting from motion between two blocks shown in A. Note east-trending fold axes, north-northeast-trending normal faults with small displacements, and high-angle reverse faults (after Lowell, 1969).

and later provided zones of weakness that were reactivated during graben formation.

If this model adequately explains the structural features within the Montaña de Comayagua structural belt, it must also be compatible with any explanation of the complex structure exposed at the village of Valle de Angeles (figs. 12A, 14). Figure 15 shows the chronological development of the sedimentary rock distribution at Valle de Angeles, if the deformation was similar to the above model. Relatively flat-lying sedimentary rocks thickening to the south overlie a zone of potential strike-slip movement in the basement. As motion began both the upward movement of material and the resultant compressional component normal to the fault plane folded and faulted the overlying sedimentary rocks. At the surface tectonic transport was away from the trend of the strike-slip fault. The break in the basement and overlying high-angle reverse faults provided easy access for intrusion of silicic dikes. Later normal faulting during graben formation modified the distribution of sedimentary rocks to give the present outcrop pattern.

This mechanism could also produce the high-angle reverse faults and intrusions exposed at El Sauce and El Rosario.

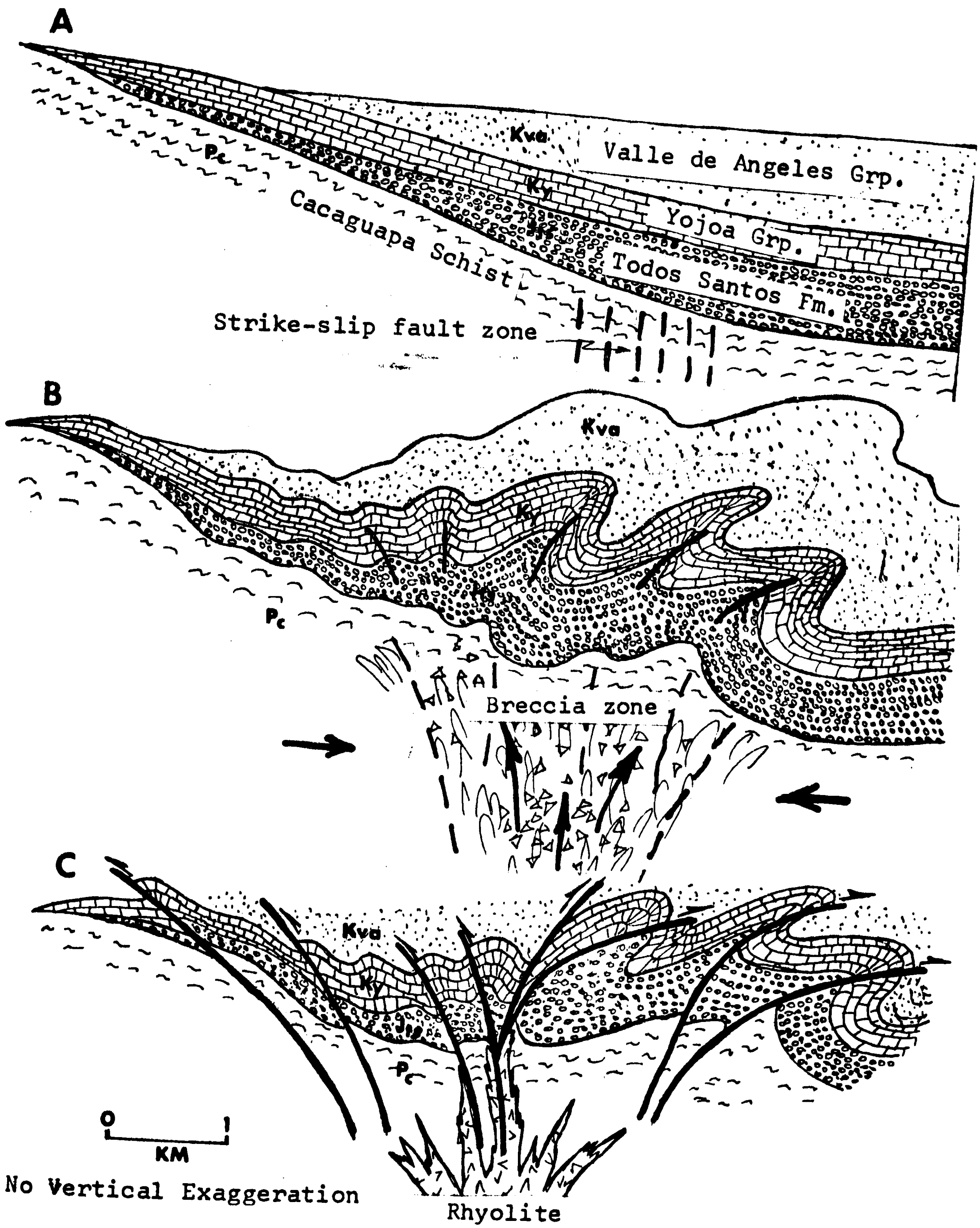


Figure 15. Development of high-angle reverse faults and overturned folds within the Montaña de Comayagua structural belt at Valle de Angeles along Section A-A'. A. Section prior to Laramide folding showing zone of incipient strike movement and compression. B. Beginning of strike-slip movement and upward bulging of overlying sedimentary rocks. Note compressional component. C. Formation of high-angle reverse faults and intrusion of rhyolite dikes. This is the same structure as shown in figure 12A without normal faults and present topography shown.

GRABEN FAULTS

Introduction

Most valleys of central Honduras are in grabens. The El Rosario Quadrangle has two valleys: the Valle de Espino, a graben, and the Valle de Comayagua, which is not a graben. Although this small valley in the southern part of the El Rosario Quadrangle bears the same name as the much larger valley to the south in the Comayagua Quadrangle, it is neither topographically nor structurally the same feature. The Valle de Comayagua of the El Rosario Quadrangle was probably formed from erosion of ignimbrites and Valle de Angeles redbeds by the Rio Humuya. The Valle de Espino is a graben that is bounded by some of the faults that extend south into the Comayagua Quadrangle to form the eastern side of the large Comayagua graben of Everett (1970). I call the graben that forms the Valle de Espino the Espino graben (fig. 17).

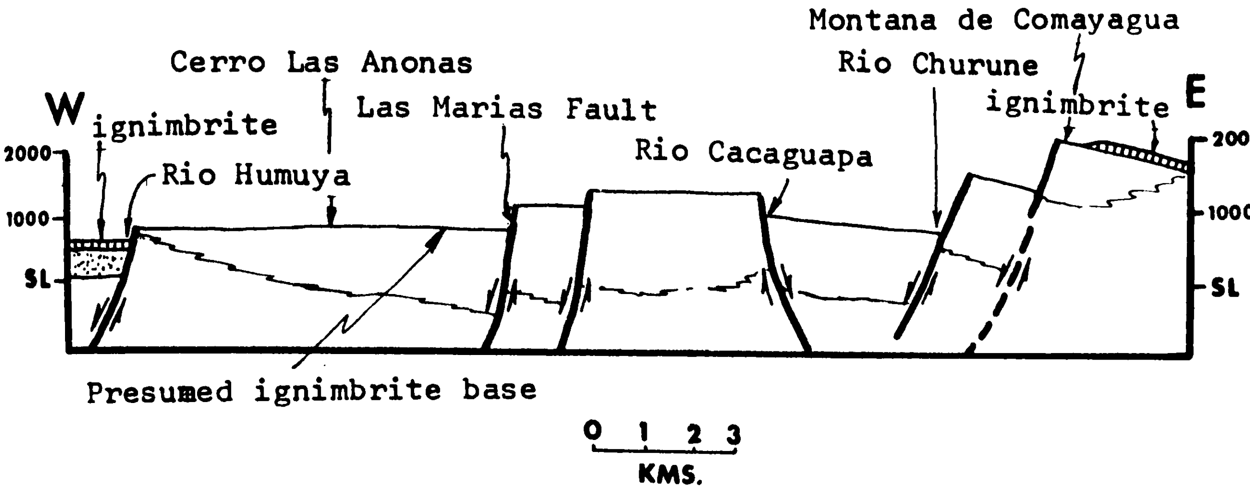
Structural Form of Espino Graben

The Espino graben structure extends from the Valle de Espino southward into the metamorphic highland in front of the Montaña de Comayagua between the rios Churune and Cacaguapa. The best region to study the graben fault system is in the metamorphic highlands. The greatest displacement of the north-trending normal faults occurs along an east-west line from the top of the Montaña de Comayagua to the

Rio Humuya.

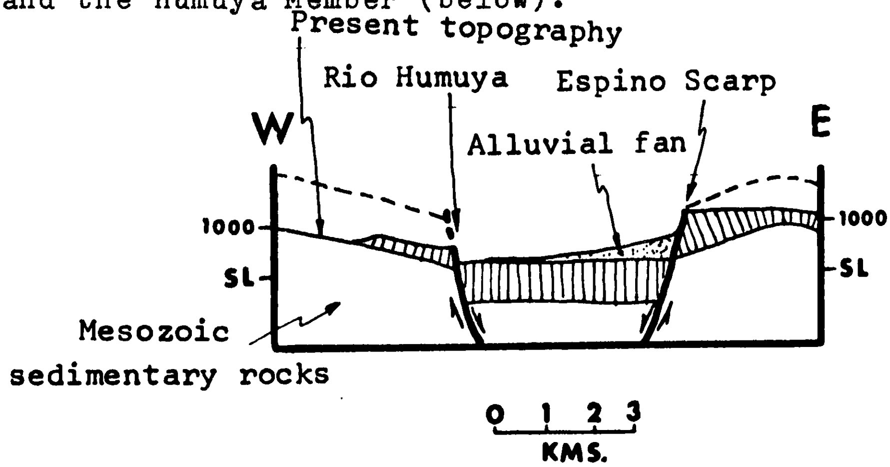
Figure 18 is a sketch showing displacement of the basement surface. Five of six major faults, mapped or inferred, successively drop the basement downward to the west, except for the block between the rios Cacaguapa and Churune. The northern end of this graben is the Espino graben. The Espino graben is probably formed by a series of downdropped, diamond-shaped blocks. The cuestas of ignimbrite that dip into the valley on both sides are roll-overs of the upthrown blocks.

Displacement across the east-trending section (fig. 16) is difficult to measure. Approximate maximum structural relief can be determined from the top of the Montaña de Comayagua to the floor of the Valle de Comayagua at Palo Pintado, if several factors are considered. First, the elevation of the La Sabana ignimbrite basal contact at Palo Pintado is about 600 meters above sea level. Second, the elevation of the basal ignimbrite on the top of Montaña de Comayagua is located, by aerial photograph interpretation, at 2100 meters above sea level. This elevation difference gives 1500 meters of present basal ignimbrite relief. From this figure must be subtracted the basal relief at the time of deposition of the ignimbrite. The ignimbrite at the top of the mountain is probably not a part of the La Sabana ignimbrites. More likely it is an ignimbrite stratigraphically



Vertical exaggeration X1 1/2

Figure 16. Diagrammatic cross section from the Humuya Gorge to the top of Montaña de Comayagua showing presumed top of basement displaced along graben faults. Present topography not shown. Ignimbrite has 1500 meters of structural relief. There may have been 800 meters of topographic relief on basement at time of ignimbrite deposition. Graben between the rios Cacaguapa and Churune is the southern extension of the Espino Graben. Rock shown without symbols is metamorphic rock of the Cacaguapa Schist. Wavy line in Cacaguapa Schist is presumed contact between the Las Marias Member (above) and the Humuya Member (below).



No Vertical Exaggeration

Figure 17. Diagrammatic cross section of the Espino Graben. Hatched area is La Sabana ignimbrites. Underlying rock is Mesozoic sedimentary rocks. Present topography is shown.

above the La Sabana ignimbrites package (Everett, 1970). Dupré (1970) has the same unit in his area deposited in places as much as 800 meters above the base of the La Sabana ignimbrites. Thus, subtracting 800 meters of possible topographic relief from 1500 meters of present structural relief, there may be as much as 700 meters of relative displacement taken up by the system of north-trending normal faults in the El Rosario Quadrangle. This figure is probably close to the displacement along the normal fault bounding the east side of the Espino graben. This is also the probable amount of relief between the basal contact of the La Sabana ignimbrite and the basal contact of the ignimbrite capping the north end of the mountain near La Laguna.

Figure 18 is a sketch showing locations and relative displacements along the major normal faults. The upper surface is the presumed base of the Tertiary ignimbrite package assuming all faults formed contemporaneously and instantaneously.

Time of Formation of Espino Graben

To the south normal faulting began after Valle de Angeles Group deposition, possibly before the deposition of the Matagalpa Formation and definitely before the deposition of La Sabana ignimbrites (Everett, 1970; Dupré, 1970). Everett and Dupré felt, however, that most of the graben formation

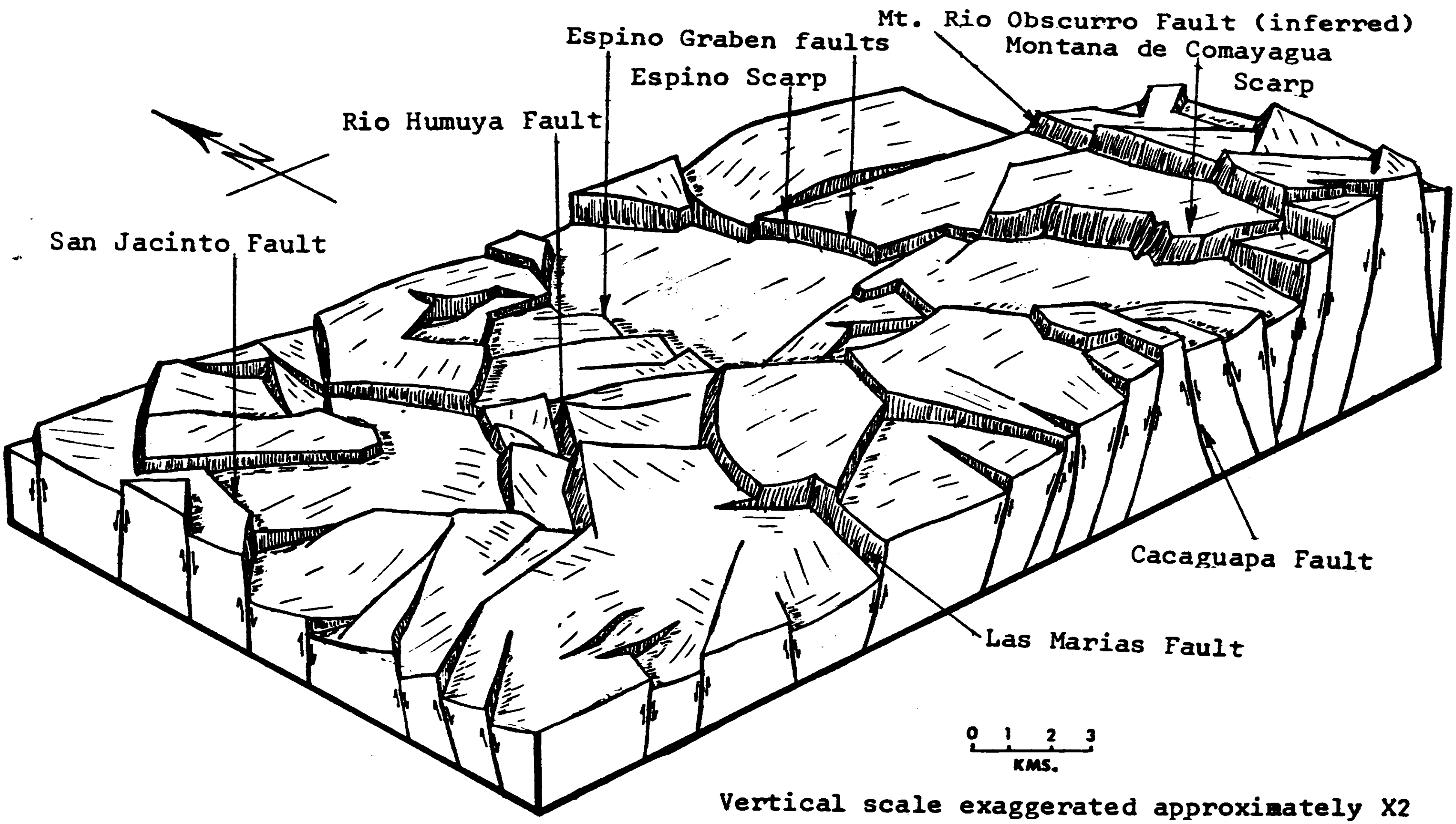


Figure 18. Graben faults displacing ignimbrite package. Diagram assumes contemporaneous and instantaneous formation of all faults. Upper surface is presumed base of Tertiary ignimbrite package.

took place after deposition of the Padre Miguel Group. This agrees well with the time of formation of the Espino graben, for lag gravel on top of cerros El Cacao and El Portillo indicates that the Valle de Espino was not topographically low until after deposition of the La Sabana ignimbrites and that the metamorphic highland was already partially exposed.

CENOZOIC UPLIFT OF MONTAÑA DE COMAYAGUA STRUCTURAL BELT

La Sabana ignimbrites dip away from the Montaña de Comayagua structural belt, about 20 degrees southwest at Palo Pintado and up to 50 degrees north of Cerro Potrero Sucio east of Cacaguapa. These dips indicate post-La Sabana uplift, either associated with graben formation or possibly uplift parallel to the Montaña de Comayagua structural belt. Farther southeast along the structural belt Everett (1970) and Dupré (1970) found evidence that much of the belt has been uplifted since extrusion of the ignimbrites. This uplift event may have produced the relief on the base of the ignimbrites around the Siguatepeque scarp in the western part of the El Rosario Quadrangle.

G E O M O R P H O L O G Y

ORIGIN OF SCARPS

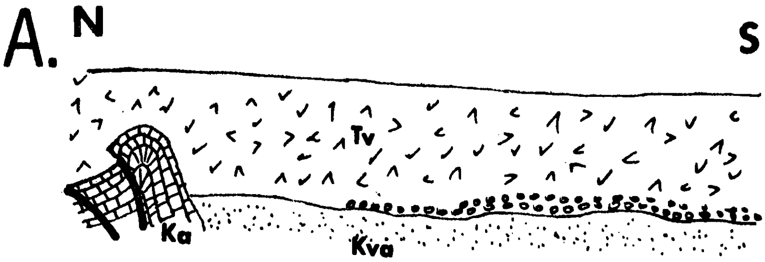
High scarps dominate the topography of the El Rosario Quadrangle forming the northern end of the valley in the Comayagua region that is considered the central segment of the Honduras depression.

SIGUATEPEQUE SCARP

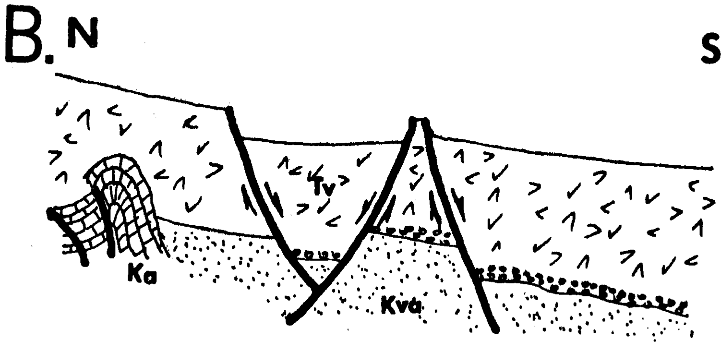
The Siguatepeque scarp is formed by a series of receding fault and fault-line scarps. The local base level of the Rio Humuya allows the river to cut a flat-bottomed valley on Valle de Angeles redbeds in front of the scarp. The high permeability of some of the ignimbrites forming the Siguatepeque plateau hinders erosion of the top surface, but erosion at the base of the scarp in fault valleys along the front of the plateau develops landslides that maintain a nearly vertical cliff face (fig. 19).

ESPINO SCARP

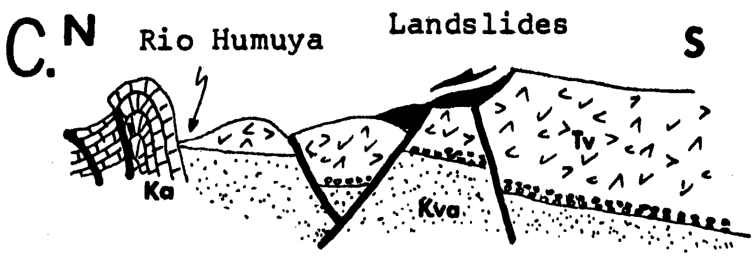
The Espino scarp bounds the east side of the Valle de Espino. It is probably a fault scarp because: 1) it has a straight trace, offset along faults oblique to its trend, and 2) the structure of the graben shows downwarping of ignimbrite on both sides of the valley with flat-lying ignimbrite



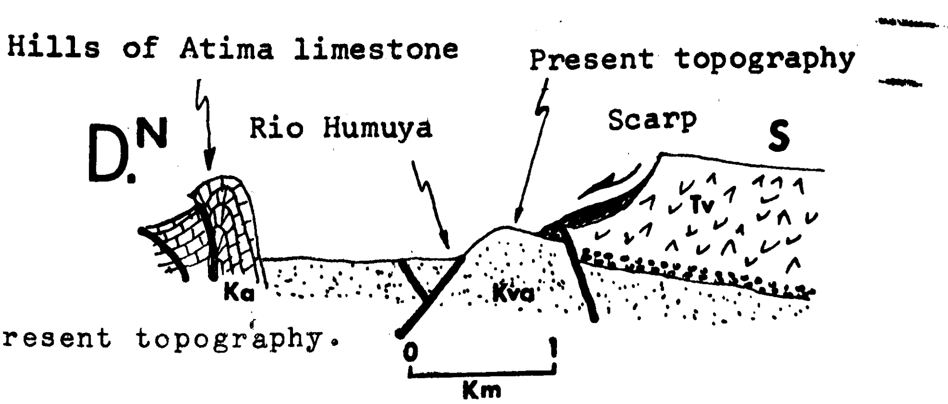
A. Immediately after ignimbrite deposition.



B. Block faulting associated with graben formation to the south.



C. Beginning of erosion by ancestral Rio Humuya.



D. Present topography.

Figure 19. Diagrammatic sketches showing development of the Siguatepeque Scarp.

forming the valley bottom (fig. 17). The trace of the fault is probably buried under the bahada that aprons the entire east side of the valley.

SAN JACINTO FAULT SCARP

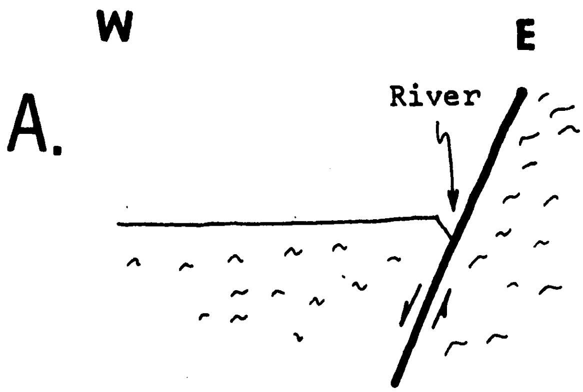
The San Jacinto fault (fig. 18; pls. 6B, 12C) which bounds the west side of the structural basin north of El Rosario is a resequent fault-line scarp, the upthrown side topographically higher than the downthrown side.

MONTAÑA DE COMAYAGUA SCARP

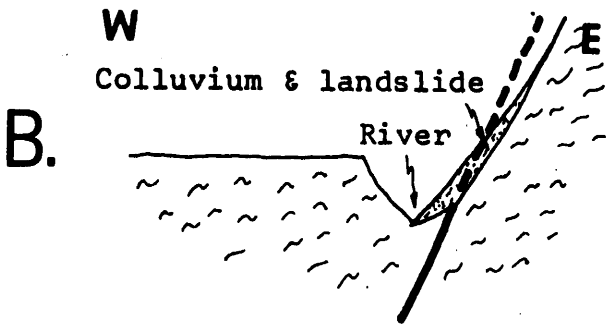
The steep Montaña de Comayagua scarp forming the western side of the Montaña de Comayagua from the top of the mountain down to the top of the Rio Churune canyon is one or more fault scarps, mantled by colluvium and landslides and modified by erosion of streams draining off the scarp.

The origin of the Rio Churune canyon at the bottom of the scarp is more complicated. Because no faults have been seen in the canyon bottom and because the west side of the canyon is metamorphic rock, whereas, the east side is landslide debris, I believe the bottom is west of a fault line. The following is a model that explains the reason for a difference in wall rock of the canyon as well as the sinuous river course in a straight-line fault valley. Essentially, while the Montaña de Comayagua scarp above the canyon is receding eastward from the fault line, the eastern canyon wall of the Rio Churune is building westward from the fault line by addition of the material shed from the fault scarp above. Material is shed into the canyon faster than the river can remove it. Originally, the canyon was probably a fault valley with downcutting proceeding on both sides. However, as landslides are dumped into the canyon the river is required to erode bedrock on the west slope of the canyon and attempt to remove the landslide debris on the east side. The river erodes the landslides faster than the bedrock, but, as fast as the toe of the slide is removed, more material from above takes its place. Thus, the east side of the canyon is rebuilt while the west side is removed permanently. The canyon bottom, therefore, is moving downward and westward away from the fault that originally set the course of the river (fig. 20A, B, C).

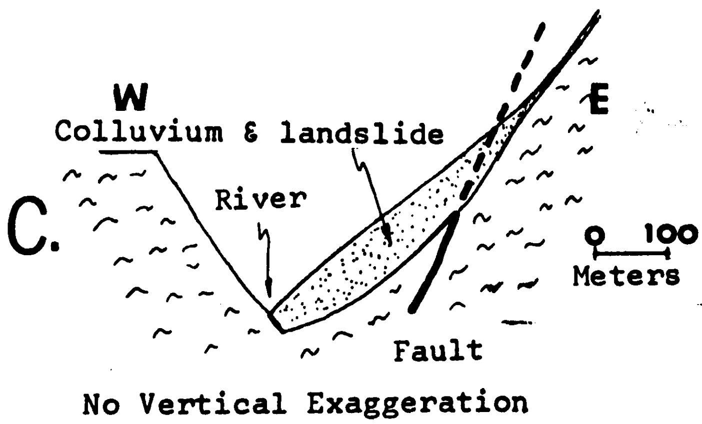
Material shed from either side of the valley forms small fans behind which the river temporarily ponds. As the pond fills and the river eventually flows over the dam, it does so at the toe of the slide. If enough material is contributed to the slide the process will eventually force the stream to cut into the valley wall on the opposite side and form a loop in its course (fig. 21).



A. Faulting and beginning of downcutting along fault.



B. Colluvium and landslides pushing stream away from fault trace.



C. Presently stream is positioned west of fault trace.

Figure 20. Formation of Rio Churune Canyon.

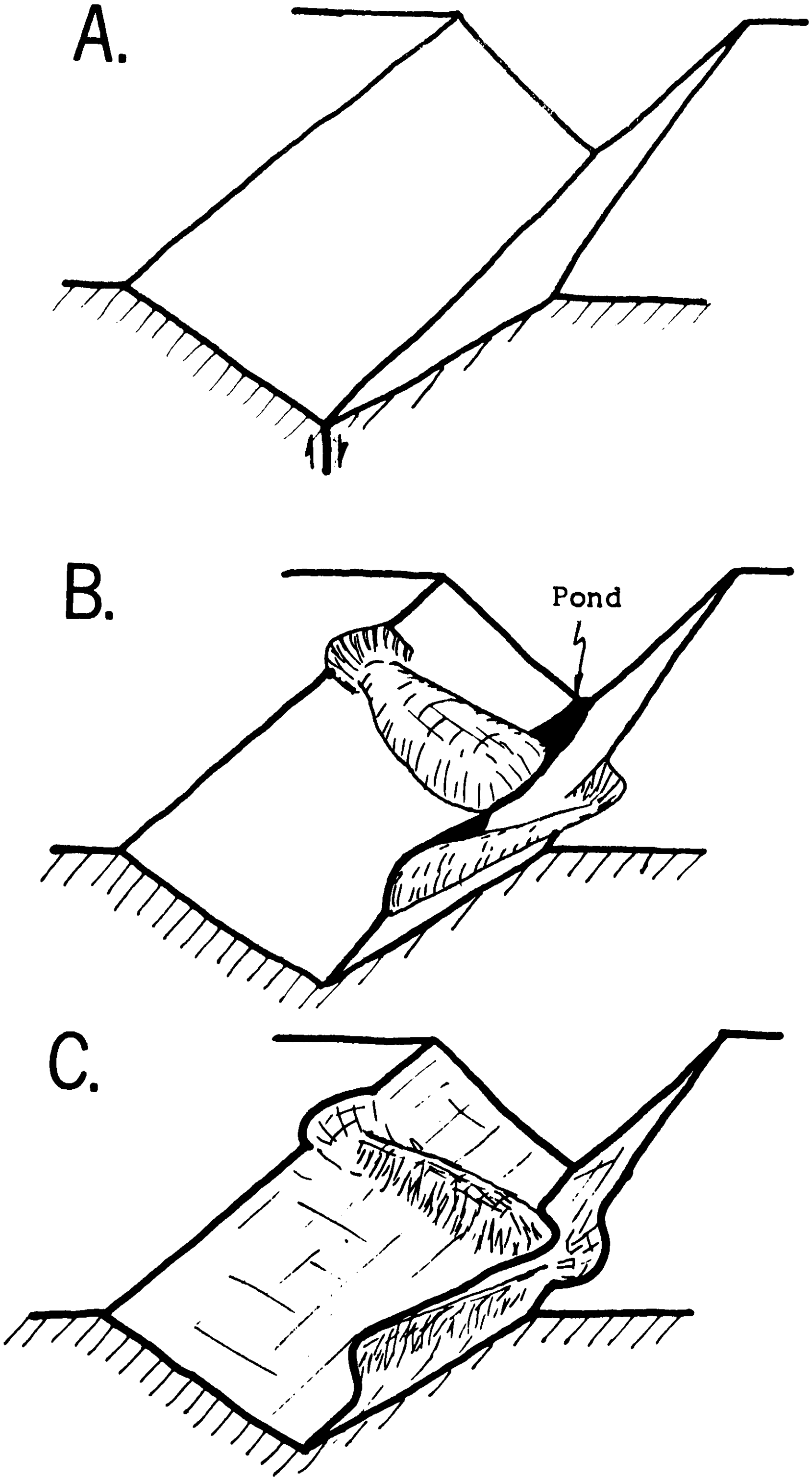


Figure 21. Development of sinuous stream course within straight-line fault valley. Process is continuous as long as landsliding occurs, continuously changing local stream path. A. Valley formed by erosion along fault. B. Landslides pond stream and divert its course around toe of slide. C. Stream entrenches along new course, even after most of slide is removed.

ATIMA LIMESTONE CLIFFS

Throughout the area massive Atima limestone forms imposing cliffs, especially where the beds are tilted. Most scarps are probably fault scarps. Scarp retreat is aided by the stratigraphy: hard, well-cemented Todos Santos conglomerate overlain by soft, marly, Orbitolina-bearing limestone, in turn overlain by thick, jointed, limestone with solution cavities and other karst features.

The process of scarp formation begins with faulting and tilting of beds, although tilting is not a necessary requirement. Scarp retreat begins at the fault and proceeds by undercutting of the thick limestone along the underlying beds of softer marly limestone. The thick limestone dip slope, once exhumed by erosional stripping of the overlying Valle de Angeles redbeds or younger rocks, does not undergo much erosion because rain water percolates down through the jointed rock and concentrates at the marl-conglomerate interface. Solution and erosion of the marl takes place as the water flows through it along the top of the conglomerate. At the scarp large jointed boulders fall off the eroding face and mantle the slopes below.

ORIGIN OF DRAINAGE

The major streams and most of their tributaries are probably subsequent, adjusting their course to flow along faults. Tributaries draining Todos Santos conglomerate shift their course to erode softer beds. The segment of the Rio Humuya flowing in the Valle de Espino may have originally been consequent, flowing in this fault-formed valley, because it has planed a wide area, at least that part in front of the alluvial fans. But most of its course now seems stabilized along faults bounding the eastern side of the valley. One small segment of the Humuya eroding granophyric granite in the Humuya Gorge is probably flowing in response to the prominent joint set within the rock (pl. 10F).

RIO HUMUYA FLOODPLAIN

VALLE DE COMAYAGUA

The N. 60° W.-trending Valle de Comayagua of the El Rosario Quadrangle was formed by erosion of weakly resistant beds, unlike the larger graben-formed Valle de Comayagua to the south. Faulting may have played a minor role in determining the orientation of the long axis of the valley, because two normal faults, one with small displacement, are parallel to the valley sides. Folding helped by tilting the sedimentary section to the southwest bringing up resistant Atima limestone along the N. 60° W. trend. Lateral planation by the Rio Humuya within the constraints of Atima limestone on the northeast and scarp retreat of the ignimbrite sequence on the southwest, formed the Valle de Comayagua of the El Rosario Quadrangle.

Cut terraces, gravel veneered surfaces, in part truncating bedrock exposures, form the bench above the present riverbed that bottoms most of the Valle de Comayagua in the El Rosario Quadrangle. The cut terraces truncate sidestream deposits as well as bedrock of the Valle de Angeles Group redbeds. These surfaces are parallel to Rio Humuya grade, but to a slightly higher base level than now exists.

VALLE DE ESPINO

The scallop-shaped toe of the southwestern side of the coalescing fans of the Valle de Espino is cut during flood stages of the rios Humuya and Churune. The Rio Humuya may have once laterally planed the bottom of most of the Valle de Espino, but lateral cutting has been progressively constrained by the advancing toe of the alluvial fans building on the east side of the valley. Portions of the Rio Humuya appear stabilized along faults bounding the west side of the valley.

METAMORPHIC HIGHLAND SURFACE

A set of circumstances, similar to those forming the present Valle de Espino, may have acted on an ancestral Rio Humuya in the metamorphic highland. Lateral planation may have, at least in part, formed the now rough surface 900 to 1000 meters above sea level on the highland. The river adjusted its position to the major faults bounding the western side of the metamorphic blocks after being forced westward by advancing alluvial fans off the ancestral Montaña de Comayagua. The river cut the Humuya Gorge and fixed its position, probably with the help of a change in base level.

LAKES

La Laguna in grid 4013, like most small lakes in the Comayagua region, is located on ignimbrite. It probably formed behind slump material damming a small valley. Either the local permeability of the ignimbrite is very low or the lake formed after the depression became coated with clay and silt.

I could not find the small pond shown on the map on the north side of Cerro El Camalotál in the southeast corner of grid 2127, and I doubt that it exists, because it is on Todos Santos conglomerate.

ECONOMIC GEOLOGY

INTRODUCTION

Silver, lead, zinc, copper, antimony, gold, mercury, manganese, and iron have all been mined with varying degrees of success in central Honduras (Roberts and Irving, 1957). Central Honduras may also have economic deposits of marble, limestone, gypsum, gravel, opal, perlite, and water. Economic petroleum reserves, as yet, have not been found. No pegmatite dikes bearing economic minerals have been found in the metamorphic rock or associated with igneous intrusions.

SILVER AND LEAD

The Opeteca silver mine was originally exploited by Spanish colonialists several hundred years ago. From 1918 to 1921 the mine was explored by the West End Consolidated Mining Company (Roberts and Irving, 1957). Some time around this period an adit was dug several hundred meters northwest along the strike of the faulted limestone beds from the canyon south of El Rosario. In the last few years the Los Angeles Mining Company has been evaluating the deposit.

Roberts and Irving (1957) reported that silver-bearing galena veins are the source of the ore. From within the adit it appears that mineral-bearing solutions reacted with the Atima limestone during intrusion of rhyolite dikes along high-angle reverse faults. The silver is bound in iron and copper sulfides.

Lead mostly in galena is associated with the silver ore at the Opoteca mine. Just northwest of the mine (grid locality 212119) I found minor amounts of fluorite at the contact between rhyolite and Valle de Angeles redbed sandstone.

COPPER

Copper minerals stain green some of the Todos Santos redbed shales in a few hundred meter square area at La Cuesta in grid 2612 on the trail between La Joya and La Colmena.

Minor amounts of malachite and azurite crystals are deposited in cracks in one outcrop of sheared marble in grid 2909. Some unknown prospector has dug pits, but there is no active mining.

MARBLE

At first glance the highly folded marble layer in the Cacaguapa Schist seems like good decorative building stone. But, most of it contains too much silica, is too highly fractured, and has poor coloring to be mined. Marble south of Cacaguapa in grid 3111 may have potential as building stone.

LIMESTONE

Atima limestone crops out over large areas of the El Rosario Quadrangle. It is mined from small pits for local use as cement.

GYPSUM

Gypsum veins fill joints in the Valle de Angeles red-beds, but they are too narrow and too widely spaced to be mined economically.

OPAL

Opal fills joints and vugs of the La Sabana ignimbrite on the hills east and north of San Antonio de la Cuesta. No gem quality opal has been found to date.

GRAVEL AND SAND

Gravel is taken from the Humuya riverbed for local building use. However, the largest deposits of gravel may be located in terrace deposits. Most gravel deposits are poorly sorted from sand to boulders 2 to 3 meters in diameter. No good quality sand has been found for construction use or for making glass.

PETROLEUM

The Atima limestone in places has concentrations of organic material. The rock gives off a petroliferous odor when broken. Nearby in the La Libertad Quadrangle Mills *et al*. (1967) reported tar seeps. However, the local structure and the proximity of the fractured limestone to the surface highly disfavors any possible petroleum concentration within the El Rosario Quadrangle.

IRON

An iron ore deposit is located in the Agalteca Quadrangle to the southeast. Here the concentration of iron oxide is related to contact metamorphism around a diorite body (Roberts and Irving, 1957). If this diorite is the same rock as the gabbro on the east side of the Montaña de Comayagua, there may be undiscovered iron ore in the southeast corner of the El Rosario Quadrangle. Accessibility would almost prohibit economic mining of this region unless there were large concentrations.

WATER

The only controlled water systems in the El Rosario Quadrangle are a series of crudely dug irrigation canals on a large ranch south of San Jeronimo. The water is taken from the Rio Churune and irrigates pasture land just north of the river. The water supply for the village of San Jeronimo comes by pipe from a small 2 meter-high dam, built in 1966 near the Espino scarp where water from the Quebrada de las Calabezas flows out of the canyon onto the alluvial fan, 2 kilometers east of San Jeronimo. By the summer of 1968 the pond behind the dam was completely filled with alluvium.

Hot spring water bubbles out of the Rio Humuya gravel bed on the north side of the river at the village of La Joya. The hot water, possibly 100-120°F, is not put to any use other than washing clothes.

Groundwater storage appears small in the El Rosario Quadrangle. The Valle de Espino has only a thin veneer of alluvium. The ignimbrite below is porous and permeable and may contain reserves of water.

IGNIMBRITE

The Padre Miguel ignimbrites are quarried and crushed for building and repairing roads in the northeastern and southwestern parts of the area. Ignimbrite is used for dimension stone in other parts of Honduras and may eventually be used as building stone here.

GEOLOGIC HISTORY

Outcrops in the El Rosario Quadrangle contain a history starting before the last metamorphic event (Paleozoic?) and continuing to the present. These events are illustrated schematically by figures 22 to 27.

The Humuya Member contains many clues to the events preceding metamorphism of the Cacaguapa Schist. Pelitic sediments were deposited, buried, metamorphosed to phyllite, uplifted, and eroded before deposition of the Humuya conglomerate. Deposition took place near source-outcrops, because the resulting conglomerate is made of poorly sorted, boulder-sized clasts. During deposition of the Humuya Member conglomerates, andesitic flows or sills were emplaced. Talc rock associated with this sequence may also attest to igneous activity. The Humuya metamorphic facies subsequently underwent a period of shearing that produced cataclastic and mylonitic textures. The time of shearing is not known.

The Las Marias Member was originally clay-rich and sandy shales, sandy limestone, and sandstone. These were buried and metamorphosed to greenschist facies, producing muscovitic and graphitic schist, marble, and quartzite. Whether this metamorphic period is the same as that which produced the schist and mylonite of the Humuya facies is not known. The Las Marias facies was folded into broad, open folds with smaller-scale internal deformation.

All the metamorphism occurred during Paleozoic time or earlier. From the time of metamorphism to the time of Todos Santos Formation deposition many events may have taken place that are now missing from the rock record in the El Rosario area, _e.g._, there are no Triassic El Plan sedimentary rocks exposed. Uplift of the metamorphic rocks to the surface with its consequent erosion may have removed all El Plan rock.

The next recorded sedimentary event was the deposition of the Todos Santos Formation. The varying thickness and environment of deposition (fanglomerates) indicate that there was considerable relief on the metamorphic highland that produced the sediments. The relief may have been produced by 1) folding and erosion, 2) block faulting, or 3) strike-slip displacement of irregular topography (fig. 22). Volcanism accompanied the early stages of deposition. The metamorphic highland produced fanglomerate and fluvial deposits of conglomerate, sandstone, and shale interbedded with volcanic rock (fig. 23). The highland was in approximately the same position as it is today. The Todos Santos Formation was deposited fairly rapidly just prior to the deposition of Neocomian (?) lower Yojoa Group carbonate rock.

The Yojoa Group is represented by two facies: 1) a

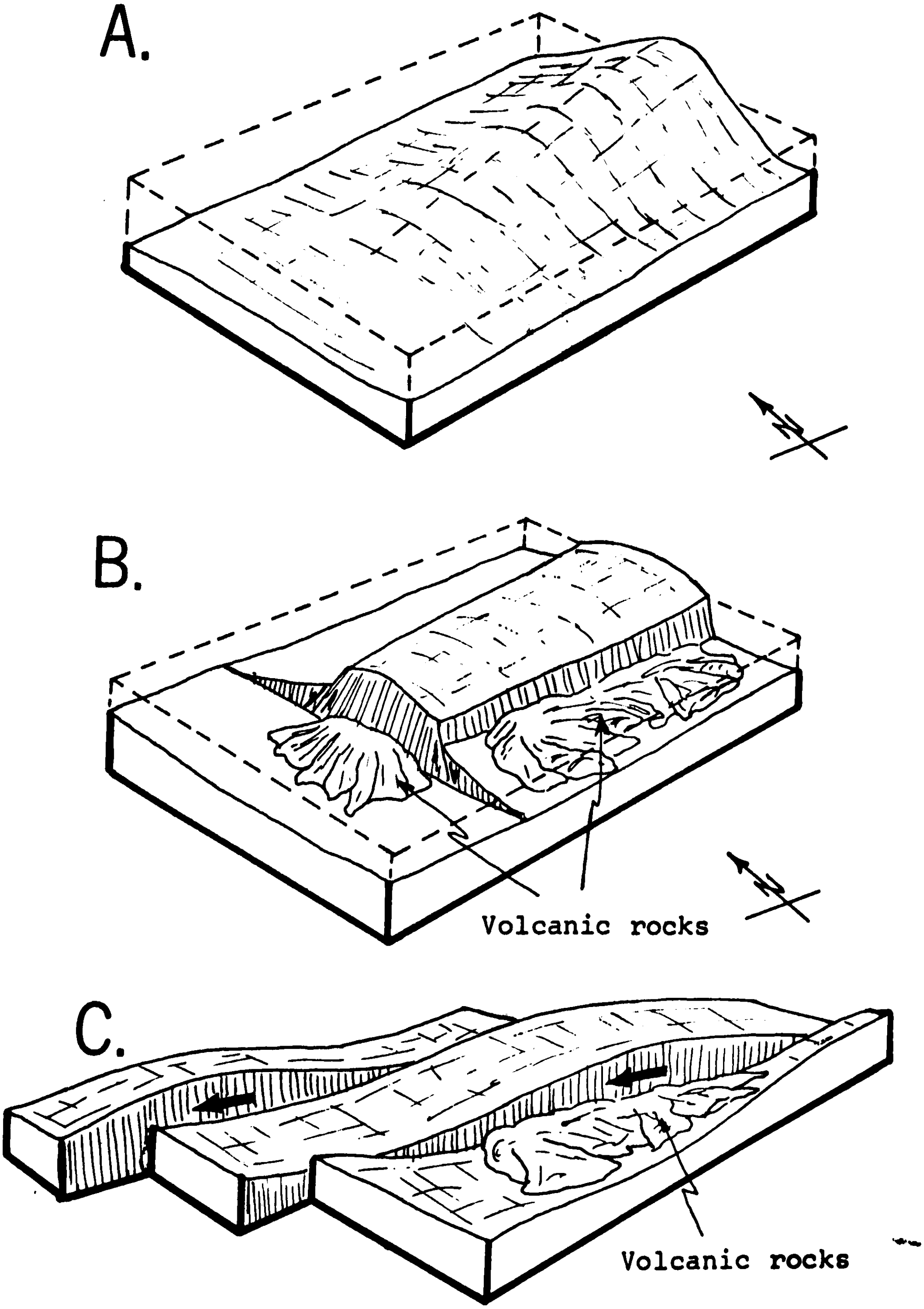


Figure 22. Possible mechanisms for producing relief on pre-Todos Santos Formation surface. Note extrusion of volcanic rock in models B and C. A. Folding. B. Block faulting. C. Strike-slip displacement of irregular topography. Figures 22-27 represent the El Rosario Quadrangle. Vertical is greatly exaggerated.

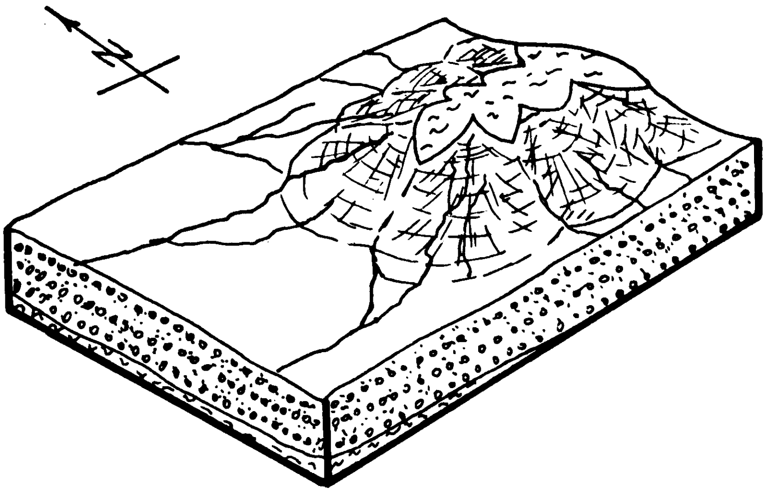


Figure 23. Fanglomerates and fluvial deposits of Todos Santos Formation shed from metamorphic highland.

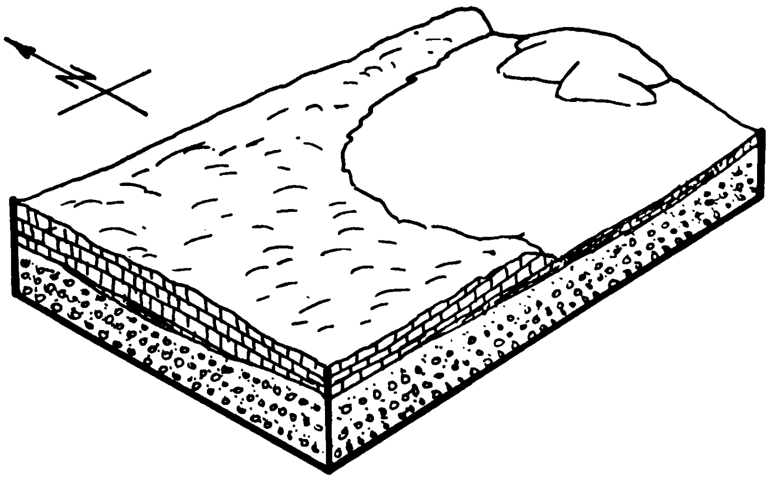


Figure 24. Cretaceous sea encroaching highlands. Marly limestone formed behind carbonate banks. As sea transgressed the banks built landward over the marly facies.

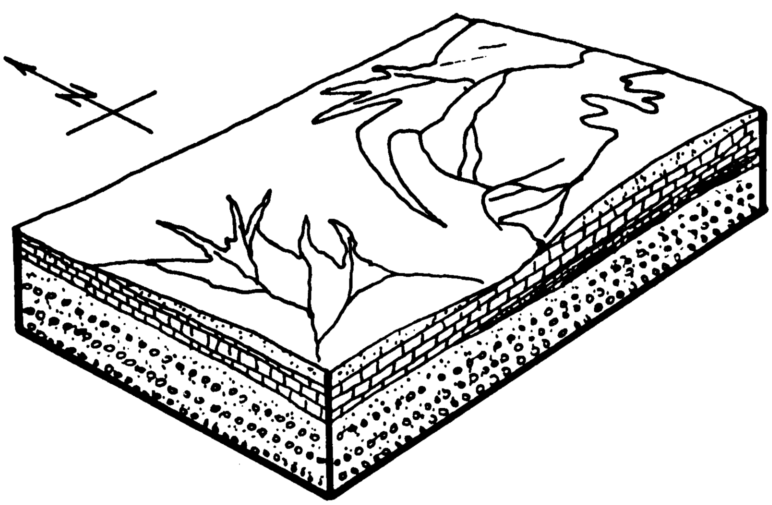


Figure 25. Deltas of Valle de Angeles Formation sand forming on Yojoa Group carbonate rocks.

lower, patchy, marly limestone, the Cantarranas Formation; and 2) an upper, massive, reef-forming limestone and dolomite, the Atima Formation. During Neocomian to Cenomanian time a quiet sea transgressed the Todos Santos and metamorphic rock. Carbonate reefs built up on the flanks of highs. Behind the reefs, clay-rich limestone was deposited in lagoons. As the sea rose and inundated the highlands the reefs built landward over the marly facies (fig. 24).

By Cenomanian time uplift provided sands that flooded the reefs forming deltaic and fluvial deposits, choking out the organisms that produced the carbonate. These sedimentary rocks form the lower redbed sandstone of the Valle de Angeles Group (fig. 25).

In other regions of central Honduras Esquias limestone is deposited on Valle de Angeles redbeds. No Esquias outcrops have been found in the El Rosario Quadrangle. This may be because: 1) the Esquias embayment did not reach southward to this area, 2) Esquias rocks are covered by ignimbrite, or 3) Esquias limestone was eroded during the following deformational event.

After deposition of Valle de Angeles redbeds, but before extrusion of mid-Miocene ignimbrite the area underwent a major deformation. This deformation produced a belt of N. 60° W.-trending, high-angle reverse faults and east-trending open folds. The resulting structure is part of the

130 kilometer-long Montaña de Comayagua structural belt. This event may be related to Laramide deformation that occurred elsewhere in Central America (fig. 26).

Rhyolite and granite were emplaced along the structural belt during or soon after the faulting and folding. Hydrothermal alteration plus silver and lead mineralization is associated with the intrusion of these silicic rocks into limestone.

During mid-Miocene time, siliceous La Sabana ignimbrites of the Padre Miguel Group were emplaced over most of the El Rosario Quadrangle with the exception of parts of the exposed metamorphic highland. Locally, the Palo Pintado gravel lies at the base of the ignimbrite. In some places basaltic flows and tuffs are emplaced at or near the base (fig. 27).

Later deposition of ignimbrite and associated sedimentary rock covered the entire area, filling in topographic lows and removing surface expression of earlier structural features.

Major graben faulting started during or just before ignimbrite deposition. Figure 18 is a representation of what the ignimbrite surface may have looked like, if all the faulting was instantaneous and no erosion took place. Some of the faults represented may have formed during an earlier deformational period and were exhumed during Quaternary

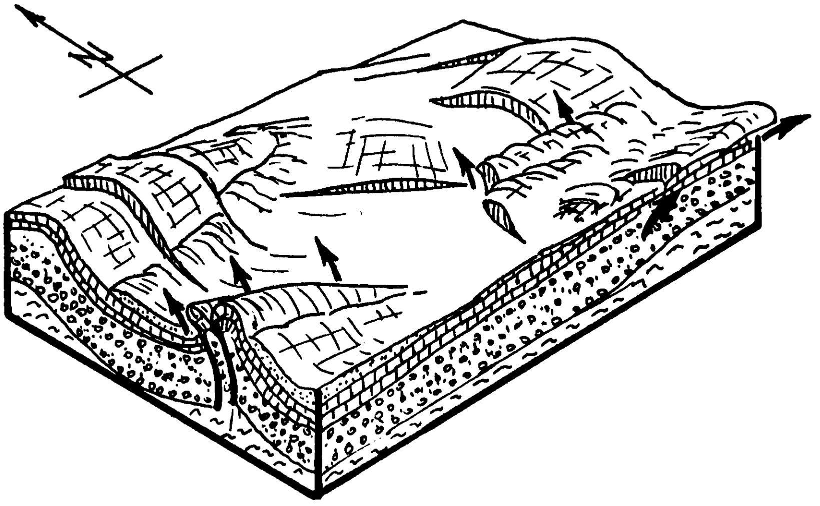


Figure 26. Development of Montaña de Comayagua structural belt deformation.

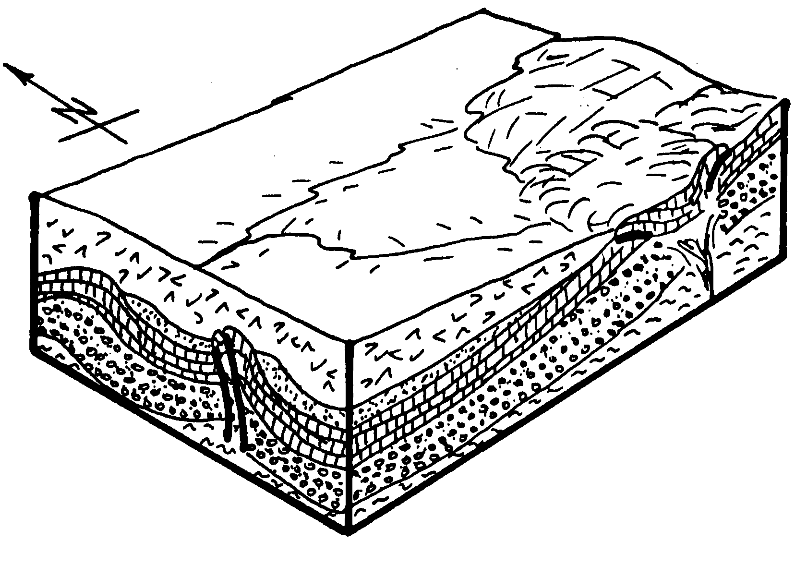


Figure 27. Deposition of La Sabana ignimbrites filling in topography formed on older rocks.

erosion.

Basalt dikes are emplaced along the north-trending graben faults. It is not known at what time the dikes were emplaced because faulting continued from early in the depositional history of the ignimbrite packages and earlier north-trending faults are predicted in the model for the development of the Comayagua structural belt.

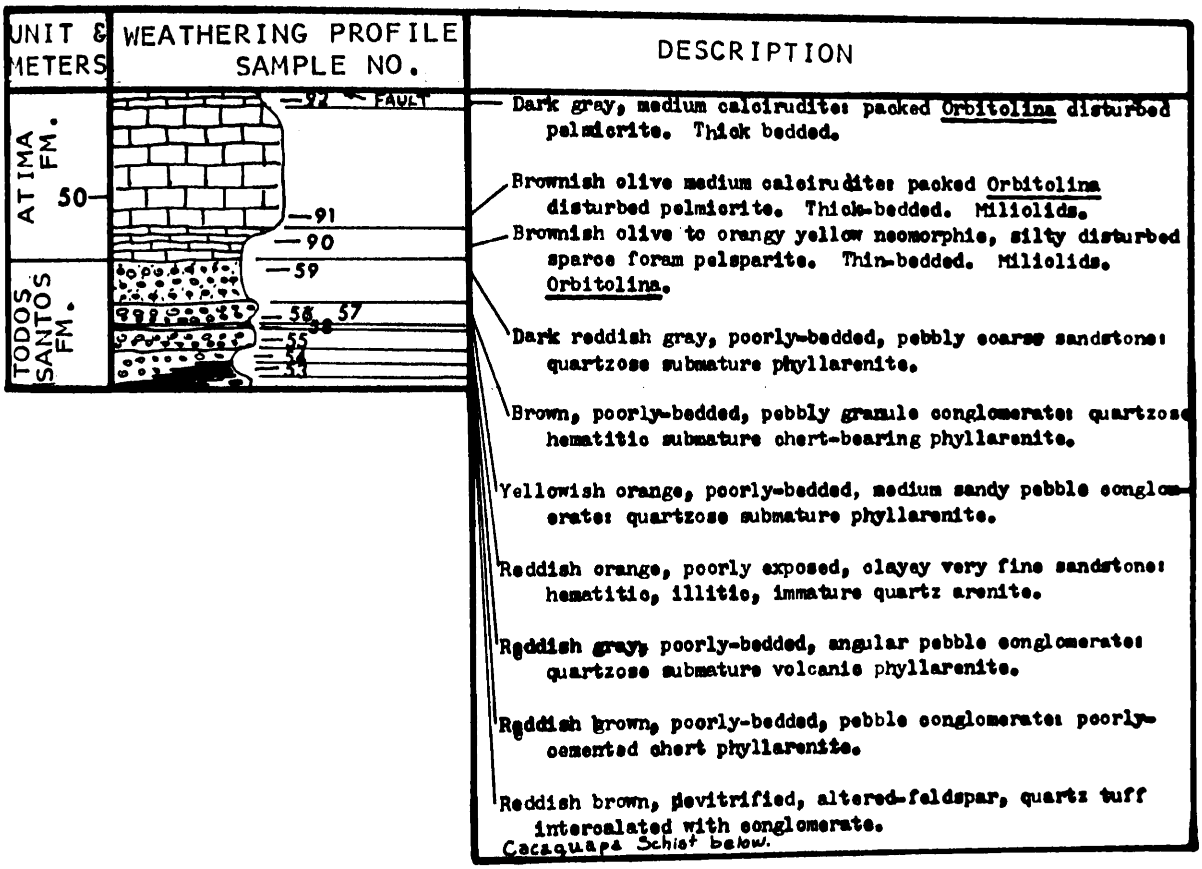
Soon after the graben faulting the ancestral Humuya started eroding and shaping the country. Renewed uplift along the Comayagua structural belt trend probably caused the river to shift its path. Graben faulting continued until recently as shown by faults in the alluvial fans of the Valle de Espino.

A P P E N D I C E S

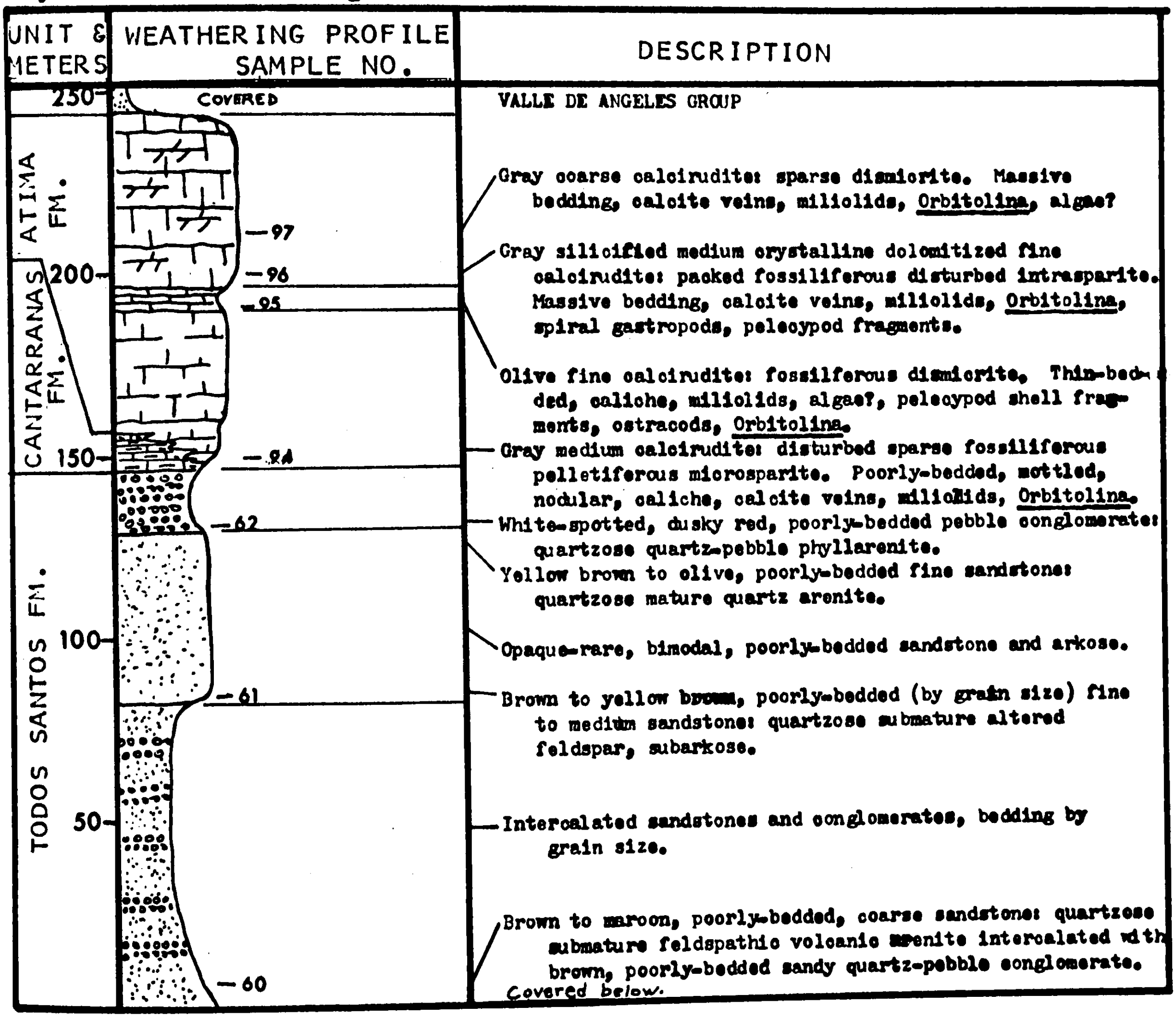
APPENDIX I - MEASURED SECTIONS

This appendix includes descriptions of four measured sections of the Todos Santos Formation and the Yojoa Group. Their locations are plotted on the geologic map (pl. 1).

Las Marias measured section I. Todos Santos Formation and lower part of Atima Formation 1 kilometer south of Las Marias. The section extends from grid coordinates 303061 to 302058. The base of the sedimentary section lies on metamorphic rocks of the Cacaguapa Schist. Metamorphic rocks have a high-angle reverse fault a few meters below base of section. Top of section is probably terminated by another high-angle reverse fault. The rocks strike N. 50° W. and dip to the south at 20° to the south.

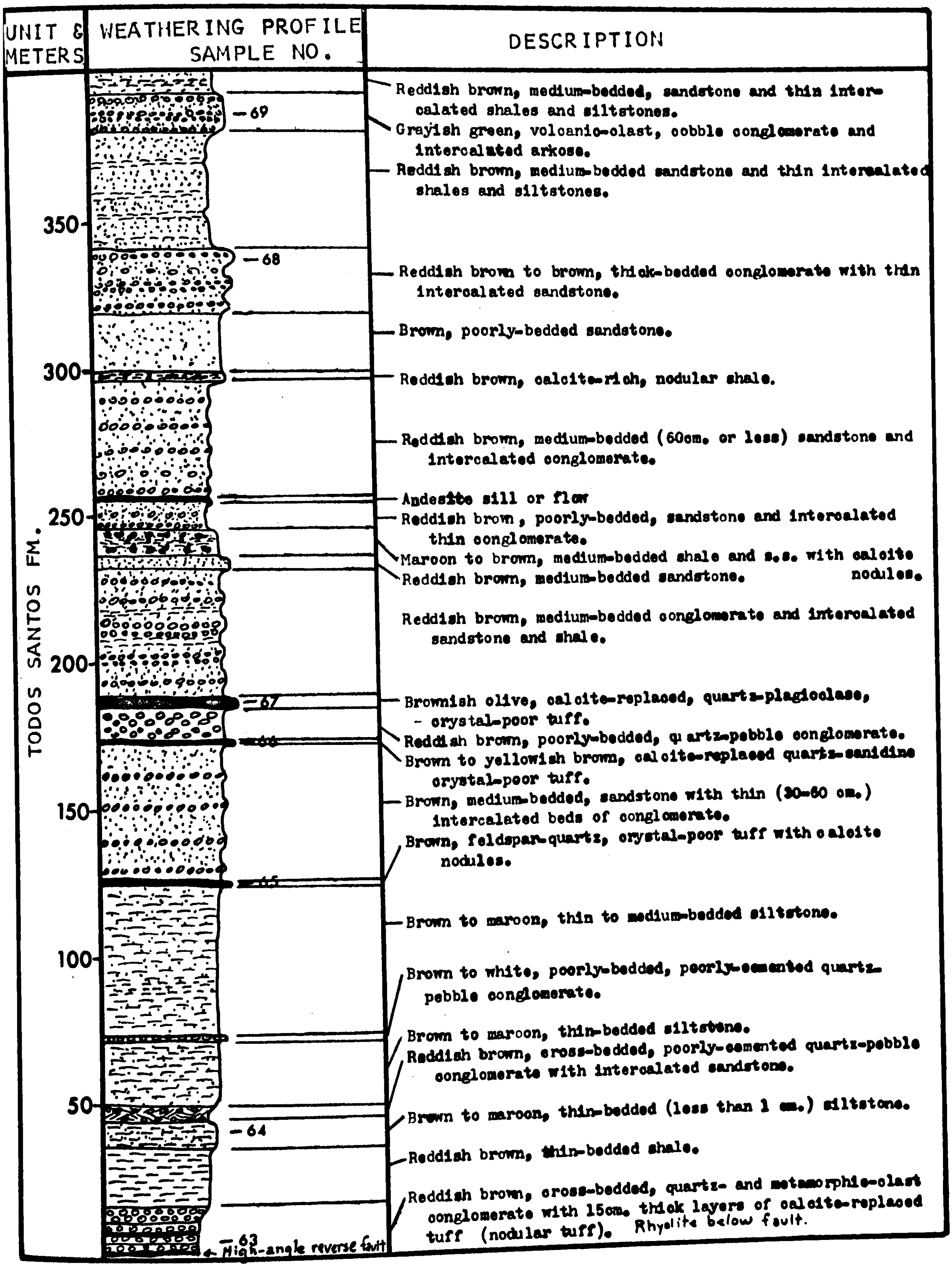


Cacaguapa measured section II. Todos Santos Formation, Cantarranas Formation, and Atima Formation at Cacaguapa. The section extends from grid coordinates 322124 to 316128. The rocks strike N. 10° W. and dip 20° to the southwest at the base and strike N. 35° E. and dip 37° to the northwest at the top. The base of the section is covered by older alluvial gravel and the top is in contact with Valle de Angeles Group sandstone covered by older alluvial gravel.

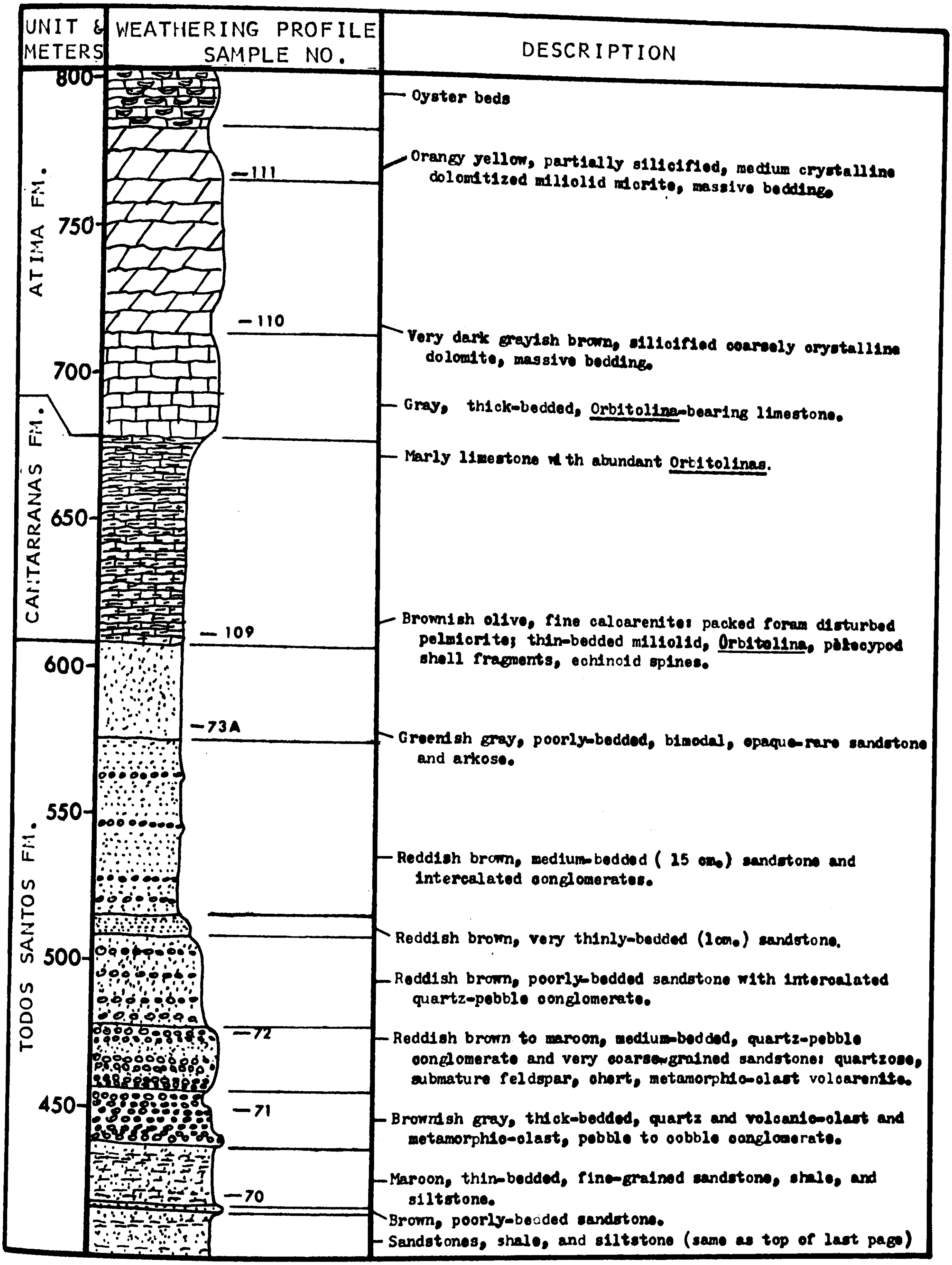


El Sauce measured section III. Todos Santos Formation, Cantarranas Formation, and Atima Formation at El Sauce. The section extends from grid coordinates 272083 to 278067. The rocks strike N. 15° E. and dip 32° to the southeast at the base and strike N. 75° W. and dip 53° to the southwest at the top. Base is high-angle reverse fault. Top is in contact with Valle de Angeles Group sandstone. This section is approximately that shown on right side of figure 12B.

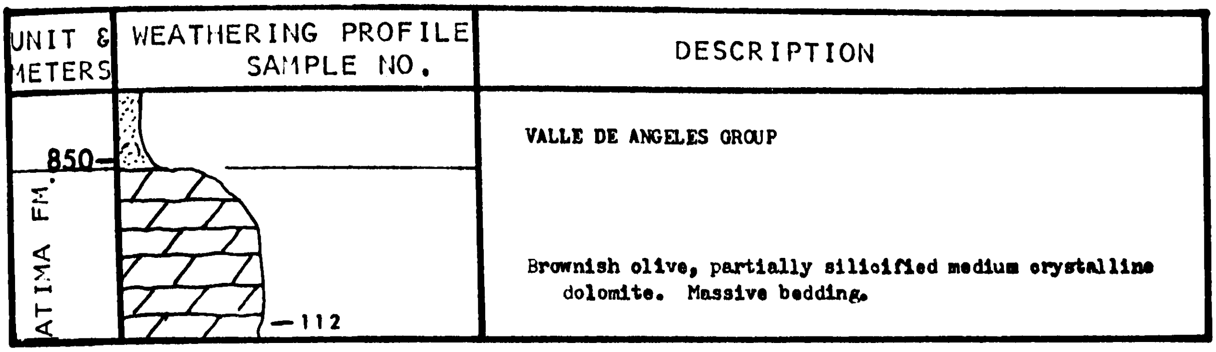
El Sauce measured section III.



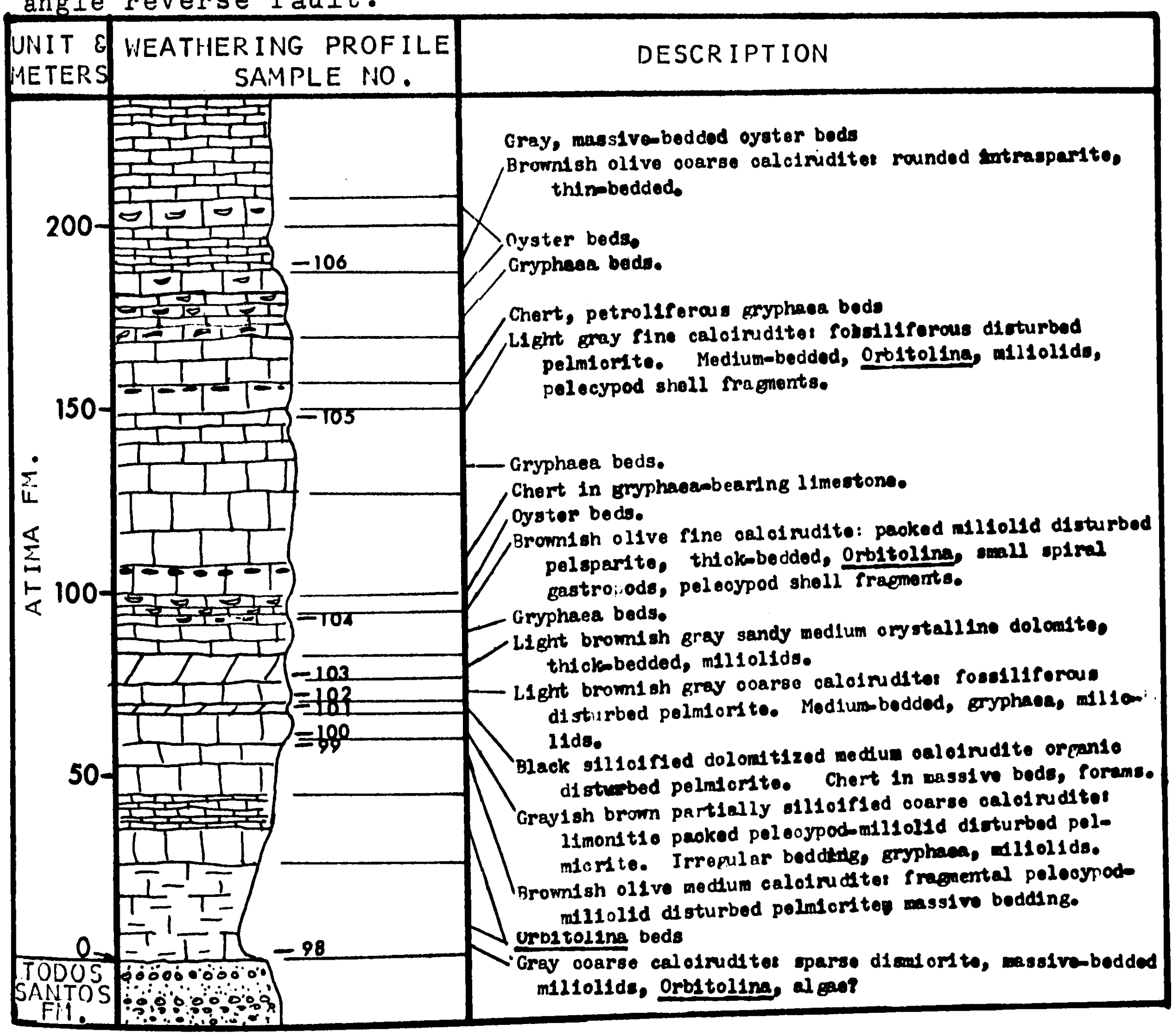
El Sauce measured section III (continued).



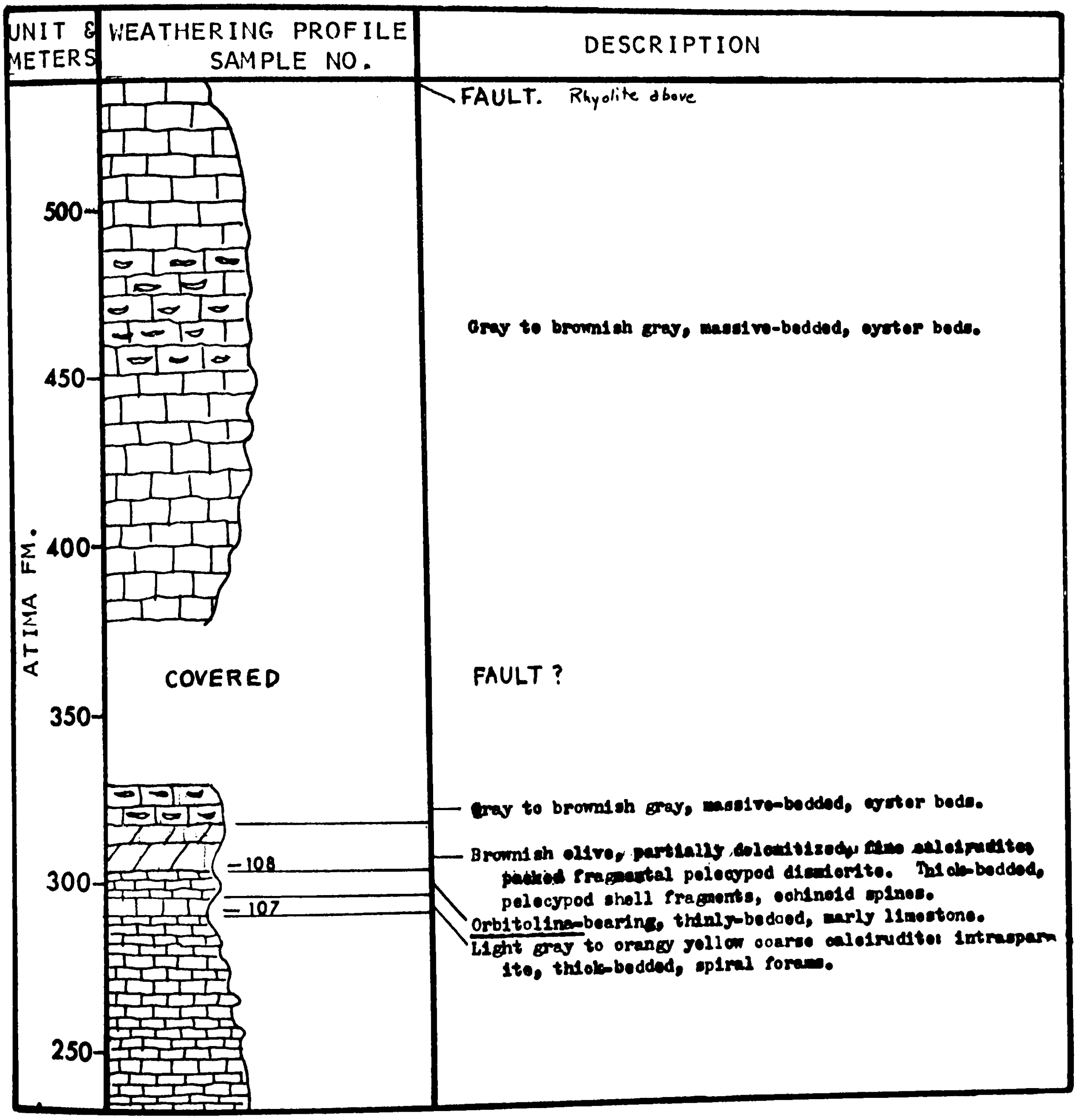
El Sauce measured section III (continued).



Las Anonas measured section IV. Atima Formation 1 kilometer east of the top of Cerro Las Anonas. Section extends from grid coordinates 274096 to 272085. The rocks strike N. 75° W. and dip 30° to the southwest at the base and dip 32° to the southwest at the top. The base lies on Todos Santos Formation. The top is in contact with rhyolite that was intruded along a high-angle reverse fault.



Las Anonas measured section IV (continued).



APPENDIX II - ROCK DESCRIPTIONS

This appendix contains descriptions of thin sections and hand specimens of metamorphic, sedimentary, and igneous rocks.

All colors were determined from the Rock-Color Chart (Goddard and others, 1951) and the Munsell Soil Color Chart (1954).

Each section has a brief discussion of the format of the descriptions and explanation of classification schemes.

METAMORPHIC ROCKS

This section describes metamorphic rocks collected from the Humuya and Las Marias members of the Cacaguapa Schist.

The format is:

Appendix number
Name
(Thin section or hand specimen number) grid location, location description. Fresh surface color (F:), weathered surface color (W:). Texture. Composition. Remarks. Metamorphic facies.

#1
Blastomylonitic quartz schist.
(Thin section 336A) 280116, Humuya Gorge, 1½ kms east of La Colmena. F: white with black and pale green streaks, W: black. Cataclastic and blastomylonitic foliated with augen-shaped clasts. Sheared, recrystallized, elongate, vacuoled, undulose quartz 80%, rare albite(?) with bent lamellae, remaining are minor muscovite, leucoxene, minor pyrite, carbon(?)(graphite?). Bent calcite filling veins.

#2
Cataclastic meta-conglomerate breccia.
(Thin section 336C) Humuya Gorge, same as 336A. F: black and yellow brown, W: black. Weakly cataclastic angular to round grains with crushed borders in mica-opaque matrix, grains up to 2 cms across, poorly sorted. Clasts include: metamorphic quartz (recrystallized?), mudstone or weathered phyllite, mica schist, muscovite-quartz schist, vein quartz, phyllite, crushed quartz-rich grains, chert (metamorphic?), hornfels, pyrite. Matrix is mica and opaque minerals probably magnetite and leucoxene.

#3
Mylonitic felsite.
(Thin section 336E) 280116, Humuya Gorge, same as 336A. F: pale green, W: grayish green. Mylonitic, crushed, sheared, granulated, foliated. Granulated quartz with minor K-feldspar(?) in a fine granulated groundmass with wispy bands and clots of leucoxene and bands of fine-grained chlorite, sericite and clay, feldspar phenocrysts altering to calcite, veins of granulated fine-grained calcite.

#4
Sheared meta-conglomerate.
(Thin section 350G, photomicrograph pl. 4G) 392054, boulder in Rio Blanco. F: dark greenish gray, W: greenish gray. Brecciated, cataclastic grains in foliated, fine-grained quartz and mica matrix, possibly two periods of shearing. Clasts up to pebble size include: hornfels, crushed and sheared quartz, leucoxene-chlorite-muscovite-quartz schist, matrix is fine-grained, crushed quartz and leucoxene and muscovite.

#5
Epidote quartzite.
(Thin section 350C) 392054, boulder in Rio Blanco. F: yellowish gray, W: light olive gray. Porphyroblastic, recrystallized(?). Slightly schistose, undulose quartz 60%, clinozoicite (grades into epidote) 40%, accessory pyrite and leucoxene in felted masses associated with epidote. Greenschist facies.

#6
Muscovite, quartz schist.
(Thin section 350E) 392054, boulder from Rio Blanco. F: dark bluish gray, W: medium bluish gray to greenish gray. Folded and crenulated schistose bands of mica in strained quartz. Fine-grained, slightly undulose quartz 80%, remaining mostly fine grains of disseminated and thin, concentrated bands of

muscovite with minor magnetite and leucoxene. Greenschist facies.

#7
Blastomylonitic metaquartzite.
(Thin section 368A) 456069, boulder from Rio El Oro near Las Moras. F: black, pale green, very light gray, W: grayish black, dark bluish black, olive gray. Blastomylonitic, brecciated, sheared, foliated. Crushed and rolled, sheared, brecciated quartz clasts in a matrix of folded, foliated muscovite, leucoxene, magnetite, chlorite, epidote, and calcite.

#8
Spotted talc schist.
(Thin section 368C) 456069, boulder from Rio El Oro near Las Moras. F: grayish olive green with pale green patches, W: light olive gray to olive gray with dusky yellow patches. Schistose. Talc minerals partially replaced by deformed calcite nodules, with accessory leucoxene, pyrite altering to hematite, and minor quartz.

#9
Mylonitic quartzite.
(Thin section 368D) 456069, boulder from Rio El Oro near Las Moras. F: light olive, W: pale olive. Foliated, sheared, granulated augen-shaped, rolled clasts in schistose matrix. Crushed, sheared quartz clasts with undulose extinction in chlorite, talc minerals(?), clay(?), and euhedral magnetite altering to hematite.

#10
Sheared arkose or granite.
(Thin section 369) 462085, Las Moras. F: pale olive, W: dusky to moderate yellow. Mylonitic, sheared, foliated, granulated, and some recrystallization of grains, coarse grains spread in matrix of crushed and pulverized, fine grains of same composition. Equal amounts of albite(?), K-feldspar, and quartz, all with slight to moderate undulose extinction and sutured borders, trace of leucoxene and limonite.

#11
Muscovite-quartz schist.
(Thin section 248) 318055, 2 kms east of Piedras Azules. F: yellow brown, W: brownish olive. Foliated and crenulated layers of quartz and muscovite-limonite. Slightly to moderately undulose extinction quartz 90%, remaining are thin bands of muscovite, limonite, chlorite altered from biotite(?), rare pyrite altering to limonite. Middle to upper

greenschist facies(?).

#12
Zoicite-vesuvianite(?)-muscovite-quartz schist.
(Thin section 112) 313087, Cerro Loma Alta, 1 km east of La Libertad Road, 2 kms southeast of El Roblito. F and W: dusky grayish blue with yellow to orange yellow streaks. Foliated by cleavage and compositional bands, porphyroblastic with unoriented porphyroblasts. Elongate, vacuoled quartz with undulatory extinction 60%, muscovite 20%, zoicite, brown chlorite, vesuvianite(?) 20%. Greenschist facies(?).

#13
Siliceous marble.
(Thin section 82) 297088, 1 km west of La Libertad Road, 2 kms south of El Roblito. F: dusky grayish blue, W: gray. Foliated, crenulated by cleavage-plane shearing, banded by composition: calcite-quartz-opaques. Coarse calcite 73%, irregular-shaped to equant grains of composite or single-grained quartz with slight to moderate undulatory extinction 25%, opaque dust with steel gray metallic luster and magnetite altering to hematite and limonite 2%, trace of apatite(?), and muscovite associated with opaque bands. Greenschist facies(?).

#14
Silicified marble-quartzite.
(Thin section 249, photomicrograph pl. 4F) 328061, 2 kms east-southeast of Las Marias. F: dusky red and bluish gray, W: brownish olive. Unoriented to bent, fine to coarse-grained, "snowflake" texture of irregularly-shaped to equant to plumose grains with sutured borders. Elongate plumose and radiating, strongly undulose quartz 90%, remaining are hematite, limonite, leucoxene, calcite. Barite(?) filling veins. Greenschist facies(?).

#15
Amphibolite (sheared meta-gabbro?).
(Thin section 343) 428130, north end of Montaña de Los Planes (Montaña de Comayagua). F: dark bluish gray with white and greenish gray streaks, W: brownish olive to light gray. Foliated, schistose, coarse grained. Clino-amphibole (hornblende?) 90%, remaining are chlorite, quartz, leucoxene, magnetite. Thin quartz-muscovite veins. Amphibolite facies.

#16
Quartz-amphibolite schist (sheared meta-gabbro?).
(Thin section 346) 416142, 1½ kms east of La Laguna. F:

greenish black with greenish gray streaks, W: greenish black. Foliated, schistose. Pale amphibole (tremolite-actinolite? or hornblende) 70%, chlorite-leucoxene patches 20%, quartz 10%, minor scapolite(?) with epidote rims, leucoxene, and magnetite. Upper greenschist facies or lower amphibolite facies.

#17A
Marble with copper mineralization.
(Hand specimen 84) 298091, 1 km west of La Libertad Road, south of El Roblito. Same marble as #13 with minor amounts of malachite and azurite crystals lining shear zones.

#17B
Muscovite-chlorite-quartz schist.
(Thin section 370) 346079, ½ km west of Agua Fria, boulders in Rio Cacaguapa. F: greenish black, W: same. Foliated and crenulated, schistose. Thin (1-5 mm) quartz veins folded within main crenulations. Quartz 85-90%, muscovite-chlorite 10-15%. Quartz has abundant inclusions, elongate grains with sutured borders and moderate undulose extinction. Green chlorite associated with muscovite in wispy clumps. Anomolous-blue chlorite in small patches and in a vermicular form within unstrained large grains of quartz, possibly vein quartz. Trace of plagioclase (n<quartz). Trace of leucoxene.

TODOS SANTOS FORMATION

This section describes thin sections and hand specimens from the Todos Santos Formation in the El Rosario Quadrangle. The classification of clastic sedimentary rocks follows Folk (1968). The volcanic rock classifications follow the scheme presented in the sections below that describe intrusive and volcanic rocks.

The format is:

Appendix number
Name
(Thin section or hand specimen number) grid locality, location. General rock classification; 5-fold name (grain size: prominent cements, textural maturity, prominent transported

constituents, main name); hardness; color (F:=fresh, W:=weathered); weathering character and bedding; porosity (pre- and post-cementing); permeability; sorting; rounding of clasts; homogeneity of clasts throughout specimen; packing; orientation of grains; grain shape; cements: (usually in order of age, volumetrically largest cement given in 5-fold name above); clasts and percentages; environment of deposition.

Colors are from the Munsell Soil Color Chart (1954). Hardness, porosity, and permeability are rough qualitative visual estimates from thin sections and hand specimens and reflect no parameter measurements. Sorting is the graphic standard deviation σ_G of Folk (1968). Rounding is visual estimate using the roundness scale of Powers (1953). No point counts were made. Grain size terminology is from Folk (1968).

#18
Volcanic-clast sandstone.
(Thin section 29) 307028, Valle de Angeles. Terrigenous; pebbly medium to coarse sandstone: chloritic, quartzose, immature, metamorphic and volcanic rock fragment plagioclase arkose; hard; F: grayish-green, W: yellow brown; bedded; very good pre-cement porosity, very poor post-cement porosity; very low perm.; poorly sorted (σ=1.5Ø); angular; homogeneous; tightly packed (pressure borders on quartz grains); poorly oriented; equant to extremely platy grains; cements: 1) chlorite, 2) quartz as overgrowths; clasts: common and composite quartz 35%, plagioclase 20%, remaining 10%: leucoxene-chlorite-quartz clasts, fine-grained trachytic plagioclase volcanic rock fragments, fine-grained quartz schist, porphyritic quartz-chlorite hornfels(?), veins up to 15 cms thick. Environment of deposition: flood plain or distal end of fanglomerate.

#19
Metamorphic-clast sandstone (spotted arkose).
(Thin section 72) 303079, 1/3 km south of La Libertad, east end of Cerro Las Anonas. Terrigenous; clayey medium to coarse sandstone: quartzose, hematite, immature, volcanic

and metamorphic fragment plagioclase arkose; friable; F: orangy red, W: same; bedded; ooor post-cement por.; fair perm.; very poor sorting (σ=1.5Ø); angular; extremely platy; cements: 1) hematite, 2) quartz, 3) hematite predominates quartz, 2 periods of hematite cementing; clasts: common quartz 20%, plagioclase, altered in part to clay 20%, composite metamorphic quartz, muscovite schist 40%, fine-grained trachytic plagioclase tuff fragments 10%, magnetite altering to hematite 5%, illite and clay mudballs, iron-stained chlorite(?) make up the remaining. Envir. of dep.: flood plain or distal end of fanglomerate.

#20
Volcanic rock (calichefied).
(Thin section 118) 290075, 1 km east of El Sauce. Tuff; medium soft; F: red brown, W: pale red to brown; crystal-poor, very fine quartz tuff, wispy, pumice fragments are rich in fine hematite dust, 80% of rock now replaced by fine to coarse calcite. Much of the hematite-calcite nodules are mottled, looks like caliche, but retains some of the wispy nature of previous tuff fragment.

#21
Light colored arkose.
(Thin section 121) 290063, Cerro de Manzanilla, 1 km southeast of El Sauce. Terrigenous; clayey medium to coarse sandstone: quartzose submature quartz arenite; hard; F: brownish olive, W: yellowish orange to yellowish brown; bedded; very good pre-cement por., very poor post-cement por.; very low perm.; poor sorting (σ=1Ø), bimodal; subrounded clasts; homogeneous; loosely packed; nonoriented; equant small grains; cements: quartz overgrowth and some iron-stained chlorite; clasts: common, strained, and vacuoled quartz 80%, fine-grained composite (coarse chert?) quartz with sericite 20%, some kaolinized(?) K-feldspar(?), rare hematite. Env. of dep.: disturbed (very little crossbedding), reworked(?) dune(?).

#22
Metamorphic and volcanic conglomerate.
(Thin section 186) 395181, San Antonio de la Cuesta-Rancho Grande Road high above Quebrada Suncuya. Terrigenous; pebbly conglomerate: clayey, quartzose submature cherty phyllarenite; medium hard; F: reddish brown, W: same; poorly bedded; very good pre-cement por., very good post-cement por.; high perm.; very poorly sorted (σ=2.5Ø); small grains subround to round, large grains angular (textural inversion); layered; loosely packed; grains oriented parallel to bedding; equant to platy clasts; cements: 1) quartz, 2) clay (illite?)

with hematite; clasts: common, strained, and composite quartz 20%, remaining 80% are lithic fragments of mica schist, leucoxene-mica schist, phyllite, quartzite, plagioclase volcanic rock fragments, magnetite altering to hematite, rare leucoxene. Hematite-clay coatings separated from clasts and incorporated in quartz cement. Env. of dep.: fanglomerate.

#23
Volcanic-clast conglomerate.
(Thin section 205, photomicrograph pl. 5C) 360204, La Libertad Road, 2½ kms north of San Antonio de la Cuesta. Terrigenous; pebble conglomerate: chloritic, hematitic submature, mixed clast volcanic arenite; hard; F: and W: dusky purplish red; poor pre- and post-cement por.; low perm.; very poorly sorted (σ=3.75$\emptyset$); subround clasts; inhomogeneous; loosely packed; nonoriented; equant to oblate grains; cements: 1) chlorite, 2) hematite, 3) quartz; clasts: mostly volcanic rock fragments of devitrified glass packages, trachytic plagioclase tuff (spilite?), plagioclase, lesser metamorphic clasts of phyllite, quartz-sericite schist, metaquartzite, and vein quartz, chert, sandstone, fan-shaped chlorite, K-feldspar altered to clay, tuffs replaced by calcite. Env. of dep.: multi-sourced fanglomerate.

#24
Metamorphic-clast conglomerate.
(Hand specimen 206) 360204, La Libertad Road, 1½ kms north of San Antonio de la Cuesta. Terrigenous; sandy granule to pebble conglomerate: quartzose, hematitic, submature, feldspar litharenite; hard; F: dark gray with green patches, W: very dark grayish brown to yellow orange; poorly bedded; good por.; low perm.; very poor sorting; inhomogeneous; loosely packed, subparallel grains (to bedding); equant to bladed grains; cements: probably quartz and hematite; clasts: quartz, vein quartz, feldspars altered to white clay, plagioclase(?), shale, metaquartzite, hematite, some calcite. Outcrop ripple(?) cross-bedded. Env. of dep.: floodplain or fanglomerate.

#25
Carbonate replaced volcanic rock.
(Thin section 207) 363206, Los Lirios, 2 kms north of San Antonio de la Cuesta. Tuff; hard; F: reddish brown and pale green, W: same; calcite replaced (almost totally) vitric tuff or pumice-rich tuff; relic pumice fragments, some fine magnetite altering to hematite, pumice fragments have coarse calcite spar growing in them. Env. of dep.: ash flow in body of water(?).

#26
Volcanic-clast sandstone.
(Thin section 211) 362212, Los Lirios, 2 kms north of San Antonio de la Cuesta. Terrigenous; coarse to very coarse sandstone: quartzose, submature, volcanic arenite; hard; F: dark reddish gray with cream patches, W: yellow orange; poorly bedded; poor por.; very low perm.; moderate sorting; subangular to subround clasts; inhomogeneous; loosely packed; unoriented; equant to bladed clasts; cements: 1) chlorite, 2) quartz, 3) minor calcite, 4) minor hematite; clasts: plagioclase, altered to clay and vacuoled 40%, trachytic plagioclase volcanic rock fragments 25%, embayed volcanic quartz 20%, magnetite altered to hematite 10%, phyllite 5%, and chlorite-magnetite-quartz grains, ilmenite(?). Env. of dep.: fanglomerate or floodplain.

#27
Calichefied volcanic rock.
(Thin section 228, photomicrograph pl. 5D) 314029, Valle de Angeles. Tuff; hard; F: and W: dusky red with gray streaks; calcite rock with silt and tuff(?) fragments; coarse-grained calcite in round, radiating crystal growths, silt-sized quartz and hematite, clay(?). Env. of dep. and genesis: caliche altered quartz crystal-poor tuff, possibly ash fall into water.

#28
Metamorphic-clast conglomerate.
(Thin section 233) 272094, Cerro Las Anonas, 1½ kms southeast of summit. Pebbly granule conglomerate: quartzose, hematitic, submature, cherty phyllarenite; medium soft; F: and W: red brown; poorly bedded; fair pre-cement por., poor post-cement por.; low perm.; very poor sorting (σ=3.0ϕ); subangular clasts; inhomogeneous; loosely packed, unoriented; equant to platy grains; cements: 1) hematite, 2) quartz; clasts: common and strained quartz 25%, coarse chert with radiolaria and sponge spicules 30%, 30% metamorphic rock fragments of quartzite, quartz-sericite-hematite schist, and muscovite schist, sandstone, leucoxene. Env. of dep.: fanglomerate.

#29
Metamorphic-clast conglomerate.
(Hand specimen 234) 272094, 1 km south of Las Anonas village. Terrigenous; sandy pebble conglomerate: quartzose(?), hematitic, submature, metaquartz(?) litharenite; F: weak red, with light gray spots, W: brown; hard; poorly bedded; poor por.; low perm.; very poorly sorted; subangular large grains to round small grains; inhomogeneous; unoriented; equant

grains; cements: quartz(?), hematite; clasts: vein or meta quartz, chert(?), hematite. Env. of dep.: fanglomerate.

#30
Metamorphic-clast conglomerate.
(Hand specimen 240) 276093, 1 km south-southeast of Las Anonas village. Terrigenous; pebble conglomerate: quartzose, submature, quartz litharenite; F: white spotted reddish browns, W: reddish brown; hard; poorly bedded; poor por.; poor perm.; poorly sorted; round clasts; inhomogeneous; loosely packed; unoriented; equant clasts; cements: quartz(?); clasts: metamorphic and vein quartz, limonite in vugs, red, fine-grained shale or phyllite. Rock similar to #29. Basal conglomerate filling scours in metamorphic basement. Env. of dep.: fanglomerate.

#31
Metamorphic-clast conglomerate.
(Thin section 246) 312059, 1½ kms east of Piedras Azules. Terrigenous; sandy pebble conglomerate: quartzose, submature, cherty phyllarenite; hard; F: orange yellow, W: yellow brown; very poorly bedded; good pre-cement por.; very poor post-cement por.; low perm.; very poorly sorted (σ=3.0ø); round clasts; inhomogeneous; equant to platy grains; cements: 1) illite, chlorite (iron stained), 2) quartz, 3) limonite, 4) chalcedonic quartz; clasts: common, strained, and composite quartz 50%, chert 20%, metamorphic rock fragments of phyllite, quartzite, quartz-sericite schist 30%, rare plagioclase, chlorite, illite, leucoxene and hematite. Env. of dep.: fanglomerate.

#32
Calichefied volcanic rock.
(Thin section 263A) 243095, Rio Humuya Gorge at Chicuás Abajo. Tuff; hard; dense; F: dark gray to brown, W: reddish black; fine to coarse-grained calcite, pisolitic granule to pebble sized balls; matrix is calcite replaced crystal-poor, fine quartz tuff; balls have tuff patches; magnetite-hematite rich layering in balls; pressure solution borders at contacts between some balls; vugs in balls have bands of calcite with a hematite layer and then filled with coarse sparry calcite; some balls retain volcanic tuff texture; some are made of radiating calcite. Env. of formation: probably caliche soil horizon developed in tuff.

#33
Calcite nodule.
(Thin section 263B) 243095, Rio Humuya Gorge at Chicuás Abajo.

Calichefied or calcite replaced terrigenous shale; hematite-illite(?)-quartz silty mudstone, replaced by calcite nodules; cracks developed after nodule formation (shown by displacement of nodular calcite rind along crack); early cracks filled with sparry calcite; later cracks filled with calcite and barite or celestite(?); F. dusky red with white veins, W: reddish brown.

#34
Shale.
(Thin section 263C) 243095, Rio Humuya Gorge at Chicuás Abajo. Terrigenous; chloritic medium silty mudstone; F: greenish gray, W: yellow brown; hard; poorly bedded; poor por.; very low perm.; very poorly sorted; subangular silt grains; homogeneous; poorly packed; equant silt grains; cements: 1) chlorite, 2) minor calcite; clasts: quartz; schist fragments, chert, mud clasts, minor anomalous blue chlorite, minor plagioclase, rare zircon, magnetite-hematite, leucoxene, illite. Env. of dep.: low energy environment, wash over muds in fluvial system(?).

#35
Metamorphic-clast and volcanic-clast conglomerate.
(Thin section 281) 287130, Rio Humuya Gorge, 3 kms west of Cacaguapa. Terrigenous; pebble conglomerate: quartzose, immature, polyclast litharenite; F: and W: browns, reddish browns, yellowish browns, cream, and white; hard; poorly bedded; good pre-cement por.; poor post-cement por.; very low perm.; very poorly sorted (σ=3.5ϕ); subangular to subround clasts; inhomogeneous; loosely packed; unoriented; equant to bladed clasts; cements: 1) quartz, 2) chalcedony; clasts: quartz, plagioclase, metamorphic clasts of quartzite, phyllite, volcanic clasts of trachytic plagioclase tuffs, devitrified glass shards with kaolinite, vein quartz, sedimentary clasts of sandstone, shale, muddy sandstone, mud balls, radiolarian chert, magnetite-hematite, and limonite. Env. of dep.: fanglomerate.

#36
Metamorphic-clast and volcanic-clast sandstone (spotted arkose).
(Hand specimen 309) 217192, Las Lagunas. Terrigenous; fine sandstone: quartzose, hematitic submature, feldspathic sublitharenite or arkose; F: gray, W: brown; medium soft, friable; poorly bedded; poor por.; low perm.; subround clasts; fairly homogeneous; unoriented; equant to bladed clasts; cements: 1) quartz(?), 2) hematite; clasts: quartz, altered feldspar(?)(white spots), chert(?), shale or phyllite fragments. Env. of dep.: flood plain(?).

#37
Calichefied volcanic rock.
(Thin section 310) 218191, Las Lagunas. Tuff; F: dark reddish gray to red brown, W: light reddish brown; calcite balls, many with high concentrations of magnetite-hematite, round grains of magnetite-hematite, and some associated with clay, balls are concentrically banded, matrix is sparry calcite cement; some remnant material appears to be crystal-poor tuff, similar to #32. Origin: calichefied soil horizon developed on tuff surface.

#38
Volcanic-clast conglomerate.
(Thin section 311) 235175, 1 km south of Las Anonas village. Terrigenous; sandy pebble conglomerate: limonitic, immature, plagioclase volcanic arenite; F: multicolored gray, cream spots, yellowish spots, W: yellow orange; hard; poorly bedded; very poor pre- and post-cement por.; very low perm.; very poorly sorted; subround to well rounded grains; inhomogeneous; loosely packed; unoriented; equant to bladed clasts; cements: 1) limonite, 2) hematite, 3) clay, 4) opal; clasts: embayed volcanic quartz; trachytic tuff fragments, plagioclase, metamorphic quartzite, phyllite, quartz-sericite schist, crenulated mica-limonite schist, mudstone, siltstone, chert, chalcedony veined mudstone and chert. Env. of dep.: multisourced fanglomerate.

#39
Light colored arkose.
(Hand specimen 312) 246197, 2 kms east of Las Lagunas. Terrigenous; very fine sandstone: quartzose, mature(?), quartz arenite or subarkose; F: orangy yellow, W: brownish olive; hard; finely laminated; poor por.; low perm.; moderately(?) sorted; homogeneous; cements and clasts similar to #21. Env. of dep.: reworked dune sand(?).

#40
Metamorphic-clast and volcanic-clast sandstone.
(Thin section 324) 300198, 1 km west of Los Plancitos. Terrigenous; silty very fine sandstone: hematitic, immature, feldspathic litharenite; F: weak red, W: very dusky red; hard; poor pre- and post-cement por.; low perm.; very poorly sorted; subangular clasts; homogeneous; unoriented; equant to bladed clasts; cements: 1) hematite, 2) quartz, 3) clay, 4) minor chlorite; clasts: vacuoled quartz, vacuoled and sericitic plagioclase, magnetite-hematite, trachytic tuff, mudstone, phyllite or layered mudstone, muscovite-leucoxene schist, chert (some radiolaria bearing). Env. of dep.: flood plain.

#41
Metamorphic-clast conglomerate.
(Thin section 326) 293193, 1 km west of Los Plancitos. Terrigenous; granule very coarse sandstone: hematitic, submature, quartz arenite; friable; F: brown with many white spots, W: dusky red; poorly-cemented, bedded by grain size; good por.; high perm.; poorly sorted; subangular to round grains; inhomogeneous; loosely packed; unoriented; equant to bladed clasts; cements: 1) illite, 2) quartz, 3) minor hematite; clasts: metamorphic quartz (strained, undulose), vein quartz, composite quartz, chert, quartz-sericite schist, rare muscovite. Env. of dep.: fanglomerate or flood plain.

#42
Volcanic-clast and metamorphic-clast conglomerate.
(Thin section 342) 287127, 3 kms west of Cacaguapa. Terrigenous; pebble conglomerate: limonitic, quartzose, submature, volcanic clast phyllarenite; hard; F: multi-colored greens, browns, creams, whites, W: yellow brown; poorly bedded; good pre-cement por.; fair post-cement por.; fair perm.; very poorly sorted; subangular to round clasts; inhomogeneous; loosely packed; unoriented; equant to bladed clasts; cements: 1) quartz, 2) limonite, 3) minor hematite; clasts: strained quartz, metaquartzite, quartz-sericite schist, phyllite, chert, devitrified glass shard tuff, trachytic, magnetite-rich, quartz volcanic rock fragments, magnetite-hematite, magnetite-limonite. Env. of dep.: fanglomerate.

#43
Clay-rich conglomerate.
(Thin section 348) 386062, 2 kms south of La Cooporativa. Terrigenous; clayey pebble conglomerate: clayey immature metamorphic clast litharenite; hard; F: multicolored reddish browns, pinks, whites, grays, yellows, and oranges, W: dark yellowish orange; poorly bedded; fair por.; fair perm.; very poorly sorted; subangular to round clasts; inhomogeneous; loosely packed; grains oriented with long directions parallel to bedding; bladed grains; cements: clay (illite?); clasts: quartzite, quartz-sericite schist, hornfels, hematite in clasts as single grains and as bands, and as streaks in clay matrix. Env. of dep.: head end of fanglomerate(?).

#44
Sheared clay-rich conglomerate.
(Thin section 350A) 392054, boulder in Rio Blanco. Terrigenous; sheared conglomerate; hard; F: moderate olive brown, W: pale olive; crushed, broken pebbles of quartz, plagioclase, and K-feldspar in matrix of chlorite, sericite, quartz, and clay. Clasts all show high undulose extinction. Origin:

sheared conglomerate of alluvial fan(?).

#45
Clay-rich conglomerate.
(Thin section 350B) 392054, boulder from Rio Blanco. Terrigenous; clayey pebble conglomerate: hematitic, submature, phyllarenite; medium hard; F: dark brownish red, W: same; poorly bedded; poor por.; low perm.; poorly sorted; angular to subangular clasts; inhomogeneous; poorly packed; poorly oriented grains; bladed clasts; cement: hematite; clasts: metamorphic rock fragments, hematite, magnetite. Env. of dep.: head end of fanglomerate(?).

#46
Clay-rich conglomerate.
(Thin section 350D) 392054, boulder from Rio Blanco. Terrigenous; pebbly mudstone: hematitic, clayey, immature, quartz arenite; soft; F: light brown to light reddish brown, W: same; crushed quartz silt and rare quartz pebbles in matrix of illite(?), hematite; patches of hematite or illite give rock a red or green spotted appearance; well bedded by aligned clay grains and layers. Env. of dep.: low energy, fluvial muds(?).

#47
Sheared clay-rich conglomerate.
(Thin section 350F, photomicrograph pl. 5E) 392054, boulder from Rio Blanco. Terrigenous; sheared clayey pebble conglomerate: quartzose, illitic, immature, phyllarenite; hard; F: light grayish green and dark reddish browns, W: grayish olive; poorly bedded; poor por.; low perm.; very poorly sorted; subangular; inhomogeneous; moderately packed; well oriented; disc-shaped grains; cements: 1) quartz, 2) illite, 3) chlorite; clasts: metamorphic rock fragments, mostly schists, phyllite, composite metaquartz, and hornfels with magnetite, hematite, and leucoxene in matrix and clasts. Rock is highly sheared and brecciated. Env. of dep.: head end of fanglomerate(?) later sheared along fault(?).

#48
Clay-rich conglomerate.
(Thin section 353B) 359039, 1 km southeast of El Ciruelo. Terrigenous; clayey pebble conglomerate: limonitic, submature to immature, phyllarenite; medium soft; F: grayish orange to light brown, W: same; similar to #45 but with higher proportion in matrix of clay, limonite, and chlorite. Rock appears to be made of sheared schist clasts or altered volcanic glass.

#49
Sheared clay-rich conglomerate.
(Thin section 353E) 359039, 1 km southeast of El Ciruelo. Terrigenous; clayey pebble conglomerate: limonitic, submature to immature phyllarenite; soft; F: dusky yellowish brown and pale pink spots, W: dusky yellowish brown; similar to #48.

#50
Metamorphic conglomerate.
(Thin section 366A) 390048, 1.8 kms north of Cerro El Cubo. Terrigenous; pebble conglomerate: quartzose, submature, phyllarenite; hard; F: very pale orange, W: dark yellowish brown; very poorly bedded, poor por.; low perm.; very poorly sorted; inhomogeneous; moderately packed; unoriented; equant to bladed grains; cements: 1) quartz, 2) illite; clasts: metamorphic rock fragments including quartz-sericite schist, composite metaquartz, quartzite, meta-chert, hornfels; opaques are rare limonite, hematite, and rare leucoxene. Env. of dep.: head of fanglomerate(?).

#51
Clay-rich conglomerate.
(Thin section 366B) 390048, 1.8 kms north of Cerro El Cubo. Terrigenous; granule sandy mudstone: hematitic, immature, phyllarenite; medium soft; F: moderate brown, W: moderate yellowish brown; poorly bedded granules of quartzite, schist, and phyllite, and quartz sand and silt in matrix of illite(?), chlorite, hematite, and limonite. Matrix is probably derived mostly from the breakdown of phyllite or mica schist after deposition. Env. of dep.: very near source.

#52
Shale.
(Thin section 366C) 390048, 1.8 kms north of Cerro El Cubo. Terrigenous; sandy mudstone: hematitic, immature, phyllarenite; soft; F: moderate brown, W: pale yellowish brown; similar to #51, but without granule-sized metamorphic rock fragments; poorly bedded; weathering produced color bands.

The following are descriptions of specimens from described sections of Todos Santos Formation (Appendix I):

#53
Volcanic rock.
(Thin section S-1-1, photomicrograph pl. 5F) Las Marias

section. Volcanic; crystal-poor, devitrified, argillized-feldspar-quartz tuff; medium soft; F: and W: dusky red with yellow orange spots; weathered; 35% phenocrysts of totally kaolinized and sericitized feldspars, embayed quartz, and pyrite altering to hematite, and kaolinite patches with irregular shapes; quartz has fluid inclusions: 65% matrix of glass shards, possibly welded, now devitrified to quartz, muscovite, kaolinite, illite, and opaques, and possibly some chlorite.

#54
Metamorphic-clast conglomerate.
(Hand specimen S-1-2) Las Marias section. Terrigenous; cobble conglomerate: hematitic, immature to submature, quartz-bearing phyllarenite; easily broken; poorly cemented; F: dusky red, W: reddish brown; weathered; poorly bedded; good post-cement por.; fair perm.; very poorly sorted; round clasts; inhomogeneous; loosely packed; equant to bladed grains, clasts parallel to bedding; cements: 1) hematite, 2) clay; clasts: metamorphic rock fragments, metamorphic quartz, vein quarts(?); basal conglomerate sitting on metamorphic basement. Env. of dep.: fanglomerate.

#55
Metamorphic-clast and volcanic-clast conglomerate.
(Thin section S-1-3) Las Marias section. Terrigenous; pebble conglomerate: quartzose, submature, volcanic-clast phyllarenite; hard; F: brownish red to greenish yellows, W: reddish gray to red brown; poorly bedded; good pre-cement por.; poor post-cement por.; low perm.; very poorly sorted (σ=3ϕ); subangular clasts; inhomogeneous; loosely packed; unoriented; equant to platy grains; cements: 1) quartz as overgrowths, 2) hematite; clasts: quartz 15%, 60% metamorphic rock fragments of phyllite, metaquartzite, muscovite schist, 20% volcanic rock fragments of devitrified glass fragments with ghost shard structure, silicifying to chert, sedimentary rock fragments of chert and shale, magnetite altering to hematite. Env. of dep.: fanglomerate.

#56
Metamorphic-clast conglomerate.
(Thin section S-1-4A) Las Marias section. Terrigenous; pebbly granule conglomerate: quartzose, hematitic, submature, cherty phyllarenite; very hard; F: light oranges, W: brown; poorly bedded; fair pre-cement por.; very poor post-cement por.; very low perm.; very poorly sorted (σ=2.5ϕ); inhomogeneous; loosely packed; unoriented; equant grains; cements: 1) quartz, 2) chlorite, 3) minor clay; clasts: 25 to 30% common quartz, remaining are chert, phyllite, metaquartzite,

muscovite schist, magnetite altering to hematite, quartz veins in metamorphic clasts. Env. of dep.: fanglomerate.

#57
Metamorphic-clast conglomerate.
(Thin section S-1-4B) Las Marias section. Terrigenous; medium sandy pebble conglomerate: quartzose, submature, phyllite; hard; F: light gray, W: yellowish oranges; weathered feldspars, poorly bedded; good pre- and post-cement por.; fair perm.; very poorly sorted (σ=2.5$\emptyset$); subround grains; homogeneous; loosely packed; unoriented; equant to platy clasts; cements: 1) quartz, 2) hematite, 3) minor chlorite; clasts: common quartz, metaquartzite, phyllite, some K-feldspar. Env. of dep.: fanglomerate.

#58
Sandstone.
(Thin section S-1-5) Las Marias section. Terrigenous; clayey very fine sandstone: hematitic, illitic, immature, quartz arenite; hard; F: very dusky red, W: reddish oranges; poorly bedded; poor post-cement por.; low perm.; very poorly sorted (σ=2$\emptyset$); angular to subround grains; homogeneous; loosely packed(?); unoriented; equant grains; cements: 1) hematite, 2) illite, 3) chlorite; clasts: mostly common quartz with illite, magnetite altering to hematite, leucoxene. Env. of dep.: flood plain(?).

#59
Metamorphic-clast conglomerate.
(Thin section S-1-6) Las Marias section. Terrigenous; pebbly coarse sandstone: quartzose, submature, phyllarenite; hard; F: reddish brown, W: dark reddish gray; slightly weathered, poorly bedded; good pre-cement por., poor post-cement por.; low perm.; very poorly sorted (σ=2.5$\emptyset$); subround grains; inhomogeneous; loosely packed; unoriented; cements: 1) quartz, 2) hematite; clasts: 20% strained quartz, remaining are metamorphic quartzite, phyllite, sandy phyllite, quartz-sericite schist, chert, minor limonite and leucoxene. Env. of dep.: fanglomerate.

#60
Volcanic-clast sandstone (spotted arkose).
(Thin section S-2-1) Cacaguapa section. Terrigenous; coarse sandstone: quartzose, submature, feldspathic, volcanic arenite; medium soft; F: brown, W: brown; weathered boulders; poorly bedded; very good pre-cement por., good post-cement por.; high perm.; poorly sorted (σ=1.3$\emptyset$); subround grains; homogeneous; loosely packed; unoriented; equant to platy grains; cements: 1) quartz, 2) minor hematite; clasts: 75%

volcanic rock fragments of plagioclase, trachytic tuffs, embayed quartz, K-feldspar, bent devitrified glass shard packages, 15% metaquartzite, remaining are common quartz, limonite, and minor leucoxene. Env. of dep.: fanglomerate or flood plain.

#61
Light colored arkose.
(Thin section S-2-2) Cacaguapa section. Terrigenous; fine to medium sandstone: quartzose, submature, kaolinite (altered feldspars?), subarkose; hard; F: olive, W: yellow brown; bedding by grain size; good pre-cement por., poor post-cement por.; low perm.; moderately sorted, bimodal (σ=.75ϕ); subround to round grains; homogeneous; moderately packed; unoriented; equant grains; cements: 1) quartz, 2) minor limonite, 3) chlorite, and 4) possibly kaolinite; clasts: 80% common quartz, 15% kaolinite grains, possibly altered feldspars, the remaining are muscovite schist, and rare hematite and leucoxene. Env. of dep.: reworked dune or beach.

#62
Metamorphic-clast and volcanic-clast conglomerate.
(Thin section S-2-5) Cacaguapa section. Terrigenous; sandy pebble conglomerate: quartzose, kaolinitic, immature, phyllarenite; hard; F: white to pinkish white, W: white spotted dusky red; slightly weathered, poorly bedded; poor pre- and post-cement por.; low perm.; very poorly sorted (σ=1.2ϕ); angular to round grains; inhomogeneous; loosely packed; unoriented; equant to irregular clasts; cements: 1) quartz, 2) kaolinite; clasts: 90% quartz composed of strained and vacuoled quartz, remaining is kaolinite and phyllite clasts, minor hematite. Env. of dep.: fanglomerate.

#63
Calichefied calclithite.
(Thin section S-4-1) El Sauce section. Volcanic(?); calichefied calclithite; medium hard; F: dusky red to red brown, W: yellow brown; neomorphic calcite similar to caliche ball conglomerate #37, quartz with calcite rims included in rock, formed by drying micrite calcite pulling away from quartz producing cavities for later sparry calcite to fill; chalcedony growing in voids; some dolomite replacing spar. Env. of dep.: calichefied fault breccia(?).

#64
Sandstone.
(Thin section S-4-2) El Sauce section. Terrigenous; fine sandstone: illitic, hematitic, immature calcareous mudball

quartz arenite; medium hard; F: dusky reddish brown, W: very dusky red; well bedded by grain size and hematite concentrations; poor pre- and post-cement; low perm.; very poorly sorted; angular to round grains; inhomogeneous; loosely packed; grains slightly aligned parallel to bedding; equant to bladed grains; cements: 1) illite, 2) hematite, 3) calcite; clasts: 75% common quartz with overgrowths, remaining 25% are calcitic and illitic mudballs, chert, plagioclase, muscovite, magnetite altering to hematite, rare zircon, and sphene. Env. of dep.: flood plain(?).

#65
Volcanic rock.
(Thin section S-4-3) El Sauce section. Volcanic; partially carbonate replaced crystal-poor quartz, plagioclase devitrified tuff; very soft; F: orange spotted brown, W: brown; embayed silt to sand sized quartz makes up 30% of phenocrysts, 70% of phenocrysts are vacuoled plagioclase with leucoxene, and K-feldspar, also magnetite altering to hematite; groundmass is fine crystals of hematite, quartz, illite that is devitrified glass shards; coarse-grained calcite nodules replacing volcanic rock, calcite includes some quartz, feldspars, and magnetite grains.

#66
Volcanic rock.
(Thin section S-4-4) El Sauce section. Volcanic; partially carbonate replaced crystal-poor quartz, quartz-illite, plagioclase tuff; hard; F: very dusky red to pale olive, W: dark reddish brown; 30% of rock are phenocrysts of embayed (resorbed) quartz, quartz-illite grains, plagioclase tuff fragments; groundmass is fine plagioclase laths, quartz, illite, and glass; rock replaced in part by coarse sparry calcite with wispy zones of hematite reflecting original tuff texture.

#67
Volcanic rock.
(Thin section S-4-5) El Sauce section. Volcanic; partially calcite replaced crystal-poor tuff, similar to #66, except quartz grains are also included in calcite replaced portions; F: very dusky gray to yellow brown, W: brownish olive; groundmass is totally devitrified.

#68
Sandstone.
(Hand specimen S-4-6) El Sauce section. Terrigenous; muddy fine sandstone: poorly cemented, immature(?), quartz arenite; friable; F: dark gray, W: black; slightly bedded, reflected

in friability; fair por.; med. perm.; homogeneous; loosely packed; equant grains; cements: poorly cemented, possibly some quartz and hematite; clasts: quartz, weathered feldspars, clay. Env. of dep.: flood plain(?).

#69
Volcanic clast in conglomerate.
(Thin section S-4-7, photomicrograph pl. 5G) El Sauce section. Terrigenous rock; volcanic clast: crystal-poor, quartz, plagioclase tuff; very hard; F: grayish pink to yellow brown, W: yellow brown; phenocrysts of embayed quartz, plagioclase (oligoclase?), K-feldspar (altered to clay), and elongate, lath-shaped opaques make up 40% of rock; other 60% is groundmass of clay and quartz with some secondary devitrified balls of radiating chalcedony.

#70
Metamorphic-clast conglomerate (spotted arkose).
(Thin section S-4-8) El Sauce section. Terrigenous; very fine sandstone: hematitic, quartzose, submature, feldspathic phyllarenite; soft, friable; F: dusky red, W: reddish brown; poorly bedded; fair pre- and post-cement por.; low perm.; moderate to poorly sorted (σ=1$\emptyset$); angular to round grains; homogeneous; moderately packed; equant to bladed grains; cements: 1) quartz, 2) hematite; clasts: quartz 65%, rarely rutilated, 25% metamorphic rock fragments of muscovite, metaquartzite, phyllite, chert, 10% fragments of altered plagioclase, magnetite altering to hematite, leucoxene, green biotite, zircon; chert is probably silicified metamorphic rock. Env. of dep.: flood plain.

#71
Volcanic-clast and metamorphic-clast conglomerate.
(Thin section S-4-9) El Sauce section. Terrigenous; granule to pebble conglomerate: quartzose, submature, poly clast litharenite to phyllarenite; medium hard; F: multi-colored browns, brownish reds, and pale pinks; W: brown; poorly bedded; good pre- and post-cement por.; low perm.; very poorly sorted (σ=2.8$\emptyset$); well rounded grains; inhomogeneous; loosely packed; unoriented; equant to bladed grains; cements: 1) quartz, 2) radially crystalline chert (chalcedony); clasts: equal amounts of volcanic and metamorphic rock fragments of vacuoled quartz, chert, metaquartzite, plagioclase (mostly altered to clay), feldspathic phyllite fragments, plagioclase tuffs, glass shard packages, volcanic quartz, phyllite with quartz veins, hematite, magnetite. Env. of dep.: fanglomerate.

#72
Volcanic-clast sandstone (spotted arkose).
(Thin section S-4-10) El Sauce section. Terrigenous; coarse to very coarse sandstone: quartzose, submature, poly fragment litharenite; medium hard; F: dusky red with orange specks, W: reddish brown; slightly weathered, poorly bedded; good pre-cement por., poor post-cement por.; low perm.; poorly sorted (σ=1.3ϕ); round to angular grains; inhomogeneous; tightly packed (pressure solution at grain borders); unoriented; equant to bladed grains; cements: quartz; clasts: 50% common quartz, remaining 50% are plagioclase, K-feldspar, chert, devitrified glass shard tuff packages, metaquartzite, plagioclase tuff fragments, phyllite, volcanic (embayed) quartz, muscovite, hematite. Env. of dep.: fanglomerate or flood plain.

#73A
Light colored arkose.
(Hand specimen S-4-11) El Sauce section. Terrigenous; very fine sandstone: quartzose, mature(?), opaque-rare, quartz arenite; hard; F: brownish olive, W: brown; similar to #61. Env. of dep.: reworked beach or dune.

#73B
Mudstone.
(Thin section 354) 368040, 1 km north of Cerro El Cubo. Terrigenous; medium clayey mudstone: clayey hematitic immature organic material bearing quartz arenite; medium soft; F: dark reddish brown, W: yellow orange; bedded by hematite concentrations and aligned clay grains; poor post-cement por.; very low perm.; very poorly sorted; angular to round grains; inhomogeneous; cements: 1) clay, 2) hematite; clasts: 15% quartz silt, 80% illite(?), some magnetite, composite quartz with sericite, chert, black organic material; quartz veins. Env. of dep.: muddy swamp or mudflow(?).

YOJOA GROUP

This section describes carbonate rocks of the Cantarranas and Atima formations of the Yojoa Group. The classification follows Folk (1968).

The format is:

Appendix number
Name
(Thin section or hand specimen-polished section number), locality, locality description. Five-fold name. Color F: (fresh), W: (weathered); composition and texture. Environment of deposition and texture. Fossils. Comments given by others who have looked at thin sections, primarily G. Lyman Dawe.

Colors are from the Munsell Color Chart (1954) and some are modified according to Folk (1969).

Cantarranas Formation

#74
Silty marl.
(Thin section 71) 306078, 1/3 km west of La Libertad Road, 1 km north of Las Marias. Very fine calcilutite: clayey fossiliferous limonitic micrite. F: yellow brown to yellow orange, W: yellow orange. Contains illite, quartz silt, and magnetite as terrigenous clasts; much organic material, limonite staining. Env. of dep.: back reef or lagoon. Fossils: Orbitolina(?), pelecypod shell fragments and echinoid fragments. Rock is highly sheared.

#75
Disturbed marl.
(Thin section 122) 289063, 1 km west of La Libertad Road, 1½ kms south-southeast of El Sauce at Cerro Manzanillas. Medium calcilutite: clayey fossiliferous dismicrite. F: brownish olive, W: orange yellow. Mottled yellow clays in micrite, some dendritic opaques possibly manganese oxides; rare quartz silt; hematite and limonite stains; disturbed (bioturbated?); some neomorphic calcite spar. Env. of dep.: back reef, lagoon. Fossils: pelecypod fragments, Orbitolina(?), organic matter, possibly wood, ostracods(?). Sparse fossiliferous micrite porbably going to microspar. Fossil material is echinoid (very fine fragments) with some spines, some thin-shelled pelecypod fragments, and some forams. Possibly some ostracod fragments.

#76
Pellet marl.
(Thin section S-4-12) El Sauce described section. Fine calcarenite: packed foram disturbed pelmicrite. F: very dark grayish brown, W: brownish olive. Churned and burrowed fossils in micrite matrix being replaced by neomorphic sparry

calcite; pellets are indistinct; trace of silt-sized quartz; foram tests filled with sparry calcite; abundant organic material; hematite dust and stains; pyrite altering to limonite. Env. of dep.: back reef, lagoon. Fossils: miliolids, Orbitolinas, pelecypod shell fragments, echinoid spines.

Atima Formation

#77
Dolomite.
(Hand specimen-polished section 17) 263067, Manzanillas. Coarsely crystalline: fossiliferous dolomitized intrasparite. F: brownish olive to olive, W: same. Coarse dolomite crystals probably replacing calcilutite; fractures filled with calcite; some limonitic clay; few fossils. Env. of dep.: ? Fossils: miliolids(?).

#78
Orbitolina marly limestone, basal Atima.
(Hand specimen-polished section 80) 297084, 1½ kms northwest of Las Marias. Layered medium calcirudite: clayey limonitic packed Orbitolina biomicrite. F: very dark yellow brown, W: dark yellow brown. 80% of rock are Orbitolina in micrite matrix; fossils are oriented parallel to bedding. Env. of dep.: back reef, lagoon. Fossils: Orbitolina.

#79
Marly limestone.
(Thin section 131) 287116, ½ km north of La Sierra, 2 kms northwest of El Roblito. Very fine calcilutite: hematitic dismicrite. F: brown, W: brown. Minor thin lenses of clayey hematitic layered mud in micrite; coarse calcite spar filling irregular holes representing disturbances (bioturbate?). Env. of dep.: low energy. Fossils: none. Sparry calcite may be related to fracturing and neomorphism obliterating all original texture.

#80
Dolomite.
(Thin section 165, photomicrograph pl. 6I) 225091, Quebrada Chicuás and El Rosario Road. Medium crystalline dolomitized fine calcirudite: hematitic micrite. F: olive gray, W: medium light gray. Dolomite rhombs replacing micrite matrix; organic material; calcite veins in fractures associated with hematite; some minor secondary chalcedony. Env. of dep.: low energy. Fossils: none. Dolomite replacing a pelmicrite.

#81
Orbitolina marly limestone, basal Atima.
(Thin section 235) 272094, Cerro Las Anonas, ½ km east of summit. Calcirudite: clayey packed *Orbitolina* biomicrite. F: dusky blue with yellowish orange streaks, W: light gray to pinkish gray. *Orbitolinas* in matrix of micrite with 1% quartz silt; yellow clay stringers between *Orbitolinas* and in stylolitic cracks. Env. of dep.: low energy. Fossils: *Orbitolina*, some echinoid fragments.

#82
Fossiliferous limestone.
(Hand specimen-polished section 236) 270095, Cerro Las Anonas. Coarse calcirudite: sparse pelecypod microsparite. F: and W: very dark gray. Pelecypod shells filled with micrite and clay, partially silicified; microspar matrix; petroliferous odor; calcite veins. Env. of dep.: pelecypod bank. Fossils: pelecypods, *Gryphaea*, *Orbitolina*.

#83
Fossiliferous limestone.
(Hand specimen 238) 267093, Cerro Las Anonas. Very coarse calcirudite: pyritic packed rudistid biosparite. F: brownish olives and white, W: brownish olive to orangy yellow. Caprinid rudistids filled with forams and shell fragments in matrix of micrite to spar with some spar neomorphism; yellow limonitic clay fills cracks;some stylolites associated with pyrite altered to limonite. Env. of dep.: rudistid reef. Fossils: caprinid rudistids, foraminifera.

#84
Orbitolina limestone.
(Hand specimen-polished section 247) 310057, 1 km east of Piedras Azules. Medium calcirudite: clayey limonitic packed *Orbitolina* disturbed biomicrite. F: very dark gray with orangy yellow stringers, W: brownish olive to dark gray. Miliolids and *Orbitolinas* in disturbed micrite matrix; yellow limonitic clay filling in between; calcite veins. Env. of dep.: low energy, back reef or lagoon. Fossils: miliolids, *Orbitolina*, bryazoans, pelecypod shell fragments.

#85
Fossiliferous limestone.
(Hand specimen-polished section 285) 392206, 2 kms northwest of Jacintillos. Calcirudite: sparse disturbed biosparite. F: and W: olive. Layers of pelecypod shell fragments and ostracod shells in a fine sparry calcite matrix.

#86
Fossiliferous limestone.
(Thin section 314) 259198, Cerro El Camalotal. Medium calcirudite: dolomitized fossiliferous disturbed pelmicrite. F: brownish olive, W: yellow brown. Fossil hash and forams in matrix of spar and pellets; some limonite. Env. of dep.: high energy (outer reef?). Fossils: Orbitolina texana, pelecypod shell fragments, abundant echinoid fragments. Some secondary silica replacement.

#87
Fossiliferous limestone.
(Thin section 315) 262200, Cerro El Camalotal. Petroliferous coarse calcirudite: sparse foraminifera disturbed pelmicrite. F: very dark brown, W: yellow brown. Fossil fragments in pellet matrix; organic material-tar? in stylolitic cracks; calcite veins. Env. of dep.: inner reef(?). Fossils: rudistid shells, miliolids, Textularia(?), Orbitolina, Gryphaea? fragments.

#88
Marly limestone.
(Thin section 322) 302198, 1 km west of Los Plancitos. Coarse calcarenite: clayey limonitic fossiliferous disturbed pelmicrite. F: yellow brown, W: yellow orange. Disturbed (bioturbated?) broken fossil hash in pellet matrix; limonite and clay. Env. of dep.: low energy, back reef. Fossils: ostracod fragments, echinoid spines. 1 to 2% very fine silt-sized quartz.

#89
Fossiliferous limestone.
(Thin section 355) 322211, 5 kms northwest of San Antonio de la Cuesta. Fine calcirudite: highly fossiliferous disturbed intrasparite. F: yellow brown, W: yellow brown. Rounded micrite-coated fossil fragments and intraclasts floating in matrix of glassy calcite spar. Env. of dep.: reef. Fossils: miliolids, Orbitolina, bryozoans, spiral gastropods, fusiformed foraminifera, ostracods, pelecypod shell fragments. Highly fossiliferous (varied) and intraclastic stromatolitic coated biosparite. Large intraclasts are full of pellets also coated thickly with stromatolite. Much of this material appears to have been ingested. The intraclasts may be large fecal pellets.

The following are descriptions of specimens from described sections of Yojoa Group (Appendix I):

#90
Silty limestone, Atima Formation.
(Thin section S-1-7) Las Marias section. Neomorphic silty disturbed sparse foram pelsparite. F: brownish olive, W: brownish olive to orangy yellow. Miliolids, Orbitolina in mud layered pelletiferous micrite; quartz silt with borders replaced by calcite 5 to 10%; finely disseminated organic material; limonite stain in cracks and along grain borders; pyrite altering to hematite, rare leucoxene. Env. of dep.: back reef, lagoon. Fossils: miliolids, Orbitolina.

#91
Limestone, Atima Formation.
(Thin section S-1-8) Las Marias section. Medium calcirudite: packed Orbitolina disturbed pelmicrite. F: very dark grayish brown-brownish olive, W: brownish olive. Orbitolina in burrowed matrix of pellets; rare grains of silt sized authigenic quartz; pyrite altering to hematite and limonite; organic material in matrix. Env. of dep.: back reef, lagoon. Fossils: Orbitolina, rare miliolids.

#92
Orbitolina limestone, Atima Formation.
(Hand specimen S-1-9) Las Marias section. Medium calcirudite: packed Orbitolina disturbed pelmicrite. F: very dark grayish brown, W: dark gray. Orbitolinas in matrix of pellets and micrite; clay in thin layers. Env. of dep.: back reef, lagoon. Fossils: Orbitolina.

#93
Fossiliferous dolomitized limestone, Atima Formation.
(Thin section S-2-3) Cacaguapa section. Dolomitized coarse calcirudite: disturbed packed fragmental pelecypod biomicrite. F: and W: very dark grayish brown with orangy yellow spots and streaks. Fossil hash of pelecypod fragments in dolomite-replaced micrite matrix; hematite stains in intraclasts; limonite stains in matrix associated with dolomite rhombs. Env. of dep.: back reef, lagoon. Fossils: pelecypod fragments.

#94
Fossiliferous limestone, Atima Formation.
(Thin section S-2-6) Cacaguapa section. Fine to medium calcirudite: disturbed sparse fossiliferous pelletiferous microsparite. F: very dark grayish brown, W: gray. Fossils in disturbed micrite matrix; matrix may have originally been pellets; stylolite cracks with tar(?); some euhedral authigenic quartz; minor hematite and limonite; calcite veins. Env. of dep.: back reef(?). Fossils: miliolids, fragmental

Orbitolina(?), other foraminifera, pelecypod shell fragments, ostracods, rudistids. Disturbed fragmental fossiliferous pelmicrite.

#95
Fossiliferous limestone, Atima Formation.
(Hand specimen-polished section S-2-7) Cacaguapa section. Fine calcirudite: fossiliferous dismicrite. F: olive, W: olive. Miliolids, pelecypod fragments, algae(?), ostracods, and Orbitolina in disturbed micrite matrix; calcite spar growing in patches; abundant organic material; hematite in stylolite cracks; calcite veins. Env. of dep.: low energy, back reef(?). Fossils: miliolids, algae(?), pelecypod shell fragments, ostracods, Orbitolina.

#96
Silicified and dolomitized fossiliferous limestone, Atima Formation.
(Thin section S-2-8) Cacaguapa section. Silicified medium crystalline dolomitized fine calcirudite: packed fossiliferous disturbed intrasparite. F: yellow brown, W: gray. Fossils in pelletiferous(?) micrite matrix that is broken into intraclasts and disturbed; dolomitized and partially replaced by silica; abundant organic material; indistinct fossils with neomorphic calcite spar replacing them; hematite and limonite in fine dust and patches; chalcedony growing in patches. Env. of dep.: high energy (within reef?). Fossils: miliolids, Orbitolina, spiral gastropods, pelecypod shell fragments, globergerina-type foraminifera, echinoid fragments. Packed fragmental biomicrite.

#97
Fossiliferous limestone, Atima Formation.
(Thin section S-2-9) Cacaguapa section. Coarse calcirudite: sparse dismicrite. F: olive, W: gray. Fossils in disturbed micrite; some of slide has intraclasts; some neomorphic calcite; hematite and limonite coating intraclasts; some pellets in matrix. Env. of dep.: low energy (back reef, lagoon?). Fossils: miliolids, algae(?), Orbitolina, echinoid fragments. Some silica replacement. Disturbing from burrowing.

#98
Orbitolina marly limestone, basal Atima Formation.
(Thin section S-3-1) Las Anonas section. Coarse calcirudite: Orbitolina pelmicrite. F: black, W: gray. Orbitolina in pellet matrix with abundant fine organic material; some neomorphic calcite replacing micrite; minor hematite stain. Env. of dep.: back reef, lagoon. Fossils: miliolids, Orbitolina,

echinoid spines.

#99
Fossiliferous limestone, Atima Formation.
(Thin section S-3-2) Las Anonas section. Medium calcirudite: fragmental pelecypod and miliolid disturbed pelmicrite. F: very dark grayish brown, W: brownish olive. Intraclasts and calcite-replaced fossil fragments in disturbed indistinct pellet matrix, now broken into intraclasts; hematite stains in cracks; limonite coats grains; few detrital silt-sized quartz grains; high organic content; some neomorphism of micrite being replaced by calcite spar; dolomite replacing micrite matrix; calcite veins. Env. of dep.: high energy (reef?). Fossils: pelecypod shell fragments, miliolids, globergerina-type foraminifera, ostracods. Some stromatolitic and bored pelecypod fragments. Iron-stained stylolites.

#100
Fossiliferous limestone, Atima Formation.
(Thin section S-3-3) Las Anonas section. Partially silicified coarse calcirudite: limonitic packed pelecypod-miliolid disturbed pelmicrite. F: brownish olive to orangy yellow, W: brownish olive-grayish brown. Fossils in indistinct pelletiferous micrite matrix, disturbed and partially replaced by spar; abundant organic material; quartz replacing spar and containing dolomite rhombs; limonite in <u>Gryphaea</u>-like shells; hematite in small crystals and coating grains; thin calcite veins. Env. of dep.: reef. Fossils: <u>Gryphaea</u>(?) shells, miliolids, echinoid spines. Pelsparite with differential replacement of some <u>Gryphaea</u> shell layers with silica.

#101
Chert, Atima Formation.
(Thin section S-3-4) Las Anonas section. Silicified dolomitized medium calcirudite: organic fossiliferous disturbed pelmicrite. F: very dark gray almost bluish gray, W: black. Organic-rich pelletiferous micrite with forams broken into intraclasts; silicified with chalcedony and quartz associated with dolomite rhombs. Env. of dep.: high energy. Chert is secondary. Fossils: foraminifera.

#102
Fossiliferous limestone, Atima Formation.
(Thin section S-3-5) Las Anonas section. Coarse calcirudite: fossiliferous disturbed pelmicrite. F: very dark grayish brown, W: brownish olive-light brownish gray. Fossils in disturbed (bioturbated?) pellet matrix being replaced by sparry calcite; abundant organic material; hematite dust;

stylolite cracks; some large dolomite rhombs. Env. of dep.: back reef, lagoon. Fossils: miliolids, *Gryphaea*(?), oyster fragments with some secondary silica replacement.

#103
Dolomite, Atima Formation.
(Thin section S-3-6) Las Anonas section. Sandy medium crystalline dolomite. F: very dark grayish brown, W: brownish olive-light brownish gray. Dolomite with some patches of sparry calcite; indistinct miliolids; rare quartz sand grains; rare hematite dust; calcite veins with dolomite rhombs in them. Env. of dep.: ?. Fossils: miliolids.

#104
Fossiliferous limestone, Atima Formation.
(Thin section S-3->) Las Anonas section. Fine calcirudite: packed miliolid disturbed pelsparite. F: very dark grayish brown to brownish olive, W: brownish olive. Pellets and forams in sparry calcite matrix; abundant organic material-tar(?); hematite dust; limonite stains; sparry calcite filling foram tests; calcite veins. Env. of dep.: back reef, lagoon. Fossils: miliolids, *Orbitolina*, small spiral gastropods, pelecypod fragments. Moderately fractured.

#105
Fossiliferous limestone, Atima Formation.
(Thin section S-3-8) Las Anonas section. Fine calcirudite: fossiliferous disturbed pelmicrite. F: very dark grayish brown, W: light gray. Fossils in disturbed indistinct pellet matrix; sparry calcite growing in matrix; few intraclasts; abundant organic material; hematite and limonite dust and stains. Env. of dep.: back reef, lagoon. Fossils: miliolids, *Orbitolina*, pelecypod fragments with algal borings, some possible algal forms.

#106
Limestone, Atima Formation.
(Thin section S-3-9) Las Anonas section. Coarse calcirudite: rounded intrasparite. F: very dark grayish brown, W: brownish olive. Rounded intraclasts with micrite coatings in sparry calcite matrix; intraclasts are pelletiferous; fossil hash in intraclasts not identifiable; stylolite cracks with clay; sparry calcite replacing micrite and intraclast fossils. Env. of dep.: moderate energy (reef?) or back beach-lagoon. Fossils: algally bored pelecypod fragments.

#107
Limestone, Atima Formation.
(Thin section S-3-10) Las Anonas section. Coarse calcirudite:

intrasparite. F: brownish olive, W: light gray to orangy yellow. Micrite breccia in sparry calcite matrix; hematite and limonite in spar; stylolite cracks with clay. Env. of dep.: high energy (reef?). Fossils: spiral foraminifera, monopleura(?) rudistid. May be a biomicrudite.

#108
Dolomitized fossiliferous limestone, Atima Formation.
(Thin section S-3-11) Las Anonas section. Partially dolomitized fine calcirudite: packed fragmental pelecypod dismicrite. F: brownish olive, W: brownish olive. Disturbed fossil hash in micrite, possibly originally pellets; sparry calcite growing in micrite; some organic material in calcite veins; minor limonite in calcite veins; minor euhedral authigenic silt-sized quartz grains in matrix. Env. of dep.: back reef, lagoon. Fossils: pelecypod shell fragments, echinoid spines(?). Fractured (calcite-filled) pelecypod biomicrudite.

#109
Pellet marl, Cantarranas Formation.
(Hand specimen S-4-12). Same specimen as #76. Echinoid (spines) bearing pelmicrite, some dasycladacean algae, 5% quartz silt, some pelecypod fragments.

#110
Dolomite, Atima Formation.
(Thin section S-4-13) El Sauce section. Silicified coarsely crystalline dolomite. F: brownish olive to orangy yellow, W: very dark grayish brown. Dolomite rhombs comprise most of rock with chalcedony and quartz filling voids; some hexagonal euhedral authigenic quartz grains-some with overgrowths; limonite in cracks and coating dolomite rhombs. Up to 5% replaced silica.

#111
Dolomitized limestone, Atima Formation.
(Thin section S-4-14) El Sauce section. Silicified medium crystalline dolomitized miliolid-bearing micrite. F: very dark grayish brown to orangy yellow, W: orangy yellow-white. Dolomitized alternating micrite and sparite bands with intercalated clay layers that are in part disturbed; quartz veins; fine hematite dust. Env. of dep.: back reef. Fossils: miliolids.

#112
Silicified dolomite, Atima Formation.
(Thin section S-4-15) El Sauce section. Partially silicified medium crystalline dolomite. F: brownish olive, W: brownish

olive. Homogeneous fine-grained dolomite with no fossils. Some quartz silt.

VALLE DE ANGELES GROUP

This section describes thin sections and hand specimens from the unnamed redbed clastic sedimentary rock formation of the Valle de Angeles Group. The classification is the same as that for the clastic rocks of the Todos Santos Formation. The format is the same as that given in the section describing Todos Santos Formation.

#113
Siltstone.
(Thin section 26C) 274068, 1 km east of Manzanillas. Terrigenous; medium siltstone: hematitic calcitic mature subarkose; medium hard; F: red brown, W: reddish brown; well-bedded, cross bedded (ripples), layers of soft sediment deformation features; burrowed; good pre-cement por., poor post-cement por.; low perm.; moderately sorted (σ=0.5ϕ); subangular grains; inhomogeneous; loosely packed; unoriented; equant, bladed, and platy grains; cements: 1) hematite, 2) calcite; clasts form possibly 80% of rock: quartz 80%, remaining are altered plagioclase, limestone clasts (micrite), chert, muscovite, magnetite altering to hematite. Env. of dep.: delta or floodplain.

#114
Siltstone.
(Hand specimen 133) 257054, El Motatal. Terrigenous; medium siltstone: hematitic calcitic mature subarkose; same as #113.

#115
Sandstone.
(Hand specimen 161) 217075, 1 km southwest of Agua Salada. Terrigenous; granule sandstone: quartzose hematitic submature quartz-chert arenite; medium hard; F: light reddish brown, W: yellow brown; poorly bedded; poor post-cement por.; low perm.; bimodally sorted; subround to round grains; inhomogeneous; loosely packed; unoriented; equant to bladed grains; cements: 1) hematite, 2) quartz(?), 3) calcite; clasts: quartz, chert,

shale. Env. of dep.: delta or floodplain.

#116
Siltstone.
Hand specimen 289) 213134, 2 kms north of El Rosario, conical hill. Terrigenous; coarse siltstone: quartzose quartz arenite; hard; F: dark gray, W: dark reddish brown; poorly bedded; poor post-cement por.; low perm.; moderately sorted; subround grains; homogeneous; cements: quartz(?); clasts: quartz. Possibly altered by hydrothermal solutions; highly fractured. Env. of dep.: fluvial(?).

#117
Carbonate replaced mudstone.
(Thin section 26A) 274068, 1 km east of Manzanillas. Terrigenous; carbonate replaced claystone; hard; F: black, W: brown; well-bedded, opaque and organic(?)-rich clay mostly replaced by sparry calcite. Opaques are mostly very fine magnetite(?), and some hematite; extremely fine-grained quartz silt is present but rare. Env. of dep.: pro-delta mud(?).

#118
Carbonate replaced mudstone.
(Thin section 26B) 274068, 1 km east of Manzanillas. Terrigenous; silty mudstone: calcitic hematitic immature quartz arenite; hard; F: black, W: brown; most of original rock was clay with lesser silt-sized quartz and hematite, now almost totally replaced by calcite. Well-bedded, cross-bedded, load casts. Env. of dep.: pro-delta mud(?).

#119
Mudstone.
(Thin section S-5-1) 225079, boulder from quebrada at Agua Salada. Terrigenous; fine sandy mudstone: hematitic calcitic immature micaceous plagioclase volcarenite; very soft; F: dark reddish brown, W: brown; poorly bedded; poor pre- and post-cement por.; low perm.; bimodally sorted; round to angular silt grains; homogeneous; loosely packed; unoriented clays; equant silt grains; cements: 1) calcite, 2) hematite; clasts: 60% silt grains of 40% quartz and 60% sauceritized plagioclase, clay fraction is illite, hematite. Burrowed(?) shown by unoriented clays and lack of bedding. Env. of dep.: delta or floodplain.

#120
Sandstone.
(Thin section S-5-2) 225079, boulder from quebrada at Agua Salada. Terrigenous; fine sandstone: poorly cemented

hematitic submature lithic subarkose; soft, friable; F: dusky red, W: light reddish brown; well-bedded by composition and grain size; very good pre- and post-cement por.; high perm.; very poorly sorted (σ=2.0$\emptyset$); subangular feldspar and subround quartz (textural inversion); layered; loosely packed; unoriented; equant to bladed grains; cements: 1) calcite, 2) quartz as overgrowths, 3) hematite; clasts: 55% quartz, 15% K-feldspar and altered plagioclase, 30% rock fragments of mudstone, chert, composite quartz, phyllite, chlorite, magnetite. Env. of dep.: delta or floodplain.

#121
Conglomerate.
(Thin section S-5-3) 225079, boulder from quebrada at Agua Salada. Terrigenous; pebble conglomerate: hematitic, calcitic submature poly clast sedlithite; medium soft; F: multicolored orangy reds, W: orange red; poorly bedded; good pre-cement por., poor post-cement por.; low perm.; very poorly sorted (σ=3$\emptyset$); subangular grains, inhomogeneous; loosely packed; unoriented grains; equant to bladed clasts; cements: 1) calcite, 2) hematite; clasts: 12% quartz, 88% rock fragments of 10% volcanic rock fragments including tuffs with devitrified "balls" and devitrified glass (quartz-chlorite) fragment packages; 18% metamorphic rock fragments including metaquartzite, muscovite schist, phyllite, heavily vacuoled quartz with vermiculite now altered to oxidized chlorite, hematite-rich clasts, and 50% sedimentary rock fragments including limestone with echinoid spines(?), chert, quartz arenite with chert cement, and reworked radiolarian chert. Env. of dep.: delta or floodplain.

#122
Sandstone.
(Thin section S-5-4) 225078, boulder from quebrada at Agua Salada. Terrigenous; coarse sandstone: calcite submature poly clast sub chert arenite; medium soft; F: reddish brown, W: reddish brown; bedded by grain size and composition; good pre- and post-cement por.; moderate perm.; poorly sorted (σ=1.75$\emptyset$); bimodal; subangular to round grains; inhomogeneous; loosely packed; elongate, bladed grains parallel to bedding; equant to bladed grains; cements: 1) quartz overgrowths, 2) hematite, 3) calcite (most prevalent); clasts: 50% quartz, 5% plagioclase; 45% rock fragments of mostly chert and some fine-grained limestone, phyllite, magnetite altering to hematite, and rare glauconite. Env. of dep.: delta or temporarily submerged floodplain.

#123
Sandstone.
(Thin section S-5-5) 225079, boulder from quebrada at Agua Salada. Terrigenous; very fine sandstone: calcitic submature epidote-rich poly clast sublitharenite; medium soft; F: dark reddish brown to brown, W: reddish gray to brown; bedded by grain size; poor pre- and post-cement por.; low perm.; moderately sorted (σ=1.5Ø); subangular grains; inhomogeneous; tightly packed; unoriented; equant to bladed grains; cements: 1) quartz overgrowths, 2) hematite, 3) chlorite, 4) calcite (predominant); clasts: 70% quartz, remaining are radiolarian chert fragments, phyllite, muscovite, muscovite-quartz schist, plagioclase, hematitic phyllite, chlorite, fine-grained limestone, abundant epidote group minerals, hematitic quartz-feldspar volcanic porphyry, hematite, leucoxene, and rare glauconite. Env. of dep.: delta or temporarily submerged floodplain.

#124
Sandstone.
(Thin section S-5-6) 225079, boulder from quebrada at Agua Salada. Terrigenous; fine sandstone: calcitic submature calclithic subchertarenite; hard; F: yellow brown, W: pale brown; bedded by grain size and composition; good pre-cement por., poor post-cement por.; low perm.; poorly sorted (σ=1.5Ø); subangular grains; inhomogeneous; very loosely packed; elongate grains oriented parallel to bedding; equant to bladed grains; cements: calcite; clasts: quartz 70%, plagioclase 5%, remaining 25% are radiolarian chert fragments and some fine-grained limestone, 5% metamorphic rock fragments of muscovite schist, phyllite, metaquartzite, some trachytic tuffs, leucoxene and chlorite devitrified glass fragments, magnetite altering to hematite, epidote, and rare glauconite. Env. of dep.: delta or temporarily submerged floodplain.

PADRE MIGUEL GROUP

This section describes selected thin sections of rocks from the Padre Miguel Group. Igneous flow rocks are named using the classification of Travis (1955). Palo Pintado Gravel is classified as the sedimentary rocks above, and ignimbrites are classified by texture and composition according to Cook (1965) and by composition according to Streckeisen (1965). Streckeisen suggested that rocks classified by phenocryst composition should have names prefixed by the term "pheno-." Some terms used in the text are defined by Ross and Smith (1961).

#125
Olivine basalt.
(Thin section 5) 254029, 1½ kms south of Palo Pintado. F: greenish black, W: grayish brown. Trachytic; fine to coarse plagioclase (labradorite?) laths 70%, interstitial brownish alteration mineral (of olivine) with some serpentine(?) 10%, minor clinopyroxene 5-7%, large crystals of resorbed quartz with pyroxene rims (picked up by flow from underlying ignimbrite?), accessory magnetite.

#126
Olivine basalt.
(Thin section 12) 244038, Los Claros. F: and W: dark reddish brown. Trachytic; zoned unaltered, plagioclase (labradorite?) laths with lesser interstitial clinopyroxene and altered olivine 50%, fine-grained hematite stained groundmass 50%.

#127
Ignimbrite, La Sabana ignimbrite.
(Thin section 303) 215138, 1 km east of San Jacinto. F: and W: pinkish gray. Tuffaceous; groundmass 25%, phenocrysts 55%; quartz with resorbed borders 60%, sanidine with ghost or overgrowths (synneusis?) 35%, lithic fragments of crystal-poor tuff 4%, pumice fragments 1%, hematite trace, groundmass of devitrified (quartz, feldspar, chlorite, axiolitic glass shards) material with "snowflake" texture. Sanidine-quartz, crystal-vitric ignimbrite: pheno-rhyolite.

#128
Ignimbrite, Cerro La Cañada ignimbrite.
(Thin section 308A) 188197, just west of quadrangle boundary 3 kms west of Las Lagunas. F: and W: very pale orange. Tuffaceous; groundmass 70%, phenocrysts 30%; sanidine 50%, resorbed quartz 25%, plagioclase (n=balsam) 25%, brown biotite 3%, hematite trace, groundmass of devitrified ghost shards. Quartz-plagioclase-sanidine, crystal-vitric ignimbrite: pheno-dacite.

#129
Ignimbrite, Cerro La Cañada ignimbrite.
(Thin section 308B) 188197, just west of quadrangle boundary 3 kms west of Las Lagunas. F: pale reddish brown, W: pale yellowish brown. Tuffaceous; groundmass 88%, phenocrysts 10%, lithic fragments 2%; sanidine 70%, quartz 30%, biotite trace, hematite trace, tuff packages (crystal-rich) 2%, groundmass of axiolitic welded shards. Quartz-sanidine, vitric-crystal ignimbrite: pheno-rhyolite.

#130
Volcanic breccia, Palo Pintado Gravel.
(Thin section 255) 241056, 1 km southwest of Plan Colorado. F: and W: light gray to orange. Breccia of clast up to 5 cms long of volcanic rock fragments, mostly pumice, trachytic plagioclase tuffs, and chalcedony in matrix of glass, clay, and zeolite, possibly prehnite; minor hematite and limonite.

#131
Carbonate nodule, Palo Pintado Gravel.
(Thin section 256) 241056, 1 km southwest of Plan Colorado. Carbonate; coarsely crystalline dolomitized sparse-miliolid disturbed pelmicrite; F: and W: brown; dolomite rhombs replacing fragmental pelecypods, ostracods, miliolids, in pellet matrix; hexagonal euhedral quartz in micrite, calcite veins, chalcedony veins. Env. of dep.: clast from basal lag gravel below ignimbrite section, probably derived from Atima Formation.

#132
Silicified basal glass, La Sabana ignimbrite.
(Thin section 270) 416196, 1 km east of Jacintillos. F: yellow brown, W: yellow orange. Very fine-grained "rice" texture. Rock is almost totally quartz with C-axes aligned more or less in 3 directions at 90° to each other. Some minor chlorite, a few calcite inclusions; opaques are minor and include hematite, limonite, and leucoxene. This is possibly a silicified basal vitrophyre with some carbonate picked up from underlying Atima Formation.

#133
Silicified basal glass, La Sabana ignimbrite.
(Thin section 272) same location as #132. Same rock as #132 but weathers with yellow and orange bands (liesegang banding?).

#134
Silicified basal glass, La Sabana ignimbrite.
(Thin section 313, photomicrograph pl. 4H) 258197, top of

Cerro El Camalotal. F: and W: dark yellowish brown. Medium-grained "rice" texture. Rock is now a quartzite of elongate quartz crystals aligned with C-axes more or less in 3 directions at 90° to each other as in #132, but much easier to see than #132; some carbonate inclusions. This is probably a silicified basal vitrophyre.

This section describes igneous intrusive rocks. The classification is from Streckeisen (1965). Tuffaceous rocks also include classification of Cook (1965).

The format is:

Appendix number
Name
(Thin section number) grid location, location description.
Fresh surface color (F:), weathered surface color (W:); texture; composition; remarks; classification.

#135
Rhyolite.
(Thin section 32) 309038, ½ km north of Valle de Angeles. F: light olive gray, W: light olive gray to olive; aphanitic porphyritic, tuffaceous; phenocrysts 30% of embayed quartz and K-feldspar with calcite replacement 60%, leucoxene-sericite-quartz packages (devitrified pumice?), quartz-sericite grains, fine-grained, wispy sericite-leucoxene-chlorite patches, leucoxene opaque minerals; groundmass of devitrified glass shards 70%. K-feldspar,-quartz vitric-crystal to vitric-lithic tuff: pheno-rhyolite.

#136
Rhyolite.
(Thin section 74) 301084, 1/3 km west of La Libertad Road, 1 km northwest of Las Marias. F: yellow, W: yellowish brown; aphanitic porphyritic, tuffaceous; phenocrysts 30% with 80% sanidine, 20% embayed quartz; groundmass 70% is very fine-grained sericite(?), chlorite, quartz with a felted texture. Quartz,-sanidine, crystal-vitric tuff; pheno-rhyolite.

#137
Rhyolite.
(Thin section 86) 291088, 1½ kms west of La Libertad Road, 3 kms east of Cerro Las Anonas. F: grayish yellow to yellow, W: grayish red purple; aphanitic porphyritic, tuffaceous;

fine-grained mosaic of serrated quartz and devitrified glass fragments with layering (flow structure?), devitrified glass fragments surrounded by concentric fine, sutured quartz layers; chalcedony stringers between fragments; leucoxene and hematite and limonite as accessories; texture retains some of the original glass structure. Secondary or devitrified, silicified rhyolite, original shards now quartz-feldspar intergrowths and clay with hematite stains. Sanidine-quartz, silicified vitric-crystal tuff; pheno-rhyolite.

#138A
Rhyolite.
(Thin section 88, photomicrograph pl. 11A) 288089, 1½ kms west of La Libertad Road, 3 kms east of Cerro Las Anonas. F: pale yellow orange, W: dark yellowish orange. Devitrified "snowflake" texture; quartz-feldspar intergrowths with altered plagioclase laths now mostly clay. Plagioclase-K-feldspar-quartz, vitric-crystal tuff; pheno-rhyolite.

#138B
Rhyolite.
(Thin section 93) 300110, ½ km west of La Libertad Road near El Roblito. F: gray, W: yellow orange; aphanitic porphyritic, tuffaceous. Euhedral, embayed quartz 25%, devitrified, leucoxene-hematite-chlorite-quartz pumice fragments with cherty-looking quartz packages 25%, groundmass 50% of very fine chlorite and quartz at incipient stages of crystallization, patches of purplish-dusty hematitic fragments, clots of muscovite associated with hematite and leucoxene, rare zircon, some limonite. Quartz, vitric-lithic tuff; pheno-rhyolite.

#139
Rhyolite.
(Thin section 99) 276103, 1 km east of village of Las Anonas. F: and W: very dark bluish gray; aphanitic; "snowflake" texture; highly vacuoled and carbonate replaced mottled groundmass with plagioclase mostly replaced by sericite and calcite and large crystals of magnetite, partly altered to hematite; minor leucoxene. Plagioclase, vitric-crystal tuff; pheno-quartz andesite to pheno-rhyolite.

#140
Rhyolite.
(Thin section 100) 267103, village of Las Anonas. F: pale reddish purple, W: brown. Aphanitic porphyritic, tuffaceous; "snowflake" texture; quartz phenocrysts are mosaics of sutured grains with slight undulatory extinction and some feldspars replaced by sericite in a groundmass of very fine

chlorite, sericite, and quartz; hematite common throughout, trace of leucoxene. Polished section shows original glass shard texture. Feldspar-quartz, vitric-crystal tuff; pheno-rhyolite.

#141
Rhyolite dike.
(Thin section 268) 222116, El Rosario. F: dusky blue to orangy yellow, W: red orange. Aphanitic porphyritic, tuffaceous; highly altered feldspars and embayed quartz with hematite, limonite, and leucoxene in a groundmass of felted looking very fine-grained sericite and chlorite and possibly clays; groundmass still retains glass shard texture; feldspars replaced by chlorite and sericite. Quartz-feldspar, vitric-crystal tuff; pheno-rhyolite.

#142
Rhyolite.
(Thin section 275, photomicrograph 11C) 265111, Rio Humuya, ½ km south of La Joya. F: pale greenish yellow, W: yellow brown. Granophyric texture; intergrowths of plagioclase (albite?), K-feldspar, and quartz showing granitic, micropegmatite, myrmakitic and perthitic textures; minor hematite and leucoxene. Granite.

#143
Rhyolite.
(Thin section 276) 257114, Rio Humuya, ½ km southeast of La Joya. F: grayish green, W: light greenish gray. Similar to #141 but with more quartz; groundmass is mostly green chlorite; patches of anomolous chlorite and calcite as altered mafics(?); feldspars replaced by epidote; fine-grained leucoxene spread throughout. Quartz-mafic(?)-feldspar, crystal-vitric tuff; pheno-quartz andesite.

#144
Rhyolite.
(Thin section 291A, photomicrograph pl. 11B) 286103, 1½ kms east of village of Las Anonas. F: very pale orange and dusky yellowish brown bands, W: moderate yellowish brown. Texture intermediate between "snowflake" and granophyric; intergrowths of quartz and K-feldspar; minor opaques of hematite in bands. Rhyolite.

#145
Rhyolite.
(Thin section 304) 208128, 1 km northwest of El Rosario. F: grayish green, W: light greenish gray. Similar to #141, but with much less leucoxene, other opaques include pyrite and

hematite. Associated with fluorite mineralization. Pheno-rhyolite.

#146
Rhyolite.
(Thin section 336E) 280116, Humuya Gorge, 1½ kms east of Cerro La Colmena. F: and W: very pale yellow to greenish gray. Aphanitic porphyritic; crushed unoriented mass of very fine-grained chlorite-muscovite-leucoxene groundmass with quartz and plagioclase altered in part to calcite, some leucoxene. Pheno-rhyolite.

#147
Rhyolite.
(Thin section 337A) 278120, Humuya Gorge, 1 km east of Cerro La Colmena. F: white, W: yellowish brown. "Snowflake" texture; coarse plagioclase crystals 25% in groundmass of fine-grained felted quartz and sericite with some clay, some radiating quartz clusters. Pheno-quartz andesite.

#148
Rhyolite.
(Thin section 337B) 278120, Humuya Gorge, 1 km east of Cerro La Colmena. F: and W: greenish gray to grayish green. Similar to #147; groundmass of fine-grained interlocking quartz with equant shapes to plumose structure, chlorite and vacuoles fill edges of clear quartz patches, large crystal of plagioclase (albite?), some sanidine, pyrite altering to limonite and hematite, magnetite associated with feldspar, rare epidote, chlorite. Pheno-quartz andesite.

#149
Rhyolite.
(Thin section 338) 284128, Humuya Gorge, 1½ kms east of Cerro La Colmena. F: grayish green, W: light greenish gray; aphanitic porphyritic, tuffaceous; phenocrysts of embayed quartz and albite(?) and sanidine in groundmass of very fine-grained quartz, sericite, and chlorite; limonite and leucoxene as accessories. Pheno-rhyolite.

#150
Rhyolite dike.
(Thin section 351) 359039, 1 km south of El Ciruelo. F: grayish green, W: light brown to pale yellowish brown; tuffaceous; phenocrysts 40%, groundmass 60%; phenocrysts of resorbed quartz, plagioclase, sanidine in groundmass of devitrified glass; matrix still retains some glass shard structure; opaques are magnetite and hematite, and fine leucoxene; minor chlorite, biotite associated with chalcedony; some lithic

fragments include quartz-sericite schist, muscovite schist fragments, biotite-quartz schist (all picked up during intrusion through basement rock). Quartz-sanidine-plagioclase, crystal-vitric tuff; pheno-quartz andesite.

#151
Gabbro.
(Thin section 226) 415145, Rio Grande, 1½ kms southeast of Las Crucitas. F: greenish black, W: light olive gray; holocrystalline, poikilitic; hornblende with zoned rims 40% poikilitically enclosing plagioclase (labradorite?) laths 30%, chlorite 30% replacing hornblende; plagioclase highly vacuoled and replaced by calcite and some quartz; sericite associated with chlorite, accessory magnetite. Hornblende gabbro, probably crystallized from wet magma.

#152
Diorite or basalt dike.
(Thin section 336B) 280116, Humuya Gorge, 1½ kms east of Cerro La Colmena. F: dark bluish gray, W: greenish black to brownish gray; dioritic texture; heavily vacuoled plagioclase 50%, brown hornblende 50%, minor chlorite, epidote, leucoxene, pyrite, apatite; hornblende has lamprophyric texture. Diorite to basalt.

REFERENCES CITED

Anderson, Thomas H., 1969, Geology of the San Sebastian Huehuetenango Quadrangle, Guatemala, Central America: Unpublished Ph.D. dissertation, The Univ. of Texas at Austin, 218 p.

Bayly, Brian, 1968, Introduction to petrology: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 317 p.

Burkart, Burke, 1965, Geology of the Esquipulas, Chanmagua and Cerro Montecristo quadrangles, southeastern Guatemala: Unpublished Ph.D. dissertation, Rice University, 121 p.

Carpenter, Robert H., 1954, Geology and ore deposits of the Rosario mining district and the San Juancito Mountains, Honduras, Central America: Geol. Soc. America Bull., v. 65, p. 23-38.

Clemons, Russell E., 1966, Geology of the Chiquimula Quadrangle, Guatemala: Unpublished Ph.D. dissertation, The Univ. of Texas at Austin, 123 p.

Cook, Earl F., 1965, Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nev. Bur. Mines Rept. 11, 61 p.

Crane, D. C., 1965, Geology of the Jocotán and Timushán quadrangles, southeastern Guatemala: Unpublished Ph.D. dissertation, Rice University, 85 p.

Dengo, Gabriel, 1965, Geological structure of Central America: Miami, Fla. International Conf. Tropical Oceanography, Nov. 1965, p. 18-24.

________ 1968, Estructura geológica, historia tectónica, y morfología de América Central: Centro Regional de Ayuda Tecnica, Mexico, 50 p.

________ 1969, Problems of tectonic relations between Central America and the Caribbean: Gulf Coast Assoc. Geol. Soc. Trans., v. 19, p. 311-320.

Dengo, Gabriel, and Bohnenberger, O., 1969, Structural development of northern Central America, in Tectonic relations of northern Central America and western Caribbean: Am. Assoc. Petroleum Geologists Mem. 11, p. 203-220.

Dixon, C. G., 1956, Geology of southern British Honduras: Belize, Brit. Hond., Government Printer, 85 p.

Dollfus, Auguste, and Mont-Serrat, E. de, 1868, Voyage geologique dans les Républiques de Guatemala et de Salvador: Paris, Imp. Impériale, 539 p.

Dupré, William R., 1970, Geology of the Zambrano Quadrangle, Honduras, Central America: Unpublished M.A. thesis, The Univ. of Texas at Austin, 128 p.

[Elvir A., Reniery], [1969?a], Mapa Geologico Nueva Armenia, Honduras, C. A.: prepared jointly by Inst. Geográfico Nac. and Dir. Gral. Minas e Hidrocarburos, sheet 2757 IIG, 1:50,000, Tegucigalpa, Honduras.

________ [1969?b], Mapa Geologico San Buenaventura, Honduras, C. A.: prepared jointly by Inst. Geográfico Nac. and Dir. Gral. Minas e Hidrocarburos, sheet 2757 IG, 1:50,000, Tegucigalpa, Honduras.

________ [1969?c], Mapa Geologico Tegucigalpa, Honduras, C. A.: prepared jointly by Inst. Geográfico Nac. and Dir. Gral. Minas e Hidrocarburos, sheet 2758 IIG, 1:50,000, Tegucigalpa, Honduras.

________ 1969d, Historia Minera de Honduras, in Trabajos tecnicos presentados en la secunda reunion de geologos de America Central: Publicaciones Geológicas del ICAITI, numero II, Guatemala, Guatemala, p. 1-7.

________ 1970, Mapa Geologico San Juan de Flores, Honduras, C. A.: prepared jointly by Inst. Geográfico Nac. and Dir. Gral. Minas e Hidrocarburos, sheet 2758 IG, 1:50,000, Tegucigalpa, Honduras.

Everett, John R., 1970, Geology of the Comayagua Quadrangle, Honduras, Central America: Unpublished Ph.D. dissertation, The Univ. of Texas at Austin, 152 p.

Everett, John R., and Fakundiny, Robert H., 1969, Post-Paleozoic tectonic history of the Comayagua Valley region, Honduras, Central America [abs.]: Geol. Soc. America Program of annual meeting 1969, p. 60-61.

Folk, Robert L., 1968, Petrology of sedimentary rocks: Austin, Texas, Hemphills, 170 p.

________ 1969, Toward greater precision in rock-color terminology: Geol. Soc. America Bull., v. 80, p. 725-728.

Foye, W. T., 1918, Notes on a collection of rocks from Honduras, Central America: Jour. Geology, v. 26, p. 524-531.

Fritz-Gaertner, R., 1891, Kaleidoscopic views of Honduras: Mining Journal, Tegucigalpa, Honduras, no. 6-8.

Goddard, E. N., Trask, Parker D., DeFord, Ronald K., Rove, Olaf N., Singewald, Joseph T., and Overbeck, R. M., 1963, Rock-color chart: Geol. Soc. America, 16 p.

Guzman, E., and de Cserna, Zoltan, 1963, Tectonic history of Mexico, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 113-129.

Helbig, Karl M., 1969, Areas y Paisajes del Nordeste de Honduras: Publ. of Banco Central de Honduras, Tegucigalpa, 287 p.

Hirschmann, T. S., 1963, Reconnaissance geology and stratigraphy of the Subinal Formation (Tertiary) of the El Progresso area, Guatemala, Central America: Unpublished M.A. thesis, Indiana Univ., 67 p.

Hoffstetter, R. G., Dengo, Gabriel, et al., 1960, Amerique Central, in Lexique stratigraphique international: Paris, Centre Nat. Recherche, v. 5, pt. 2a, 361 p.

Hugh, K. E., 1965, Columna estratigrafica de Honduras: Informe de la Primera Reunion de Geologos de America Central, San Jose, Costa Rica, February 1965, Anexo 3, p. ix-x.

Imlay, R. W., 1944a, Cretaceous formations of Central America and Mexico: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 607-614.

__________ 1944b, Cretaceous formations of the Greater Antilles, Central America and Mexico: Geol. Soc. America Bull., v. 55, p. 1005-1045.

Knowlton, F. H., 1918, Relations between the Mesozoic floras of North and South America: Geol. Soc. America Bull., v. 29, p. 607-614.

Lloyd, J. J., 1963, Tectonic history of the South Central

American orogen, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 88-100.

Long, L. E., and Clemons, Russel, E., 1969, Rb-Sr isotope study of the Chiquimula Pluton, Guatemala [abs.]: Geol. Soc. America Program of annual meeting 1969, p. 137.

Lowell, James D., 1969, On the origin of upthrusts [abs.]: Geol. Soc. America Program of annual meeting 1969, p. 138.

Mackin, J. Hoover, 1960, Structural significance of Tertiary volcanic rocks in southwestern Utah: Am. Jour. Sci., v. 258, p. 81-131.

McBirney, Alexander R., 1963, Geology of part of the central Guatemalan Cordillera: Univ. of California Publ. Geol. Sci., v. 38, p. 177-242.

__________ [ed.], 1969, Tectonic relations of northern Central America and the western Caribbean--the Bonacca expedition: Am. Assoc. Petroleum Geologists Mem. 11, 329 p.

McBirney, Alexander R., and Williams, Howell, 1963, The origin of the Nicaraguan depression [abs.]: Internat. Union Geod. and Geophys. Gen. Assembly XII, Berkeley, Calif., August 1963, v. 7, p. 16.

__________ 1965, Volcanic history of Nicaragua: Univ. of California Publ. Geol. Sci., v. 55, 73 p.

McBirney, Alexander R., and Bass, Manuel N., 1969, Structural relations of pre-Mesozoic rocks of northern Central America, in Tectonic relations of northern Central America and the western Caribbean: Am. Assoc. Petroleum Geologists, Mem. 11, p. 269-280.

Mills, R. A., 1959, Habra petroleo en Honduras?: Petroleo Interamericana, v. 17, no. 5, p. 39-44.

Mills, R. A., Hugh, K. E., Feray, D. E., and Swolfs, H. C., 1967, Mesozoic stratigraphy of Honduras: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 1711-1786.

Molnar, Peter, and Sykes, Lynn R., 1969, Tectonics of the Caribbean and Middle America regions from focal mechanisms and seismicity: Geol. Soc. America Bull.,

v. 80, p. 1639-1684.

Moody, J. D., 1963, Tectonic patterns of Middle America [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 47, p. 1207-1246.

Munsell Soil Color Charts, 1954, Baltimore, Maryland, Munsell Color Company.

Nelson, T. H., and Temple, P. G., 1969, Global tectonics and migration of oceanic ridges and trenches: Publication of Esso Production Research Company, Houston, Texas, 23 p.

Newberry, J. S., 1888, Rhaetic plants from Honduras: Am. Jour. Sci., v. 36, ser. 3, p. 342-351.

Olsen, E. C., and McGrew, P. O., 1941, Mammalian fauna from the Pliocene of Honduras: Geol. Soc. America Bull., v. 52, p. 1219-1243.

Powers, M. C., 1953, A new roundness scale for sedimentary particles: Jour. Sedimentary Petrology, v. 23, p. 117-119.

Powers, S., 1918, Notes on the geology of eastern Guatemala and northwestern Spanish Honduras: Jour. Geology, v. 26, p. 507-523.

Pushkar, Paul, 1968, Strontium isotope ratios in volcanic rock of three island arc areas: Jour. Geophys. Research, v. 73, p. 2701-2714.

Redfield, A. H., 1923, The petroleum possibilities of Honduras: Econ. Geology, v. 18, p. 474-493.

Richards, H. G., 1963, Stratigraphy of earliest Mesozoic sediments in southeastern Mexico and western Guatemala: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 10, p. 1861-1870.

Roberts, Ralph J., and Irving, Earl M., 1957, Mineral deposits of Central America: U. S. Geol. Survey Bull. 1034, 205 p.

Ross, Clarence S., and Smith, Robert L., 1961, Ash-flow tuffs: their origin, geologic relations and identification: U. S. Geol. Survey Prof. Paper 366, 81 p.

Rowley, Peter D., 1968, Geology of the southern Sevier Plateau, Utah: Unpublished Ph.D. dissertation, The Univ. of Texas at Austin, 340 p.

Sapper, Karl T., 1899, Uber Bebirgsbau und Boden des nordlichen Mittleamerika: Petermann Mitt., Erg.-Bd. 27, 118 p.

__________ 1905, Uber Bebirgsbau und Boden des sublichen Mittleamerika: Petermann Mitt., Erg.-Bd. 32, 82 p.

__________ 1937, Mittleamerika, Handbuch der regionalen Geologie: Heidelberg, Steinman und Wilckens, 160 p.

Schuchert, Charles, 1935, Historical geology of the Antillean-Caribbean region: New York, John Wiley, 811 p.

Smith, Robert L., 1960, Ash flows: Geol. Soc. America Bull., v. 71, p. 795-842.

Stirling, Matthew W., 1969, Solving the mystery of Mexico's great stone spheres: Nat. Geog., v. 136, p. 295-300.

Strickeisen, A., 1965, Die Klassifikation der Eruptivegesteine: Geol. Rundschau, v. 55, p. 478-491.

Travis, Russel B., 1955, Classification of rocks: Quarterly, Colorado School of Mines, v. 50, no. 1, 98 p.

Vaughn, T. W., 1918, Geologic history of Central America and West Indies during Cenozoic time: Geol. Soc. America Bull., v. 27, p. 615-630.

Vinson, G. L., 1962, Upper Cretaceous and Tertiary stratigraphy of Guatemala: Am. Assoc. Petroleum Geologists Bull., v. 46, p. 425-456.

Vinson, G. L., and Brineman, J. H., 1963, Nuclear Central America, hub of the Antillean transverse belt, <u>in</u> Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 101-112.

Walper, J. L., 1960, Geology of Cobán-Purulhá area, Alta Verapaz, Guatemala: Am. Assoc. Petroleum Geologists Bull., v. 44, p. 1273-1315.

Weaver, C. E., 1942, A general summary of the Mesozoic of South America and Central America: 8th Am. Sci. Congr. Proc., v. 4, Geol. Sci., p. 179-180.

Weyl, Richard, 1961, Die Geologie Mittleamerikas: Geb. Borntraeger, Berlin, 266 p.

Williams, Howell, and McBirney, Alexander R., 1969, Volcanic history of Honduras: Univ. California Publ. Geol. Sci., v. 85, 101 p.

Woodring, W. P., 1954, Caribbean land and sea through the ages: Geol. Soc. America Bull., v. 65, p. 719-732.

Zoppis Bracci, Luigi, 1957, Estudio geologico de la region de Palacagüina y de su deposito de antimonio: Nicaragua Servicio Geol. Nac. Bol., no. 1, p. 29-34.

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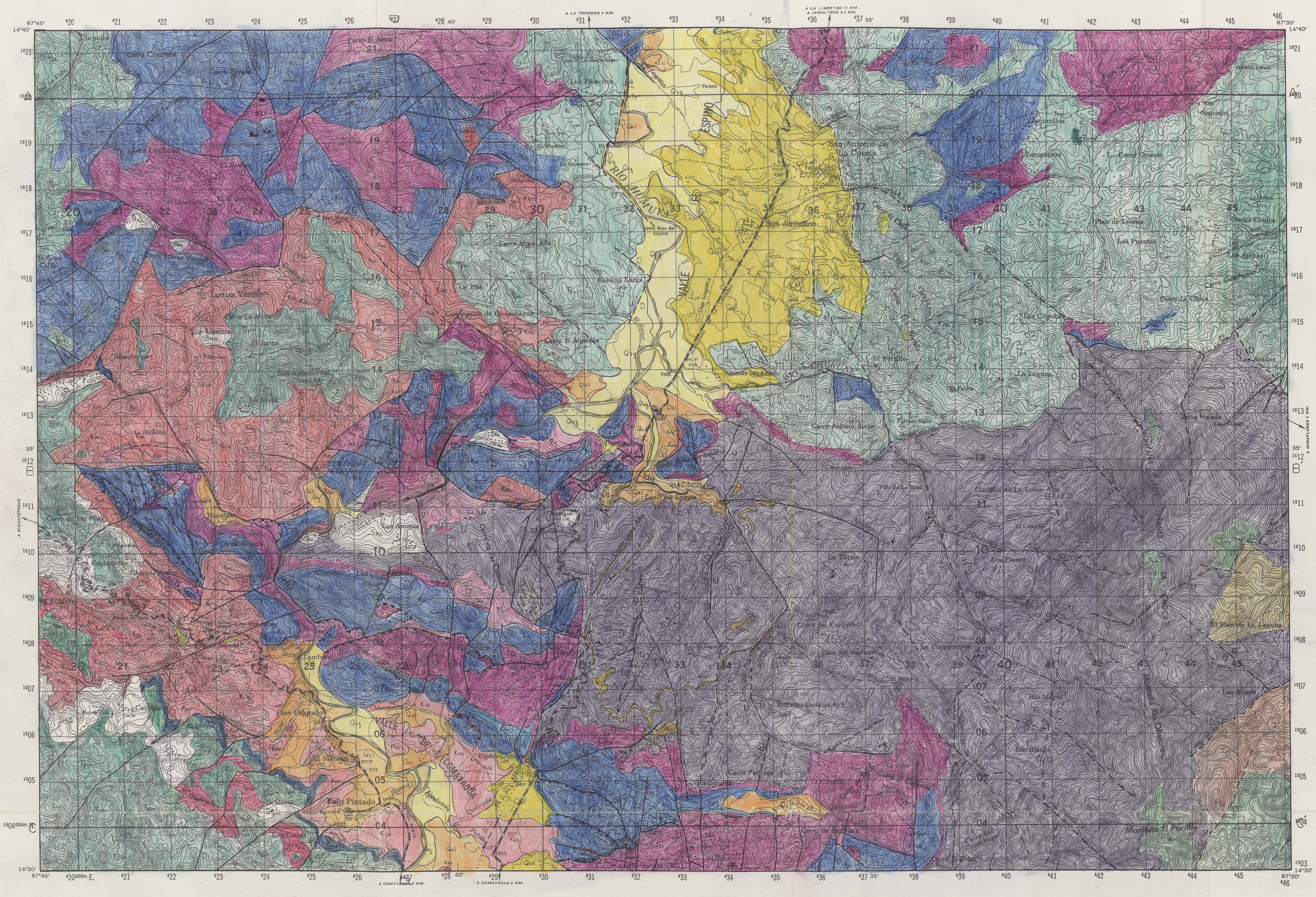
PLATE 1



EXPLANATION

MAP UNITS

QUATERNARY

FLUVIAL DEPOSITS
Qal, pediment and terrace gravel; Qaf, alluvial fans; Qsg, flood-plain and channel deposits.

TERTIARY

OLDER VALLEY DEPOSITS
Terrace gravel. (Qtd)

PADRE MIGUEL GROUP
Tpm, ignimbrite and associated tuff and volcanic-derived sedimentary rock. Tpmb, basalt flow and lapilli tuff. Tpmg, devitrified basal vitrophyre. Tpmp, Palo Pintado gravel

CRETACEOUS

VALLE DE ANGELES GROUP
Redbeds; shale, siltstone, sandstone, and conglomerate. (Kva)

YOJOA GROUP
Ka, mainly thick-bedded limestone and dolomite of the Atima Formation; Kcn, thin-bedded limestone of the Cantarranas Formation.

JURASSIC ?

TODOS SANTOS FORMATION
Redbeds; interbedded conglomerate, sandstone, siltstone, and shale with volcanic rocks. (Jts)

PALEOZOIC

CACAGUAPA SCHIST
Muscovite and chlorite schist, quartzite, and marble of the Las Marias Member; meta-conglomerate, mylonite, graphite-quartz schist, and meta-volcanic rocks of the Humuya Member Pcm; marble-quartzite Pcgr; mylonitized granite or arkose. (Pc)

MOSTLY CENOZOIC

EL ROSARIO RHYOLITE (Tir)

GABBRO (Tgb)

DIKE
Tb; basalt and diorite dikes.
Tr; thin El Rosario Rhyolite dikes.

SYMBOLS

Normal faults (U, upthrown side; D, downthrown side: dashed where inferred, dotted where concealed).

High-angle reverse faults (saw-teeth on upper plate: dashed where inferred).

Photo-linear and faults with small displacements.

Contact (dashed where approximately located).

Folds (showing trace of axial plane and bearing and plunge of axis. (a) anticline, (b) overturned anticline (showing direction of dip of limbs).

Strike and dip of beds: (a) normal, (b) overturned. (c) from photo interpretation

Horizontal beds.

Strike and dip of joints.

Strike of vertical joints.

Strike and dip of foliation.

Strike of vertical foliation.

Direction and amount of plunge of lineations.

MINE PROSPECT PIT

Line of measured section.

Slump or landslide (showing predominant formation included in debris).

SCALE

1 0 1 2 3 4
Kilometers

CONTOUR INTERVAL 20 METERS

Grid North
True North
Magnetic North

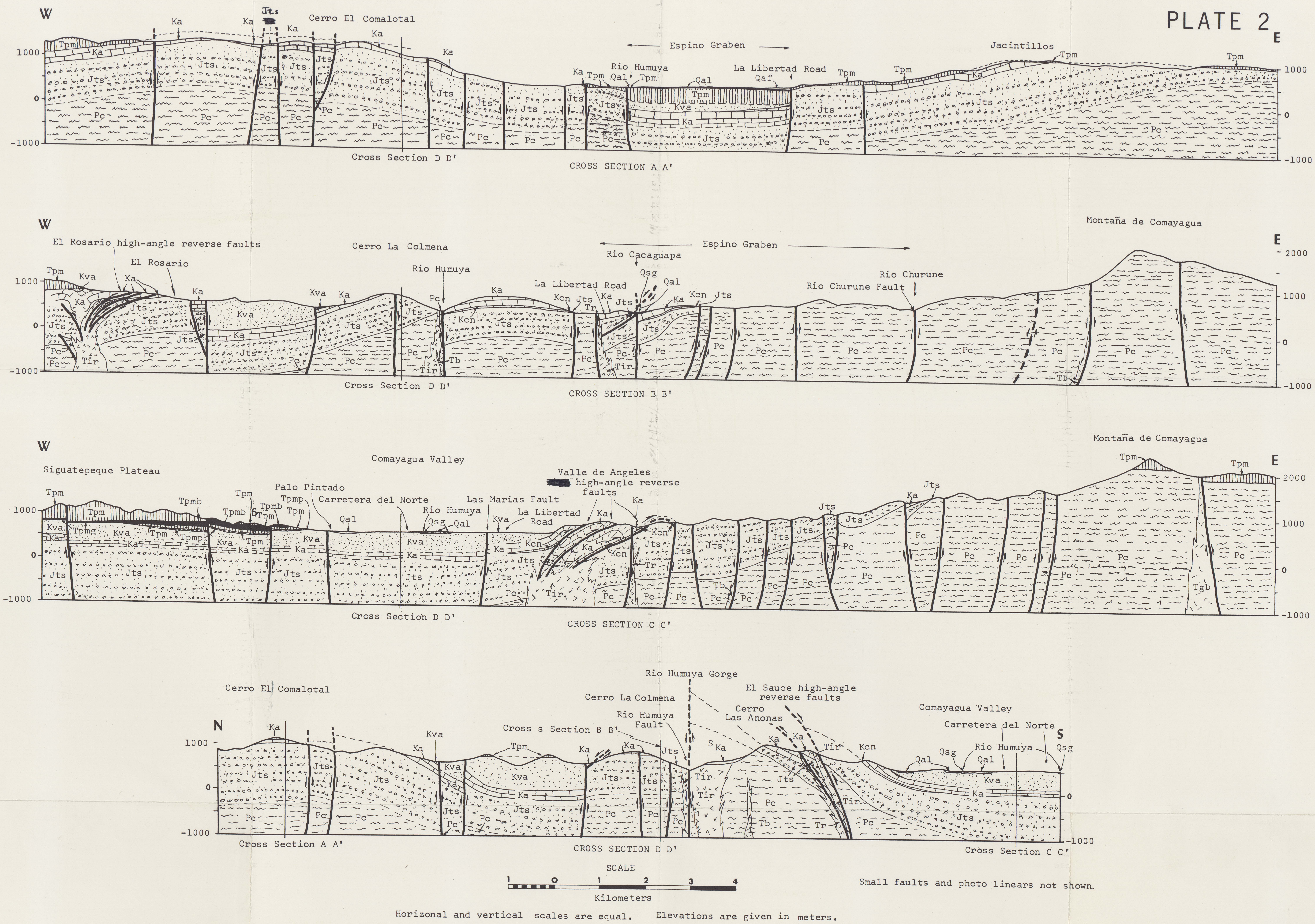
Approximate Mean Declination 6°42'

GEOLOGY MAPPED BY ROBERT H. FAKUNDINY IN 1968 AND 1969 FOR THE UNIVERSITY OF TEXAS AT AUSTIN, DIRECCIÓN GENERAL DE MINAS E HIDROCARBUROS DE HONDURAS, INSTITUTO GEOGRÁFICO NACIONAL DE HONDURAS, AND INSTITUTO CENTROAMERICANO DE INVESTIGACIÓN Y TECNOLOGÍA INDUSTRIAL (ICAITI), GUATEMALA.

TOPOGRAPHIC BASE BY THE INSTITUTO GEOGRÁFICO NACIONAL DE HONDURAS IN COLLABORATION WITH THE INTER-AMERICAN GEODETIC SURVEY -- SHEET 2659 I.

GEOLOGIC MAP OF THE EL ROSARIO QUADRANGLE, HONDURAS

PLATE 2



GEOLOGIC CROSS SECTIONS OF THE EL ROSARIO QUADRANGLE, HONDURAS

Robert H. FAkundiny, 1970

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