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FIRST PALEOGENE SELACHIFAUNA OF THE MIDDLE AMERICAN-CARIBBEAN-ANTILLEAN REGION, LA MESA DE COPOYA, WEST-CENTRAL CHIAPAS—GEOLOGIC SETTING

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ABSTRACT

The area lies between 16º35'-16º45' N Lat. and 93º00'-93º10' W Long; and consists of 323.3 km^2 of moderately rugged terrain set between 380-1,240 mamsl, formed by these units: Sierra Madre Limestone (Middle Cretaceous, light olive gray, thick bedded biomicrite, 800 m thick occurring in the southwest), Angostura Formation (Late Cretaceous, light gray, medium bedded, sparsely fossiliferous biomicrite to biomicrudite and calcarenite, 300-350 m. thick, cropping out both in the southwest and northeast), Soyaló Formation (Paleocene, gray, shaly, thin bedded, arkosic-phyllarenitic, clayey siltstone, 150 m. thick; it is exposed in the outer margins of the lowlands that surround La Mesa de Copoya, which is the outstanding physiographic feature of the area), El Bosque Formation (Early Eocene, grayish red, medium to thick bedded, phyllarenitic sandstone and breccioid conglomerate, 100 m. thick, occurring out in the southern lowlands.), and San Juan Formation (Middle Eocene, marly -quartz phyllarenitic- biomicrite to biosparrudite with biostromic zones, intercalated with biomicrudite-supported, coarse grained sand-granule-to-gravel, quartz phyllarenitic sandstone to conglomerate; the unit becomes less limy upward (upper third), is 450 – 500 m. thick, makes up both La Mesa and the slope around it, and bears the name-sake selachifauna. Quaternary deposits complete the sequence.

The Pre-Quaternary units are broadly folded into a NW-SE trending syncline, disrupted by faults. The area largely records Cretaceous-Paleogene marine sedimentation -punctuated by Early Eocene continental deposition- that ceased sometime during the Tertiary, probably by Late Miocene time, because of a change in the tectonic regime that led to folding, fracturing/faulting and regional uplift. Subsequent erosion nearly removed the Tertiary units, the remainder is preserved in the syncline nucleus.

RESUMEN

El área se encuentra entre los 16º35´ - 16º45´ Lat. N y 93º 00´ - 93º10´ Long. W., incluye 323.3 km^2 de terreno con relieve moderadamente abrupto, situado entre 380-1,240 msnmm, formado por estas unidades: Caliza Sierra Madre (biomicrita mesocretácica de color gris oliváceo claro, estratificación gruesa, 800 m de espesor, expuesta en el suroeste), Formación Angostura (biomicrita a biomicrudita y calcarenita tardicretácica de color gris claro, estratificación mediana 300-350 m de espesor, aflorante tanto en el suroeste como en el noreste), Formación Soyaló (pizarra arcillosa arcósicofilarenítica paleocénica de color gris, estratificación delgada, 150 m de espesor, presente en el margen externo del terreno bajo que rodea a La Mesa de Copoya, la cual es el rasgo fisiográfico principal del área), Formación El Bosque (arenisca y conglomerado lechoso filarenítico eocénico temprano de color rojo grisáceo, estratificación mediana, 100 m de espesor, que aflora en la parte sur del terreno mencionado), Formación San Juan (biomicrita a biosparrudita margosa –cuarzofilarenítica– de color anaranjado amarillento pálido a gris oliváceo claro, intercalada por arenisca y conglomerado de cuarzo-filarenita del mismo color, con matriz de biomicrita muy fosilífera; la unidad es mesoeocénica y se hace menos calcarea hacia arriba–tercio superior- tiene 450-500 m de espesor, forma tanto La Mesa como el declive que la bordea, y porta a la selacifauna homónima). Depósitos cuaternarios completan la secuencia.

Las unidades precuaternarias estan plegadas en un sinclinal amplio dispuesto en dirección NW-SE, el cual está dislocado por fallas. El área registra principalmente sedimentación marina cretácico-paleogénica (salvo por deposición continental eocénica temprana), que terminó en algún lapso del Terciario, problamente en el Mioceno temprano, debido a un cambio en el regimen tectónico, el cual condujo a plegamiento, fracturamiento/fallamiento y levantamiento regional. Erosión posterior ha removido la mayor parte de la secuencia terciaria, preservándose el remanente en el núcleo del sinclinal.

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INTRODUCTION

SCOPE AND PURPOSE

The State of Chiapas lies in Middle America, a region that has attracted the attention of neontologists and Earth scientists alike, because it holds a great biodiversity, a complex geologic makeup (not as yet well understood), and a rich and diverse fossil record that ranges from the Late Paleozoic to the Pleistocene. The large amount of scientific literature on Chiapas, attests to this long sustained interest. For all the geologic and paleontologic work done, major problems persist, because the objective data-base remains comparatively small.

The presence of Paleogene-Early Neogene tropical marine deposits and rich fauna in the Middle American-Caribbean-Antillean region is long known [cf. Schuchert, 1935; Woodring, 1954, 1957-1964,1970; Müllerried, 1957; Frost and Langenheim, 1974]. Surprisingly, sharks and bony fishes, conspicuous dwellers of such environments had not been reported in this vast region. Further, Cretaceous and Paleogene tropical shark and bony fish faunas are poorly known worldwide, thus hampering the knowledge on the evolution and biogeographic distribution of many lineages.

In order to increase the data-base and help to bridge this significant paleontological gap, we report on a collection of Middle Eocene sharks teeth from west-central Chiapas, the first Paleogene carcharofauna ever to be reported from the Middle American-Caribbean-Antillean Region, and describe and discuss the geology of the area where the fauna occurs.

METHODS AND MATERIAL

Work was conducted following standard procedures, using the appropriate materials and equipment according to the job to be done. Geologic mapping, aimed at a reconnaissance level, was executed at a scale 1:50,000; field observations were recorded directly on the air photos. Petrographic descriptions are based on field data, 226 hand samples and 61 thin sections; petrographic nomenclature is that of Folk (1968), color names follow Goddard and others (1963); strata thickness is expressed according to Ingram (1954). Structural directions do not imply polarity, unless otherwise stated.

The topographic base is taken from INEGI, 1984 (Hoja Tuxtla Gutiérrez El5C69, Carta Topografica esc, 1:50,000). The air photos used are: INEGI, black and white, Sinfa Flight, Z:E15-1lR: L:218, numbers 5, 6, 7, 8, 9, 10; idem, L:219, numbers 5, 6, 7, 8, 9, 10; all at scale 1:75 000; the magnifications of these photos 1:50 000 (performed from the positives); air photos from Compañía Mexicana de Aerofoto, Flight 1038, numbers 486-487, scale 1:38,000, taken in 1953, and idem Flight 3lR567, numbers 7-10 to 2-10; scale 1:50,000.

The equipment includes a mirror stereoscope Wild ST4 with oculars X3; a mirror stereoscope Condor T-22 designed for double observation; a petrographic binocular microscope Zeiss, with oculars l0X and objectives 2.5X, l0X and 40X, a stereoscopic microscope Olympus, with oculars l0X, and zoom objective ranging 0.75 to 6.4X, a Brunton compass, a 50 m steel tape, geologist's picks, altimeter Thommen; and a modified Jacob's staff.

GEOGRAPHIC SETTING

The Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa Area lies in west-central Chiapas between 16º35'- 16º45' N Lat. and 93º00' - 93º10' W Long.; it includes some 323.3 km^2 of moderately rugged terrain, formed by Cretaceous and Cenozoic rock units (Figure 1 and Plate l), resting in the 380 to 1240 mamsl interval (Plate l). The chief land feature is La Mesa de Copoya, a subellipsoidal, NW-SE oriented faulted plateau, largely capped by erosion-resistant, cliff-forming limestone strata from the middle Eocene San Juan Formation. The Ríos Grijalva (in the east) and Suchiapa (in the south), are the main streams that drain the area. The valleys give way to folded ranges developed in Cretaceous limestone units (Plate 1).

LITHOSTRATIGRAPHY

PREVIOUS WORKS

Detailed published works on the Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa Area or on the Mesa de Copoya per

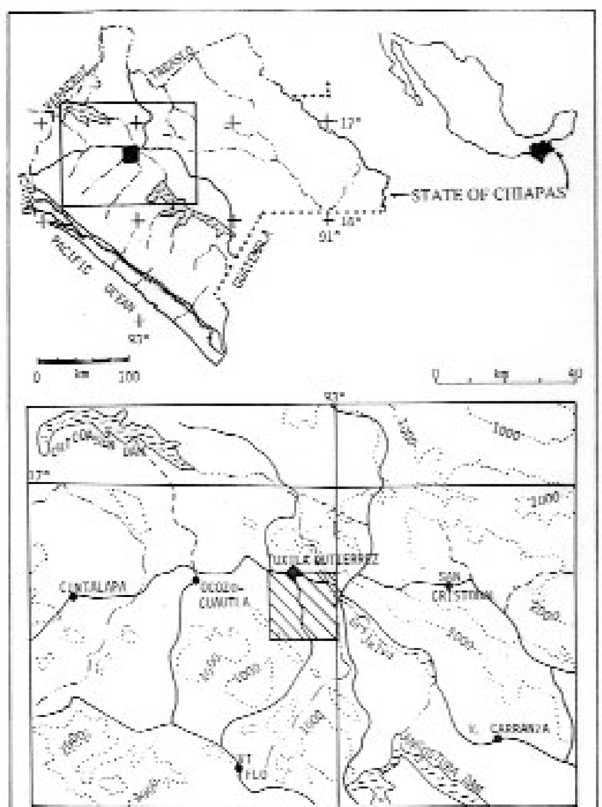
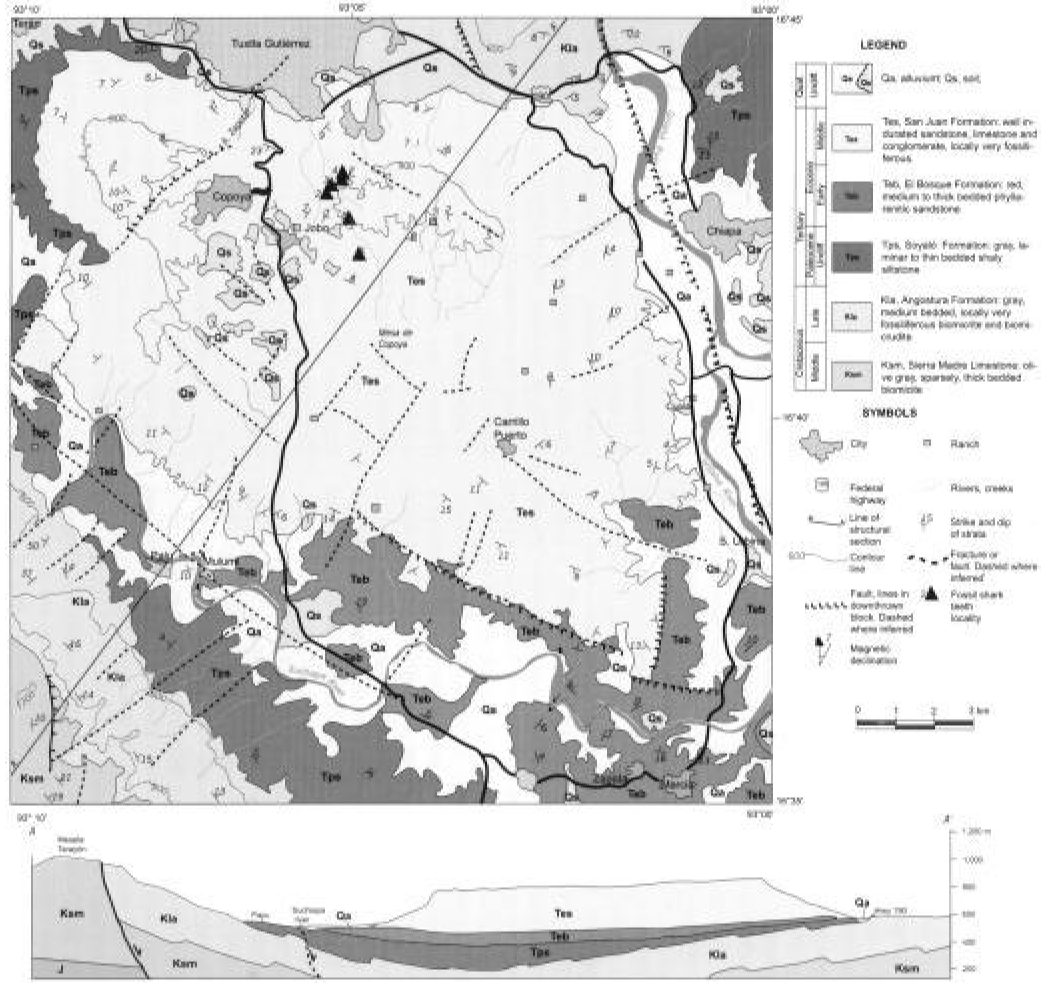


Figure 1. Location of the Tuxtla-Gutiérrez- Chiapa de Corzo-Suchiapa area, Chiapas (hatched square below), where the Mesa de Copoya occurs.

Plate 1. Geologic map and structural section of the La Mesa de Copoya area, Chiapas, Mexico.



se, are scarce. Schuchert (1935) assigned the Eocene and Oligocene marine strata of Chiapa de Corzo and La Mesa de Copoya to the El Triunfo Formation, a unit proposed by Verwiebe (1925) for similar strata exposed in other parts of central Chiapas.

Durham and others (1955, p. 987-991), summarily described the geology of the Tuxtla Gutiérrez-Suchiapa-Cerro Colorado Area, they recognized on La Mesa's southern slope a Middle Eocene, 150-210 m thick sedimentary marine sequence, furnished a faunal list, identified red beds of possible post-Paleocene age at Cerro Colorado (a noticeable red hill located southeast of La Mesa de Copoya cf. Plates I and V, Figure D, this study), and reported the presence of dark gray shales in Tuxtla Gutiérrez. Structurally, these authors considered that " the post-Paleozoic sediments are folded into a broad gentle syncline trending northwest-southeast." (*op. cit.*, p. 987), but to explain the stratigraphic relationships of the rock bodies observed at Cerro Colorado (*op. cit*., p. 989), raised the possibility of faulting in La Mesa's southern end.

Gutiérrez-Gil (1956) and Contreras-Velázquez (1956) summarized the geology of Chiapas; in the study area they recognized the Copoya Syncline, developed in Eocene rocks (*cf.* Gutiérrez-Gil, *op. cit.* fig. 8, map scale 1: 117,650), and other units (Contreras-Velázquez, *op. cit.* fig. 1, map scale 1: 166, 666). Müllerried worked and published extensively in Chiapas, his major contribution (Müllerried, 1957), is a book aimed at the general public, where he summarily deals with the geology of Central Chiapas. Frost and Langenheim (1974, Text-fig. 3 and p. 7-9, 13, 16, 18-20, 23-25, and 365), presented a lithostratigraphic differentiantion for west-central Chiapas, illustrating it in a generalized geologic map, scale 1: 666, 666; there only groups are discriminated, and faults bounding the Copoya Syncline are postulated.

Other regional papers that bear on the geology of the area are: Webber and Ojeda (1957) discriminate Eocene to Pliocene units in south-central Chiapas. Chubb (1959), Richards (1962, 1963); Sánchez-Montes de Oca (1969, 1979), Castro-Mora *et al*., (1975), Quezada-Muñetón [1987(1990)], Michaud and Fourcade (1989), and Alencaster and Michaud (1990), deal extensively on the Mesozoic stratigraphy and tectonics of central Chiapas, illustrating their interpretations in small scale geologic maps, where informal chronostratigraphic units and generalized structural features are presented. The same applies to the geologic state maps scale 1:500,000 of López-Ramos (1975), and De la Rosa *et al*. (1989, Appendix D). Complete this roster INEGI (1985, Hoja Tuxtla), perhaps one of the most consulted regional references; it is a geologic map of central Chiapas, scale 1: 250, 000, where informal chronostratigraphic units are discriminated and correlated to lithostratigraphic ones; in the study area, an unnamed NW-SE oriented syncline, and a few fractures perpendicular to it, are shown.

Finally, three unpublished papers that bear directly to the study area, are considered. Sánchez-Montes de Oca (1978), is a field guide on the tectonic framework of Chiapas, illustrating it in maps scale 1:250,000; in the study area, Cretaceous and Paleogene units are recognized. De la Llata *et al.* (1979), present a geologic report on northern Chiapas, illustrated in maps scale 1: 50 000, where chronostratigraphic units are broadly outlined. Aguilar-Piña (1993), made a Biology senior thesis on the biostratigraphy (based on Paleogene foraminifera) of El Jobo, a small village located in La Mesa de Copoya; he assigned the bearing unit to the Lomut Formation (González-Alvarado, 1963), disregarding significant stratigraphic differences between the type section and El Jobo section.

To conclude, the preceding paragraphs show that although the Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa Area has been investigated for a long time, with very different approaches and interests, major problems pertaining its stratigraphy, structural geology and paleontology still remain. The present paper, aimed at establishing the geologic setting of La Mesa de Copoya Selachifauna, is our contribution to their elucidation.

STRATIGRAPHIC SUCCESSION

The pre-Cenozoic basemente consists of the Middle Cretaceous Sierra Madre Limestone, and the Late Cretaceous Angostura Formation; both make up block-and-folded mountains located in the northeast and south west corners of the area. On the other hand, the Cenozoic deposits crop out in 87.7% of the area, which largely corresponds to La Mesa de Copoya and surrounding valleys; they include the Paleocene Soyaló Formation, the Early Eocene El Bosque Formation, the Middle Eocene San Juan Formation, and Quaternary deposits (Figure 2, and Plates I and II, Fig. A). These formations have a long and involved taxonomic-nomeclatural history, as dicussed elsewhere [(Ferrusquía-Villafranca, 1996 (1997), p. 29, 34, and 38]. This led to revise, redefine or supplement their definitions (Ferrusquía-Villafranca, *op .cit.*); such modified lithostratigraphic conceptions are applied in the study area.

SIERRA MADRE LIMESTONE

It is proposed (Böse, 1905) the name Sierra Madre Limestone for the extensive carbonate platform strata that make up the namesake sierra and associated mountains in Chiapas. Its taxonomic and nomenclatural history is quite involved [Ferrusquía-Villafranca, 1996(1997), p. 16-17], so that the formal definition is credited to Gutiérrez-Gil (1956, p. 22-23); regarding its rank and age, we follow the general usage for this unit [*cf*., Chubb, 1959; Castro-Mora *et al*., 1975; Steele, 1985 (1986); Rosales-Domínguez *et al*., 1997].

The Sierra Madre Limestone crops out in the southwest, occupies only 5.25 km^2 (*ca*. 1.6 % of the area *cf.* Plate I), and chiefly consists of light olive gray 5Y 6/1, well indurated, thickly bedded, sparsely fossiliferous biomicrite (Plate III, Fig. B), pelmicrite and intramicrite; it is partly dolomitized, and bears chert (nodules and thin layers). The strata form gently tilted (10º- 17º to the E and NE) monoclinal blocks. In the area, the lower contact is not exposed; the upper one is an unconformity with the overlying Angostura Formation, with which the Sierra Madre Limestone also shows fault contacts. Locally the estimated thickness of this unit is 800 m (Figure 2), but regionally, it is about 2,500 m [Sánchez-Montes de Oca, 1979; Steele, 1985(1986); Quezada-Muñetón, 1987(1990)]. The Sierra Madre was deposited in a shallow marine platform environment, under low energy conditions, without terrigenous influx.

The fossils *Orbitolina texana* and *Nummoloculina heimi*, suggest an Albian-Cenomanian age for this unit in the area, which corresponds to the Middle Cretaceous regional age-assignment given to it (*cf. op cit.*, and Gutiérrez-Gil, 1956; Castro-Mora *et al.*, 1975; Michaud and Fourcade, 1989; Rosales *et al.*, 1997). In South and Southeastern Mexico, the Sierra Madre Limestone is correlative (Figure 3) to the Teposcolula Limestone of northwestern Oaxaca (Ferrusquía-Villafranca, 1976), and to the Morelos Formation of Morelos and Guerrero States (Fries, 1960).

ANGOSTURA FORMATION

TAXONOMIC-NOMENCLATURAL DIGRESSION

The Upper Cretaceous of Chiapas is widely distributed throughout the State, and has been extensively studied, so that its geologic and paleontologic literature is voluminous; however, the work has been carried out unsystematically, with different methodologies and scientific frameworks [*cf.* among others Gutiérrez-Gil, 1956; Chubb, 1959; López-Ortiz, 1960; Sánchez-Montes de Oca, 1969, 1979; Frost and Langenheim, 1974; Castro-Mora *et al.*, 1975; Pecheaux, 1984; Meneses-Rocha, 1985; Michaud, 1987; Michaud and Fourcade, 1989; Quezada-Muñetón, 1987(1990), Alencáster and Michaud, 1990; Feldmann *et al.*, 1996; Rosales-Domínguez *et al.*, 1997, and the unpublished geologic reports and field guides made by PEMEX geologists].

Therefore much disagreement exists on basic issues such as the lithostratigraphic differentiation, which in turn determines the number of different units that make up the Upper Cretaceous in Chiapas, the criteria used to differentiate them, the rank of the units, their extent, constitution, age and precise configuration, as well as their space and time relationships. The problem is compounded by the profusion of named units erected with no regard to the professional stratigraphic practice of the day, *i.e.*, without compliance to the pertinent stratigraphic code (CSN, 1933; ACSN, 1961, 1970; and NACSN, 1983), and their undiscriminated and uncritical subsequent use.

FORMATIONAL ASSIGNMENT, LOCATION AND GEOMORPHIC EXPRESSION

The Upper Cretaceous limestone strata that crop out in the area's northeast and southwest, are tentatively assigned to

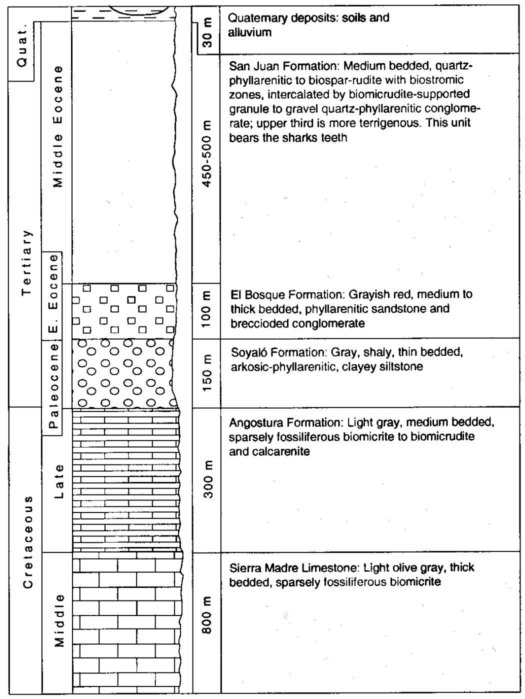


Figure 2.- Generalized lithostratigraphic column of the Tuxtla Gutiérrez-Chiapa de Corzo- Suchiapa Area, Chiapas.

the Angostura Formation [*sensu* Sánchez-Montes de Oca, 1969, 1978; and Quezada-Muñetón, 1987(1990)], because the lithic composition, stratigraphic position, fossil content, relationships and age of this rock body, are closer to the Angostura's than to the Ocozocuautla Formation, (*sensu* Gutiérrez-Gil, 1956; Chubb, 1959; Frost and Langenheim, 1974; and Castro-Mora *et al.*, 1975). However, in a reconnaissance work like this, to pass on judgement on the validity of either unit, or to settle the problem of their time/space relationships, would be out of place, and it is not even attempted.

The Angostura Formation makes up the block-and-folded mountains that bound to the NW and SE, the narrow depression where the Cenozoic sequence crops out; the Angostura occupies 33.75 km^2 (*i. e.*, 9.77% of the area), and altitudinally lies between 400 to 1,000 mamsl (Plate 1).

THICKNESS, LITHOLOGY AND GENETIC-ENVIRONMENTAL INTERPRETATION

The Angostura Formation has in the area an estimated thickness of 300-350 m (Figure 2), which corresponds to 3/4 of the reported maximum thickness near Oxchuc (Quezada-Muñetón, 1987(1990), p. 22). This unit shows a modest

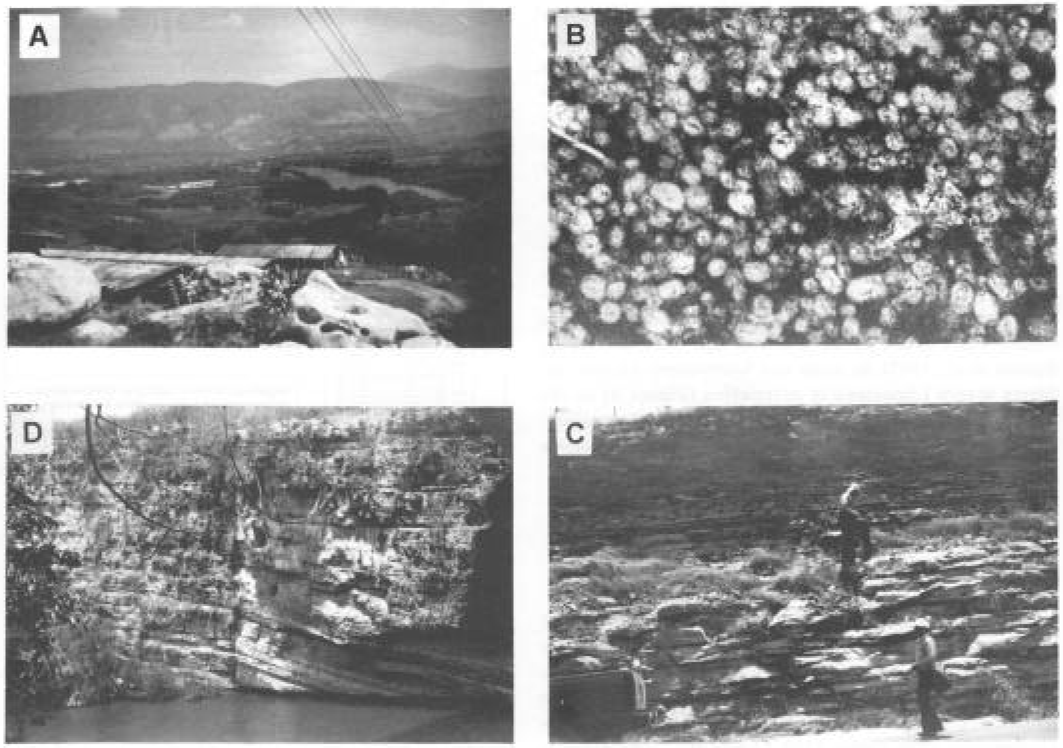


Plate II. General View, Sierra Madre Limestone and Angostura Formation. Figure A. Panoramic of the study area as seen from a site located 4 Km SW of Suchiapa Village. Angostura Formation blocks of thick strata appear in the foreground; the Soyaló and El Bosque Formations occupy the middleground, making up the lowlands adjacent to the Río Suchiapa, and the San Juan Formation forms the slope of La Mesa de Copoya, in the background. Figure B. Sierra Madre Limestone: Photomicrograph in normal light of sample FV97-9, Biomicrite and pelmicrite collected in the Meseta Tarayón, about 5.5 Km SW of Pacú; in the field pellets dominate, and are placed in a micritic matrix. Line represents to 0.2 mm. Figure C. Angostura Formation: Roadcut located on the Panamerican Highway, 2 Km ESE of its junction to Libramiento Sur; the outcrop shows the typical appearence of this unit; bedding is medium to thin, strata are nearly horizontal. Figure D. Angostura Formation: Cliff on the Río Grijalva by the Panamerican Highway Old Bridge; strata dip to the SSW, and appear cut by a normal fault of slight displacement.

lithodiversity, chiefly included are marly biomicrite, marly biosparite, biointrasparite, biolithite and bioclastite.

The limestones are frequently light to dark gray (very light gray N8 to medium dark gray N 4), orange and pinkish shades are much less common; weathered surfaces vary from medium gray N 5, yellowish gray 5 Y 7/4 to dusky yellow 5 Y 6/4 to pale yellowish brown 10 YR 6/6 (Plate II, Figs. C and D). The fine grained textural varieties are more abundant than others. Most varieties show some terrigenous, sediment content evidenced by the presence of silt size quartz grains (200 to 250 microns in diameter), that show undulous extinction, clay, and occasionally feldspar grains, smaller than those of the quartz; the amount of terrigenous clastics, estimated from thin sections, ranges from 2 % to 12 % or even 15 % of the rock volume.

Sparry cement may be a major component, forming euhedral to subhedral crystals that vary from 20 to 200 microns in diameter. The common allochemical grains include intraclasts, microfossils, bioclasts (Plate III, Figs. C and D); pellets and oolites are rare. Fossils are not abundant throughout the section, and only locally some parts may be quite fossiliferous; however, in the area neither biostromes nor bioherms are present. The varieties listed are but part of the textural and compositional lithic spectrum shown by this unit, so there are many gradations; however, because of the reconnaissance nature of this work, no attempt was made to cartographically discriminate the lithovarieties observed.

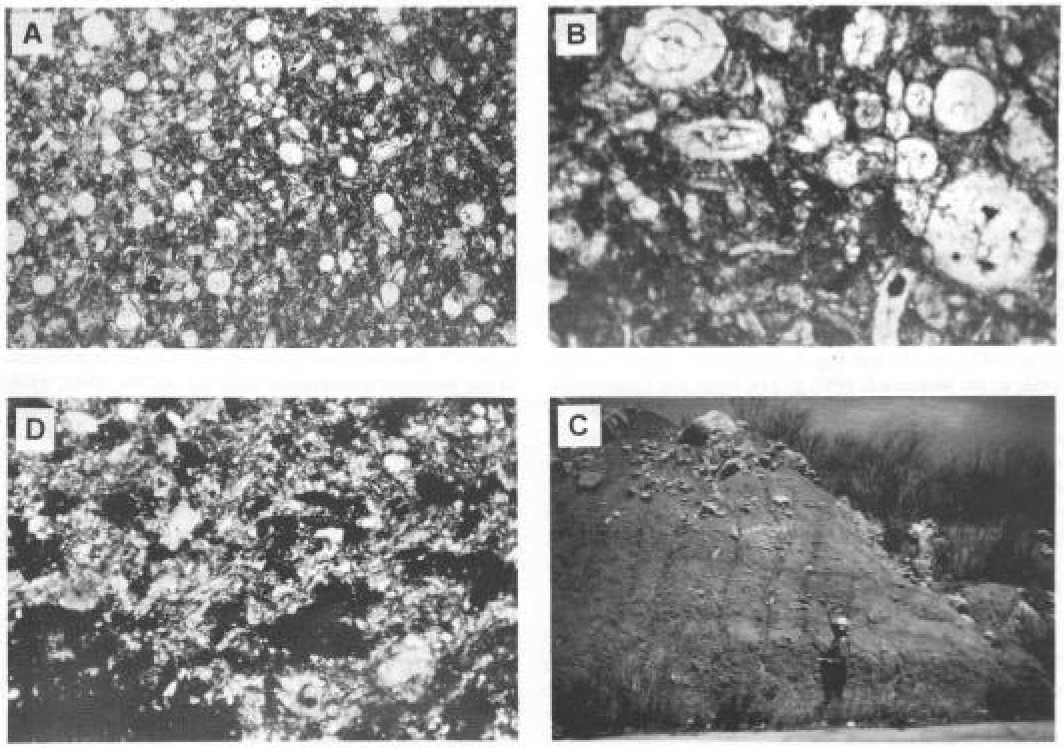


Plate III. Angostura and Soyaló Formations. Figures A and B. Angostura Formation: Photomicrographs in normal light of sample FV97-1, marly biomicrite collected from a road cut in the Panamerican Highway located 1.7 Km E of its junction with theTuxtla-Gutiérrez Libramiento Sur; the terrigenous clastics largely consist of silt-sized quartz grains, set in a micritic matrix that also bears abundant planktonic foraminifera; they are better seen in Figure B. Line under Figure A represents 0.5 mm, and under Figure B, only 0.2 mm. Figure C. Soyaló Formation: Outcrop located in the Tuxtla Gutiérrez-Terán Highway, in a circle close to the former; the typical appearence of this unit is well displayed. Figure D. Soyaló Formation: Photomicrograph in polarized light of sample FV97-8, silty claystone collected from an outcrop by the Río Suchiapa Bridge at Plan de Mulumí; notice the mixture of fibrous clay and micritic calcite, surrounding black prismatic holes once occupied by quartz crystals. Same scale as in Figure B.

Stratification varies from thin to medium (5-15 cm) in the southwestern block, but tends to be thicker (30 to 70 cm) in the northeastern one (Plate II, Figs. C and D). Stylolites are scarce to moderately abundant; fracturing is also present.

The biomicrite indicates lime sedimentation under low energy conditions, receiving scarce to moderate amounts of fine terrigenous clastics, probably at shallow to moderate depths; the sparite suggests a greater energy regime, such as one generated by currents strong enough to winnow the lime ooze; occasional churning of the sea-bottom by even stronger currents, and its subsequent redeposition, is evidenced by intraclastic conglomerates; the biolithite and bioclastite varieties indicate high energy and shallow depth. These environments suggests a paleogeographic scenario dominated by a shallow to moderately deep platform that sank *pari pasu* to sedimentation. This interpretation coincides with that one proposed regionally for the Angostura Formation [*cf.* Gutiérrez-Gil, 1956; Chubb, 1959; Sánchez-Montes de Oca, 1969, 1978; Castro-Mora *et al.*, 1975; Quezada-Muñetón, 1987 (1990); and Rosales-Domínguez *et al.*, 1997].

STRUCTURE AND STRATIGRAPHIC RELATIONSHIPS

The Angostura Formation in the area is exposed in two separate blocks (Plate I); the northeastern block is smaller, the strata have a structural position that varies from nearly horizontal to 10° (Plate II, Figs. C and D), but the dip-direction changes from SSE to SSW, thus disclosing faulting; at least two NNW faults could be evidenced in the field. The southwestern block strata have low dips (10° to 16°) to the northeast, except by the Río Suchiapa, where they are strongly tilted and dips to NW, evidently due to faulting.

The Angostura Formation lower contact (with the Sierra Madre Limestone), was already discussed; the upper one with the overlying Paleocene Soyaló Formation, is obscured by soil, rock debris, thick vegetation and frequent faulting; however, the slight to moderate difference between the structural attitude of both units in places close to the contact, led us to tentatively interpret it as unconformable. lt should be noted though, that there is disagreement on the interpretation of the contact between the Angostura and Soyaló Formations [discordant: Sánchez-Montes de Oca, 1969, p. 18; Castro-Mora et al., 1975, p. 125 and Fig. 4; concordant: Gutiérrez-Gil, 1956, p. 24; Müllerried, 1957, p. 114; Frost and Langenheim, 1974, p. 16; and Quezada-Muñetón, 1987 (1990), p. 50, among others], and that the greater plasticity of the Soyaló Formation, may have caused a different response to deformation than that of the Angostura Formation, thus accounting for their different structural attitude. Further work, beyond the scope of this paper, is needed to solve the problem.

PALEONTOLOGY, AGE AND CORRELATION

Gutiérrez-Gil (1956), Chubb (1959), Langenheim and Frost (1974), and Quezada-Muñetón [1987 (1990)] among others, list an abundant micro-and macrofauna from the Angostura Formation, that lead them to place it in the Late Cretaceous, although with differences in detail and precision. In the area, a few milliolids, Nummoloculina sp., Globotruncana ventricosa, Globigerina sp. and other planktonic foraminifera were detected, which also indicate a Late Cretaceous age for these strata. This unit is correlative (Figure 3) with the Ocozocuautla Formation of Chiapas, [Sánchez-Montes de Oca, 1969, 1978; Quezada-Muñetón, 1987(1990)], assuming it to be a valid, truly different lithostratigraphic unit from the Angostura Formation; with the Yucunama Marl of Oaxaca (Ferrusquía-Villafranca, 1976), and with the Méndez Formation of Northeastern México (Sánchez-Montes de Oca, 1979).

SOYALÓ FORMATION

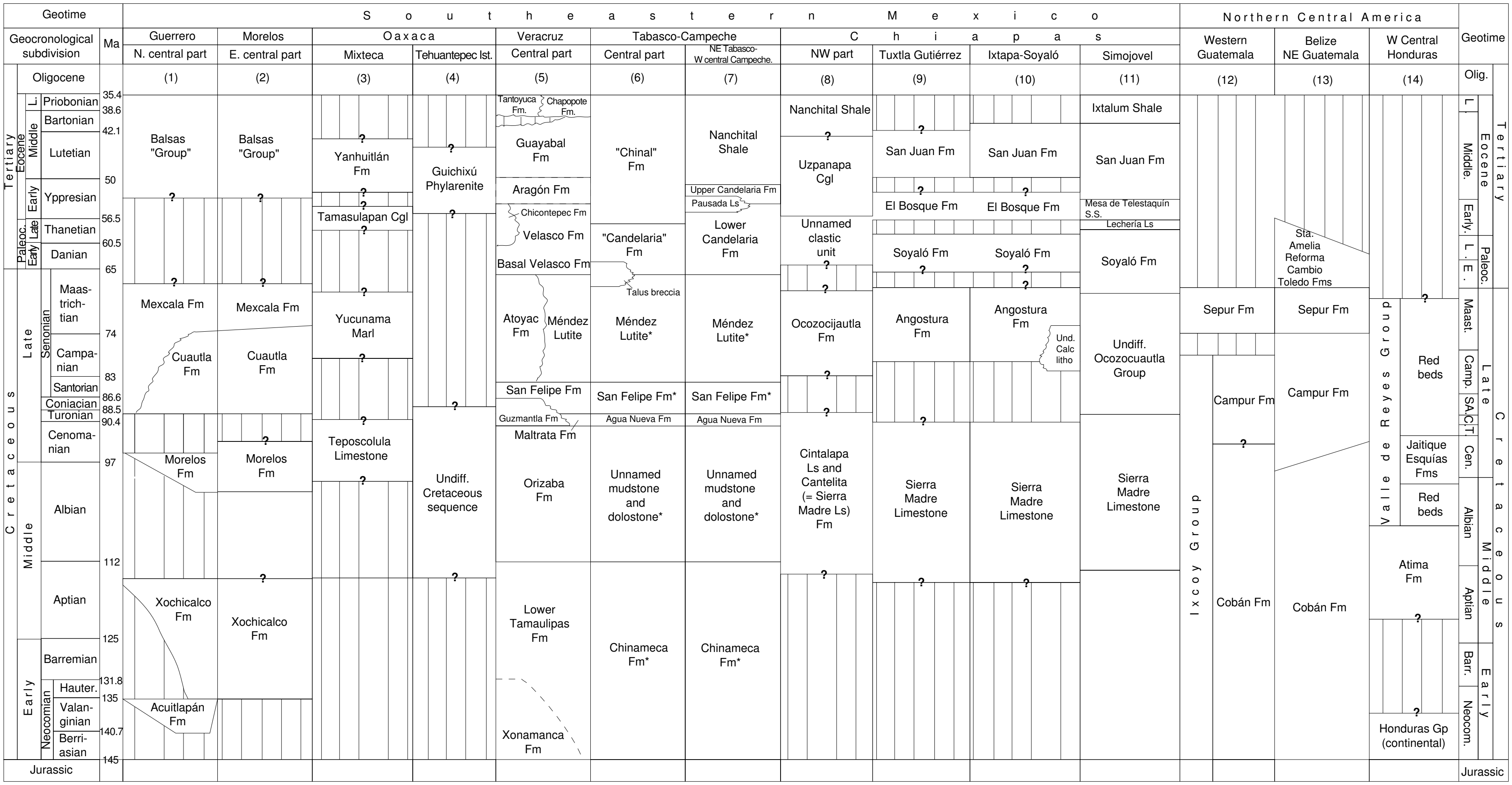
FORMATIONAL ASSIGNMENT, LOCATION, EXTENT AND GEOMORPHIC EXPRESSION

Partial Synonymy.- Soyalo Shale plus Lecheria Limestone (Heuer, 1965, fide Frost and Langenheim 1974, p. 16); Soyaló Formation (González-Alvarado, 1965); Soyaló Shale plus Lecheria Limestone (Allison, 1967, fide Frost & Langenheim 1974, p. 19); idem (Frost and Langenheim 1974, p. 16-18, and Text-fig. 5); Tpal(lu-ar), informal unit (INEGI, 1985); Tp, unnamed Paleocene Limestone, marl, lutite and sandstone unit (De la Rosa et al., 1989, Appendix D); Soyalo Formation (summarily described in De la Rosa et al., 1989, p. 46-47). None of these units complies with the requirements of the pertinent stratigraphic code (cf. ACSN, 1961, 1970; NACSN, 1983).

Assignment.- According to the revised definition [Ferrusquía-Villafranca, 1996(1997), p. 29], the Soyaló Formation includes shale, siltstone and fine-grained, arkosic-phyllarenite, with a calcareous matrix; common colors are grayish orange 10 YR 7/4 (weathering to dark yellowish orange 10 YR 6/6), yellowish gray 5 Y 7/2 (weathering to dusky yellow 5 Y 6/4), and dark yellowish brown 10 YR 4/2 (with no weathering change); it is laminar to thinly bedded, occasionally interbedded with friable, phyllarentic conglomerate, and frequently in the upper part with very pale orange 10 YR 8/2 micritic limestone; its thickness is 500 m to 600 m, it shows moderate dips (20° to 30°), and extensive faulting; it unconformably rests on the Angostura Formation, unconformably underlies the El Bosque Formation, and has fault contacts with other units; its age is Paleocene to earliest Eocene; the Type Section is located on the Emiliano Zapata-Victoria Grajales trail, Municipality of Soyaló, Chiapas some 35 km to the east of the study area.

The strata assigned to this unit in the area show most of the characteristics listed above, leaving no doubt about the presence of this unit there. This formation crops out mostly on the edges of the depression that surrounds La Mesa de Copoya, between 400 to 500 mamsl (rarely up to 600 m); largest outcrops occur south of Suchiapa, north of Chiapa de Corzo,

Figure 3.- Correlation chart of Cretaceous to Paleogene lithostratigraphic units in selected areas of southeastern Mexico and northern Central America. Vertical hatchure indicates lack of record.
Sources: Time scale modified from Harland et al. (1989), and Haq and Van Eysinga (1994). (1) North-central Guerrero State, Fries (1960). (2) East-central Morelos State, Fries (1960). (3) Mixteca Alta, Northwestern Oaxaca State, Ferrusquía-Villafranca (1976). (4) Isthmus of Tehuantepec, Eastern Oaxaca State, Ferrusquía-Villafranca, in press (1988). (5) Central Veracruz State, Salvador and Quezada-Muñetón (1989). (6) Macuspana Basin, Central Tabasco State, Salvador and Quezada-Muñetón (1989) (Cretaceous units in the subsurface). (7) Northeasttern Tabasco-Western Campeche, modified from Frost and Langenheim (1974), Text-fig. 9, and Salvador and Quezada-Muñetón (1989) (Cretaceous units in the subsurface). (8) North-western Chiapas State, modified from Frost and Langenheim, ibid, and Salvador and Quezada-Muñetón (1989). (9) Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa Area, West-Central Chiapas State, this report. (10) Ixtapa-Soyaló Area, West-Central Chiapas State, Ferrusquía-Villafranca (1996) (1997). (11) Simojovel Area, North-Central Chiapas State, Frost and Langenheim, ibid, and Salvador and Quezada-Muñetón, op. cit. (12) Western Guatemala, modified from Maurrasse (1990a-c). (13) Northeastern Guatemala and Belize, modified from Frost abd Langenheim, ibid, and Maurrasse, op. cit. (14) Western and Central Honduras, modified form Maurrasse, op. cit., and Donnelly et. al., 1990.


Geotime
Southeastern Mexico
Northern Central America
Geocronological subdivision
Ma
Guerrero N. central part
Morelos E. central part
Oaxaca
Mixteca
Tehuantepec Ist.
Veracruz Central part
Tabasco-Campeche
Central part
NE Tabasco-W central Campeche.
Chiapas
NW part
Tuxtla Gutiérrez
Ixtapa-Soyaló
Simojovel
Western Guatemala
Belize NE Guatemala
W Central Honduras
Geotime
Oligocene
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
Olig.
Tertiary
Eocene
Paleoc.
L.
Middle
Early
Late
Priobonian
Bartonian
Lutetian
Yppresian
Thanetian
Danian
Cretaceous
Late
Middle
Early
Senonian
Neocomian
Maas-trich-tian
Campa-nian
Santorian
Coniacian
Turonian
Cenoma-nian
Albian
Aptian
Barremian
Hauter.
Valan-ginian
Berri-asian
Jurassic
35.4
38.6
42.1
50
56.5
60.5
65
74
83
86.6
88.5
90.4
97
112
125
131.8
135
140.7
145
Balsas "Group"
Mexcala Fm
Cuautla Fm
Morelos Fm
Xochicalco Fm
Acuitlapán Fm
Yanhuitlán Fm
Tamasulapan Cgl
Yucunama Marl
Teposcolula Limestone
Guichixú Phylarenite
Undiff. Cretaceous sequence
Tantoyuca Fm.
Chapopote Fm.
Guayabal Fm
Aragón Fm
Chicontepec Fm
Velasco Fm
Basal Velasco Fm
Atoyac Fm
Méndez Lutite
San Felipe Fm
Guzmantla Fm
Maltrata Fm
Orizaba Fm
Lower Tamaulipas Fm
Xonamanca Fm
"Chinal" Fm
"Candelaria" Fm
Talus breccia
Méndez Lutite*
San Felipe Fm*
Agua Nueva Fm
Unnamed mudstone and dolostone*
Chinameca Fm*
Nanchital Shale
Upper Candelaria Fm
Pausada Ls
Lower Candelaria Fm
Nanchital Shale
Uzpanapa Cgl
Unnamed clastic unit
Ocozocijautla Fm
Cintalapa Ls and Cantelita (= Sierra Madre Ls) Fm
San Juan Fm
El Bosque Fm
Soyaló Fm
Angostura Fm
Und. Calc litho
Sierra Madre Limestone
Ixtalum Shale
Mesa de Telestaquín S.S.
Lechería Ls
Undiff. Ocozocuautla Group
Sepur Fm
Ixcoy Group
Campur Fm
Cobán Fm
Sta. Amelia Reforma Cambio Toledo Fms
Valle de Reyes Group
Red beds
Jaitique Esquías Fms
Atima Fm
Honduras Gp (continental)
Middle.
Early.
L.
E.
Maast.
Camp.
SA
C
T
Cen.
Albian
Aptian
Barr.
Neocom.
?

and south of Terán (Plate I); the areal extent covers a surface about 38.3 km^2, roughly 12 % of the study area. The Soyaló Formation makes up low, rounded and elongated hills, frequently separated by deeply incised gullies (Plates III, Fig. C and IV, Fig. B).

THICKNESS, LITHOLOGY, AND GENETIC-ENVIRONMENTAL INTERPRETATION

In the Type Area the Soyaló Formation is at least 600 m thick, but in the study area is only 150 m thick at most (Figure 2), its lithodiversity is very limited, the chief variety being a light olive gray 5Y 5/2 (weathering to dusky yellow 5 Y 6/4), shaly, lightly silty argillite (Plate III, Fig. D); the clay (illite and montmorillonite) makes up at least 4/5 of the rock, forming an extensive matrix where scarce, silt-size quartz, biotite, and other mafics (both translucent and opaque) grains are immersed; by far the first is the dominant mineral. Another variety is a light olive brown 5 Y 5/6, immature, lime-cemented quartzitic, mica-bearing phyllarenitic siltstone (Plate IV, Figures A and B), and very fine grained sandstone; the matrix is abundant, the clasts are poorly sorted, include polycrystalline quartz with strongly unduloes extinction, amphibole, pyroxene and even a few dark metamorphic rock fragments, as well as biotite and muscovite; quartz again is the dominant mineral. The shaly habit and laminar to thin bedding are the chief primary structures.

Other lithovarieties such as calcareous clayey mudstone and coarser grained phyllarenitic sandstone are much less common. The micritic variety that makes the Lechería Member in the Ixtapa-Soyaló Area [Frost and Langenheim, 1974; Ferrusquía-Villafranca, 1996(1997)], seems not to be present here. However, marly rudite and calcarenite bearing gastropods and pelecypods were observed in small outcrops close to Cerro Colorado, near Emiliano Zapata (formerly Blas López). From localities in this vicinity, Durham et al.(1955 p. 988), reported Paleocene invertebrates.

The most probable depositional environment of the Soyaló Formation, is a moderately deep marine bottom, subdued to strong terrigenous influx, perhaps related to a river mouth where fine grained clastics were continuously washed in. The lamination and thin bedding indicate that the energy regime was low. Turbiditic sedimentation may have occurred, as suggested by Frost and Langenheim (1974, p. 18), but its evidence was not detected in the area.

STRUCTURE AND STRATIGRAPHIC RELATIONSHIPS

The Soyaló Formation strata do not show a regular dip pattern, although most dips are low angle (4° to 8°, Plate I): Those north of Chiapa de Corzo show steep to moderate dips toward the east and southwest; the strata south of Suchiapa vary from nearly horizontal to 4°, to 7° to the northeast, southeast and northwest; those near Terán display low to moderate dips to the east-northeast, east and south-southwest. The cause of this diverse dip is the presence of numerous faults that disrupt the strata into many small blocks. This unit shows a similar style of deformation in the Ixtapa-Soyaló Area [Ferrusquía-Villafranca, 1996 (1997)]. The lower contact of the Soyaló Formation was already described; the upper contact with the overlying El Bosque Formation was observed in the area only in a small outcrop on the Río Suchiapa, near the trail that joins the Galecio Narcia Village and the river (Plate IV, Fig. C); there it is an angular unconformity between the Soyaló strata dipping 23° to Sl8°E, and the El Bosque strata dipping 17º to Nl8ºW; in other places, Quaternary deposits cover this contact (Plate I). Because of the scarce evidence available, the contact between these units is tentatively interpreted as discordant.

PALEONTOLOGY, AGE AND CORRELATION

The Soyaló Formation is very sparsely fossiliferous. As mentioned elsewhere, Durham et al. (1955, p. 988) reported from the Cerro Colorado vicinity Turritela nasula, Mesalia sayi and Venericardia cf. V. densata, indicative of a Paleocene age. Frost and Langenheim (1974) collected Globorotalia velascoensis and G. rex, (indices of the Paleocene-earliest Eocene) in the Ixtapa-Soyaló Area. Finally, the unconformity that separates the Cretaceous Angostura from the Soyaló Formation, plus the identified fossils, led us to assign the Soyaló to the Paleocene. This unit is correlative (Figure 3) with the Lower Candelaria Formation of Tabasco (Frost and Langenheim, 1974), and with the Velasco Formation of the Gulf Coastal Plain (Salvador and Quezada-Muñetón, 1989).

EL BOSQUE FORMATION

FORMATIONAL ASSIGMENT, LOCATION, EXTENT AND GEOMORPHIC EXPRESSION

Partial Synonymy.- El Bosque Formation (López-Vega, 1963); idem (González-Alvarado, 1965, 1967); Telestaquin Mesa Limestone (Heuer, 1965 fide Frost and Langenheim, 1974, p. 20); idem (Allison, 1967 fide Frost and Langenheim, 1974, p. 20); idem (Frost and Langenheim, 1974, p. 20 et seq. and Text-fig. 5); Te(lm-ar), informal unit (INEGI, 1985); Teb, unnamed Eocene lutite, sandstone, conglomerate and limestone units (De la Rosa et al., 1989, Appendix D); El Bosque Formation (summarily described in De la Rosa et al., 1989, p. 48-49). None of these units complies with the requirements of the pertinent stratigraphic code (cf. ACSN, 1961, 1970; NACSN, 1983).

Assignment.- As redifined [Ferrusquía-Villafranca, 1996 (1997)], El Bosque Formation chiefly consists of grayish red 5R 4/2, phyllarenitic to arkosic-phyllarenitic, fine to coarse grained sandstone, and granule to cobble conglomerate, set in medium to thick strata that show moderate to steep dips with

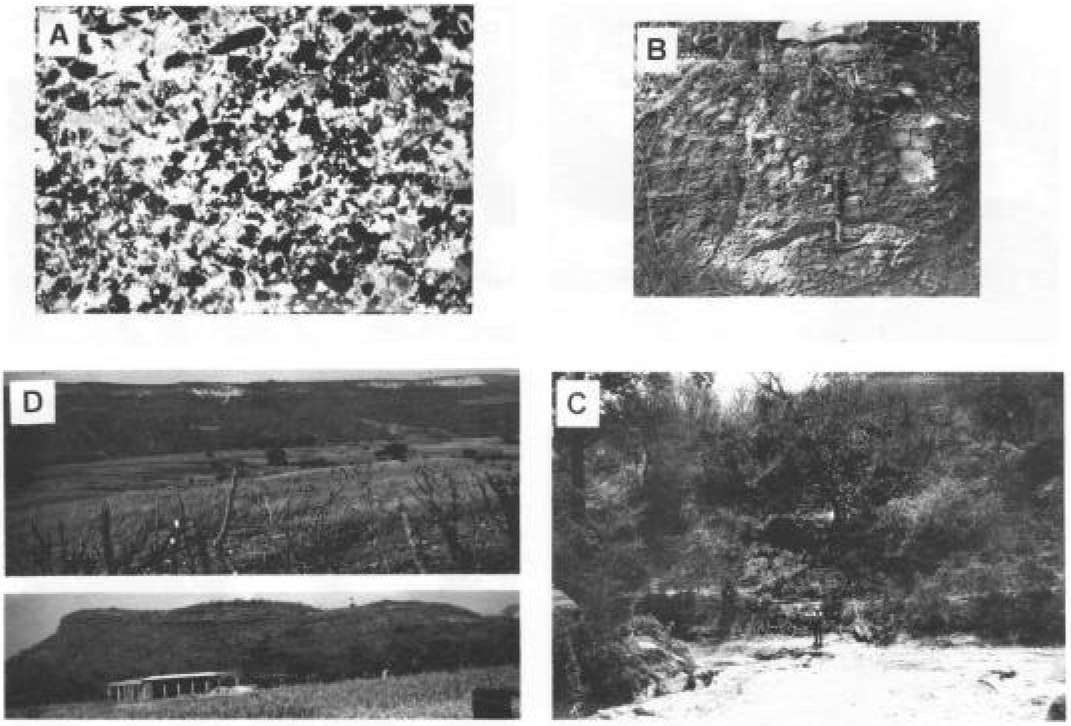


Plate IV. Soyaló and El Bosque Formations. Figure A. Soyaló Formation: Photomicrograph in polarized light of sample FV97-7, clayey siltstone collected from an outcrop on the Río Suchiapa southern bank, by the trail to Galecio Narcia; the rock largely consists of quartz grains set in a clayey matrix. Line represents 0.5 mm. Figure B. Soyaló Formation: Outcrop close to the Panamerican Highway, about 2.5 km east of the Belisario Domínguez Bridge, near Tuxtla Gutiérrez (*cf.* Plate I); this unit consists here of silty claystone set in thin to medium beds. Figure C. The Soyaló Formation-El Bosque Formation contact: it is displayed in the Río Suchiapa channel, close to the trail to Galecio Narcia; the Soyaló Formation strata are cream colored and thin, dipping up to 23° to S18°E; El Bosque Formation strata are brownish red, medium to thick, and dip 17° to N18°W. Figure D. El Bosque Formation: The Cerro Colorado as seen from El Salvador Ranch, located about 2.1 km WNW of this hill; it is mainly composed of El Bosque strata.

no discernible pattern; the unit is 2,000 m thick, overlies (concordantly?) the Soyaló Formation, and underlies the San Juan Formation; it is of Early Eocene age, and its Principal Reference Section is the outcrop on Arroyo Lajita, close to km 23 of the lxtapa-Soyaló highway.

In the study area (Plate I), the strata assigned to El Bosque show most of these features, allowing the recognition of this unit there; it crops out in the south-central part, forming an irregular belt from San José and Pacú to G. Narcia, covering 32.15 km^2 (*i. e.*, 10 % of the area, see Plate I). El Bosque forms very low, rolling hills sited between 400 to 550 mamsl (Plate IV, Figs. D and E, V, Fig. A); a few such hills are steep sided, because of faulting, such as the Cerros Colorado (Plate IV, Fig. D) and Chiñua (Plate I).

THICKNESS, LITHOLOGY AND GENETIC-ENVIRONMENTAL INTERPRETATION

This formation is thin in the area (*ca.* 100 m, Figure 2), pinching out to the northeast; it mainly consists of grayish red 5R 4/2 to moderate reddish orange 10 R 6/6 (without weathering change) sandstone and granule conglomerate, friable to moderately lithified, set in medium to thick beds (Plate V, Figs. C and D). The clasts are angular to subround, of low to medium sphericity, poorly to moderately sorted; the dominant mineral is milky white, polycrystalline quartz of evident metamorphic origin, frequently showing conchoidal fracture, and a film cover of hematite, suggestive of extensive in situ weathering. The lack of authigenic

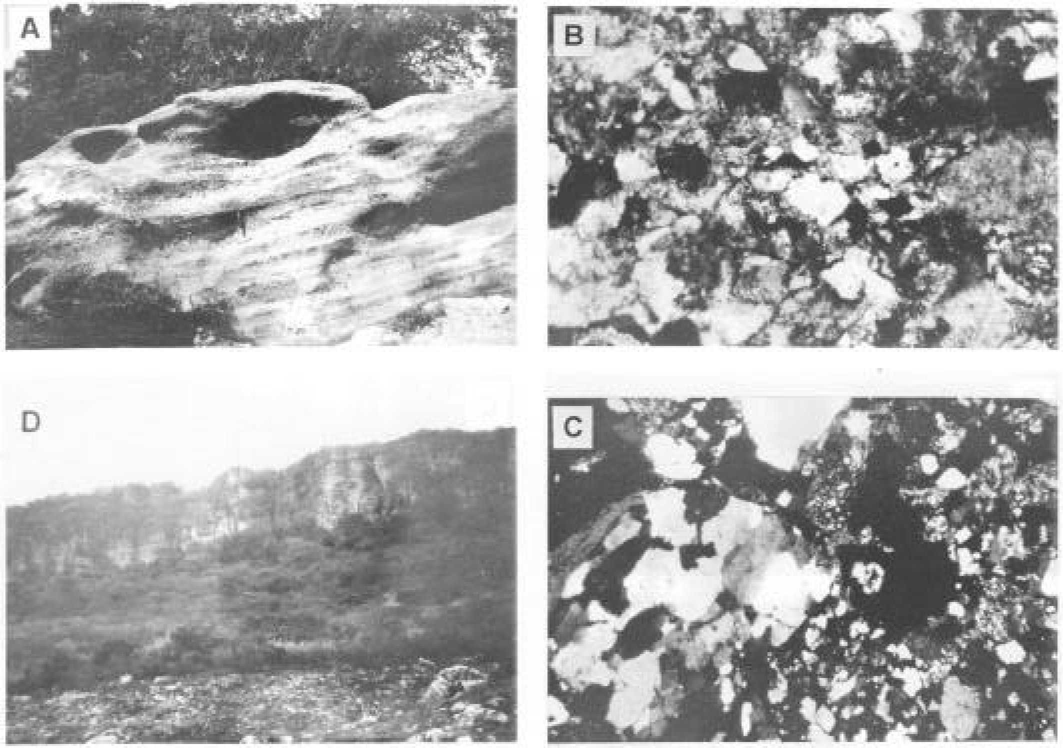


Plate V. El Bosque and San Juan Formations. Figure A. El Bosque Formation: Outcrop in the Río Suchiapa channel, close to the trail to Galecio Narcia; thick strata made by the conglomeratic variety form this exposure. Figure B. El Bosque Formation: Photomicrograph in polarized light of sample FV97-49, immature, quartz phyllarenitic sandstone collected in the peneplained lowlands of Pacú, about 1.3 km northwest of this village; most quartz grains are angular, biotite appears as subhedral, greenish clasts. Line represents 0.2 mm. Figure C. El Bosque Formation: Photomicrograph in polarized light of sample FV97-6, quartzphyllarenitic, very coarse sandstone to granule conglomerate collected in the Río Suchiapa (the outcrop depicted in Figure A); on the lower left, a polycrystalline quartz granule is readily apparent; the breakage of such granules generates the angular individual quartz grains seen in finer grain lithovarieties. Line represents 0.5 mm. Figure D. San Juan Formation: La Mesa de Copoya's eastern cliff, as seen on the road to el Sabino Ranch, at a place located 4 km southwest of Chiapa de Corzo; the cliff is fresh, devoid of vegetation, whereas the talus blocks are heavily vegetated.

overgrowths indicates that the sand grains are not reworked. Heavily argillized feldspar is present, forming smaller and less frequent clasts that those of quartz. The metamorphic rock fragments are even less abundant, and show extensive weathering. The matrix makes about 10-15 % of the rock volume and largely consists of phyllarenitic silt and strongly hematized clay.

The coarser varieties are brecciod conglomerates, where the metamorphic rock fragments (mostly sericite-muscovite schists, granulite and quartz gneiss) are more common than in the finer grained ones. Fine grained sandstone and siltstone varieties, of the same phyllarenitic composition, are very scarce.

El Bosque Formation was deposited on land, mostly as traction and saltation load in river channels, as alluvial fans, and as suspended load in flood plains, perhaps close to littoral environments, by a system of meandering rivers. The source area was probably not far; it consisted mainly of metamorphic uplifted bodies, probably part of the Chiapas Massiff.

STRUCTURE AND STRATIGRAPHIC RELATIONSHIPS

Strata in this unit show dips (7° to 18°) without a discernible pattern (Plate I), because faults cut through them; north of Suchiapa beds dip to the northwest and northeast; midway between Suchiapa and Cerro Colorado, the dip is to the northeast; in the Cerro itself the beds dip to the east and southeast; on the north side of the Río Suchiapa, near Cerro Colorado, the beds dip to the northeast.

The lower contact with the Soyaló Formation, was already discussed (Plate IV, Fig. C). The upper contact with

San Juan Formation, is obscured by faults, vegetation and Quaternary deposits; in the few places where it was examined, it appears to be an unconformity, because an abrupt change in lithic atributes was discerned among the strata of both units in a narrow zone by the postulated contact.

PALEONTOLOGY, AGE AND CORRELATION

No fossils were found in these strata from the study area, however, in marine and transitional strata of this unit, in the Ixtapa-Soyaló Area, Frost and Langenheim (1974, p. 20), reported the soritid megaforaminifera Rhapydionina limbata, and R. guatemalaensis, indicative of the Early Eocene. This datum and the stratigraphic position are the basis to assign El Bosque Formation to this time interval. Formal continental Early Eocene lithostratigraphic units are scarce in Southeastern Mexico, thus the correlation of El Bosque Formation is limited (Figure 3); it is correlative with the Yanhuitlan Formation of the Mixteca Region nortwestern Oaxaca (Ferrusquía-Villafranca, 1976); with the Ghichixú Phyllarenite of the Isthmian region, eastern Oaxaca [Ferrusquía-Villafranca, in press (1998)]; with the Upper Candelaria Formation of Tabasco and Campeche [Frost and Langenheim, 1974; Quezada-Muñetón, 1987(1990)], with the Nanchital Shale, also of this State (Salvador and Quezada-Muñetón, 1989), and with the Aragón Formation of the Veracruz Basin (Cruz-Helú et al., 1977; Salvador and Quezada-Muñetón, op. cit.).

SAN JUAN FORMATION

FORMATIONAL ASSIGMENT, LOCATION, EXTENT AND GEOMORPHIC EXPRESSION

Partial Synonymy.- San Juan Shale (Licari, 1960, p. 23, fide Frost and Langenheim, 1974, p. 20); San Juan Formation (Allison, 1967, p. 95, fide Frost and Langenheim, 1974, p. 20); San Juan Formation partim (Frost and Langenheim, 1974, p. 20, et seq., Text-fig. 5); To (cz) informal unit (INEGI, 1985); To, unnamed Oligocene limestone, lutite, sandstone and conglomerate unit (De la Rosa et al., 1989, Appendix D); Copoya Limestone (De la Rosa et al., 1989, p. 49-50); and Lomut Formation (proposed by González-Alvarado, 1963; recognized in the study area by Aguilar-Piña, 1993, p. 35, notwithstanding significance differences between the Copoya section and the Lomut Type Section). None of these units complies with the requirements of the pertinent stratigraphic code (cf. CSN, 1933; ACSN, 1961, 1970; NACSN, 1983).

Assignment.- Following the supplemented definition [Ferrusquía-Villafranca, 1996 (1997), p. 38], the San Juan Formation consists of pale yellowish orange 10 YR 8/6, granule to fine gravel, very well indurated, biomicrite/biosparite-matrixed, highly fossiliferous (abundant megaforaminifers), quartz-phyllarenitic conglomerate, set in thick to very thick strata; intercalated with fine grained, quartz-phyllarenitic sandstone of the same color with a biomicrite matrix, set in medium thick strata; by phyllarenitic siltstone of light olive gray 5 Y 6/1 color (weathering to dark yellowish orange 10 YR 6/6) and shaly character, set in thin to laminar strata, that frequently develop cone-in-cone structures. There are also beds of light olive brown 5 Y 5/6 (weathering to dusky yellow 5 Y 6/4), phyllarenitic siltstone of grayish orange pink 5YR712 color (weathering to dark yellowish orange 10 YR 6/6), with planty of biomicritic matrix, set in thick strata; and highly fossiliferous biomicrite, and biomicrosparite to mesosparite bearing abundant megaforaminifera, set in medium to thick strata; and by light olive gray 5 Y 5/6 (weathering to yellowish brown 10 Yr 5/4), shaly, friable, clayey, phyllarenitic siltstone, set in thick strata. Biostromes dominated by pelecypods, Dasycladaceae and corals, are sparsely distributed throughout the sequence, and may be locally abundant. The estimated thickness is 800 to 1,000 m. The San Juan Formation overlies El Bosque and underlies the Masanilo Formation, but also shows fault contacts with other units; it is of Middle Eocene age. The Type Section is located close to the Ríos La Cueva and El Coco, in the lxtapa-Soyaló Area.

The strata in the study area assigned to this formation show most of these features, particularly significant is the occurrence of granule-fine gravel, with biomicrite matrix, highly fossiliferous quartz-phyllarenite. This is a very rare lithic variety [cf. Ferrusquía-Villafranca, 1996(1997), p. 40-43]; thus leaving no doubt on the presence of the San Juan Formation in this area, as already proposed by Frost and Langenheim (1974, p. 22); however, their conception of this unit is partly different than the one applied here, as discussed elsewhere (Ferrusquía-Villafranca, op cit. p. 38).

The San Juan Formation (Plate I) has an areal extent of 135 km^2, which corresponds to 40.9% of the study area; it forms La Mesa de Copoya (Plates IV, Fig. E, and V, Fig. D), largely capped by a stratiform blanket of well indurated, highly fossiliferous limestone; land-slide blocks of varied size, (hundreds to thousands of meters wide and/or long), shape and structural attitude, detached from the blanket cap, nearly cover the adjacent lowlands (Plate I).

THICKNESS, LITHOLOGY, AND GENETIC-ENVIRONMENTAL INTERPRETATION

The estimated thickness of this formation in the area is 450 m to 500 m (Figure 2). Lithically, the San Juan Formation is the most diverse. Listed below are the common varieties.

Variety l: Well sorted granule-gravel conglomerate of quartz phyllarenite with biomicrite/biosparite matrix (Plate VI, Figs. A and B)

This is a very characteristic variety, because of its hardness, grit-like appearence and abundant fossil content;

dominant colors are pale yellowish orange 10 YR 8/6, and pale yellowish brown 10 YR 6/2. Framework clasts are well rounded, well sorted grains 4 to 16 mm in diameter (the 4 to 8 mm size fraction is more frequent), chiefly of milky white, polycrystalline quartz, metachert and pyroxene granulite (greenstone), set in a voluminous groundmass of biomicrite to biosparite/mesosparite (in the later the calcite microcrystals are 20 to 40 microns in diameter), where the framework clasts "float" (i. e., do not have mutual contacts); the groundmass bears abundant benthonic megaforaminifera. The framework clasts:groundmass ratio varies from 2:3 to 3:2, so that this variety may become a kind of "marly" limestone.

The coexistence of well sorted, well rounded, granule to gravel size clasts with micrite and abundant benthic foraminifera is paradoxical, because each sedimentary fraction calls for contrasting energy regimes, high in the first and low in the second; this is also reflected in the difficulty to place this lithic variety in any classification system of sedimentary rocks (cf. Folk, 1959; 1968; McBride, 1963; Dunham, 1962; Embry and Klovan, 1971; Friedman and Sanders, 1978; Einsele, 1992). The possible origin of this kind of rock, is discussed elsewhere (Ferrusquía-Villafranca, 1996 (1997), p. 42). This variety usually forms thick beds.

Varieties 2 and 3: Well sorted quartz phyllarenitic sandstone and siltstone with biomicrite/biosparite matrix (Plate VI, Figs. C and D, VII, Figs A and B)

These are the fine grained equivalents of the previous variety; other properties are similar; they are thin to medium bedded.

Variety 4: Shaly to clayey phyllarenitic siltstone with biomicrite-matrix

Typically this variety has a larger amount of detrital clay, which causes its shaly parting. Dominant colors are medium light gray N6, and light olive gray 5 Y 8/1; quartz of undulous extinction forms most silt size clasts; this variety is set in thin to very thin beds.

Variety 5: Biomicrite/Biomicrosparite and Biomesosparite of megaforaminifera (Plate VII, Fig. C)

This is a common and quite distinctive lithovariety, because the foraminifera are so abundant, that the rock is actually a kind of coquina. The commonest color is grayish orange pink 5 YR 7/2, weathering to light brown 5 YR 6/4. The matrix is lime ooze and microspar or mesospar (i. e., a fabrics formed by anhedral to subhedral calcite crystals, 20 to 30 microns in diameter) in diverse proportions; the matrix makes up to 20% of the rock. The foraminiferan testae are usually white; Raadshovenia guatemalaensis and Rhapydionina limbata, common Middle Eocene Caribbean-Chiapasan taxa were identified in the area. Durham et al.(1955), Frost and Langenheim (1974), and Aguilar-Piña (1993), reported other megaforaminifer taxa (cf. Table 1). This variety forms medium beds.

Variety 6: Biostromic Biomicrite/Biomicrosparite and Biomesosparite (Plate VII, Fig. D, VIII, Figs. A-C)

This lithovariety is very well indurated, and may form erosion-resistant features. The most frequent color is pale to moderate brown 5 YR 4/4, that weathers to light to moderately dark gray N6. The matrix makes 15% to 25% of the rock. Micro-and macrofossils are common; partial chert replacement of skeletal aragonite, is frequent. Beside the foraminifera, fossils include Dasycladaceae algae, scleractinian corals (both hermatypic and non-hermatypic), gastropods, pelecypods and some vertebrates (sharks teeth, reptilian and mammalian remains). This lithovariety forms medium to thick strata; those that cap La Mesa de Copoya are largely composed of it.

It should be noted that the cartographic discrimination of the lithovarieties observed in the San Juan Formation, was beyond the scope of the present study; it appears however, that the unit becomes sandier upward, as could be observed on the slopes of Cerro Mactumatzá, located in the northwestern end of La Mesa de Copoya, where the limestone varieties are rare, chiefly restricted to the lower 30 to 40 m.

The most likely environment of deposition for this unit is a shallow marine platform, located not far from the littoral zone, subdued to a moderate terrigenous influx. Within this general setting, local conditions differed from place to place, being, shallower or deeper, nearer or farther from the coast, with low, medium or high wave or current energy, and with little or much terrigenous influx, thus generating the several lithic varieties. These conditions, of course, may have changed through time (either rhythmically, episodically or randomly).

STRUCTURE AND STRATIGRAPHIC RELATIONSHIPS

The San Juan Formation strata show low to moderate dips that seem not to define a consistent pattern (Plate I), because of extensive faulting. La Mesa de Copoya is being reduced, because marginal faulting continuously breaks away blocks that form a moderately steep talus, that extends from the bottom depression that surrounds La Mesa, to the fresh, nearly vertical cliffs that bound it all around (Plates I and V, Fig. D). The land-slid blocks are commonly polygonal, show different structural attitudes (from quasi horizontal, as the block that makes up the football field of the Copoya Village), to moderately to strongly tilted, usually away from La Mesa (Plate I). The land-sliding is active at present, as evidenced in the Santa Josefina Ranch house, a poultry farm located on the northeastern slope of La Mesa, where one of the main buildings shows vertical fissures trending north-south (Plate VIII, Fig. D), and the terrain is moving toward the east (i. e., to the Río

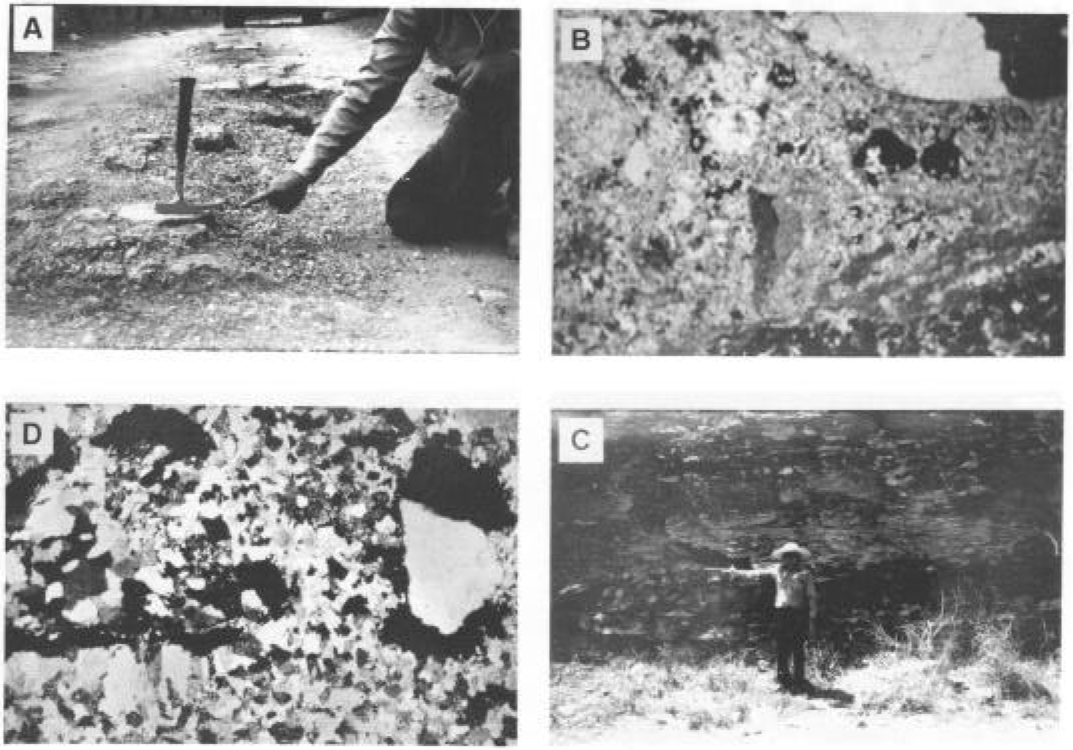


Plate VI. San Juan Formation. Figure A. Outcrop in the Copoya Village-Cerro Mactumaczá summit road, showing the conglomeratic lithovariety.
Figure B. Lithovariety 1: Well sorted, biomicrite/biosparite-matrixed, granule to gravel conglomerate of quartz phyllarenite. Photomicrograph in polarized light of sample FV97-11, Lithovariety 1 collected about 2 Km southwest of Terán. Notice one polycrystalline quartz granule on the top right and one of metachert on the lower right; both are partly shown, and set in a biomicrite matrix, which bears foraminifers. Line represents 0.5 mm. Figure C. Lithovariety 2: Outcrop in the Copoya Village's Football Field, which is located about 1.0 Km NE of the village; the sandstone lithovariety forms thin to mediumly thick, brownish strata.
Figure D. Lithovariety 2: Well sorted, biomicrite/biosparite-matrixed phillarenitic sandstone: Photomicrograph in polarized light of sample FV97-17, Lithovariety 2 collected in the Copoya Village-Cerro Mactumatzá summit road, close to the former; polycrystalline quartz grains outnumber others; the amount of clay is larger. Same scale as in Figure B.

Grijalva); this and other-buildings are frequently repaired, but to no avail.

The extensive faulting, numerous land-slid blocks, vegetation and Quaternary deposits obscure the stratigraphic relationships with the underlying units. Traverses from Tuxtla Gutiérrez, Terán, Playa Vista, and Cupia to the Mesa de Copoya (Plate I), show Soyaló Formation strata unconformably overlain by strata from land-slide blocks of San Juan Formation; however the relation between the Soyaló and in situ San Juan strata, was not observed. On the southern margin of La Mesa, San Juan Formation strata are in fault contact with Quaternary deposits and with strata of El Bosque Formation. These facts are parsimoniously interpreted as follows: It is postulated that the San Juan Formation overlies (unconformably?) El Bosque Formation, particularly so in the southern part of La Mesa de Copoya; that El Bosque feathers or pinches out toward the north, hence it does not crop out on the northern slope of La Mesa; and that the Soyaló Formation unconfomably underlies the San Juan in the areas where El Bosque Formation is not present (see structural section in Plate I). This interpretation was hinted at by Durham *et al.* (1955).

No Tertiary units overlie the San Juan Formation in the study area, where only Quaternary deposits, mostly soils, partly cover it.

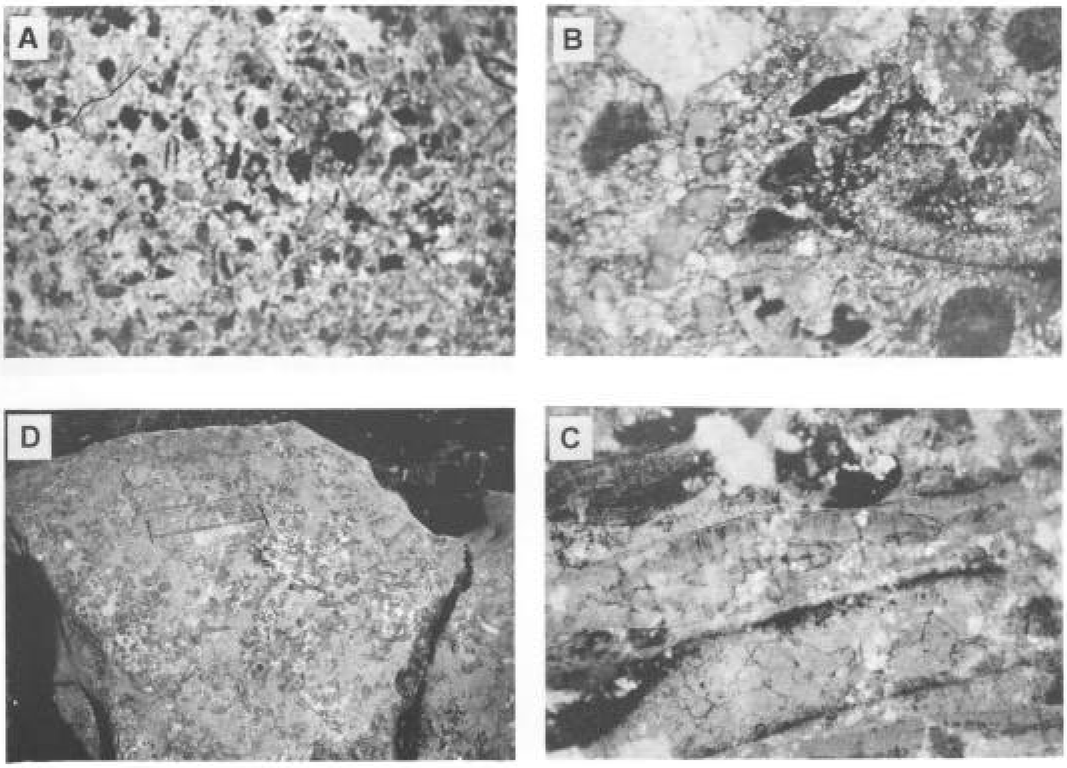


Plate VII. San Juan Formation. Figure A. Lithovariety 3: Well sorted, quartz phyllarenitic siltstone with a biomicrite/biosparite-matrix. Photomicrograph in polarized light of sample FV94-5C, Lithovariety 3 collected on the trail by the Río Zapotal about 1.0 km north of the Cerro Hueco Jailhouse; individual, highly angular quartz grains make the bulk of the terrigenous clastics. Line represents 0.5 mm. Figure B. Idem. Same sample but other field and higher magnification. The foraminifers are abundant; on the upper left an angular quartz grain stands out. Line represents 0.2 mm. Figure C. Lithovariety 5: Biomicrite of megaforaminifera (a kind of coquina). Photomicrograph in normal light of sample FV94-47, Lithovariety 5 collected on La Mesa de Copoya, near vertebrate fossil locality 5, about 1.0 km northeast from El Jobo: three longitudinal sections of Lepidocyclina sp. are depicted. Same scale as in Figure A. Figure D. Lithovariety 6: Biostromic biosparite: Outcrop in the Copoya Village Football Field, located 1.0 Km northeast of the village; notice the large amount of macrofossils present. The ruler measures 15 cm.

PALEONTOLOGY, AGE AND CORRELATION

Table 1, is a composite list of fossil invertebrate taxa recovered by various authors from this unit, at several localities in the area. Particularly significant age-wise, are the larger foraminifera and scleractinian corals, which are indicative of a Middle Eocene age. The biostromes disclose a marine, very diverse, and seemingly highly productive community that lived in a shallow marine environment, with warm, tropical, well agitated, well oxygenized waters; it appears that true massive reefal structures were not developed in the area.

The correlation of the San Juan Formation with comparable units in Southeastern Mexico, is hampered by the infomal character of many such units [*cf.* Cruz-Helú *et al.*,1977; Quezada-Muñetón, 1987(1990)]; as near as we can assess, this formation is correlative (Figure 3) with the Uzpanapa Conglomerate of Chiapas (Frost and Langenheim, 1974, Quezada-Muñetón, *op cit.*) and with the Guayabal Formation of the Veracruz Basin, Gulf Coastal Plain (Cruz-Helú *et al.*, 1977; Salvador and Quezada-Muñetón, 1989).

QUATERNARY DEPOSITS

The reconnaissance nature of this work precluded the stratigraphic differentiation of the Quaternary System in the area. In lieu of only a gross distiction between soils and alluvial deposits is presented (Plate I). The Quaternary

Table 1. Identified taxa from Middle Eocene San Juan Formation at La Mesa de Copoya, Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa area, west-central Chiapas, southeastern Mexico.

PROTOZOA
Ord. FORAMINIFERIDA
- Fam. Miliolidae
  - Quinqueloculina sp. (3)
- Fam. Soritidae
  - Rhapidionina limbata (2)
- Fam. Alveolinidae
  - Raadshovenia guatemalensis (1 & 2)
- Fam. Nummulitidae
  - Nummulites floridensis (3)
  - N. striatoreticulatus * (1 and 3)
- Fam. Discocyclinidae
  - Pseudophragmina teres * (3)
  - P. advena * (1)
  - P. zaragosenensis (1)
- Fam. Amphisteginidae
  - Amphistegina parvula (3)
  - Amphistegina sp. (1)
- Fam. Lepidocyclinidae
  - Lepidocyclina antillea (1)
  - Helicostegina dimorpha * (1 and 3)
- Fam. Cymbaloporidae
  - Fabiania cubensis (1)
  - Eofabiania cushamani (3)

COELENTERATA-ANHOZOA-OCTORALLIA (2)
Ord. COENOTHECALIA
- Fam. Helioporidae
  - Heliopora mexicanae

ANTHOZOA-ZOANTHARIA (2)
Ord. SCLERACTINIA
- Fam. Pocilloporidae
  - Stylophora cf. S. Cambridgensis *
- Fam. Acroporidae
  - Astreopora esperanzae *
  - Haimesastraea peruviana
- Fam. Siderastreidae
  - Siderastrea scotia *
  - Actinacis barretti *
  - A. caribensis*
- Fam Poritidae
  - Goniopora copayens *
- Fam. Montilivaltiidae
  - Placosmilia copoyensis *
- Fam. Rhizangiidae
  - Rhizangia sp.
- Fam. Meandrinidae
  - ?Syzygophyllia sp.

MOLLUSCA-GASTEROPODA (2 and 4)
Ord. PROSOBRANCHIA
- Fam. Cerathiidae
- Cerathium sp.

MOLLUSCA-PELECYPODA (2 & 4)
Ord. PTERIODAE
- Fam. Ostreidae
- Ostrea sp.

VERETEBRATA-CHONDRICHTHYES (4)
Ord. ORECTOLOBIFORMES
- Fam. Ginglymostomatidae
- Nebrius sp.

Ord. LAMNIFORMES
- Fam. Carcharidae
  - Striatolamia macrota
  - Carcharias sp.
- Fam. Odontaspidae
  - ?Odontaspis sp.
- Fam. Lamnidae
  - Isurus cf. I. precursor
- Fam. Carcharodontidae
  - Carcharodon auriculatus *
- Fam. Gen and sp. indet.

Ord. CARCHARHINIFORMES
- Fam. Hemigaleidae
  - Hemipristis sp.
- Fam. Carcharhinidae
  - Galeocerdo sp.
- Fam. Gen. and sp. indet.

* Middle Eocene index taxon

Sources: (1) Durham et al. (1955, p. 986-987), material from Cerro El Zanate, western part of La Mesa de Copoya; taxonomy updated following Frost and Lengenheim (1974), and Butterlin (1981). (2) Frost and Lengenheim (1974, p. 23) and systematics sections thereof; material from unidentified localities (probably Cerro El Zanate and the Tuxtla Gutiérrez-Suchiapa Highway). (3) Aguilar-Piña (1993, p. 17-24), material from El Jobo; following Butterlin, op. cit. (4) This report, material from several localities on La Mesa de Copoya, see Plate I.

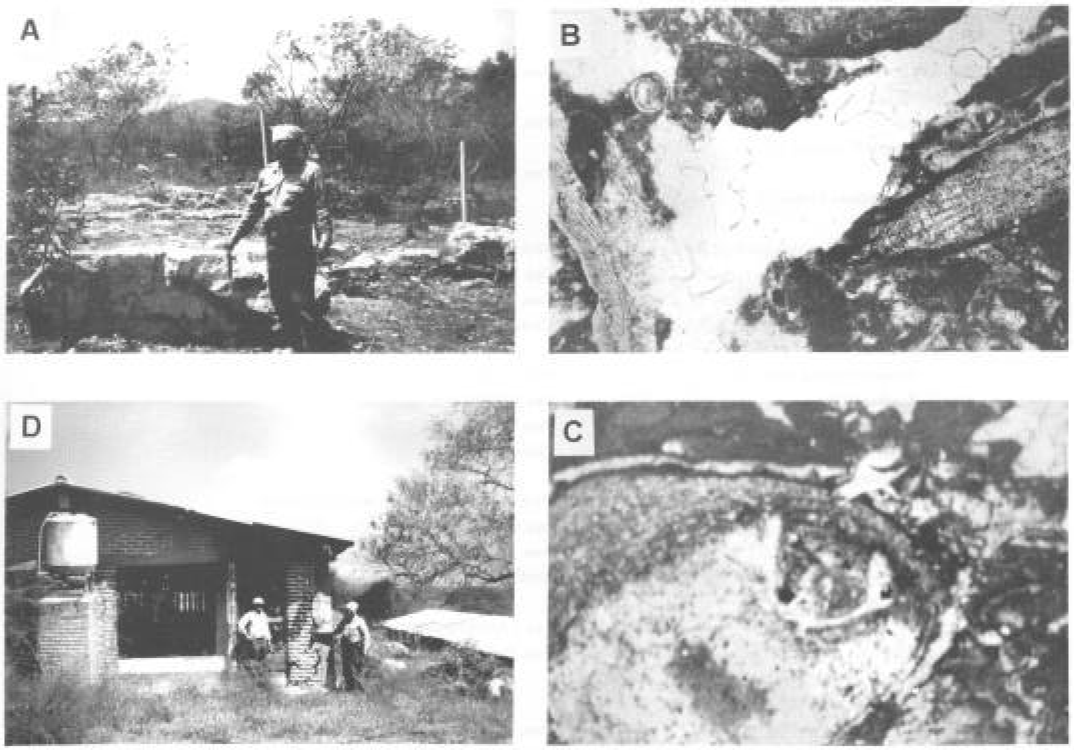


Plate VIII. San Juan Formation. Figure A. Lithovariety 6: Biostromic biosparite : Block of thick bedded limestone occurring in the Copoya Village Football Field, which lies 1.0 km northeast from it; this is the erosion-resistant lithovariety that caps La Mesa de Copoya. Figure B. Same Variety. Photomicrograph in normal light of sample FV97-14, Lithovariety 6, collected near Fossil Vertebrate Locality 4, sited about 1.2 km northeast from El Jobo; a megaforaminifer and a transverse section of a small pelecypod are displayed. Line represents 0.5 mm. Figure C. Same Variety. Photomicrograph in normal light of sample FV93-8.2, Lithovariety 6, collected near Fossil Vertebrate Locality 3, placed about 1.3 km northeast from El Jobo; a transverse section of a small pelecypod is shown. Same scale as in Figure B. Figure D. Vertical fissure at main building of Santa Josefina Poultry Farm, located on the road to El Sabino Ranch, about 2 km west-southwest from Chiapa de Corzo. The fissure strikes N15°W roughly paralleling the Río Grijalva, and is related to the eastward sliding of the limestone block on which the farm is built.

deposits occupy about 68.3 km^2, which correspond to 20.5 % of the total area; their total thickness does not exceed 30 m, and show a horizontal structural attitude.

Soils

Patches of territory adjacent to the Copoya and El Jobo Villages, have been cleared from their natural vegetation by burning, and then devoted to weather-dependent agriculture (Plate I). The soil is a thin, dark brown rendzine, developed on limestone strata of the San Juan Formation.

Alluvial Deposits

They occur in and around the Ríos Grijalva, Santo Domingo and Suchiapa, occupying most of the narrow depression that surrounds La Mesa de Copoya (Plate I). On the river channels, the alluvium displays a wide textural expression, including clay, silt, sand and gravel to cobble size clasts; terraces have developed upon narrow sand fills in the Río Grijalva, near Chiapa de Corzo (INEGI, 1985, and Plate I of this study). Adjacent to the river channels, in the flood plains, clay, silt and fine sand have been deposited; these plains are largely used for agriculture. Quartz and metamorphic rock fragments make the better part of the alluvial deposits. Not discriminated in the map (Plate I), are colluvial deposits located mostly around the cliffs of La Mesa de Copoya, and at the base of steep slopes on the southwestern part of the area.

STRUCTURAL GEOLOGY

PREVIOUS STUDIES

Sapper (1894) and Böse (1905) outlined the structural geology of Chiapas, the latter pointed out that in central Chiapas the Tertiary strata occupy a broad, NW-SE oriented syncline, bounded to the NE and SW by anticlines developed in Cretaceous strata. Verwiebe (1925) showed that similar anticlines also occur within the "syncline", thus disclosing that the Tertiary strata were actually folded into several synclines. Schuchert (1935), was the first to outline a syncline in La Mesa de Copoya area. Durham et al. (1955), raised the possibility that the syncline of Copoya is faulted on the southern margin. Gutiérrez-Gil (1956, Fig. 8, a geologic map of the Tuxtla Gutiérrez area, scale 1:117,650); and Contreras-Velázquez (1956, Fig. l, a geologic map of the Tuxtla Gutiérrez-Ocozocuautla area, scale 1:181,200), plotted and named the Copoya Syncline, showing it intersected by a perpendicular normal fault, and marginally unbounded by faults. Gutiérrez-Gil (op. cit., Fig. 1, a geologic map of southern Chiapas, scale 1:666,666) also depicts the NW-SE oriented fold-belt structure of the Central Depression and adjacent northern mountainous region. The Tuxtla-Gutiérrez-Copoya area lies inside the belt, close to its southern limit. Several normal faults perpendicular to the belt axis, are also shown.

Chubb (1959, Fig. 1, a geologic map of the Central Depression's western part, scale 1:600,000), showed that the Postcretaceous basins and synclines (the Copoya included), are offset en echelon. The CCGM, (1968,1976, Mexico's geologic maps scale 1:2,000,000), show that the fold-belt is affected by faults, some of them bound synclines or anticlines. Sánchez-Montes de Oca (1969), ably synthetized the work of PEMEX geologists in Chiapas, stressing the large extent of sinistral strike-slip faulting in central Chiapas (op. cit., Fig. 3A); faults trend NW and E, being parallel to oblique to the fold-belt axis. Further elaboration of this, led to the recognition and description of Chiapas' Strike-Slip Tectonic Province (Sánchez-Montes de Oca, 1978, 1979; Meneses-Rocha, 1991), and to link its development to plate tectonic motions. This province largely corresponds to the Central Depression Physiographic Province (cf. Müllerried, 1957, Map 4; Frost and Langenheim, 1974, Text-fig. 1).

Frost and Langenheim (1974, p. 7 et seq., and Text-fig. 3, a map scale 1:650,000) studied west-central Chiapas, and concluded that the region includes three major synclines, separated by as many anticlines, both transected by faults set en echelon; the Copoya is one of such synclines, and appears to be faulted on both northeast and southwest margins. However, later geologic works on this region, have ignored Frost and Lahgenheim's contention (cf. De la Llata, et al., 1979; INEGI, 1985; Michaud and Fourcade, 1987; De la Rosa et al., 1989), so that La Mesa de Copoya area is structurally interpreted as a syncline marginally unbounded by faults. In fact, the faults perpendicular to the syncline axis, already recognized by Gutiérrez-Gil (1956), and Contreras-Velázquez (1956), are only recorded in INEGI (1985).

This brief review shows that the structure of west-central Chiapas, in spite of the extensive work done, is not fully known yet, and that more detailed and regional studies are needed; our contribution to this end, is presented below.

FOLDS

The broad syncline structure underlying La Mesa de Copoya Area, is plainly evident by the geographic distribution of the Cenozoic lithostratigraphic sequence, which is sourrounded on all but the southeast side, by Cretaceous strata, thus the axial direction is NW-SE. However, the expected pattern of convergent dips toward the syncline axis of both lithostratigraphic sequences, is not apparent; instead, they show a seemingly disorderly array of dips and strikes, as presented elsewhere, and summarized below (Plate I).

The Sierra Madre Limestone dips 10°-20° to the E and NE. Strata of the Angostura Formation in the northern block vary from nearly horizontal to 10° SSE to SSW; those of the southern block chiefly dip 10°-16° to the NE (as expected), except close to the Río Suchiapa, on its northwestern portion, where they are very steep and trend NE. The Soyaló Formation surrounds La Mesa, but does not have a consistent dip: strata in the southern part vary from nearly horizontal to dips of 4°-7° to the NE, NW and SE; strata in the block north of Chiapa de Corzo vary from 5° to nearly vertical, and dip to the E, SW and NW; the strata located across the Ríos Grijalva-Santo Domingo junction dip 5° to the E. El Bosque Fornation strata show low dips (5°-10°) to the NE by El Salvador Ranch, to the E and SE in Cerro Colorado (near E. Zapata), to the SE and NNE; to the NNW in the Rios Suchiapa-Santo Domingo junction area, and to the NE also close to the Río Suchiapa, near El Potrerón Ranch.

The significant difference between the expected dips of an evident syncline, and the observed ones, occurs because faulting has subsequently disrupted the original broad fold structure; after uplift, subsequent erosion exposed the Cretaceus (limestone) core of the anticlines and nearly erased the Tertiary sequence, i.e., the syncline fill.

FRACTURES AND FAULTS

Figure 4 shows the strike frequency distribution of the main fractures and faults discerned in the study area; the former vastly outnumber the latter. The structural pattern is similar in both the Cretaceous and Tertiary units (Plate I), thus indicating that they were defomed during the same episode. In terms of frequency, two major (NE and NW), and two subordinate (N and E) systems were detected.

The NE and NW Systems

These systems include some 84 % of the fractures and faults recorded (Plate I). 32% fall in the N35° -55° E field, and 20% in the N35° -55° W (Figure 4). The fields lie at right angle to each other, indicating that the fault systems are conjugate. Main structures belonging to these systems correspond to the fracture underlying the Río Suchiapa, as well as the fault contacting El Bosque and San Juan Formations, and the fault on the western part of La Mesa de Copoya (Plate I; INEGI, 1985). Further, the natural drainage network closely follows these directions. Most faults are normal, but the scarcity of outcrops makes it very difficult to estimate the displacement. The topographic features related to the contact zone, and the different dips of the adjacent formations on either side, is parsimoniously best interpreted postulating that faulting disrupted the broad syncline underlying La Mesa de Copoya Area (Plates I-II).

La Mesa de Copoya Marginal Faults

The configuration of La Mesa is largely controled by the prevailing structural fabric (NW-SE and NE-SW), still discerned in the present-day northeastern and southwestern margins (Plate I). Regional uplift and subsequent erosion of the Tertiary sequence in the area, largely unroofed the San Juan Formation down to the highly erosion-resistant limestone blanket that now caps much of La Mesa, thus contributing to its sculpture. The Cerro Mactumactzá, located on the northwestern end of La Mesa, is the only remnant of the Tertiary sequence that once laid above this blanket.

Later on, marginal faulting generated the vertical cliffs and land-slide blocks that nearly cover La Mesa's slope and adjacent lowlands (the Pericopoya Land-Slid Block Zone, see Plate I), thus completing its shaping. Most blocks dip away from La Mesa (Plates I- II). These blocks, usually capped by the erosion-resistant limestone, allowed the development of a large and intricate system of underground caverns (partly occupied by groundwater currents), which is just beginning to be investigated (G. Cartas, Inst. Hist. Nat., Tuxtla Gutiérrez, Chis., oral comm., March, 1997). The name Cerro Hueco (hollow hill), given to a place on La Mesa's northern slope, attests to the local knowledge of this fact.

The N and E Systems

These systems are less common, the strikes vary from due N-S or E-W, to 20° off in either direction (Figure 4); some structures that belong to these systems correspond to the Ríos Santo Domingo and Grijalva courses (Plates I-II).

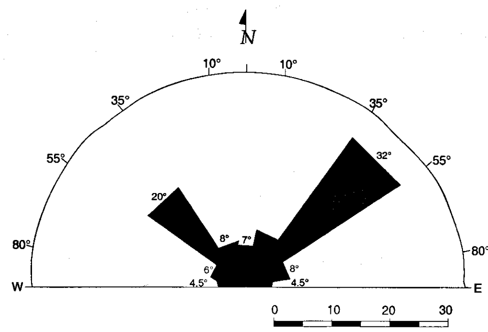


Figure 4. Diagram that shows the structural direction frequency of the main fractures and faults observed in the Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa area, Chiapas.

Strike-slip Faults

Wrench faults were not detected in the area, however, given the scarcity of outcrops, and the reconnaissance nature of the study, this is hardly surprising. The staggered or *en echelon* arrangement of the Central Depression mountain ranges (INEGI, 1984; 1985, and an uncontroled mosaic of high altitude air photos from west-central Chiapas) and of its anticlines, synclines and other structural features (Chubb, 1959, Fig, l; Sánchez-Montes de Oca, 1969, Fig. 3A-4; 1979, Fig. 1l; Frost and Langenheim, 1974, Text-Fig. 3; INEGI, 1985; Carfantan, 1986; De la Rosa *et al.*, 1989), may indicate that sinistral strike-slip faulting occurs in the area, which is part of the Central Depression.

COMMENTS ON THE AGE, ORIGIN AND REGIONAL SIGNIFICANCE OF THE DEFORMATION

Direct evidence from the structural features of the area only indicates that folding and faulting must have occurred following deposition of the San Juan Formation, *i. e.*, after the Middle Eocene. Regional evidence suggests that the main structural activity occurred in the Late Miocene [*cf.* Frost and Langenheim, 1974; Carfantan, 1986; and Ferrusquía-Villafranca, 1996 (1997) among others].

As for the origin, folding calls for a compressional stress field, that shortly afterwards must have changed to a distensional or transtensional one, to produce faulting and basin development. Principal forces involved in folding and faulting, must have been oriented in a nearly NE-SW fashion, thus allowing some shearing. The sinistral strike-slip faulting calls for a NW-SE maximum stress, and it has been linked to large scale plate motions (cf. Sánchez-Montes de Oca, 1979; Carfantan, 1986); and particularly to the Chortis Block eastward displacement (Pindell and Barret, 1990), however, much detailed work is needed, to prove these contentions.

SYNOPSIS OF GEOLOGIC HISTORY

The oldest geologic event recorded in the area, is the shallow marine lime deposition on a stable platform, free from terrigenous influx, that generated the Sierra Madre Limestone, during the Middle Cretaceous (Albian-Cenomanian); through this interval, the platform sank pari pasu to sedimentation, allowing the deposition of at least 300 m of strata, after diagenesis and lithification. A slight change in the tectonic activity, probably produced tilting of the platform, prior to the deposition of lime under the variety of environmental conditions (shallow to moderately deep, low to high kinetic energy, lacking to moderate terrigenous influx, near shore to off shore), that produced the Angostura Formation during the Late Cretaceous (Campanian-Maastrichtian); again sinking of the platfom occurred at a rate similar to that of deposition, thus making possible the accumulation of a thick sedimentary pile, sufficient to generate after diagenesis and lithification, at least the 350 m thickness of strata, recorded in the study area.

At the end of the Cretaceous and beginning of the Paleocene, a change in the tectonic activity took place, inclining the sea bottom, as evidenced by the unconformity separating the Angostura and Soyaló Fomations; a moderate deepening of the sea, and a greater terrigenous influx also occurred; under such conditions, the latter unit was deposited during the Paleocene. The tectonic activity changed by the end of the Paleocene, shallowing the sea floor, and even subaerially exposing it in lowlands close to the littoral zone; under these largely continental conditions, the fluvial system existing in the region, generated by Early Eocene time an accumulation of phyllarenitic detrital material derived from neighboring highlands (composed by metamorphic rocks), which is El Bosque Formation.

The tectonic activity changed again, subsidence and a marine transgression took place; the advancing sea was tropical and shallow, locally and/or episodically, it was subdued to terrigenous influx, and was inhabited by a highly productive community, able to sustain large predaceous vertebrates, such as sharks (see Part II). The resulting lithostratigraphic unit is the Middle Eocene San Juan Formation.

Marine sedimentation continued in the region from the Eocene on to at least the Early Miocene, as evidenced in other parts of central Chiapas [Frost and Langenheim, 1974; Sánchez-Montes de Oca, 1979; INEGI, 1985; Ferrusquía-Villafranca, 1996(1997)]; the sedimentation became more and more continental during the Middle Miocene, becoming fully continental by the Late Miocene (Ixtapa Fomation, cf. Ferrusquía-Villafranca, op. cit.), ceasing altogether afterwards. However, in the study area no direct record of these processes remains, because it was eroded away, so that the San Juan Formation became the uppermost exposed Tertiary unit. After sedimentation ended in the area (whenever it actually happened), the tectonic activity produced folding, faulting, (normal and strike-slip) and uplift. The tectonic regime changed from compression to tension and/or transtension, and transform; the regional significance of these changes, and its relation to the tectonic framework and evolution, is not well understood.

The structural processes outlined above, conferred the study area, some of its major features; erosion completed modeling it, largely unroofing the Tertiary sequence down to the well indurated limestone blanket (of San Juan strata) that caps La Mesa de Copoya, and removing great volumes of sedimentary material in its surroundings, thus partly exposing the Soyaló and El Bosque Fomations. During the Quaternary, weathering has produced soils of various kinds related to the parental substratum, and fluvial sedimentation has accumulated alluvial deposits in the valleys and low lands.

SUMMARY AND CONCLUSIONS

1.- The Tuxtla Gutiérrez-Chiapa de Corzo-Suchiapa Area, west-central Chiapas, Southeastern Mexico, lies between 16º35’-16º45’ N Lat. and 93º00’-93º10’ W Long; it consist of 323.3 km^2 of moderately rugged terrain set between 380-1,240 mamsl, formed by Cretaceous to Cenozoic sedimentary rock bodies.

2.- The lithostratigraphic sequence includes the Sierra Madre Limestone (Middle Cretaceous, light olive gray, thickly bedded biomicrite), the Angostura Formation (Late Cretaceous, light gray, medium bedded, sparsely fossiliferous biomicrite to biomicrudite and calcarenite), the Soyaló Formation (Paleocene, gray, shaly, thin bedded, arkosic-phyllarenitic, clayey siltstone), the El Bosque Formation (Early Eocene, grayish red, medium to thick bedded, phyllarenitic sandstone and breccioid conglomerate), and the San Juan Formation (Middle Eocene, marly -quartz-phyllarenitic-biomicrite to biosparrudite with biostromic zones, intercalated with biomicrudite-supported, coarse grained sand-granule-to-gravel, quartz phyllarenitic sandstone to conglomerate; upper third is less limy), which makes up La Mesa de Copoya -i.e., the chief physiographic feature in the area-, and bears the name-sake selachifauna. Quaternary deposits complete the sequence.

3.- The Pre-Quaternary units are broadly folded into a NW-SE trending syncline, disrupted by faults. The area largely records Cretaceous-Paleogene marine sedimentation –punctuated by Early Eocene continental deposition– that ceased sometime during the Tertiary, probably by Late Miocene time, because of a change in the tectonic regime that led to folding, fracturing/faulting and regional uplift.

Subsequent erosion nearly removed the Tertiary units, which remain partly preserved in the syncline nucleus.

ACKNOWLEDGEMENTS

These are expressed in Part II.

BIBLIOGRAPHY

Allison, R. C., 1967, The Cenozoic stratigraphy of Chiapas, Mexico, with discussions of the classification of the Turritellidae and selected Mexican representatives: Univ. California (Berkeley), Ph. D. Dissertation, 319 p., unpublished.

ACSN (American Commission on Stratigraphic Nomenclature), 1961, Code of Stratigraphic Nomenclature: American Association of Petroleum Geologists, Special Publication, 22 p.

———1970, Code of Stratigraphic Nomenclature, 2º Ed.: American Association of Petroleum Geologists, Special Publication, 28 p.

Aguilar-Piña, M., 1993, Bioestratigrafía general del Terciario (Paleogeno) de la Localidad El Jobo, Tuxtla Gutiérrez, Chiapas: Universidad Nacional Autónoma de México, Facultad de Ciencias, Tesis Profesional, 59 p., unpublished.

Alencaster, G., and Michaud, F., 1990, Rudistas (Bivalvia-Hippuritacea) del Cretácico Superior de la Región de Tuxtla Gutiérrez, Chiapas (México): Universidad Autónoma de Nuevo León, Facultad de Ciencias de la Tierra, Actas, v. 4, p. 175-193.

Böse, E., 1905, Reseña acerca de la geología de Chiapas y Tabasco: Instituto Geológico de México, Boletín 20, p. 5-100.

Butterlin, J., 1981, Claves para la determinación de macroforaminiféridos de México y del Caribe, del Cretácico Superior al Mioceno: México, D.F., Instituto Mexicano del Petróleo, 219 p. (Non ser. publ.)

Carfantan, J.C., 1986. Du Systeme Cordillerien nord-Amaericain au Domaine Caraibe-Etude geologique du Mexique Meridional: Université de Savoie, Travaux du Departament de Sciences de la Terre Num. 7, vol. I, 1-297 p., vol. II, Planch. I-XXII.

Castro-Mora, J., Schlaepher, C. J., and Rodríguez, E. M., 1975, Estratigrafía y microfacies del Mesozoico de la Sierra Madre del Sur, Chiapas: Asociación Mexicana de Geólogos Petroleros, Boletín, v. 27, p. 1-39.

CCGM (Comité de la Carta Geológica de México), 1968, Carta Geológica de la República Mexicana, escala 1:2,000,000, 3a Ed. México.

———1976, Carta Geológica de la República Mexicana, escala 1:2,000,000, 4a. Ed., México.

Contreras-Velázquez, H., 1956, Reseña de la Geología del Sureste de México: Congreso Geológico Internacional, XXa. Sesión, México, Excursión C-7, p. 39-122.

Cruz-Helú, P., Verdugo V., R., and Bárcenas, P., R., 1977, Origin and distribution of Tertiary conglomerates, Veracruz Basin, Mexico: American Association of Petroleum Geologists, Bulletin, v. 61, p. 207-226.

CSN (Committee on Stratigraphic Nomenclature), 1933, Clasification and nomenclature of rock units: American Association of Petroleum Geologists, v. 17 p. 843-868; and Geological Society of America Bulletin, v. 14, p. 423-459

Chubb, L. J., 1959, Upper Cretaceous of Central Chiapas, Mexico: American Association of Petroleum Geologists, Bulletin, v. 43, p. 725-756.

De la Llata, R., Gutiérrez, C. R., Moreno, C. R., Buchelli, G. M., and Carfantan, J. CH., 1979, Geología y Tectónica del Sureste de México, principalmente del Norte de Chiapas (Zona Peñitas-Chicoasen-Itzanturi): Universidad Nacional Autónoma de México, Instituto de Geología, Oficina Regional SE, Tuxtla Gutiérrez, Chiapas, Informe Final, 191 p. y 9 mapas esc. 1:50 000 de areas 15' x 20': Hojas Chapultepec, Chenaló, Copalo, Copainalá, Fitutal, Quechula, Sayulá, Simojovel, Soyaló y Tuxtla Gutiérrez.

De la Rosa, Z., J. L., Ebolim, A., and Dávila, S., M., 1989, Geología del Estado de Chiapas: Tuxtla Gutiérrez, Chis., CFE [Comisión Federal de Electricidad, (Subdir. Constr., Unid. Estud. Ingen. Civil, Superintend. Estud. Zona Sureste)], Publ. Especial G-10, viii + 192 p. and 1 geol. map esc. 1:500,000 (Publication of limited distribution).

Donnelly, T. W., Horne, G. S., Finch, R. C., and López-Ramos, Ernesto, 1990, Nothern Central America, the Maya and Chortis block, in Dengo, G. and Case, J. E., Edits., Decade of North American Geology, Volume H: The Caribbean Region. Boulder, Colo., Geological Society of America Inc., p. 37-76.

Durham, R. J., 1962, Classification of carbonate rocks according to depositional texture, in Ham, N. E., edit., Classification of carbonate rocks; Tulsa, Okla., American Association of Petroleum Geologists, Memoir 1, p. 108-121.

Durham, J.W., Arellano, A.R.V,. and Peck, J.H., 1955, Evidence for no Cenozoic Isthmus of Tehuantepec Seaways: Geological Society of America Bulletin, v. 66, p. 977-992.

Einsele, G., 1992, Sedimentary basins—Evolution, facies and sedimentary budget: New York, Springer-Verlag, x + 1-628 p.

Embry, A. F., and Klovan, F. E., 1971, A Late Devonian reef tract on northeastern Banks Island, Northwest Territories: Canadian Petroleum Geology, Bulletin, v. 19, p. 730-781.

Feldmann, R.M., Vega, F., Tucker, A.B., García-Barrera, P., and Avendaño, J., 1996, The oldest record of Lophoranina (Decapoda: Raninidae) from the Late Cretaceous of Chiapas, Southeastern Mexico: Journal of Paleontology, v. 70, p. 296-303.

Ferrusquía-Villafranca, I., 1976, Estudios geológico-paleontológicos en la Región Mixteca. Parte 1—Geología del área Tamazulapan-Teposcolula-Yanhuitlán, Mixteca Alta, Estado de Oaxaca: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín 97, 160 p.

———1996 (1997), Contribución al conocimiento geológico de Chiapas—El Area Ixtapa-Soyaló: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín 109, 130 p.

———in press (1998), Contribución al conocimiento geológico de Oaxaca—El área Laollaga-Lachivizá: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín 110.

Folk, R. L., 1959, Practical petrographic classification of limestones: American Association of Petroleum Geologists, Bulletin, v. 43, p. 1-38.

———1968, Petrology of Sedimentary Rocks: Austin, Tex, Hemphill's, 170 p.

Friedman, G. M., and Sanders, F. E., 1978, Principles of Sedimentology: New York, John Wiley & Sons, xiii + 792 p.

Fries, Carl, Jr., 1960, Geología del Estado de Morelos y de partes adyacentes de México y Guerrero, Región Central Meridional de México: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín 60, 236 p.

Frost, S. H., and Langenheim, R. L., JR., 1974, Cenozoic Reef Biofacies, Tertiary larger foraminifera and scleractinian corals from Chiapas, Mexico: Dekalb, Ill., Northern Illinois University Press, 388 p.

Goddard, E. N., Trask, P. D., Deford, R. K., Rove, 0. N., SingewaldI, J. T., Jr., and Overbeck, R. M., 1963, Rock Color Chart: Geological Society of America.

González-Alvarado, J., 1963, Exploración geológica del Area Tumbalá-Chilón, Chiapas, Coatzacoalcos, Ver., Petróleos Mexicanos, Superintend. Gen. Explor. Zona Sur, Informe Geológico No. 490, 107 p., unpublished.

———1965, Geología del Area Ixtapa-San Cristóbal de las Casas, Chiapas: Idem, Informe Geológico, Num. 507, unpublished.

Gutiérrez-Gil, R ., 1956, Bosquejo geológico del Estado de Chiapas: Congreso Geológico Internacional, XXa. Sesión, Excursión C-15, p. 9-32.

Haq, U.B., and Van Eysinga,W.B. 1994, Geological Time Table: New York, Elsevier Science Inc. (Wall Chart).

Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., and Smith, D.G., 1989, A Geologic Time Scale: New York, Cambridge University Press, 263 p.

Heuer, R. E., 1965, Geology of the Soyaló-Ixtapa Area, Chiapas, Mexico: University of Illinois at Urbana, M. Sc. Thesis, 146 p., unpublished.

INEGI (Instituto Nacional de Estadística, Geografía e Informática), 1984, Hoja Tuxtla Gutiérrez El5-D51, Carta Topográfica esc. 1:50,000: México, D. F., INEGI, SPP (Secret. Program. Presup., since 1992 part of the SHCP, Secret. Hda. Cred. Publ.).

———1985, Hoja Tuxtla Gutiérrez El5-11, Carta Geológica esc. 1:250,000: México, D. F., INEGI, SPP (Secret. Program. Presup., since 1992 part of the SHCP, Secret. Hda. Cred. Publ.).

Ingram, R. L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks: Geological Society of America Bulletin, v. 65, p. 937-938

Licari, J. P., 1960, Foraminifera of the Simojovel Region, Chiapas, Mexico: University of California at Berkeley, M. A. Thesis, 131, unpublished.

López-Ortiz, R. L., 1960, Geología y posibilidades petroleras de los sedimentos cretácicos en la parte sureste del frente de la Sierra Madre de Chiapas: Asociación Mexicana de Geólogos Petroleros, Boletín, v. 14, p. 135-151.

López-Ramos, Ernesto, 1975, Carta Geológica del Estado de Chiapas, escala 1:500,000: Universidad Nacional Autónoma de México, Instituto de Geología, Serie Mapas Geológicos Estatales (Blueprint map of limited distribution).

López-Vega, J, 1963. Informe Geológico del Area Bochil-San Cristóbal, Chiapas: Coatzacoalcos, Ver., Petróleos Mexicanos, Superintend. Gen. Explor. Zona Sur, Informe Geológico No. 499, unpubl.

Maurrasse, F.J-M.R. 1990a. Stratigraphic correlation for the Circum-Caribbean region, in Dengo, G., and Case, J.E., edits., Decade of North American Geology, Volume H: The Caribbean Region, Boulder, Colo., Geol. Soc. America Inc., Plate 4.

———1990b. Stratigraphic correlation for the Circum-Caribbean Region: The Caribbean Region, Boulder, Colo., Geol. Soc. America Inc., Plate 5a.

———1990c. Stratigraphic correlation for the Circum-Caribbean Region: The Caribbean Region, Boulder, Colo., Geol. Soc. America Inc., Plate 5b.

McBride, E. F., 1963, A classification of common sandstones: Journal of Sedimentary Petrology, v. 33, p. 664-669.

Meneses-Rocha, J. J., 1985, Tectonic evolution of the Strike-slip Fault Province of Chiapas, México: University of Texas at Austin, Master's Thesis, 315 pp, unpblished.

———1991. Tectonic development of the Ixtapa graben, Chiapas, Mexico: University of Texas at Austin, Ph. D. Dissertation, 425 p., unpublished.

Michaud, F., 1987, Stratigraphie et Paleontologie du Mesozoique du Chiapas (Sud-Est Du Mexique): Univ. Paris 6, Doct. Thesis, Mem. Strat. 6, 301 p., unpubl.

Michaud, F., and Fourcade, E., 1989, Paleogeografía del Campaniano Superior-Maestrichtiano de la Región Central del Estado de Chiapas (Sur de México): Universidad Autónoma de Nuevo León, Facultad de Ciencias de la Tierra, Actas, v. 2, p. 213-216.

Mülleried, F. K. G. 1957, La Geología de Chiapas: México, D.F., Ediciones del Gobierno del Estado de Chiapas, 180 p.

NACSN (North American Commission on Stratigraphic Nomenclature), 1983, North American Stratigraphic Code: American Association of Petroleum Geologists, Bulletin, v. 67, p. 841- 875, 11 figs., 2 tbs.

Pecheaux, J. F., 1984, Le Senonien Supérieur-Tertiare de Chiapas (S.E. Mexique) et ses macroforminiferes: Université de Nice, These Doct. 3me. Cycle, p v + 153.

Pindell, J.L., and Barrett, S.F., 1990, Geological evolution of the Caribbean Region—A plate tectonic perspective, in Dengo, G., and Case, J.E., edits., Decade of North American Geology, Volume H: The Caribbean Region: Boulder, Colo., Geological Society of America Inc., p. 405-431.

Quezada-Muñetón, J.M., 1987(1990), El Cretácico Medio-Superior y el límite Cretácico Superior Terciario Inferior en la Sierra de Chiapas: Asociación Mexicana de Geólogos Petroleros, Boletín, v. 39, p. 3-98.

Richards, H. F., 1962, Cyclic deposits in the Cretaceous Ocozocuautla Formation of Central Chiapas, Mexico: Journal of Sedimentary Petrology, v. 32, p. 99-103.

———1963, Stratigraphy of Early Mesozoic sediments in Southeastern Mexico and Western Guatemala: American Assoc. Petrol. Geol., Bull., v. 47, p. 1861-1870.

Rosales-Domínguez, M. C., Bermudez-Santana, J. C., and Aguilar-Piña, M., 1997, Mid and Upper Cretaceous Foraminiferas assemblages from the Sierra de Chiapas, Southeastern Mexico: Cretaceous Research, v. 18, p. 697-712.

Salvador, A., and Quezada-Muñetón, J. M., 1989, Stratigraphic Correlation Chart of the Gulf of Mexico Basin, in Salvador A., edit., The Gulf of Mexico Basin. Geology of North America, Vol. J, Plates, Plate 5. Boulder Colo., Geological Society of America Inc.

Sánchez-Montes de Oca, R., 1969, Estratigrafía y paleogeografía del Mesozoico de Chiapas: México, D. F., Instituto Mexicano del Petróleo, Seminario sobre Exploración Petrolera, Mesa Redonda Núm. 5, p. 1-31. (Publication of limited distribution).

———Coordinador, 1978, Libreto-Guía de la III Excursión Geológica al Sureste de México; IX Excursión Geológica de Petróleos Mexicanos: Coatzacoalcos, Ver., Petróleos Mexicanos, Superintend. Gen. Explor. Zona Sur, 58 p., 3 map scale 1: 1,000,000, 1 map scale 1: 2,000,000 and 2 structural sketch sections, unpublished.

———1979, Geología petrolera de la Sierra de Chiapas: Asociación Mexicana de Geólogos Petroleros, Boletín, v. 31, p. 67-97.

Sapper, K., 1894, Informe sobre la geografía física y la geología de los Estados de Chiapas y Tabasco: Agricultura, Minería e Industria de México, Boletín 3, p. 67-97.

Schuchert, C. 1935, Historical geology of the Antillean-Caribbean Region: New York, John Wiley and Sons Co., 811 p.

Steele, D. R., 1985(1986), Physical stratigraphy and petrology of the Cretaceous Sierra Madre Limestone, west-central Chiapas: Universidad Nacional Autónoma de México, Instituto de Geología, Boletín 102, Pt. 1, p. 1-101.

Verwiebe, W. A., 1925, Geology of Southern Mexico oil fields: Panamerican Geologist, v. 44, p. 121-138.

Webber, B. N., and Ojeda, R. J. 1957, Investigación sobre lateritas fósiles en las regiones Sureste de Oaxaca y Sur de Chiapas: Instituto Nacional de Recursos Minerales, Boletín 37, 67 p.

Woodring, W. P. 1954, Caribbean land and sea through the ages: Geological Society of America Bulletin, v. 65, p. 719-732.

———1957-1964, Geology and Paleontology of the Canal Zone and adjoinig parts of Panama: United States Geological Survey Profesional Paper 306. Part A, p. 1-145; Part B, p. 146-239; Part C, p. 240-297.

———1970, Geology and Paleontology of the Canal Zone and adjoinig parts of Panamá; Description of Tertiary Mollusks (Gastropods: Eulimidae, Marginellidae to Helminthoglyptidae): United States Geological Survey Profesional Paper 306, Part D, p. 299-452.

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