Univ. Nal. Autón. México, Inst. Geología, Bol. 103, pt. 2, p. 103-245, 26 pls., 21 figs., 2 tables.

Part 2

BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL ANALYSIS OF THE SIERRA MADRE LIMESTONE (CRETACEOUS), CHIAPAS

by

LOWELL E. WAITE

Mobil Exploration and
Production-Research Division
Houston, Texas

Study completed within the framework of an agreement for mutual scientific collaboration of the University of Texas at Arlington with Instituto de Geología of Universidad Nacional Autónoma de México

TABLE OF CONTENTS

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

TABLE OF CONTENTS *(continued)*

ILLUSTRATIONS

ILLUSTRATIONS *(continued)*

SUMARIO

La Caliza Sierra Madre, de edad cretácica, aflora en el Estado de Chiapas en la parte suroriental de México, donde consiste de unos 2,575 m[1] o más de calizas y dolomitas acumuladas en la parte interna de la plataforma. Esta unidad estratigráfica, que constituye una roca almacenadora importante de hidrocarburos de la franja prolífica de La Reforma en la región de la Sonda de Campeche que se encuentra más al norte, contiene un conjunto moderadamente rico de fósiles que sólo ha sido estudiado a nivel de reconocimiento previamente. El presente estudio constituye una investigación a fondo de la biota de la Caliza Sierra Madre que se presenta en afloramientos aledaños al poblado de Ocozocuautla en Chiapas centro-occidental, con objeto de determinar la edad de esta unidad estratigráfica y el ambiente de su depósito. La información aquí presentada puede sumarse a los datos litológicos y petrográficos detallados (véase Steele en la Parte 1 de este Boletín) y así tener un marco litológico-bioestratigráfico para la Caliza Sierra Madre en la parte centro-occidental del Estado de Chiapas.

La Caliza Sierra Madre en el área estudiada está formada de brecha de dolomita y dolomita (unos 825 m), cubiertas por 1,775 m de calizas fosilíferas. Las calizas pueden subdividirse en 10 unidades litológicamente distintas definibles bioestratigráficamente. De éstas, cuatro unidades, que constituyen la mayoría de los sedimentos, son calizas algáceas y de pellas, ricas en fangos y contienen foraminíferos y rudistas. Otras dos unidades delgadas están formadas por calizas ricas en fangos y por clásticos terrígenos finos y contienen foraminíferos planctónicos. Otras dos unidades delgadas consisten de calizas oolíticas, libres de fangos, mientras que una unidad contiene un conjunto mixto formado por fósiles planctónicos y bentónicos. No pudo estudiarse la última unidad de estas 10 por haber carecido de acceso. La brecha de dolomita y dolomita se consideran como pertenecientes a una sola unidad litológica distinta, aunque no fue estudiada en detalle por carecer de fósiles identificables.

Los foraminíferos y algas son los organismos dominantes de la Caliza Sierra Madre, aunque se presentan en cantidades variables moluscos, equinoides, corales, ostrácodos, esponjas, radiolarios, tubos de gusanos e icnofósiles. Los foraminíferos planctónicos y otros fósiles bioestratigráficamente significativos son lo suficientemente abundantes para la determinación precisa de la edad y ambiente de depósito de las calizas.

Con base en las primera y última ocurrencias de las especies de foraminíferos planctónicos, pueden definirse principalmente seis unidades informales bioestratigráficas en las calizas:

Zonas de foraminíferos bentónicos:
- zona de *Nummoloculina heimi*
- zona de *Pseudolituonella reicheli*
- zona de *Dicyclina schlumbergeri*

Zonas de foraminíferos planctónicos:
- zona de *Rotalipora cushmani*
- zona de *Marginotruncana marianosi*
- zona de *Whiteinella archeocretacea*

[1] Ver nota de pie en la p. 111.

La biozonificación sugiere que los 1,775 m superiores de la Caliza Sierra Madre en la parte centro-occidental de Chiapas son del Albiano-Santoniano medio. Aún es problemático definir la edad precisa de la brecha de dolomita y dolomita subyacentes, aunque su posición estratigráfica les infiere una edad neocomiana-aptiana. Una edad aptiana (o ligeramente más antigua) a santoniana media para la totalidad de la Caliza Sierra Madre permite su correlación parcial con la Formación Ixcoy del noroccidente de Guatemala y con las formaciones Cobán y Campur del suroriente de Guatemala.

El análisis estadístico, apoyado por computadora, de la ocurrencia de los fósiles y de la abundancia relativa de los tipos de fósiles encontrados en las unidades de caliza, permitió la definición de seis biofacies, representando cada una ambientes de depósito diferentes. La biofacies A, que consiste de miliólidos, algas rojas y bivalvos no rudistas, junto con la biofacies B que consiste principalmente de foraminíferos orbitolínidos, se interpretan como representativas de ambientes de plataforma interna a intermareas; las profundidades del agua probablemente fueron de 10 m o menos y las aguas probablemente no fueron restringidas, teniendo salinidades variables. La biofacies B, en la cual predomina *Pithonella* así como foraminíferos planctónicos, corales y esponjas, se interpreta como representativa de ambiente de plataforma media marina abierta, donde las profundidades del agua variaron de 10 a 30 m. La biofacies D, formada por oolitos y escombros de material esquelético desgastado y redondeado, se interpreta como representativa de depósito encima o cerca de un cayo de la plataforma o de un banco; las profundidades del agua fueron lo suficientemente someras para permitr una alta agitación junto o cerca de la base del oleaje de buen tiempo. La biofacies E, formada por algas verdes y fangos calcáreos, se considera como representativa de ambiente de intermareas, con aguas marinas normales cálidas y limpias dentro de la zona fótica. La biofacies F, que consiste de dolomita o fango calcáreo y algas verdes-azules, se interpreta como representativa de depósito en la zona de supramarea en aguas hipersalinas que periódicamente se secaron. A pesar de los ambientes de depósito de la Caliza Sierra Madre, que varían desde el de supramarea hasta el de plataforma media abierta, la mayor parte de los sedimentos se depositó bajo condiciones de baja energía sobre una plataforma interna amplia, cubierta por aguas marinas someras algo restringidas. La presencia de estos ambientes durante el Cretácico en la parte centro-occidental de Chiapas apoya la teoría en cuanto a la existencia de una plataforma carbonatada grande de aguas someras en el sureste de México durante la mayor parte del Cretácico.

El análisis de la distribución de biofacies a través del tiempo muestra que los ambientes de depósito cambiaron de acuerdo con un patrón regular y predecible de crecimiento (*aggradation*) de la plataforma, seguido por inundación marina. Tres ciclos de disminución/aumento en la profundidad están registrados en los sedimentos de la plataforma interna de la Caliza Sierra Madre, cada uno de los cuales tuvo una duración de 5-10 Ma. Se registraron cotas altas relativas del nivel del mar en dos ocasiones, una durante el Cenomaniano medio-tardío y la otra durante el Coniaciano-Santoniano; se aprecian cotas bajas durante el Cenomaniano medio y Turoniano. Las causas de tales ciclos encima de una plataforma carbonatada amplia y de agua somera probablemente sean complejas y pudieran haber resultado de una combinación de ajustes del nivel global del mar, de la producción local de carbonatos y de la actividad tectónica del macizo de Chiapas cercano.

Hace aproximadamente 80 Ma, durante el Santoniano medio, finalizó el depósito de la Caliza Sierra Madre, cuando la actividad tectónica regional propició la invasión de la plataforma carbonatada por sedimentos clásticos. La producción de carbonatos se detuvo, terminando una era prolífica en la sedimentación carbonatada en el sureste de México.

ABSTRACT

The important hydrocarbon reservoir of the prolific Reforma oil-producing area of southern Mexico, the Sierra Madre Limestone (Cretaceous), crops out in Chiapas, where it consists of 2,600 m of platform interior limestones and dolomites.

In the outcrop area the Sierra Madre Limestone consists of 11 lithologic units. The lower 825 m (unit 1) is unfossiliferous beds of dolomite breccia. The upper 2,575 m[1] (units 2-11) includes miliolid and algal-bearing pellet wackestones and packstones containing a diverse benthonic foraminiferal population; coral and gastropod-bearing, sponge spicule wackestones with planktonic foraminifera; rudist-bearing skeletal and pellet wackestones and packstones; laminated lime mudstones; dolomitized mudstones; and ooid-bearing worn skeletal fragment grainstones. In west-central Chiapas the Sierra Madre Limestone conformably overlies the San Ricardo Group of Neocomian age and is unconformably overlain by the Ocozocuautla Formation of Campanian-Maastrichtian age.

Six informal biostratigraphic zones, based mainly on the first and last occurrences of key foraminiferal species, indicate that units 2-11 of the Sierra Madre Limestone range in age from late Albian (or slightly older) to early-middle Santonian in the study area and correlate with the upper two-thirds of the Ixcoy Formation of northwestern Guatemala and the upper two thirds of the Coban Formation and the lower part of the Campur Formation of southeastern Guatemala.

Six biofacies are defined in the Sierra Madre Limestone on the basis of fossil occurrences and relative abundance. The environments of deposition indicated by these biofacies include a highly restricted marine lagoon and platform evaporitic environment, a restricted to open inner shelf and intertidal environment, a high energy shoal or middle shelf bank environment, and an open, low energy middle shelf environment. Most of the Sierra Madre Limestone in west-central Chiapas was deposited in low energy, inner shelf water in depth of 10 m or less, although intervals of high energy deposition and three deeper water zones are present.

The Sierra Madre Limestone includes three marine sedimentary cycles recorded by platform interior sediments. Each cycle was of approximately 5-10 Ma duration and began with deepening of the water and ended with shallowing of the water. The cycles probably resulted from the interrelationship of local carbonate production levels, local and regional tectonics, and local and world-wide sea level fluctuations.

[1] See foot note on p. 111.

INTRODUCTION

The Cretaceous Sierra Madre Limestone is exposed in Chiapas, the southernmost state of the Republic of Mexico (Figure 1) where it comprises approximately 2,600 m[1] of platform interior limestones and dolomites. Although the Sierra Madre Limestone is a major hydrocarbon-producing formation in the Reforma oil fields of the Bay of Campeche area to the north and its age and depositional record are important in interpreting broader aspects of the Mesozoic history of the Gulf of Mexico region, the geology of the Sierra Madre Limestone remains relatively unknown.

This research represents the initial stages of a regional study undertaken by faculty members at The University of Texas at Arlington, within the framework of an agreement for mutual scientific collaboration with the Instituto de Geología, Universidad Nacional Autónoma de México, to understand Mesozoic tectonics and basin formation in southern Mexico.

PURPOSE OF STUDY

The purpose of this study is to document the age and depositional environments of the Sierra Madre Limestone in west-central Chiapas primarily on the basis of its fossil content, and to compare these findings with the results of Steele's (1982) petrographic study of this stratigraphic unit in the same area.

SIGNIFICANCE OF STUDY

The age of the Sierra Madre Limestone spans much of Cretaceous time. The formation was deposited in the ancestral Gulf of Mexico and has become a principal hydrocarbon reservoir of the Reforma oil fields (Figure 1). Proven and potential oil reserves for this region are estimated to be greater than 34 billion barrels (Viniegra-Osorio, 1981). The geographic location of the outcrop area and the deeply weathered jungle-covered outcrops of the formation have discouraged field studies of the formation and few details of the age, lithology, paleontology, and depositional environments of the Sierra Madre

[1] Subsequent work in the area south of Río Venta and directly across the river from measured Section X (Figure 1, Plate 1) by Guillermo Moreno (The University of Texas at Arlington graduate student) has demonstrated that the combined thickness of units 1, 2, and 3 (Figure 4, and Plate 1) is 2,140 m and not 1,286 m as estimated during the course of this investigation. Thus the total thickness of the Sierra Madre in this area would be 3,429 m.

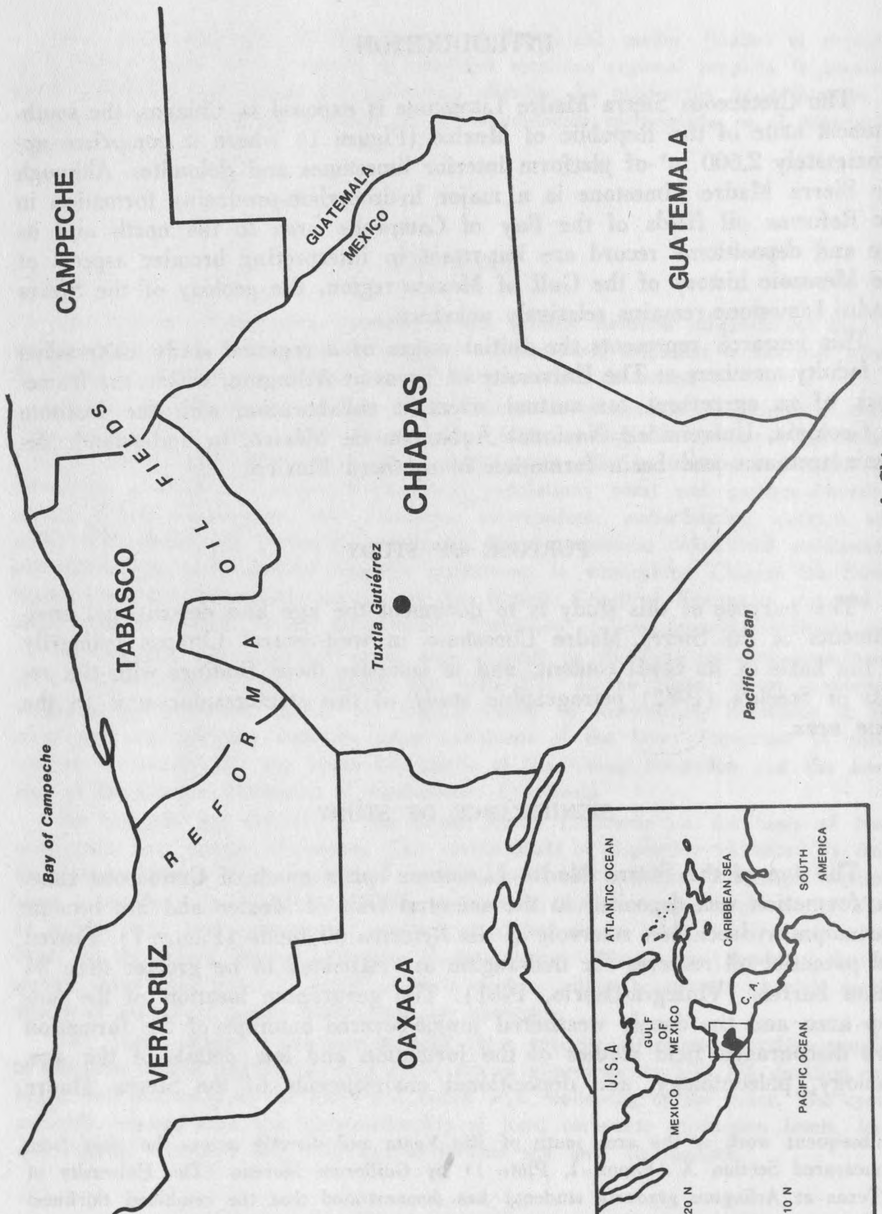


FIGURE 1.—Location map of Chiapas.

Limestone are known. The present study and that of Steele (1982 and Part 1 of this Boletín) present a detailed lithostratigraphic and biostratigraphic framework of the Sierra Madre Limestone in west-central Chiapas. Extension of these studies can provide a basis for interpreting the subsurface Cretaceous stratigraphy in southern Mexico and the geologic history of this important oil province in the Bay of Campeche area.

AREA OF STUDY

The Sierra Madre Limestone crops out in broad bands trending northwest-southeast throughout a large region of central Chiapas (Figure 2). The present study was conducted in an area of approximately 50 km², about 40-50 km west of Ocozocuautla (Figure 3). A relatively good road system provides access throughout the study area.

Exposures of the Sierra Madre Limestone are generally poor due to overgrowth of thick tropical vegetation and the development of karst topography. Best exposures of the formation in the study area occur along the Pan American Highway and along the Río Venta (Figure 3). Several important measured section localities are accessible via unpaved roads and foot paths. Access to many localities during the summer months (wet season) is possible only by four-wheel drive vehicle or by foot, due to daily afternoon tropical rains.

METHOD OF STUDY

A detailed, composite, 2,590 m thick stratigraphic section was measured, described, and correlated during 10 weeks in the summer of 1980. The establishing of relationships among widely distributed exposures was made possible by the relatively simple geological structure of the study area; consequently, the composite stratigraphic column was constructed with a significant degree of confidence. Field work was done with David R. Steele of the University of Texas at Arlington, who has done a detailed petrographic analysis of the Sierra Madre Limestone (Steele, 1982 and Part 1 of this Boletín).

Stratigraphic thicknesses of individual measured sections were determined with the use of a Jacob's staff and Brunton compass. Where outcrop control was poor, thicknesses were estimated using the method of Mandelbaum and Sanford (1952). A sampling interval of 3 m was generally used to collect rock samples, unless significant lithologic changes were noted over a smaller interval. Over 600 rock samples were recovered and brought back to the University of Texas at Arlington for detailed study.

All rock samples were slabbed, etched with dilute hydrochloric acid, and

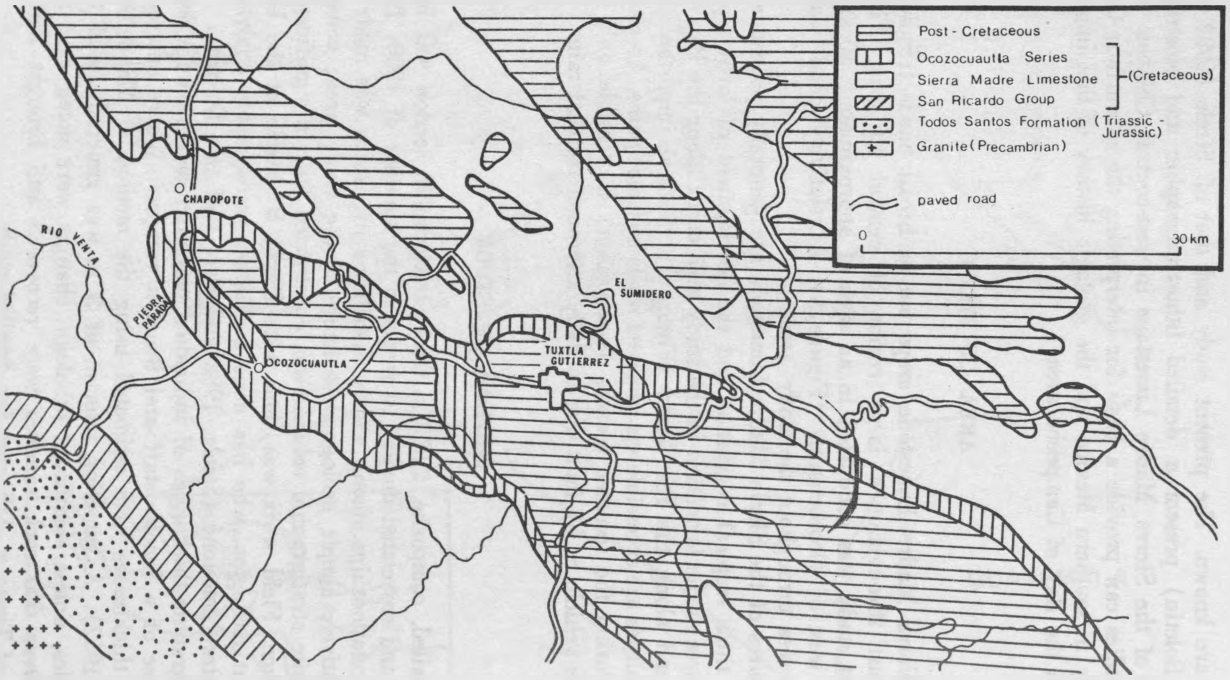


FIGURE 2.—Generalized geologic map of central Chiapas (from Chubb, 1959).

FIGURE 3.—Main area of study, west-central Chiapas.

polished on one side to enhance details. Visual examination of slabbed samples under a low power binocular microscope allowed for the selection of individual samples to be thin sectioned. Approximately 500 thin sections were examined in the present study.

Individual thin section samples were examined under low power with a petrographic microscope, and were described using the carbonate rock classification scheme of Dunham (1962). Since the Sierra Madre Limestone is highly indurated and fossils do not weather freely from it, most biologic components were best studied in thin section. Thin section analysis allowed most microfossils contained in each sample to be identified and classified to the generic or specific level.

The occurrence and relative abundance of each fossil type were recorded for each sample. For any given sample, fossils were separated into taxonomic groups and counted. Each group was assigned to an arbitrary relative abundance category: absent; rare (1-5 individuals per sample); sparse (6-10 individuals per sample); common (11-25 individuals per sample); or abundant (> 25 individuals per sample).

First and last occurrences of foraminiferal species and genera allowed for the definition of six informal biostratigraphic zones which can be compared with other local zonations (*i.e.*, Castro-Mora *et al.*, 1975) and general zonations (*i.e.*, Van Hinte, 1976).

Depositional environments of the Sierra Madre Limestone were determined by defining six biofacies based mainly on fossil content. Biofacies were determined quantitatively with the use of a C.D.C. Cyber 760 computer by generating a correlation matrix and cluster analysis of the data (Harbaugh and Merriam, 1969; Kaesler, 1969; Purdy, 1963). A detailed discussion of the methods used appears in a following section of this text. Paleoenvironmental interpretations based on individual biofacies were made by comparing these associations with both modern and other ancient biological associations.

ACKNOWLEDGMENTS

This publication is the result of M. S. thesis research completed at the University of Texas at Arlington, under the direction of Dr. B. F. Perkins. The author wishes to express his appreciation to Dr. Perkins and to the thesis committee members, Dr. C. I. Smith and Dr. Burke Burkart, for their assistance with the research and preparation of the manuscript. The writer is especially grateful to David R. Steele, friend and field partner, who equally contributed toward completion of the measured sections and preparation of samples for laboratory examination. Ing. Luis Lozano, of the Comisión Federal de

Electricidad, graciously provided field assistance in the form of maps, lodging, and technical advice from his staff.

The following individuals provided technical advice which greatly facilitated the paleontological analysis: J. P. Beckmann, University of Zürich; B. K. Rogers, Mobil Exploration and Producing Services, Inc.; J. F. Longoria, The University of Texas at Dallas; C. L. McNulty, The University of Texas at Arlington; and I. Premoli-Silva, University of Milan. C. T. Kalkomey, Mobil Research and Development, provided advice with the computer assisted statistical analysis of paleontologic data. D. W. Kirkland and S. E. Arkturk, also with Mobil, provided constructive criticism of the manuscript and supportive advice.

The United States Geological Survey, through a grant to The University of Texas at Arlington, financed the field, laboratory and manuscript preparation expenses.

REGIONAL GEOLOGIC SETTING

The Sierra Madre Limestone represents a part of the southern extension of a carbonate dominated depositional interval that existed in the ancestral Gulf of Mexico during most of Cretaceous time. Platform edge and platform interior carbonates of Cretaceous age in southern Mexico and northern Central America were formed in extensive carbonate bank and carbonate platform environments that existed in the region during this time and that has been called the "Great Carbonate Bank of Yucatán" by Viniegra-Osorio (1981). The Sierra Madre Limestone of Chiapas, and time equivalent carbonates in Guatemala comprise a major portion of the carbonate platform, both in time and space.

The most recent and widely accepted theories regarding the origin of the Gulf of Mexico indicate the Gulf was formed by the separation of South America from North America by rifting in Permo-Triassic time (Pindell and Dewey, 1982). As a result of early rifting, several large, arcuate-shaped graben basins separated by highlands began to form along the outer rim of the ancestral Gulf (Figure 4). In southern Mexico, the Chiapas-Guatemala basin extended southeastward from the Isthmian embayment through Chiapas and into Guatemala (Murray, 1961; Dengo, 1975). The basin is bounded to the southwest by the Chiapas massif (Sierra Madre del Sur), a batholithic complex composed of Precambrian metamorphic rocks and Upper Cambrian intrusives, and bounded to the northeast by the Libertad arch.

Early intermittent flooding of the Chiapas-Guatemala basin by marine waters occurred soon after initial rifting. By Late Jurassic time, two major depositional sequences had been established in southern Mexico (Figure 5). The first was composed mainly of salt and evaporites, which were presumably

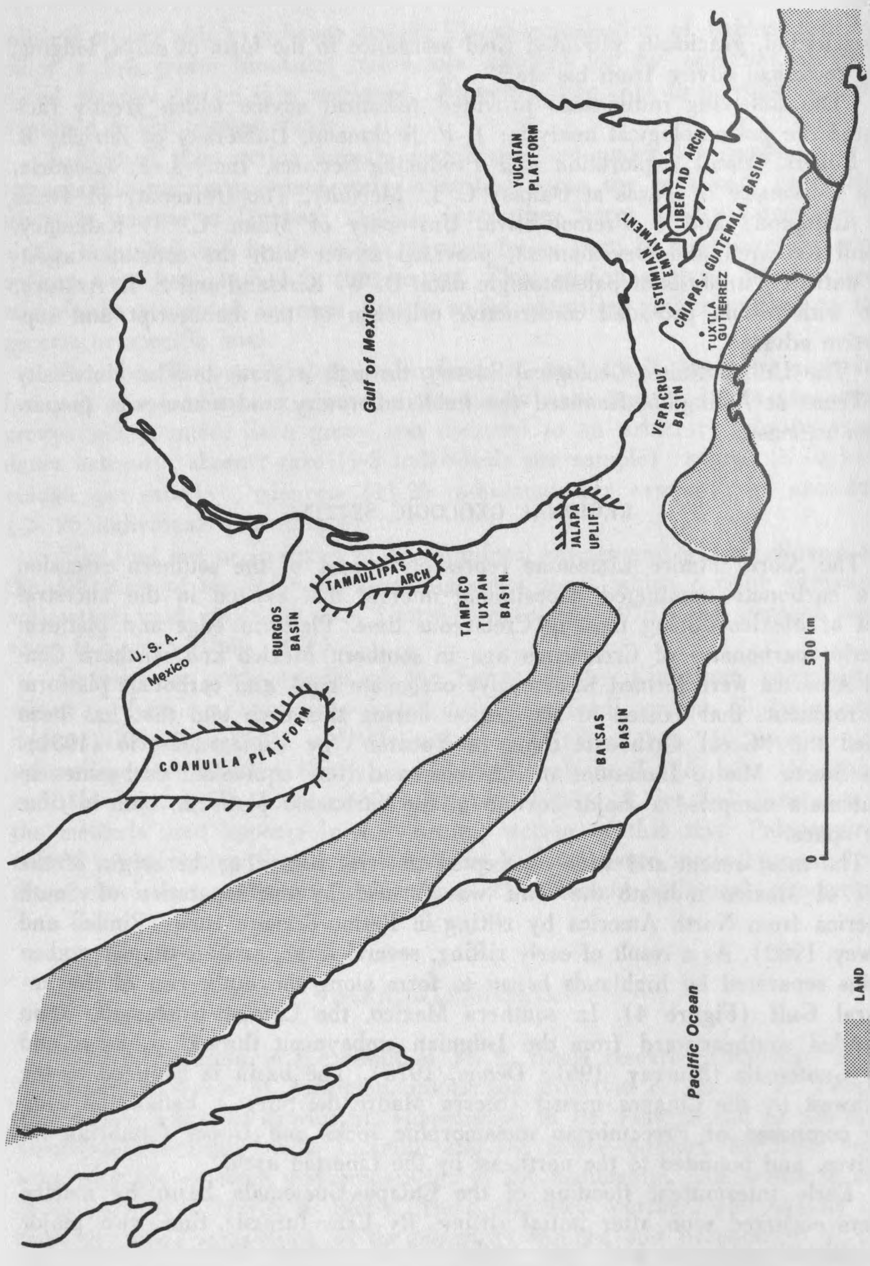


FIGURE 4.—Basins and adjacent highlands of Mexico.

precipitated out of shallow, hypersaline, ancestral Gulf of Mexico waters (Viniegra-Osorio, 1971). The second was composed of continental red beds. These red beds make up the Triassic-Jurassic Todos Santos Formation (Figure 6), which were deposited in large alluvial fans and braided streams that prograded off the Chiapas massif and adjacent highlands (Richards, 1963; Blair, 1981). Interbedded andesite and dacite volcanics associated with Todos Santos clastics have been radiometrically (K/Ar) age-dated by Castro-Mora and others (1975) as 148 $\pm$ 6 Ma (early Callovian) The Todos Santos red beds lie nonconformably on igneous and metamorphic rocks of the Chiapas massif in west-central Chiapas (Richards, 1963), and nonconformably on crystalline basement of slightly metamorphosed upper Paleozoic Santa Rosa Group in southern Chiapas and northwestern Guatemala (Burkart and Clemons, 1972).

The exact age of the salt and the stratigraphic relation between the salt and the red beds have been questioned by Viniegra-Osorio (1971, 1981) and by others. Most workers agree that most of the salt underlies the red beds but that some younger salt may be contemporaneous with red bed deposition (Viniegra-Osorio, 1971). According to Bishop (1980), the salt underlies the Berriasian Chinameca Limestone, therefore, "...the salt must be of Jurassic age and it is certainly pre-Berriasian" (Bishop, 1980).

By Late Jurassic-Early Cretaceous time, continental and evaporitic depositional cycles were gradually replaced by a pattern of more normal marine sedimentation and carbonate platform development. At this time, the north-south opening of the Atlantic Ocean led to the inundation of the Gulf of Mexico and surrounding land areas (Viniegra-Osorio, 1981). Subsidence of the Chiapas-Guatemala basin, combined with the transgressing marine waters, led to the formation of the Chinameca Limestone (Figure 6) which has been age-dated using microfossils as Tithonian-Hauterivian (Castro-Mora *et al.*, 1975). The Chinameca Limestone has been described as a dark, thin-bedded, sometimes sandy, deeper-water limestone (Contreras-Vázquez and Castillón-Bracho, 1968), with a mixed benthonic and planktonic fauna (Castro-Mora *et al.*, 1975). In southwestern Chiapas and Guatemala, time-equivalent sediments of the Chinameca Limestone were deposited. These marginal marine sediments, which consist of thin-bedded limestones, marl, shale, siltstone, sandstone, gypsum, and anhydrite, comprise the Neocomian San Ricardo Group (Richards, 1963; Castro-Mora *et al.*, 1975). Burkart and Clemons (1972) recognized that the San Ricardo sediments were missing in parts of northwestern Guatemala, as a result of local high paleotopography. Likewise, the San Ricardo sediments are not present everywhere in Chiapas (Castro-Mora *et al.*, 1975), perhaps due to the high paleotopography of the Chiapas massif. Hence, depending on Late Jurassic-Neocomian depositional topography, the Todos Santos-San Ricardo-Chinameca sequences (Figure 6) were deposited in continental, shallow marine, or deeper-water environments.

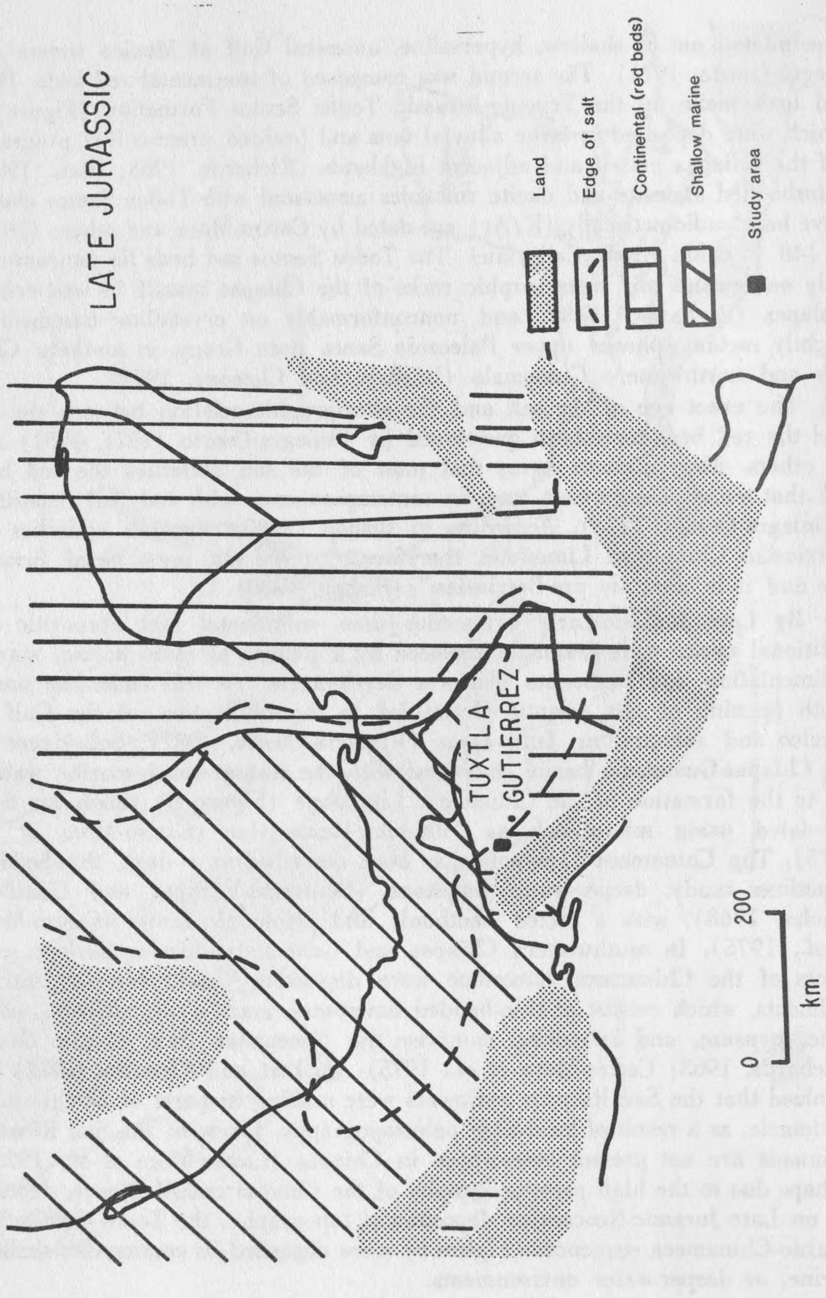


FIGURE 5.—Late Jurassic paleogeography, southern Mexico (after Viniegra-Osorio, 1981).

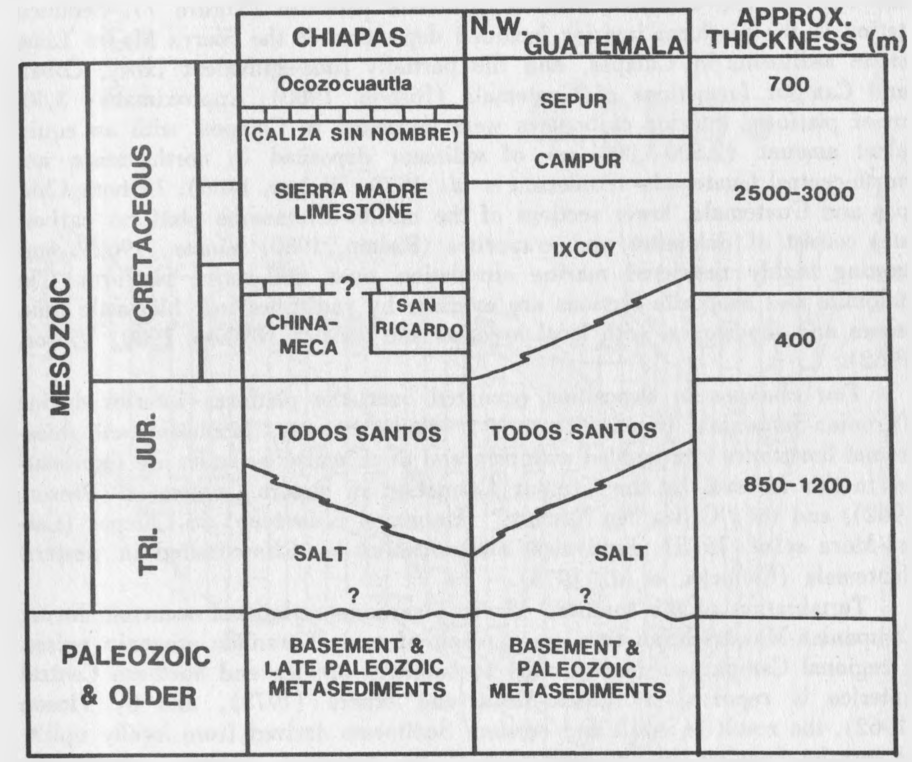


FIGURE 6.—Generalized Mesozoic stratigraphy, Chiapas and northwestern Guatemala (after Bishop, 1980).

Further subsidence of the Chiapas-Guatemala basin, together with an overall deepening of the transgressing marine waters, led to the stabilization of the carbonate platform by Aptian time (Viniegra-Osorio, 1981). By Albian-Cenomanian time, a seaward carbonate bank had also developed. Rudist-bearing shelf edge buildups, similar to the well known buildups of northern Mexico and Texas (Bay, 1977; Enos, 1974), were fully established around the edge of the southern Mexico carbonate platform (Figure 7). Sedimentation in the platform interior included deposition of the Sierra Madre Limestone sediments in Chiapas, and the partially time-equivalent Ixcoy, Coban, and Campur formations of Guatemala (Bishop, 1980). Approximately 3,400 m of platform interior carbonates were deposited in Chiapas, with an equivalent amount (2,500-3,000 m) of sediment deposited in northwestern and north-central Guatemala (Anderson *et al.*, 1973; Walper, 1960). In both Chiapas and Guatemala, lower sections of the middle Cretaceous platform carbonates consist of dolomites and evaporites (Bishop, 1980; Vinson, 1962), suggesting highly restricted marine circulation over the entire platform. The dolomite and evaporite sections are overlain by rudist-bearing, bioclastic limestones and mudstones, with local breccias and clastics (Bishop, 1980; Vinson, 1962).

Few changes in deposition occurred over the platform interior during Turonian-Santonian time (Figure 8). Rudist-bearing, bioclastic and biostromal limestones interbedded with thin and thick mudstone units are represented in this interval by the Campur Formation in eastern Guatemala (Vinson, 1962), and the "Caliza Sin Nombre" (Unnamed Limestone) in Chiapas (Castro-Mora *et al.* 1975). Equivalent strata cannot be differentiated in western Guatemala (Clemons, *et al.*, 1974).

Termination of the southern Mexican carbonate platform occurred during Campanian-Maastrichtian time, as a result of early Laramide orogenic pulses. A regional Campanian unconformity in southern Mexico and northern Central America is reported by Castro-Mora and others (1975), and by Vinson (1962), the result of uplift and erosion. Sediments derived from locally uplifted terrains resulted in the formation of the marginal marine Ocozocuautla series in Chiapas (Chubb, 1959), and the time-equivalent marginal marine Campur Formation of Guatemala (Vinson, 1962). Both of these formations are considered to be Campanian-Maastrichtian in age (Chubb, 1959; Vinson, 1962).

PREVIOUS STUDIES OF THE SIERRA MADRE LIMESTONE

Previous studies of the Sierra Madre Limestone have been on a reconnaissance level, and little detailed lithologic or paleontologic data have been

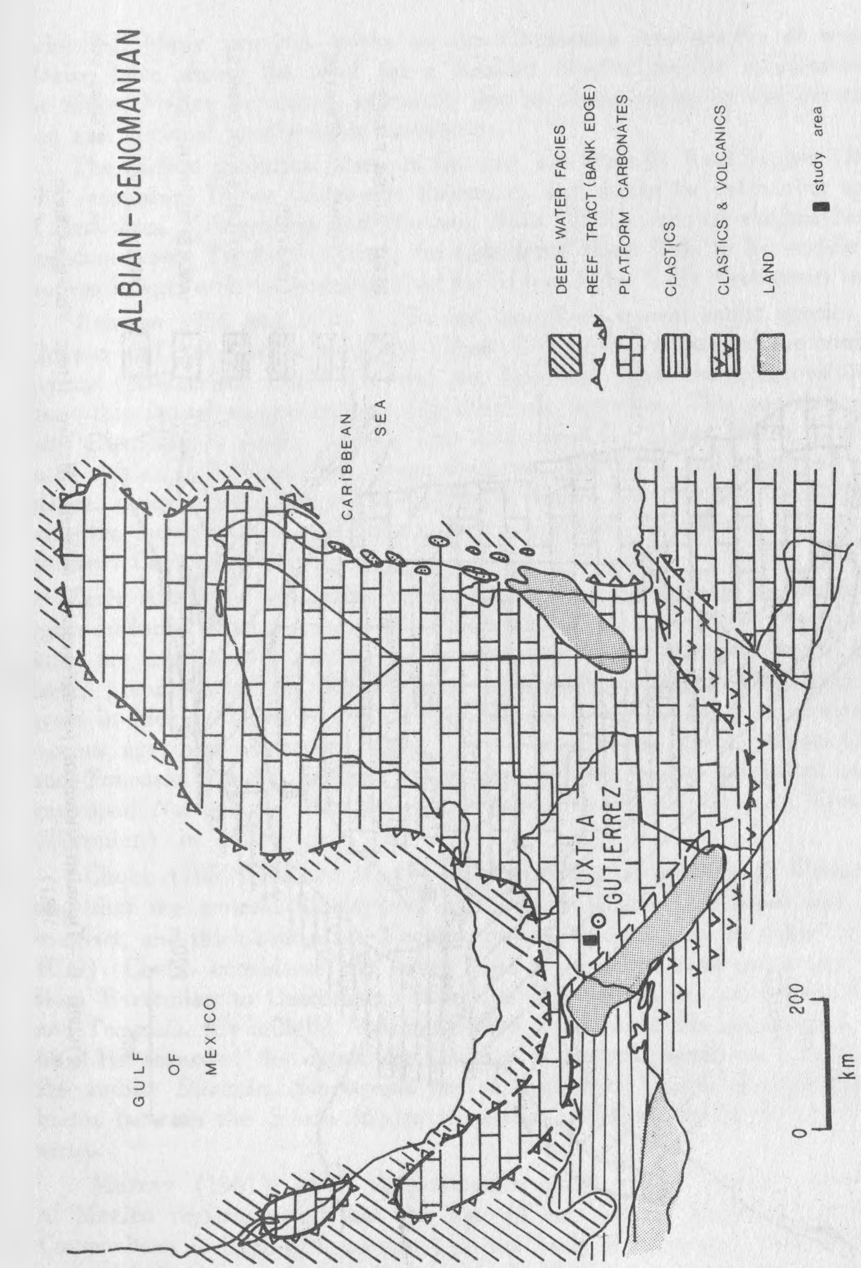


FIGURE 7.—Albian-Cenomanian paleogeography, southern Mexico (from Viniegra-Osorio, 1981).

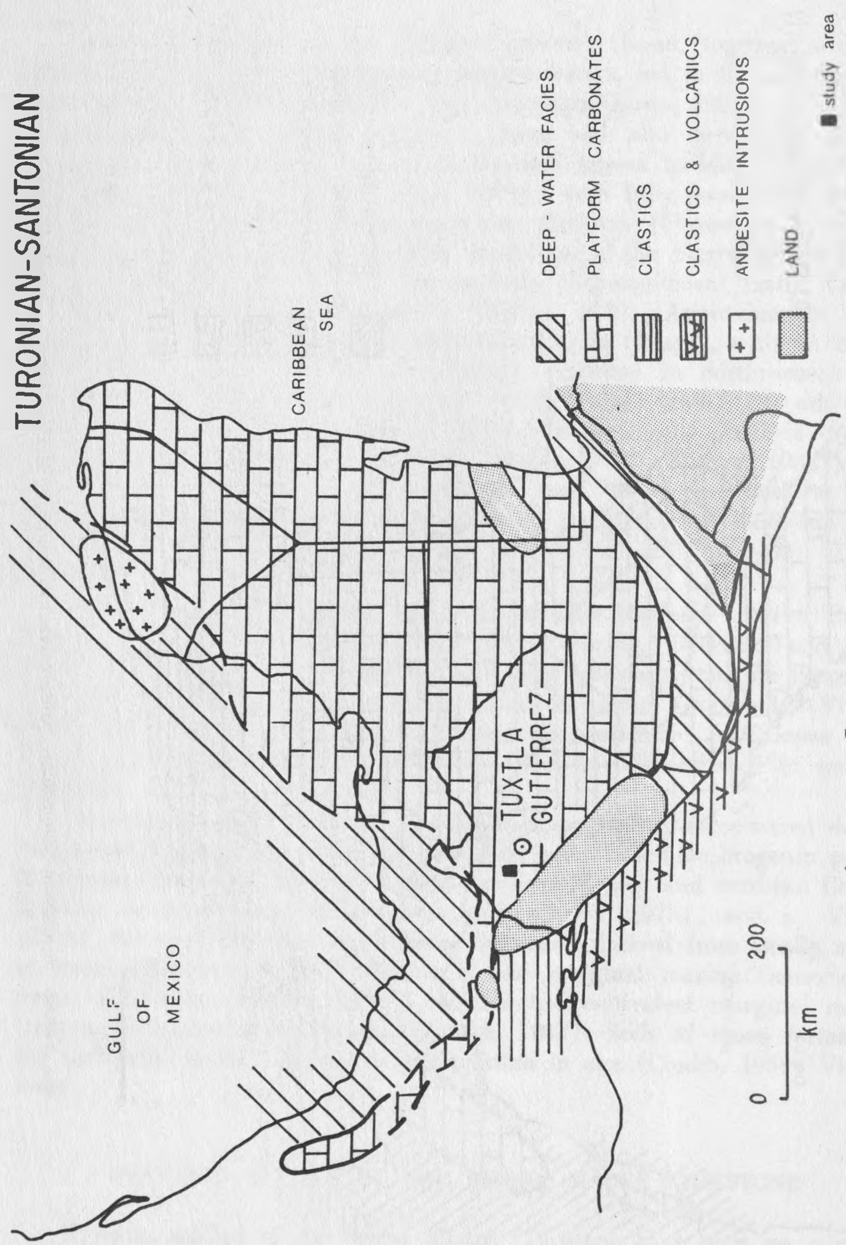


FIGURE 8.—Turonian-Santonian paleogeography, southern Mexico (from Viniegra-Osorio, 1981).

published. Many previous works on the Cretaceous stratigraphy of southern Mexico have shown the need for a detailed biostratigraphic examination of the Sierra Madre Limestone, primarily due to discrepancies in age determination and regional stratigraphic correlation.

The earliest geological study in Chiapas was done by Karl Sapper (1894), who recognized Upper Cretaceous limestones and dolomites containing species of *Radiolites, Sphaerulites* and *Nerinea*. Böse (1905) studied rudistid-bearing limestones near Tuxtla Gutiérrez; he considered these beds to be middle Cretaceous in age, and the bed described by Sapper to be Early Cretaceous in age.

Between 1930 and 1936, Müllerried described several rudist species from Chiapas and published a complete Upper Cretaceous rudist and ammonite sequence (Müllerried, 1942). He did not, however, show the relationship between this faunal succession and the lithologic sequence. This correlation was later attempted by Imlay (1944), who considered the Sierra Madre Limestone to be Aptian to Turonian in age on the basis of miliolid and gastropod assemblages. Imlay (1944) suggested the Sierra Madre Limestone to be correlative with the lower part of the Coban, Ixcoy, Comitan, and White limestones of northern Central America.

Early studies of the Sierra Madre Limestone by Petróleos Mexicanos geologists included work done by Ing. Gutiérrez-Gil in 1949-1950. Details of his study are unpublished, but the results were summarized in an Excursion Guidebook, prepared for the 20th Session of the International Geological Congress in Mexico (Gutiérrez-Gil, 1956). He assigned an Early to middle Cretaceous age to the limestone based on the occurrences of the rudists *Caprina* and *Toucasia*. On the basis of occurrences of the rudist *Radiolites* and the gastropod *Nerinea*, he considered the uppermost 150 m as Late Cretaceous (Turonian) in age.

Chubb (1959) studied the Upper Cretaceous formations of Chiapas, noting that the general lithology of the Sierra Madre Limestone was "hard, compact, and thick-bedded, and white, cream, or pale gray in color" (Chubb, 1959). Chubb considered the lower part of the limestone to range in age from Barremian to Cenomanian based on occurrences of the rudists *Caprina* and *Toucasia*, the miliolid *Nummoloculina heimi*, and the foraminifer *Cuneolina*. He regarded the upper age limit as Turonian, based on occurrences of the rudists *Durania, Sauvagesia* and *Distefanella*. Chubb also postulated a hiatus between the Sierra Madre Limestone and the overlying Ocozocuautla series.

Murray (1961), in a comprehensive study of the geology of the Gulf of Mexico region, noted that the age of the Sierra Madre Limestone was Comanchean (Albian-Cenomanian), on the basis of abundant rudistid, miliolid, and orbitolinid assemblages. He tentatively placed the upper age boundary as

Turonian, and correlated the Sierra Madre Limestone with the Coban, Ixcoy, Repasto, and White limestones of northern Central America.

López-Ramos (1969) presented a general stratigraphic column for the southeast Chiapas-northwest Guatemala region (López-Ramos, 1969, fig. 4), and divided the Sierra Madre Limestone into the lower Cantela member and the upper Jolpabuchil member. He described the Cantela member as thin-bedded, gray, sucrosic dolomite, grading upward into massive-bedded, gray, cream, and brown microcrystalline dolomite. Interbedded with the dolomite he noted two limestone beds containing planktonic foraminifera, but no detailed explanation was given as to the exact content or origin of the beds. The upper Jolpabuchil member was described as consisting of thin, alternating beds of gray to brown fossiliferous limestone, marly limestone, and lithographic limestone, and was age-dated as Turonian to Campanian. López-Ramos considered the Sierra Madre Limestone to be conformable in his study area with both the underlying Neocomian-Albian San Ricardo beds, and the overlying Campanian-Maastrichtian Ocozocuautla series. He indicated that the Sierra Madre Limestone was correlative with the upper two-thirds of the Coban Formation of Guatemala.

Zavala-Moreno (1971) examined the stratigraphy of the Sierra Madre Limestone in the Sumidero Canyon, north of Tuxtla Gutiérrez, and divided the section informally into two units based on lithology and age. He defined the lower Cantela member as consisting of dolomite and biomicrite, and noted these beds to contain orbitolinid foraminifera of early Albian age. This member is overlain by the upper Cintalapa member, which was reported to consist of fossiliferous lime wacke-, pack-, and grainstones of late Albian to Cenomanian age.

Castro-Mora and others (1975) did an extensive study of the stratigraphy and microfacies of the Mesozoic of the Sierra Madre del Sur. Their study included paleontologic information from 28 measured section localities, 25 of which included Sierra Madre Limestone beds. Like Zavala-Moreno (1971), Castro-Mora and others (1975) also divided the Sierra Madre Limestone into a lower Cantela member and an upper Cintalapa member. They reported that the Cantela member consisted of fine-grained dolomite and biomicrite, and considered it to be Albian in age, on the occurrences of *Orbitolina* and *Nummoloculina heimi*. The overlying Cintalapa member was described to consist of medium-grained dolomite, biogenic micrite, partially dolomitized micrite, and biogenic pelmicrite. The age of the Cintalapa member was considered to be Cenomanian, based on occurrences of the foraminifera *Nummoloculina heimi, Planomalina buxtorfi, Rotalipora appenninica,* and *Praeglobotruncana stephani*. Castro-Mora and others (1975) defined the upper age limit of the Sierra Madre Limestone as Cenomanian. Overlying the limestone they described the "Caliza Sin Nombre" as consisting of interbedded biomicrite, micrite, biogenic pelmicrite, and biogenic intramicrite. The "Caliza Sin Nombre" was age-dated as Turonian-Santonian, based on occurrences of *Dicyclina schlumbergeri, Pseudolituonella reicheli, Valvulammina picardi, Spiroloculina, Globotruncana sigali, Praeglobotruncana stephani, Pithonela,* and *Calcisphaerula*. They consider the Sierra Madre Limestone and the "Caliza Sin Nombre" to be unconformable with both the underlying San Ricardo beds and the overlying Ocozocuautla series, based on fossil occurrences.

Most recently, Bishop (1980) published a comprehensive study on the petroleum geology of northern Central America. He synthesized previous outcrop studies of the Sierra Madre Limestone and presented limited subsurface data describing the lithofacies of the unit. Bishop (1980) is in agreement with Chubb (1959) that the age of the limestone ranges from Neocomian to Turonian, but Bishop indicates that age dates for the lower part are scarce. Bishop (1980) considers the environment of deposition of the Sierra Madre Limestone to be shallow water, low energy, platform interior, and high energy bank edge and reef associated carbonates. He noted, however, that some deeper-water intervals were also present, based on microfaunal content. He also suggested the presence of a large, relatively nonrestricted carbonate platform in central and western Chiapas. His inference in regard to "non-restriction" is based on a lack of collapse breccias in Chiapas, compared to Guatemala. The equivalent Coban Limestone of Guatemala contains massive beds of evaporite-solution collapse breccia, which indicates a more restricted carbonate platform in Guatemala (Bishop, 1980).

Previous interpretation of the age limits of the Sierra Madre Limestone by various workers is shown in Figure 9.

As mentioned, regional correlation of the Sierra Madre Limestone with time-equivalent rocks in Guatemala is uncertain. Several workers have examined the Ixcoy and Coban Formations of Guatemala, and considered them to be coeval in part to the Sierra Madre Limestone (Figure 10). Walper (1960) studied the Cretaceous of Guatemala and considered the Ixcoy Formation to be Early Cretaceous in age, and the Coban Formation as Late Cretaceous. He noted the lower age limit of the Ixcoy as Neocomian, based on the occurrence of *Orbitolina*. He assigned the age of the Coban to be Cenomanian-Turonian, based on the occurrence of the miliolid *Vertebralina*. Walper (1960) considered the Ixcoy-Coban interval to be time-equivalent to the Sierra Madre Limestone of Chiapas.

Vinson (1962) defined the Coban Formation in Guatemala as ranging from Neocomian to Turonian in age, and considered the Ixcoy coeval with the lower Coban beds.

Anderson and others (1973) defined the Ixcoy Formation as the entire carbonate interval between the clastics of the Todos Santos Group (Jurassic) and the Sepur Formation (Campanian-Maastrichtian), and stated that the Ix-

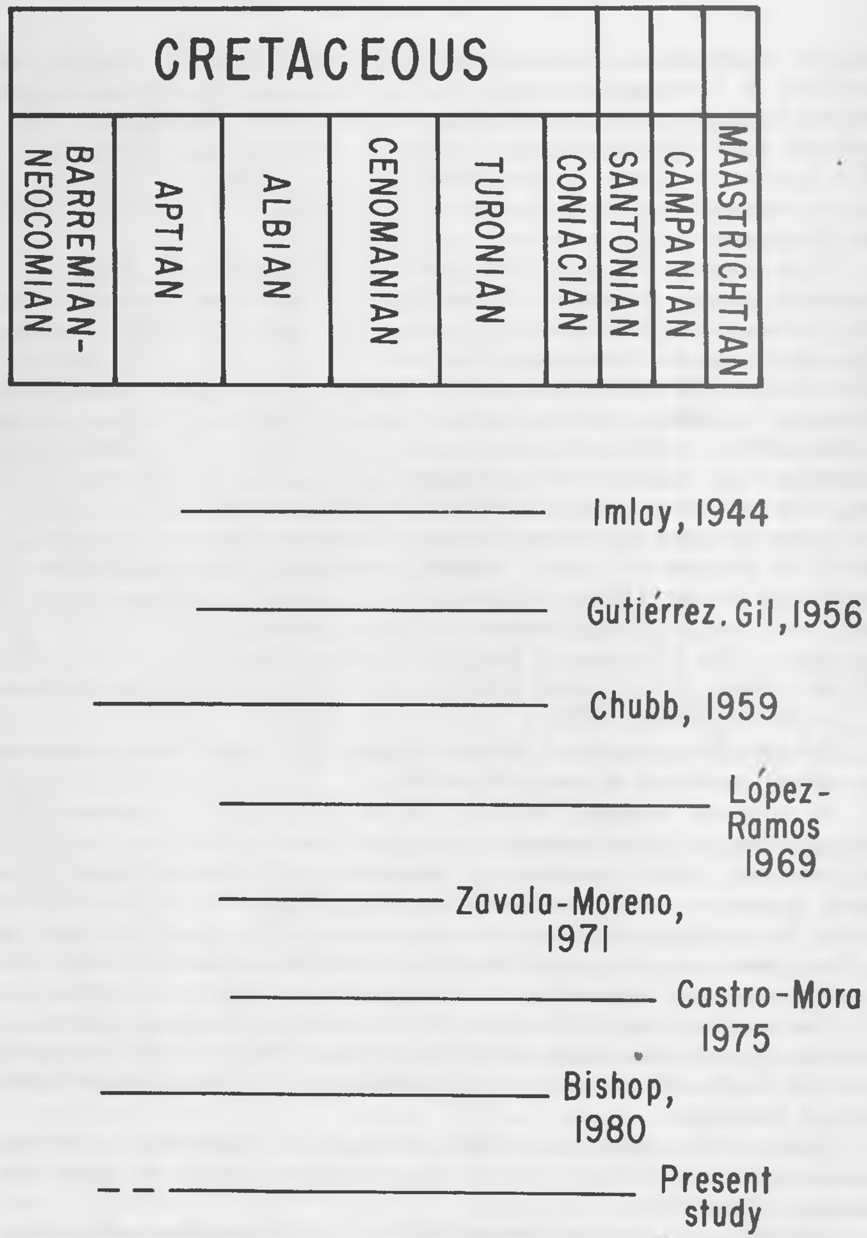


FIGURE 9.—Previous age interpretations of the Sierra Madre Limestone by various workers.

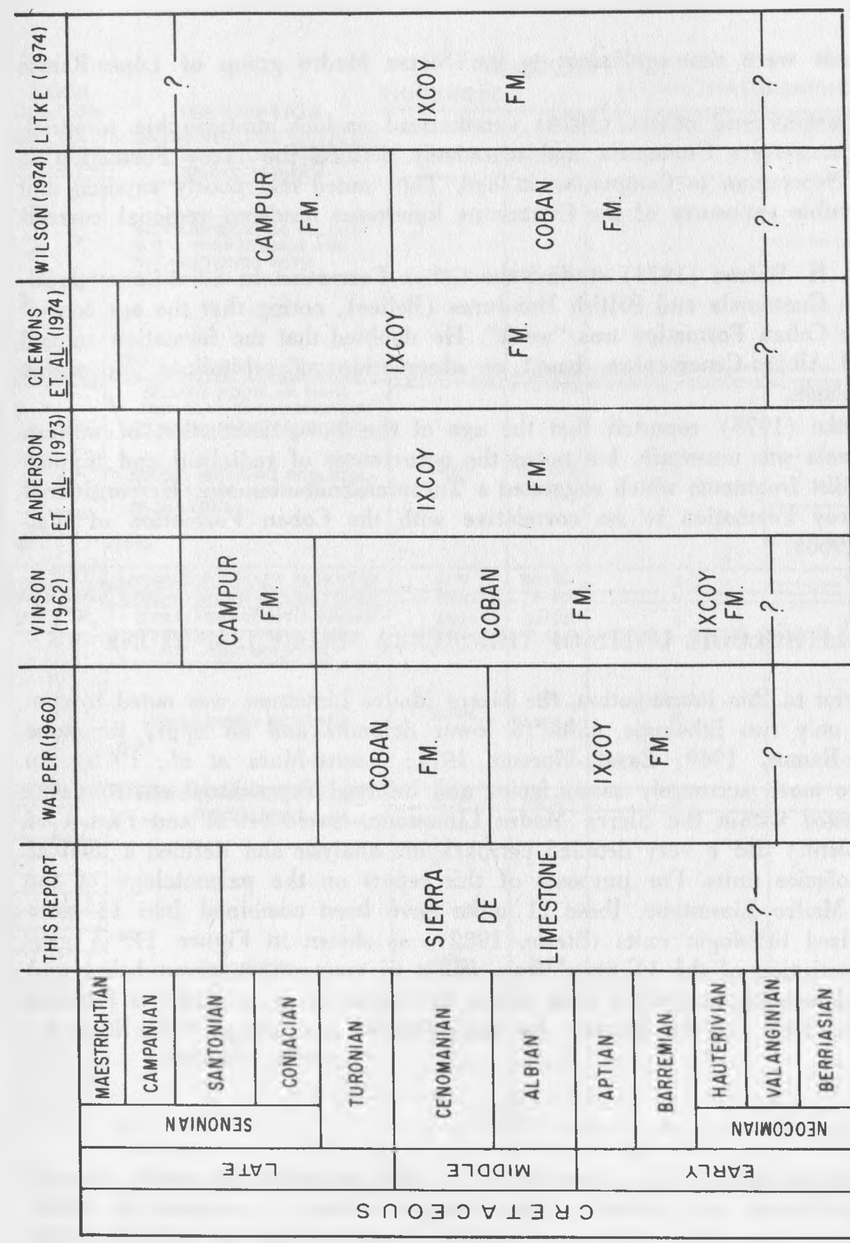


FIGURE 10.—Previous correlations of the Cretaceous limestones of Guatemala with the Sierra Madre Limestone.

coy beds were time-equivalent to the Sierra Madre group of López-Ramos (1969).

Clemons and others (1974) summarized various stratigraphic terminologies in western Guatemala and tentatively defined the Ixcoy Formation as being Neocomian to Campanian in age. They noted that poorly exposed and inaccessible exposures of the Cretaceous limestones hindered regional correlation.

H. H. Wilson (1974) studied the Coban Formation in 10 different localities in Guatemala and British Honduras (Belize), noting that the age control for the Coban Formation was "weak". He doubted that the formation ranged beyond Albian-Cenomanian, based on observations of orbitolinid and rudist assemblages.

Litke (1975) reported that the age of the Ixcoy Formation in western Guatemala was uncertain, but noted the occurrences of radiolitid and hippuritid rudist fragments which suggested a Turonian-Santonian age. He considered the Ixcoy Formation to be correlative with the Coban Formation of Walper (1960).

LITHOLOGIC UNITS OF THE SIERRA MADRE LIMESTONE

Prior to this investigation, the Sierra Madre Limestone was noted to consist of only two lithologic units: a lower dolomite and an upper limestone (López-Ramos, 1969; Zavala-Moreno, 1971; Castro-Mora *et al.*, 1975). In order to more accurately assess facies and inferred depositional environments represented within the Sierra Madre Limestone, Steele (1982 and Part 1 of this Boletín) did a very detailed petrographic analysis and defined a total of 21 lithofacies units. For purposes of this report on the paleontology of the Sierra Madre Limestone, these 21 units have been combined into 11 more generalized lithologic units (Steele, 1982), as shown in Figure 11. A general description of the 11 units, from oldest to youngest, is given below and their relationship to Steele's units shown in Figure 11. The reader is referred to Steele (Part 1 of this Boletín) for more detailed descriptions of the lithology.

UNIT 1

Description.—Unit 1 consists of a thick sequence of poorly exposed dolomite breccia and dolomite. The dolomite breccia is composed of small, angular to sub-angular, light gray to buff, dolomite clasts in a fine-grained, light gray dolomite matrix. Rare exposures of the dolomite breccia show bedding to be thin and slightly nodular. The dolomite breccia weathers to a grassy

ROCK COLUMN

DESCRIPTION	THICKNESS	SAMPLE#	LITHOSTRATIGRAPHIC UNIT: THIS REPORT	LITHOSTRATIGRAPHIC UNIT: AFTER STEELE (1982)
SLIGHTLY NODULAR DICYCLINA PACKSTONES WITH WHOLE RUDISTS	105m	481-512	11	21, 20
MILIOLID-BEARING PELLET-ALGAL PACKSTONES AND WACKESTONES WITH BENTHONIC FORAMINIFERA	551m	290-480	10	19, 18, 17
OOLITIC GRAINSTONES	28m	283-289	9	16
YELLOW NODULAR MARL AND CLAY WITH ABUNDANT PLANKTONICS, ECHINOIDS	17m	270-282	8	15
RUDIST-BEARING SKELETAL-PELLET WACKESTONES AND PACKSTONES.	465m	91-269	7	14, 13, 12, 11
LAMINATED PELLET PACKSTNS	37m	84-90	6	10
OOID-BEARING GRAINSTONES	25m	76-83	5	9, 8
CORAL-GASTROPOD WACKESTONES BEARING PLANKTONIC FORAMINIFERA	86m	62-75	4	4-7
UNMEASURED INTERVAL	384m	NO SAMPLES	3	3
MILIOLID-BEARING PELLET PACKSTONES	67m	25-61	2	2
DOLOMITE AND DOLOMITE BRECCIA	825m	1-24	1	1

Figure 11.—Generalized rock column and lithologic units of the Sierra Madre Limestone, west-central Chiapas.

slope that is discernible in the field. The breccia is thought to be of collapse origin, formed by the removal of a portion of the San Ricardo beds which contained gypsum and anhydrite.

Directly overlying the dolomite breccia is a thick, highly resistant section of coarse-grained, gray to light brown dolomite which grades upwards into fine-grained, dark gray to light gray dolomite (Plate 1, A). Both the coarse-grained dolomite and the younger fine-grained dolomite is vuggy in places, and fresh surfaces yield a strong petroliferous odor.

THICKNESS.—Due to poor outcrop control, the thickness of unit 1 was estimated by the method of Mandelbaum and Sandford (1952) to be 825 ± 35 m. In the study area, approximately 200-300 m of the total comprise the lowermost dolomite breccia.

LOCATION.—Rare exposures of unit 1 were studied along the Pan American Highway, from the lower contact of the Sierra Madre Limestone to Cascada El Aguacero (Figure 3; J-1 to H-6).

CONTACTS.—Field observations in the study area show a conformable lower contact between unit 1 and the underlying San Ricardo Group. Unit 1 is conformably overlain by unit 2.

CORRELATION.—Unit 1 corresponds to measured sections VII, II, VIII, XII, IX, IV and the lower 50 m of measured section V (Figure 3), and includes samples 1-24 (Figure 11). Unit 1 of this report correlates with unit 1 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Important sedimentological and paleontological structures observed in the field include molds of cerithid gastropods noted in measured section IX, algal laminations in measured sections IX and IV, and possible tepee structures (Plate 1, B) noted in measured section IV.

UNIT 2

DESCRIPTION.—Unit 2 consists of thin-bedded, light brown to dark miliolid wackestones and packstones with occasional mudstones, dolomite, intraclasts, and *Toucasia*-bearing pellet packstones.

THICKNESS.—The total thickness of unit 2 is 67 m.

LOCATION.—Unit 2 was studied at the "miliolid hills", along the west side of the roads to Cascada El Aguacero, near the intersection of the road and the Pan American Highway (Figure 3; F-6 and G-6).

CONTACTS.—Unit 2 conformably overlies unit 1, and is overlain by unit 3, an unmeasured interval.

CORRELATION.—Unit 2 corresponds to the upper 71 m of measured section V (Figure 3), and includes samples 25-61 (Figure 11). Unit 2 of this report correlates with unit 2 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—A small mound or buildup was noted approximately 23 m above the lower contact of unit 2. The mound consists of medium-bedded, *Toucasia*-bearing, shell fragment wackestones, with abundant miliolids and two inter-bedded mudstone units. Strata were noted to drape over the core of the mound (Plate 2, A). The presence of rudists together with the draping of younger beds over the mound may indicate a biologic structure with depositional topography. Other distinguishing features of unit 2 include a 20 cm bed near the top of the unit which exhibited a dark color with a strong petroliferous odor, several bioturbated beds and occasional laminated and stylolitic beds.

Unit 2 contains a microfauna dominated by the miliolid *Nummoloculina heimi* and the problematical red algae *Polygonella*. Other biota noted in unit 2 include sparse benthonic foraminifera, ostracod shell fragments and rare serpulid worm tubes.

UNIT 3

DESCRIPTION.—Unit 3 consists of an unmeasured interval. Accessible exposures of this part of the Sierra Madre Limestone could not be located in the study area.

THICKNESS.—Total thickness of unit 3 was estimated by the method of Mandelbaum and Sanford (1952) to be 384 m.

LOCATION.—The unmeasured interval was located on inaccessible sheer cliffs along the Río Venta (Plate 2, B).

CONTACTS.—The lower and upper contacts of unit 3 are not exposed.

CORRELATION.—Unit 3 of this study corresponds to unit 3 of Steele (1982 and Part 1 of this Boletín).

UNIT 4

DESCRIPTION.—Unit 4 consists of poorly exposed, thin-bedded, light brown, coral-gastropod wackestones and mudstones with sponge spicules, oysters and planktonic foraminifera.

THICKNESS.—Total thickness of unit 4 is 86 m.

LOCATION.—Unit 4 was studied near the Río Venta, approximately 7 km northwest of Ocozocuautla (Figure 3; A-1).

CONTACTS.—The contact of unit 4 and unit 3 is not exposed; however, unit 4 is conformably overlain by unit 5.

CORRELATION.—Unit 4 corresponds to the lowermost 86 m of measured section X (Figure 3), and includes samples 62-75 (Figure 11). Unit 4 of this study correlates with units 4, 5, 6, and 7 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 4 contains an important planktonic microfossil assemblage. *Pithonella* and planktonic foraminifera occur abundantly at various intervals, usually with interbeds of silicified oysters.

UNIT 5

DESCRIPTION.—Unit 5 consists of ooid-bearing, worn skeletal grainstones, and occasional coral and gastropod-bearing wackestones.

THICKNESS.—Total thickness of unit 5 is 25 m.

LOCATION.—Unit 5 was studied near the Río Venta, approximately 7 km northwest of Ocozocuautla (Figure 3; A-1).

CONTACTS.—Unit 5 conformably overlies unit 4, and is conformably overlain by unit 6.

CORRELATION.—Unit 5 corresponds to a 25 m interval of measured section X (Figure 3) and includes samples 76-83 (Figure 11). Unit 5 of this study correlates with unit 8 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 5 is distinguished in the field by the presence of trough cross-stratification, which weathers to a nodular appearance. Beds are heavily iron-stained. Small solitary corals, high-spired gastropods and rudist fragments were noted to occur throughout the unit.

UNIT 6

DESCRIPTION.—Unit 6 consists of laminated pellet packstones and mudstones, with a 25 m covered interval at the top of the unit.

THICKNESS.—Total thickness of unit 6 is 37 m, the upper 25 m being covered.

LOCATION.—Unit 6 was studied near the Río Venta, approximately 7 km northwest of Ocozocuautla (Figure 3; A-1).

CONTACTS.—Unit 6 conformably overlies unit 5 and is conformably overlain by unit 7.

CORRELATION.—Unit 6 corresponds to a 37 m interval of measured section X (Figure 3) and includes samples 84-90 (Figure 11). Unit 6 of this study corresponds to units 9 and 10 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 6 is distinguished by thick, lenticular beds and mudstones that exhibit millimeter-thick laminae. Microfossil occurrences include rare planktonic foraminifera (*Praeglobotruncana stephani*).

UNIT 7

DESCRIPTION.—Unit 7 consists of poorly exposed, thin to thick-bedded, light brown pellet and algal-bearing wackestones and packstones with miliolids, benthonic foraminifera, rudist bivalves, and mollusk and ostracod shell fragments.

THICKNESS.—Total thickness of unit 7 is 465 m.

LOCATION.—Unit 7 was studied in an area east of the Río Venta, approximately 5-7 km northwest of Ocozocuautla (Figure 3; A-2, B-4, C-5).

CONTACTS.—Unit 7 conformably overlies unit 6 and is conformably overlain by unit 8.

CORRELATION.—Unit 7 corresponds to the uppermost 336 m of measured section X (Figure 3), all of measured section XIII, and the lower 63 m of measured section XI (Figure 3). Unit 7 includes samples 91-269 (Figure 11). The study of unit 7 was complicated in the field by the presence of a faulted, overturned anticline, which occurs at the top of measured section X. The fault makes exact correlation between measured sections X and XIII uncertain.

Unit 7 of this report correlates with units 11, 12, 13, and 14 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 7 is distinguished by the first occurrence of large *Radiolites* shell fragments and occasional whole *Radiolites*. The rudist shell fragments are often winnowed and usually grade upward into a mudstone. Unit 7 is also characterized by a diverse microfauna consisting of benthonic foraminifera, algae, *Toucasia* fragments, and occasional miliolids. Burrowing is noted throughout unit 7 and becomes more frequent near the top of the unit, as does the occurrence of miliolids. Increased frequency of burrowing and an increase in the number of miliolids correlate well with an overall thickening of beds near the top of unit 7.

UNIT 8

DESCRIPTION.—Unit 8 consists of well exposed, highly weathered, yellow nodular marl with interbedded clay.

THICKNESS.—Total thickness of unit 8 is 17 m.

LOCATION.—Unit 8 was studied along a logging road, approximately 5-6 km northwest of Ocozocuautla (Figure 3; C-5).

CONTACTS.—Unit 8 conformably overlies unit 7 and is conformably overlain by unit 9.

CORRELATION.—Unit 8 corresponds to a small interval of measured section XI (Figure 3), and includes samples 270-282 (Figure 11). Unit 8 of this report correlates with unit 15 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 8 is a reliable stratigraphic marker in the study area due to lithology and contained biota. Two distinct nodular intervals were noted in the study area. The lower nodular interval consists of 13 m of dark yellow, relatively less resistant, highly weathered beds which contain several interbedded yellow-red to brown clay layers. Baseball-sized and smaller phosphatic and calcareous nodules weather out of the clays. Overlying the lower nodular interval is a 4 m-thick upper nodular interval containing dark gray, relatively more resistant beds which lack clay and form a prominent ridge.

Unit 8 contains a diagnostic fossil assemblage consisting of abundant whole echinoids, gastropods, clams and trace fossils, all of which weather out freely from the marl. In addition to these fossils, further collecting of the marl interval by C. I. Smith, Burke Burkart and J. G. McPherson, all of the University of Texas at Arlington, yielded two small ammonite specimens, one of which was vertically imbedded.

The phosphatic and calcareous nodules contain a microfossil assemblage consisting of *Pithonella* and planktonic foraminifera. This assemblage is near-identical to the planktonic assemblage of unit 4 (Premoli-Silva, personal communication, 1981).

UNIT 9

DESCRIPTION.—Unit 9 consists of well exposed, massive-bedded, light brown to gray, oolitic and rounded worn shell fragment packstones and grainstones.

THICKNESS.—Total thickness of unit 9 is 28 m.

LOCATION.—Unit 9 was studied along a logging road, approximately 5-6 km northwest of Ocozocuautla (Figure 3; C-5).

CONTACTS.—Unit 9 is conformably overlain by unit 10 and conformably overlies unit 8.

CORRELATION.—Unit 9 corresponds to a small interval of measured section XI (Figure 3) and includes samples 282-289 (Figure 11). Unit 9 of this study correlates with unit 16 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—Unit 9 consists entirely of oolites and highly winnowed, rounded, worn shell fragments in a calcite spar matrix (Plate 3). Samples near the bottom of the unit contain the coarsest grains and exhibit trough cross-stratification. Unit 9 fines upwards, the samples at the top of the unit being more muddy, fine-grained and worn. The biota of unit 9 is composed only of shell fragments, with rare miliolids, benthonic foraminifera and problematical red algae.

UNIT 10

DESCRIPTION.—Unit 10 consists of poorly exposed, light brown to cream, pellet, algal and miliolid-bearing wackestones and packstones, with occasional mudstones.

THICKNESS.—Total thickness of unit 10 is 551 m.

LOCATION.—Unit 10 was studied along a logging road, approximately 4 km northwest of Ocozocuautla (Figure 3; C-5 to C-6).

CONTACTS.—Unit 10 conformably overlies unit 9, and is conformably overlain by unit 11.

CORRELATION.—Unit 10 corresponds to the major part of measured section XI (Figure 3) and includes samples 290-480 (Figure 11). Unit 10 of this report correlated with units 17, 18, and 19 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—The lowermost 70 m of unit 10 consist primarily of mudstones and wackestones bearing miliolids, pellets, and algae. The mudstones are often finely laminated. Occasional whole oyster packstones or whole rudist packstones occur in this lowermost interval.

The next 360 m of unit 10 consist mainly of pellet, algal, and shell fragment packstones and wackestones, with occasional burrowed, laminated mudstones. The shell fragments consist primarily of *Radiolites* and oysters, and are often winnowed. Occasional whole rudist specimens occur in this interval.

The next 121 m of unit 10 are characterized by the occurrence of the robust gastropod *Actaeonella*? sp. Large, whole *Actaeonella*? in association with small whole rudists in growth position form small mounds, averaging 1-2 m in height and several meters in length at the top of this interval.

The remaining 10 m of unit 10 consist of mudstones and algal-bearing pellet packstones and wackestones that contain a diverse benthonic foraminiferal population, with rare planktonic foraminifera.

UNIT 11

DESCRIPTION.—Unit 11 consists of well exposed, medium to thick-bedded, light brown, nodular wackestones and packstones.

THICKNESS.—Total thickness of unit 11 is 105 m.

LOCATION.—Unit 11 was studied along a logging road in the Piedra Parada valley, and on the "x" hill, just northwest of Rancho San Luis (Figure 3; C-7 to C-8).

CONTACTS.—Unit 11 conformably overlies unit 10. The upper contact of unit 11 represents the upper contact of the Sierra Madre Limestone with the overlying Ocozocuautla series. In the study area this contact is not exposed, and is defined by the occurrence of abundant, iron-stained, sandstone float.

CORRELATION.—Unit 11 of this report corresponds to all of measured section VI (Figure 3) and includes samples 481-512 (Figure 11). Unit 11 of this report correlates with units 20 and 21 of Steele (1982 and Part 1 of this Boletín).

DISTINGUISHING FEATURES.—The base of unit 11 is characterized by highly nodular beds averaging 0.5 m in thickness. Small chert nodules, 3-8 cm in diameter, weather out of these nodular beds. The highly nodular beds contain a diverse benthonic foraminiferal population, including abundant occurrences of *Dicyclina schlumbergeri*. Also present are sparse miliolids, rare planktonic foraminifera, corals, sponge spicules, echinoid fragments, and radiolarians. Whole rudist bivalves in growth position are abundant in the top 55 m of unit 11. Largest specimens, 18 cm in diameter, occur at the very top of unit 11. Two individual rudist mounds which extend laterally for several meters were noted just below the top unit 11.

THICKNESS OF THE SIERRA MADRE LIMESTONE IN WEST-CENTRAL CHIAPAS

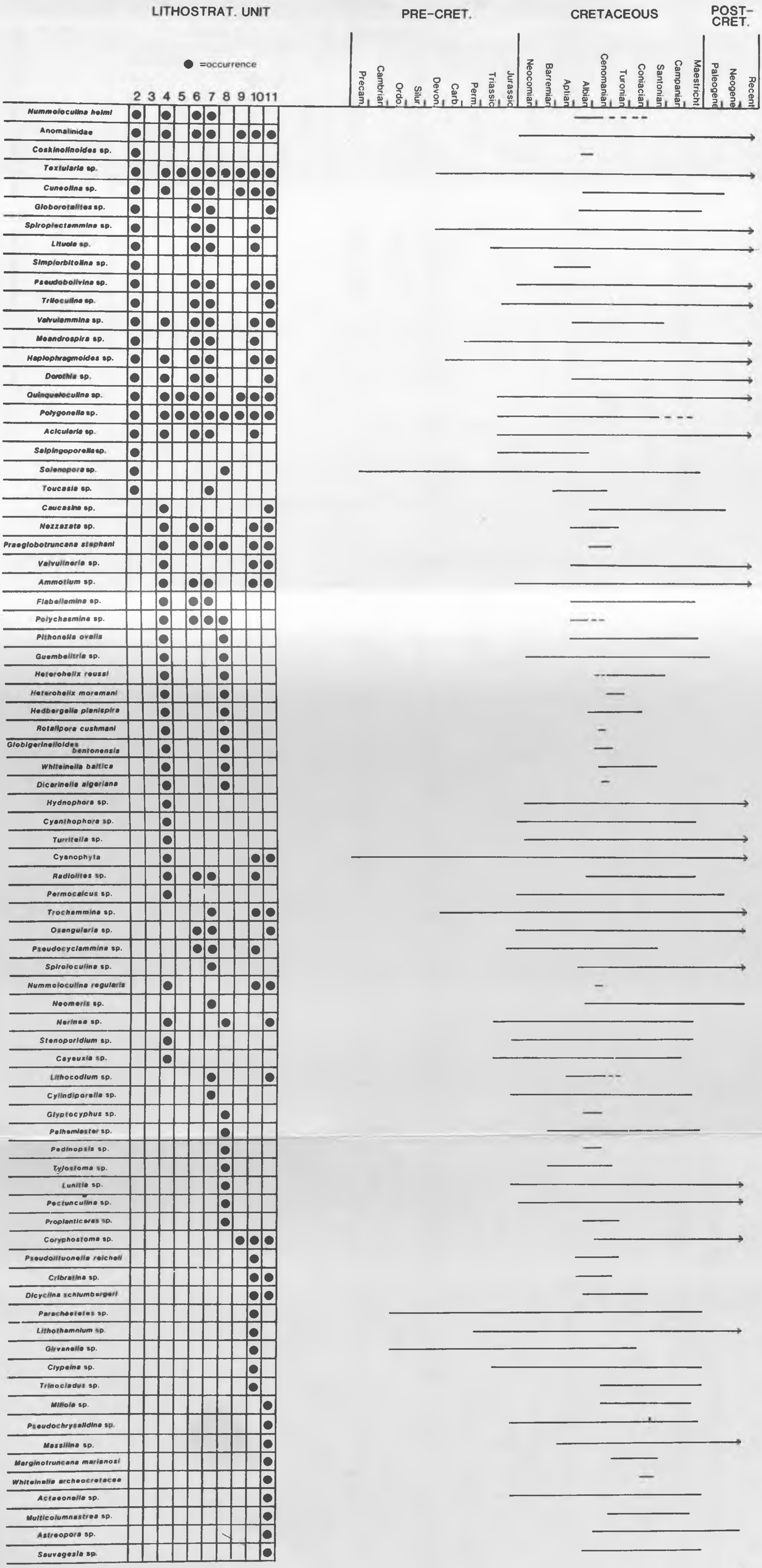
The total thickness of the Sierra Madre Limestone as determined by the present study is 2,590 m ± 35 m. It should be noted that more recent work on the Sierra Madre Limestone in an area northwest of the present study area has shown that the thickness of the formation may approach 3,450 m (C. I. Smith, personal communication, 1983).

BIOSTRATIGRAPHY OF THE SIERRA MADRE LIMESTONE

Fossil occurrences and fossil distribution throughout units 1-11 indicate that the Sierra Madre Limestone in west-central Chiapas ranges in age from Aptian (or slightly older) to middle Santonian (Figure 12). The absence of identifiable fossils that can be age-dated throughout unit 1 (dolomite breccia and dolomite) does not permit accurate age determination for this unit. Younger units, however, do contain identifiable and biostratigraphically significant assemblages. Three intervals (units 4, 8, and 11) provide adequate fossil control for a detailed biostratigraphic analysis of the upper 1,735 m of the Sierra Madre Limestone.

FOSSIL OCCURRENCES

Table 1 displays the occurrences of all identified fossil genera and species contained in units 2-11. The biota are listed in order of decreasing age, *i.e.*,


LITHOSTRAT. UNIT
● =occurrence
2 3 4 5 6 7 8 9 10 11
PRE-CRET.
CRETACEOUS
POST-CRET.
Precam.
Cambrian
Ordo.
Silur.
Devon.
Carb.
Perm.
Triassic
Jurassic
Neocomian
Barremian
Aptian
Albian
Cenomanian
Turonian
Coniacian
Santonian
Campanian
Maestricht.
Paleogene
Neogene
Recent
Nummoloculina heimi
Anomalinidae
Coskinolinoides sp.
Textularia sp.
Cuneolina sp.
Globorotalites sp.
Spiroplectammina sp.
Lituola sp.
Simplorbitolina sp.
Pseudobolivina sp.
Triloculina sp.
Valvulammina sp.
Meandrospira sp.
Haplophragmoides sp.
Dorothia sp.
Quinqueloculina sp.
Polygonella sp.
Acicularia sp.
Salpingoporella sp.
Solenopora sp.
Toucasia sp.
Caucasina sp.
Nezzazata sp.
Praeglobotruncana stephani
Valvulineria sp.
Ammotium sp.
Flabellamina sp.
Polychasmina sp.
Pithonella ovalis
Guembelitria sp.
Heterohelix reussi
Heterohelix moremani
Hedbergella planispira
Rotalipora cushmani
Globigerinelloides bentonensis
Whiteinella baltica
Dicarinella algeriana
Hydnophora sp.
Cyanthophora sp.
Turritella sp.
Cyanophyta
Radiolites sp.
Permocalcus sp.
Trochammina sp.
Ozangularia sp.
Pseudocyclammina sp.
Spiroloculina sp.
Nummoloculina regularis
Neomeris sp.
Nerinea sp.
Stenoporidium sp.
Cayeuxia sp.
Lithocodium sp.
Cylindiporella sp.
Glyptocyphus sp.
Pelhemiaster sp.
Pedinopsis sp.
Tylostoma sp.
Lunitia sp.
Pectunculina sp.
Proplanticeras sp.
Coryphostoma sp.
Pseudolituonella reicheli
Cribratina sp.
Dicyclina schlumbergeri
Parachaetetes sp.
Lithothamnium sp.
Girvanella sp.
Clypeina sp.
Trinocladus sp.
Miliola sp.
Pseudochrysalidina sp.
Massilina sp.
Marginotruncana marianosi
Whiteinella archaeocretacea
Actaeonella sp.
Multicolumnastrea sp.
Astreopora sp.
Sauvagesia sp.

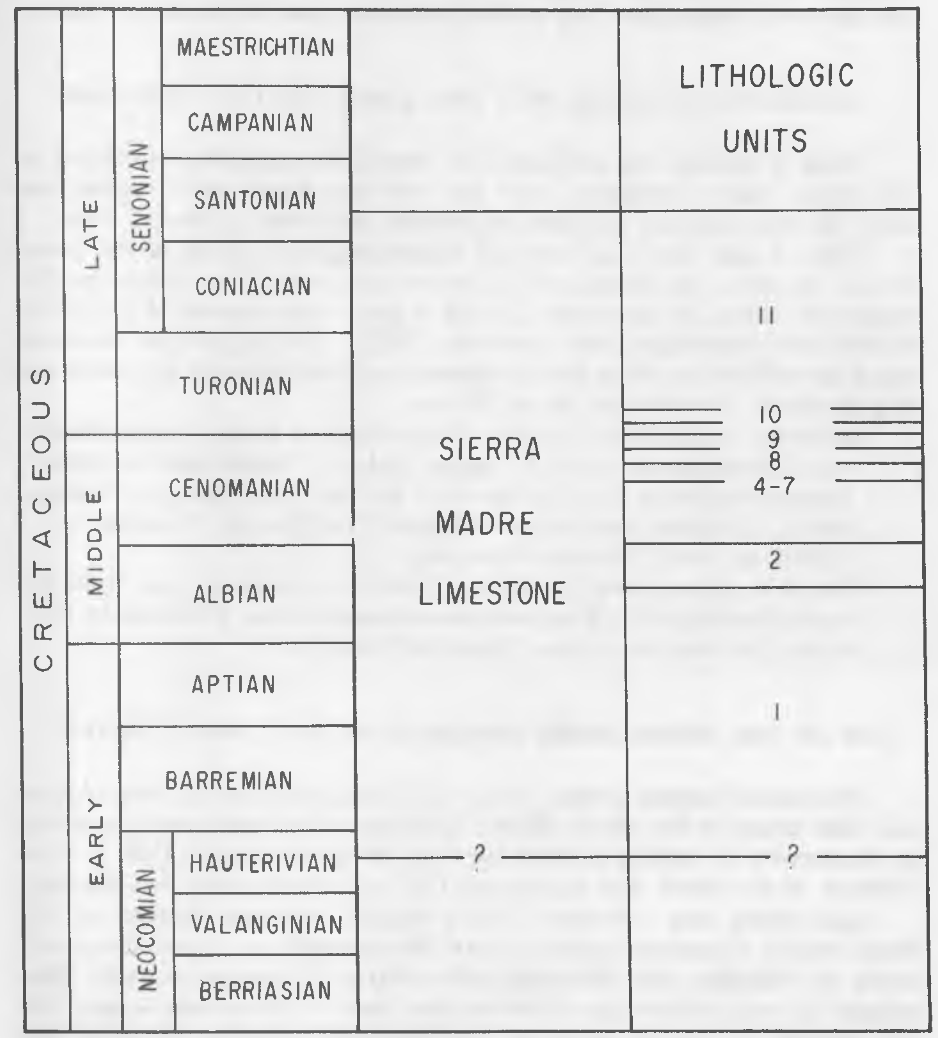


FIGURE 12.—Age of the Sierra Madre Limestone in west-central Chiapas.

those fossils which occur in the oldest unit are listed first, followed by those contained in successively younger units. Fossil ranges for individual genera and species, as determined from available literature, are also shown in Table 1.

FORAMINIFERAL DISTRIBUTION AND BIOSTRATIGRAPHIC ZONATION

Table 2 displays the distribution of identified foraminifera contained in the Sierra Madre Limestone. First and last occurrences (total ranges) are noted for each species; probable occurrences are noted by dashed lines.

Table 2 also shows the informal biostratigraphic zonation of the Sierra Madre Limestone, as determined in the present study. The biostratigraphic framework utilized in this study is based in part on the schemes of Van Hinte (1976) and Castro-Mora and coworkers (1975). The six informal biozones, which are defined on either first occurrences or total ranges of key benthonic and planktonic foraminifera, are as follows.

Benthonic foraminiferal biozones: *Nummoloculina heimi*—*Simplorbitolina* sp.—*Coskinolinoides* sp. zone (upper Albian); *Pseudolituonella reicheli*-*Pseudocyclammina* sp.—*Spiroloculina* sp. zone (middle-upper Cenomanian); *Dicyclina schlumbergeri*—*Pseudochrysalidina* sp.—*Massilina* sp.—*Miliola* sp. zone (Turonian-Santonian).

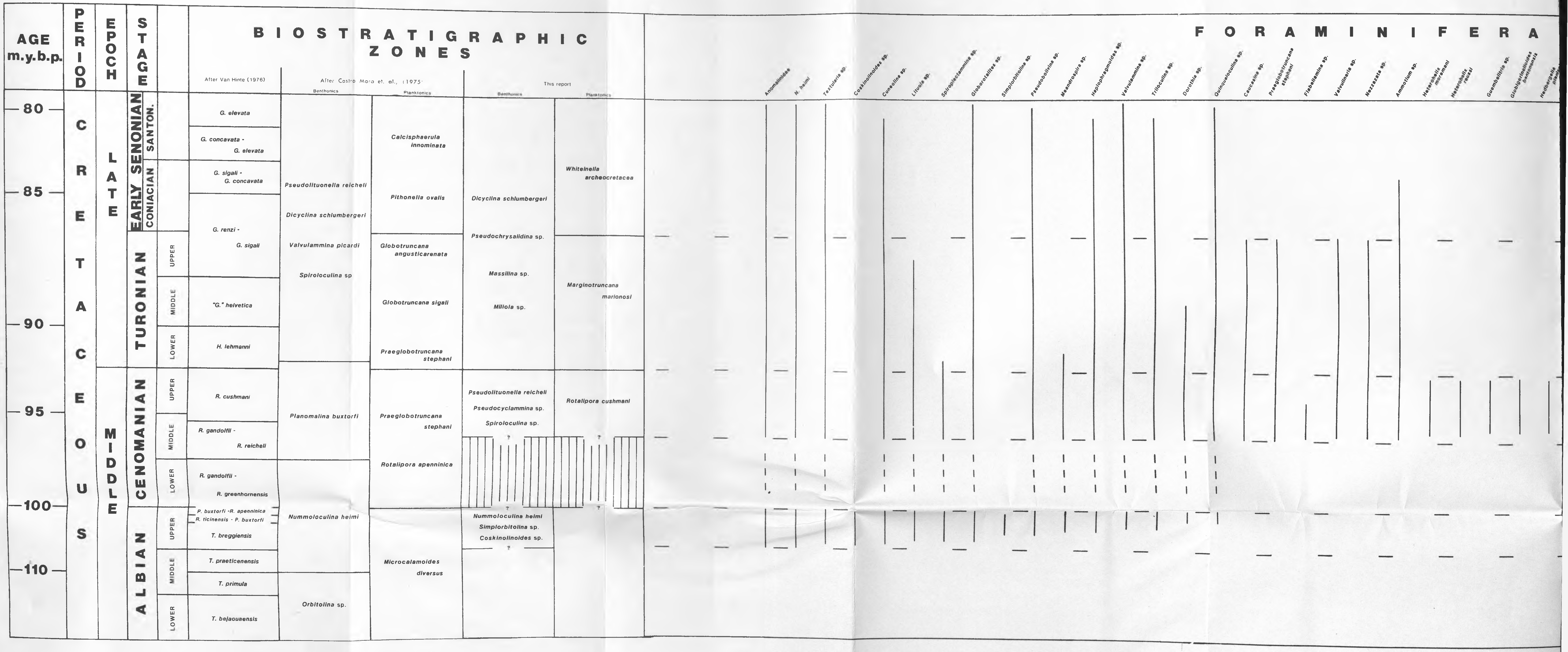
Planktonic foraminiferal biozones: *Rotalipora cushmani zone* (middle-upper Cenomanian); *Marginotruncana marianosi* zone (Turonian); *Whiteinella archeocretacea zone* (Coniacian-Santonian).

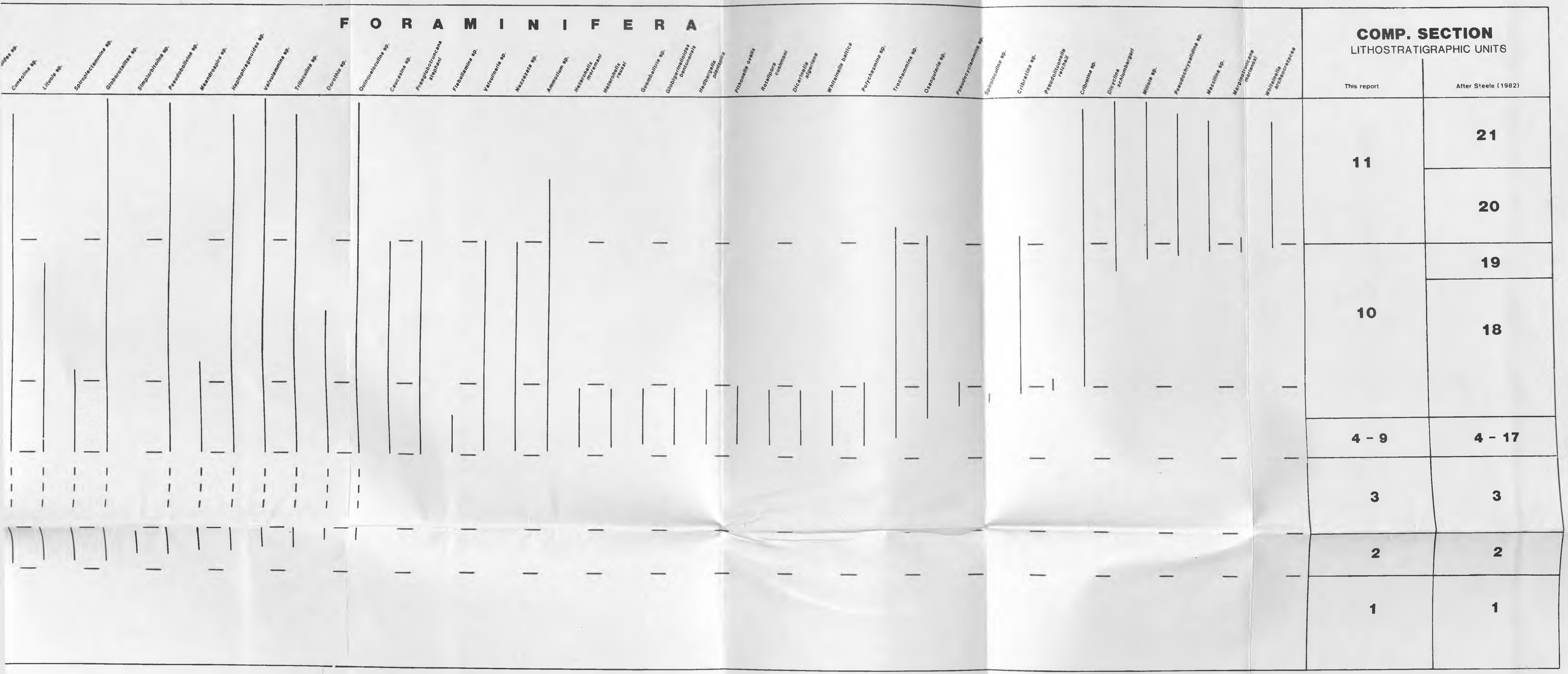
AGE OF THE SIERRA MADRE LIMESTONE IN WEST-CENTRAL CHIAPAS

Neocomian?-lower Albian (unit 1).—The occurrence of lower Albian and older strata of the Sierra Madre Limestone in the study area could not be documented by paleontological methods in the present study. Unit 1 is dolomitized to the extent that no recognizable microfossils could be identified.

Castro-Mora and coworkers (1975) studied lowermost sections of the Sierra Madre Limestone dolomite near Ocozocuautla and noted the occurrences of *Orbitolina* and *Microcalamoides diversus* in certain intervals. They assigned an early Albian age to the samples based on these occurrences. This age assesment can be extrapolated to stratigraphically equivalent dolomite beds in the present study area, but exact correlation is impossible without microfossil control. Conceivably the lower part of unit 1 may contain beds of Aptian and older age, but this is speculative until future studies yield microfossils that can be age-dated.

Upper Albian (unit 1?, unit 2, unit 3?).—Upper Albian strata include


AGE m.y.b.p.
PERIOD
EPOCH
STAGE
BIOSTRATIGRAPHIC ZONES
After Van Hinte (1976)
After Castro Mora et. al., (1975)
Benthonics
Planktonics
This report
Benthonics
Planktonics
FORAMINIFERA
80
85
90
95
100
110
CRETACEOUS
LATE
MIDDLE
EARLY SENONIAN
SANTON.
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
UPPER
MIDDLE
LOWER
G. elevata
G. concavata - G. elevata
G. sigali - G. concavata
G. renzi - G. sigali
"G." helvetica
H. lehmanni
R. cushmani
R. gandolfii - R. reicheli
R. gandolfii - R. greenhornensis
P. buxtorfi -R. apenninica
R. ticinensis - P. buxtorfi
T. breggiensis
T. praeticenensis
T. primula
T. bejaouaensis
Pseudolituonella reicheli
Dicyclina schlumbergeri
Valvulammina picardi
Spiroloculina sp
Planomalina buxtorfi
Nummoloculina heimi
Orbitolina sp.
Calcisphaerula innominata
Pithonella ovalis
Globotruncana angusticarenata
Globotruncana sigali
Praeglobotruncana stephani
Praeglobotruncana stephani
Rotalipora apenninica
Microcalamoides diversus
Dicyclina schlumbergeri
Pseudochrysalidina sp.
Massilina sp.
Miliola sp.
Pseudolituonella reicheli
Pseudocyclammina sp.
Spiroloculina sp.
?
Nummoloculina heimi
Simplorbitolina sp.
Coskinolinoides sp.
Whiteinella archeocretacea
Marginotruncana marionosi
Rotalipora cushmani
Anomalinidae
N. heimi
Textularia sp.
Coskinolinoides sp.
Cuneolina sp.
Lituola sp.
Spiroplectammina sp.
Globorotalites sp.
Simplorbitolina sp.
Pseudobolivina sp.
Meandrospira sp.
Haplophragmoides sp.
Valvulammina sp.
Triloculina sp.
Dorothia sp.
Quinqueloculina sp.
Caucasina sp.
Praeglobotruncana stephani
Flabellamina sp.
Valvulineria sp.
Nezzazata sp.
Ammotium sp.
Heterohelix moremani
Heterohelix reussi
Guembelitria sp.
Globigerinelloides bentonensis
Hedbergella planispira


F O R A M I N I F E R A
...oides sp.
Cuneolina sp.
Lituola sp.
Spiroplectammina sp.
Globorotalites sp.
Simplorbitolina sp.
Pseudobolivina sp.
Meandrospira sp.
Haplophragmoides sp.
Valvulammina sp.
Triloculina sp.
Dorothia sp.
Quinqueloculina sp.
Caucasina sp.
Praeglobotruncana stephani
Flabellammina sp.
Valvulineria sp.
Nezzazata sp.
Ammodium sp.
Heterohelix moremani
Heterohelix reussi
Guembelitria sp.
Globigerinelloides bentonensis
Hedbergella planispira
Pithonella ovalis
Rotalipora cushmani
Dicarinella algeriana
Whiteinella baltica
Polychasmina sp.
Trochammina sp.
Osangularia sp.
Pseudocyclammina sp.
Spiroloculina sp.
Cribratina sp.
Pseudolituonella reicheli
Cribratina sp.
Dicyclina schlumbergeri
Miliola sp.
Pseudochrysalidina sp.
Massilina sp.
Marginotruncana marianosi
Whiteinella archeocretacea
COMP. SECTION
LITHOSTRATIGRAPHIC UNITS
This report
After Steele (1982)
11
21
20
10
19
18
4 - 9
4 - 17
3
3
2
2
1
1

possibly an undetermined amount of the upper part of unit 1, all of unit 2 and possibly an undetermined amount of unit 3 (Figure 13). An Albian age is indicated by the first occurrence of *Nummoloculina heimi*, together with the first and last occurrences of *Simplorbitolina* sp. and *Coskinolinoides* sp.. *Nummoloculina heimi* is a miliolid well known from the Albian-Cenomanian of Mexico, Texas, and Florida (Conkin and Conkin, 1958). *Simplorbitolina* sp. and *Coskinolinoides* sp. are large orbitolid foraminifera which are restricted to Aptian-Albian strata (Dilley, 1973; Douglas, 1960). In addition to these diagnostic genera, first occurrences of the benthonic foraminifera *Cuneolina pavonia*, *Globorotalites* sp., *Valvulammina* sp., and *Dorothia* sp. indicate a lower age limit of Albian (Frizzell, 1954; Loeblich and Tappan, 1964; Saint-Marc, 1977). The first and last occurrences of the algae *Salpingoporella* in unit 2 are consistent with an Albian age assesment (Johnson, 1964).

LOWER-MIDDLE CENOMANIAN (UNIT 3).—Unit 3 consists of 384 m of strata which were not collected or studied due to inaccessability. Stratigraphic position of unit 3 indicates that the lower-middle Cenomanian boundary may fall within unit 3, assuming a continuous section between the uppermost beds of unit 2 and the lowermost beds of unit 3.

MIDDLE-UPPER CENOMANIAN (UNITS 4-10).—Middle-upper Cenomanian strata include units 4, 5, 6, 7, 8, 9, and the lower half of unit 10 (Figure 14). Several important fossil occurrences are noted in this interval which indicate a middle-late Cenomanian age.

Units 4 and 8 contain a near-identical planktonic foraminiferal assemblage consisting of *Rotalipora cushmani*, *Heabergella planispira*, *Heterohelix reussi*, *H. moremani*, *Globigerinelloides bentonensis*, *Dicarinella algeriana*, and *Whiteinella baltica*. This assemblage is best assigned to the *R. cushmani* Zone of Van Hinte (1976) (Premoli-Silva, personal communication, 1981). Van Hinte (1976) and Pessagno (1967) consider the *R. cushmani* Zone to range in age from middle to late Cenomanian. Postuma (1971), however, considers the *R. cushmani* Zone to be restricted to the late Cenomanian. Postuma (1971) isolates the middle Cenomanian from the late Cenomanian by differentiating a *R. greenhornensis* Zone. It is possible that some specimens identified in the present study as *R. cushmani* might actually be better assigned to *R. greenhornensis*. Due to a lack of well preserved specimens, however, the planktonic assemblages of units 4 and 8 are age-dated as middle-late Cenomanian.

Other fossil occurrences that indicate a middle-late Cenomanian age for units 4-10 include the following: first and last occurrence of *Radiolites* sp., which has a lower age limit of Cenomanian (Coogan, 1977); first and last occurrence of *Spiroloculina* sp., which has a lower age limit of Cenomanian (Loeblich and Tappan, 1964); first and last occurrence of *Pseudolituonella reicheli*, well known from the upper Cenomanian of Europe and southwest Asia (Loeblich and Tappan, 1964); first occurrence of *Nummoloculina re-*

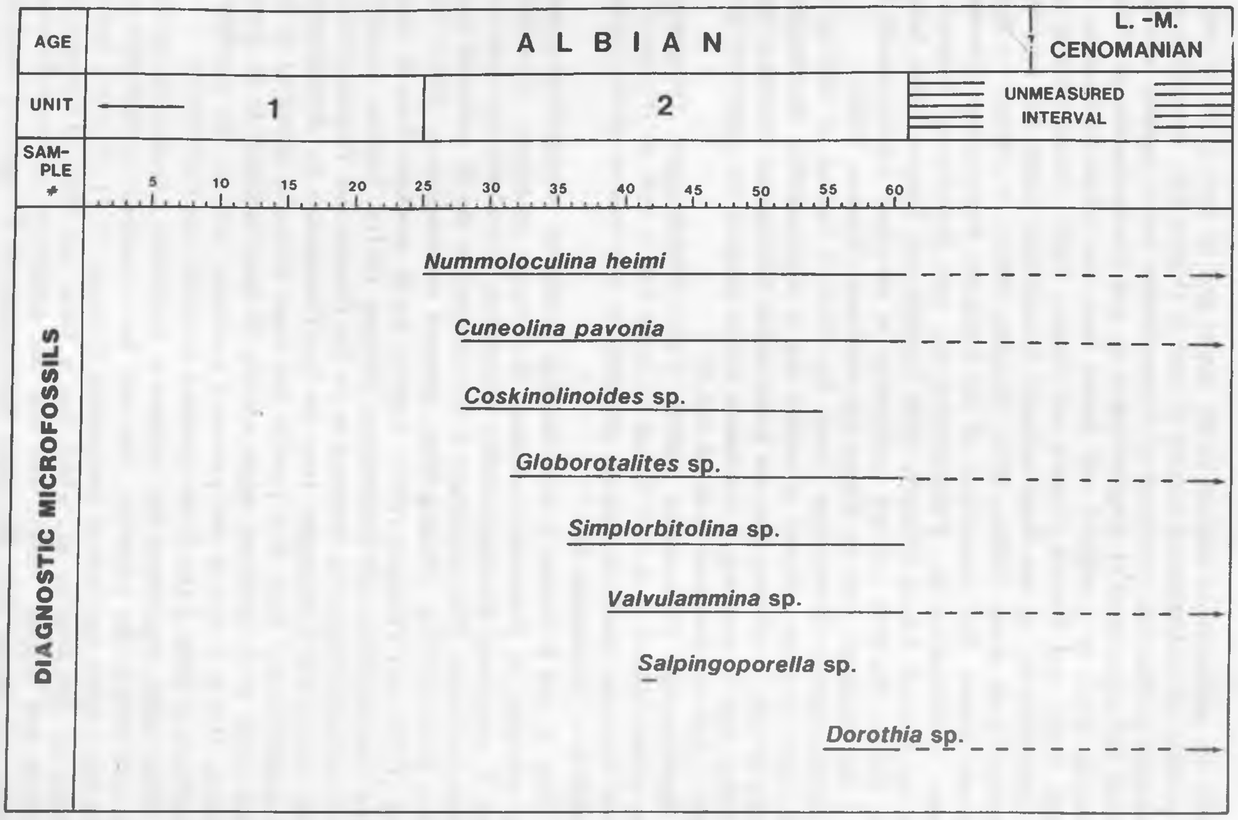


FIGURE 13.—Important fossil occurrences, unit 2 (upper Albian).

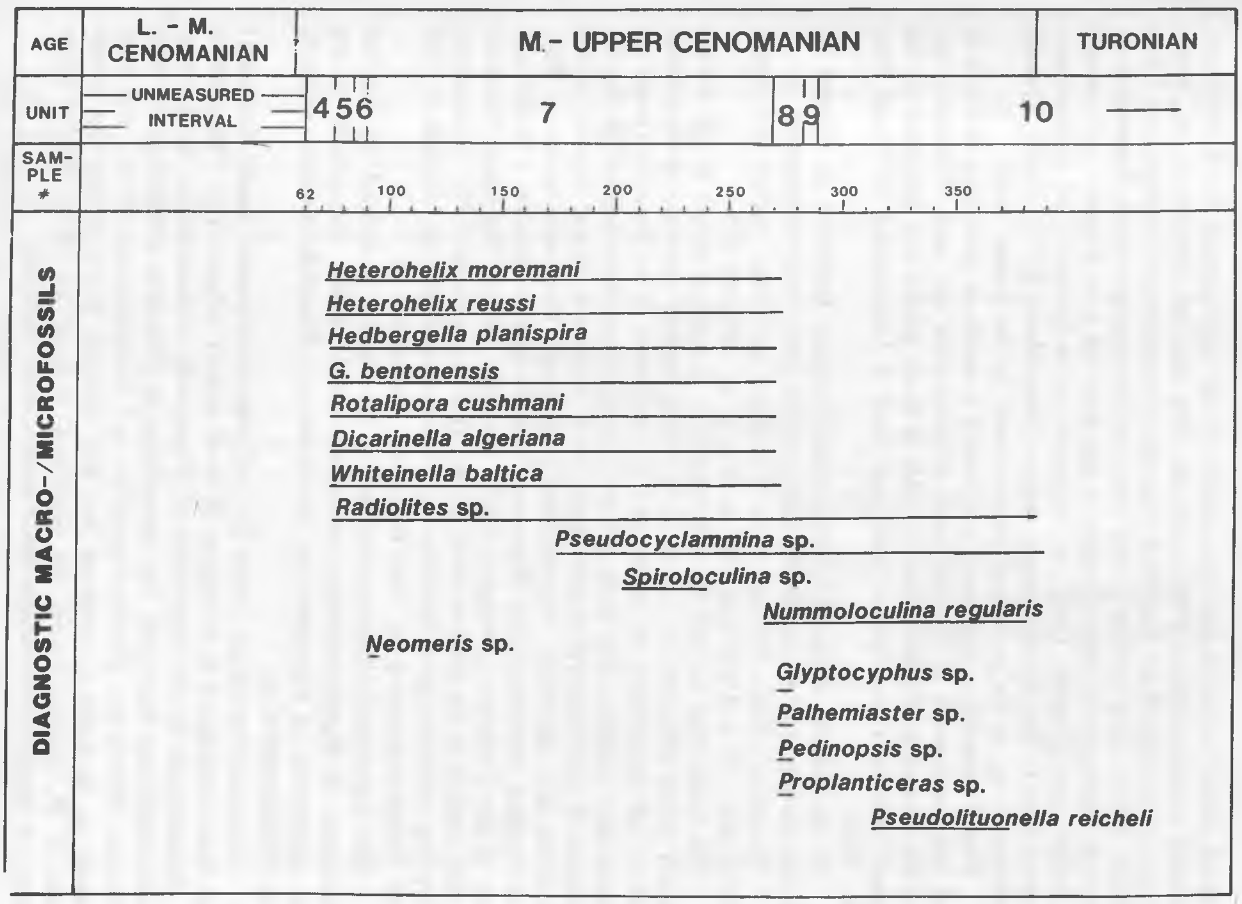


FIGURE 14.—Important fossil occurrences, units 4-10 (middle-upper Cenomanian).

gularis, which ranges in age from middle to late Cenomanian (J. P. Beckman, personal communication, 1980); and the first and last occurrence of *Neomeris* sp., a dasyclad algae described from the Cenomanian of Mexico and Libya (Elliot, 1955). Also of note is the first and last occurrence of *Pseudocyclammina* sp. Although the genus ranges in age from the Late Jurassic to Santonian (Loeblich and Tappan, 1964), it is known to be indicative of Albian-Cenomanian beds in the Mediterranean region (Saint-Marc, 1977). Hence, *Pseudocyclammina* sp. is an important marker fossil in the present study.

Unit 8 contains a diagnostic macrofossil assemblage consisting of the first and last occurrences of the echinoids *Glyptocyphus* sp., and *Pedinopsis* sp., and the ammonite *Proplanticeras* sp. All of these genera are restricted to the Upper Cretaceous and have a lower age limit of Cenomanian (Fell and Pawson, 1966).

In the present study, the Cenomanian-Turonian boundary is defined by the last occurrences of *Pseudolituonella reicheli* and *Pseudocyclammina* sp.

Turonian (units 10 and 11).—Turonian age strata include the upper half of unit 10, and the lower 30 m of unit 11 (Figure 15).

The upper half of unit 10 corersponds to samples collected in the Piedra Parada valley (Figure 3; C-6 to C-7). This interval contains no significant first or last occurrences of fossils, and is considered to be Turonian based on stratigraphic position. The lower 30 m of unit 11 are characterized by the occurrence of well exposed nodular beds which contain a highly diverse, mixed benthonic and planktonic foraminiferal assemblage. First occurrences of *Marginotruncana marianosi* and *Whiteinella archeocretacea* indicate a lower age limit of late Turonian (Pessagno, 1967; Lamolda, 1977). The upper Turonian is also marked in the present study by the first occurrences of the foraminifera *Dicyclina schlumbergeri*, *Massilina* sp., *Pseudochrysalidina* sp., *Miliola* sp., the coral *Multicolumnastrea* sp., and the rudist *Sauvagesia* sp.

The Turonian-Coniacian boundary in this report is defined by the last occurrence of *Marginotruncana marianosi*, which closely corresponds to the last occurrences of *Caucasina* sp., *Nezzazata* sp., *Praeglobotruncana stephani*, and *Valvulammina* sp.

Coniacian-Santonian (unit 11).—Coniacian-Santonian (early Senonian) age strata correspond to the upper 75 m of unit 11 (Figure 15). This interval is characterized by the occurrence of *Whiteinella archeocretacea*, exclusive of *Marginotruncana marianosi*. The assemblage of *Dicyclina schlumbergeri*, *Massilina* sp., *Miliola* sp., *Pseudochrysalidina* sp.. *Multicolumnastrea* sp., and *Sauvagesia* sp. is noted to continue into this interval. Based on the last occurrence of *W. archeocretacea*, the uppermost beds of the Sierra Madre Limestone are dated as no younger than early-middle Santonian.

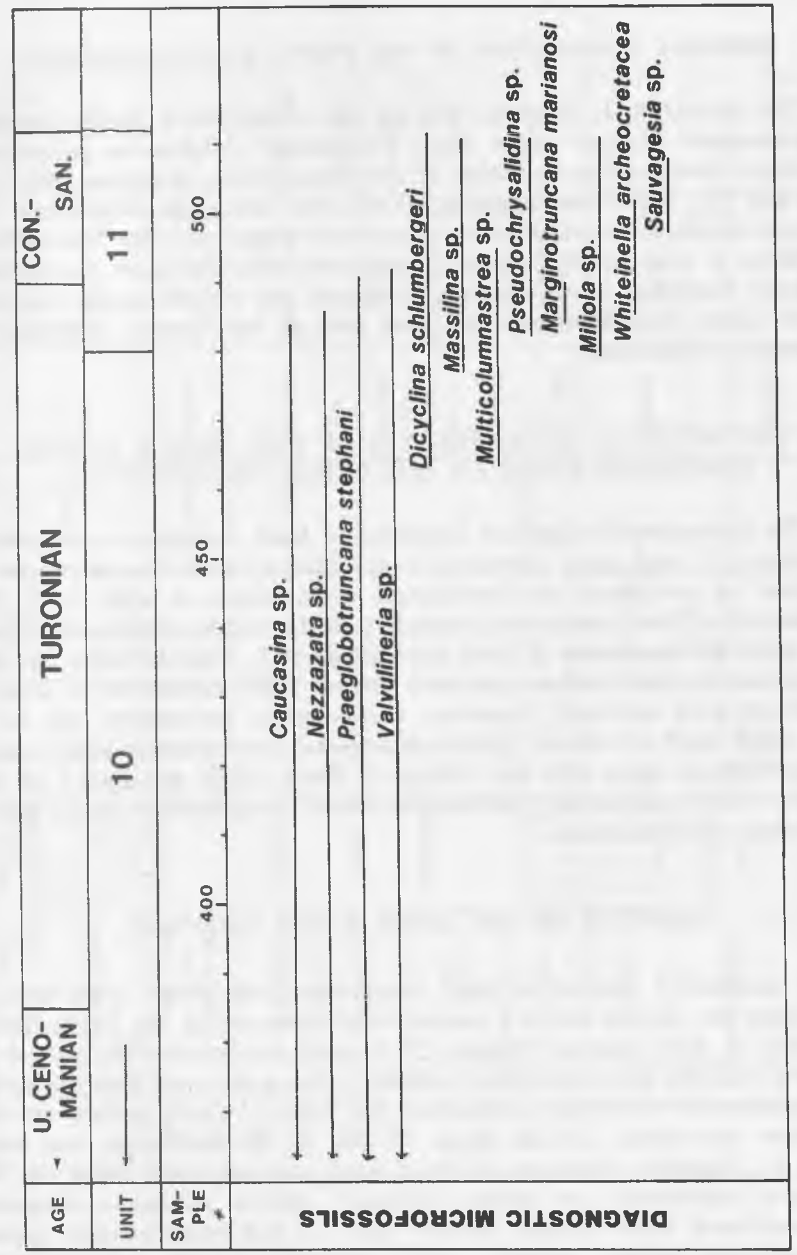


Figure 15.—Important fossil occurrences, units 10-11 (Turonian-Santonian).

REGIONAL CORRELATION OF THE SIERRA MADRE LIMESTONE

The present study indicates that the age of the Sierra Madre Limestone in west-central Chiapas ranges from (Neocomian?) Aptian to early-middle Santonian. Stratigraphic correlation of the Sierra Madre Limestone with European and U.S. Gulf Coast reference sections, and with local sections from Mexico and northern Central America is shown in Figure 16. The Sierra Madre Limestone of west-central Chiapas is correlative with the upper two-thirds of the Ixcoy Formation of northwestern Guatemala and with the upper two-thirds of the Coban Formation and the lower part of the Campur Formation of southeastern Guatemala.

DEPOSITIONAL ENVIRONMENTS OF THE SIERRA MADRE LIMESTONE BASED ON BIOLOGICAL OCCURRENCES

The comprehensive data set consisting of fossil occurrences and relative abundance of fossil types contained in the Sierra Madre Limestone can be combined to reconstruct the depositional environments of units 1-11. The combination of fossil occurrences together with the relative abundance of fossil types yields the association of fossil types (biofacies). These biofacies can then be compared to both modern and other ancient fossil associations in order to reconstruct more accurately important environmental parameters such as relative water depth circulation. Paleoenvironmental interpretations based mainly on fossil content agree with the findings of Steele (1982 and Part 1 of this Boletín), who made similar paleoenvironmental interpretations based mainly on lithologic characteristics.

BIOFACIES OF THE SIERRA MADRE LIMESTONE

A quantitative analysis of fossil occurrences and relative abundance of fossil types was used to define a number of biofacies within the Sierra Madre Limestone. A flow diagram (Figure 17) is used to illustrate the method of statistical analysis. All thin sections included in this study were observed under low magnification in order to determine the types of fossils present as well as relative abundance of these types. A total of 28 fossil types was noted (Table 3). Relative abundance of fossil types was calculated based on the number of individuals per sample. Arbitrary relative abundance categories were established, which include: absent; rare, 1-5 individuals/sample; sparse, 6-10 individual/sample; common, 11-25 individuals/sample; and abundant, > 25 individuals/sample. Abundance data were then coded, using the following

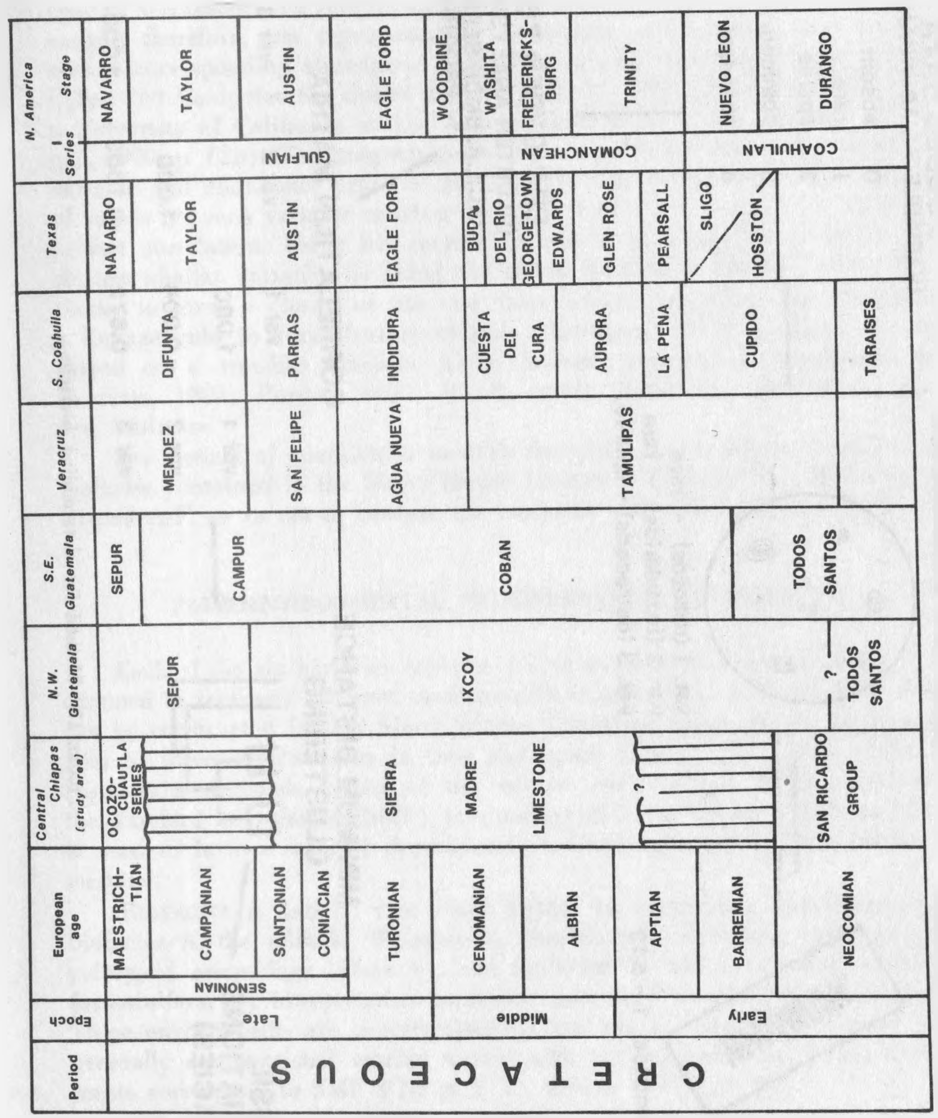


FIGURE 16.—Regional correlation of the Sierra Madre Limestone.

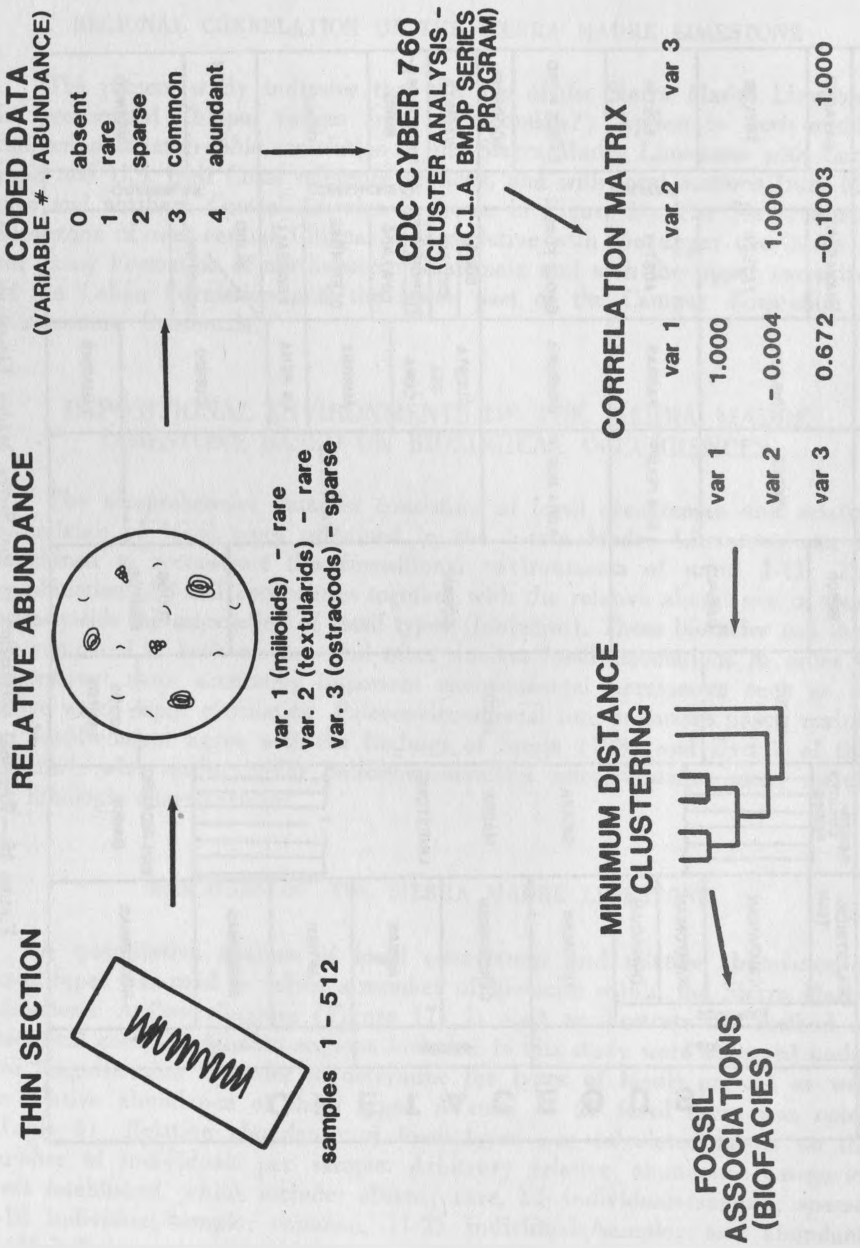


FIGURE 17.—Method for determining biofacies.

system: 0=absent; 1=rare; 2=sparse; 3=common; and 4=abundant. Each sample, therefore, was represented by a number of variables, each variable with a corresponding abundance code. The data set was entered into a CDC Cyber 760 Computer for cluster analysis (Purdy, 1963; Kaesler, 1969), using a University of California at Los Angeles Biomedical Series Program (Hartigan, 1979, p. 623). The program constructs a correlation matrix by comparing variable and abundance data for each sample. The correlation matrix consists of values for each variable ranging from +1.0 to −1.0, with +1.0 indicating perfect correlation. Using the correlation matrix as input, the program then clusters similar variables by using the initial correlation between pairs of variables to form a cluster of the two most similar variables, and then using a linkage rule to form further clusters (Hartigan, 1979). Clusters are displayed on a tree-like diagram which isolates associations (Harbaugh and Merriam, 1969; Purdy, 1963). In the present study the associations represent biofacies.

The method of quantitative analysis described above defines a total of six biofacies contained in the Sierra Madre Limestone (Figure 18). Biofacies are labeled A-F, so as not to confuse the biofacies with lithologic units 1-11.

PALEOENVIRONMENTAL INTERPRETATION OF BIOFACIES

Each of the six biofacies contains a unique assemblage of fossils which are assumed to represent different environments of deposition. A depositional model can be constructed for the Sierra Madre Limestone which shows the relationship of these environments in time and space (Figure 19). Each of the six biofacies corresponds to one of the various environments. Where applicable, the standard microfacies (SMF) terminology of J. L. Wilson (1975, p. 63-69) is used to further describe depositional environments of the Sierra Madre Limestone.

BIOFACIES A AND B: THE INNER SHELF TO INTERTIDAL ENVIRONMENTS.—Biofacies A, the miliolid, *Polygonella*, benthonic foraminifera, and non-rudist pelecypod assemblage (Plate 4), and biofacies B, which includes orbitolinid foraminifera, are interpreted to represent inner shelf to intertidal environments. These environments are characterized by low energy, shallow (10 m or less), generally non-restricted marine waters with varying salinities. These environments correspond to SMF 8-10 of J. L. Wilson (1975, p. 65).

The abundance of miliolids (particularly *Nummoloculina heimi*) and *Polygonella* indicates very shallow water depths. Present-day miliolids are characteristic of shallow, tropical waters (Norton, 1930; Bandy, 1964), and abundant, diverse populations of miliolids are excellent indices of near-shore conditions (Bandy and Arnal, 1960). In modern marine environments, miliolids are par-

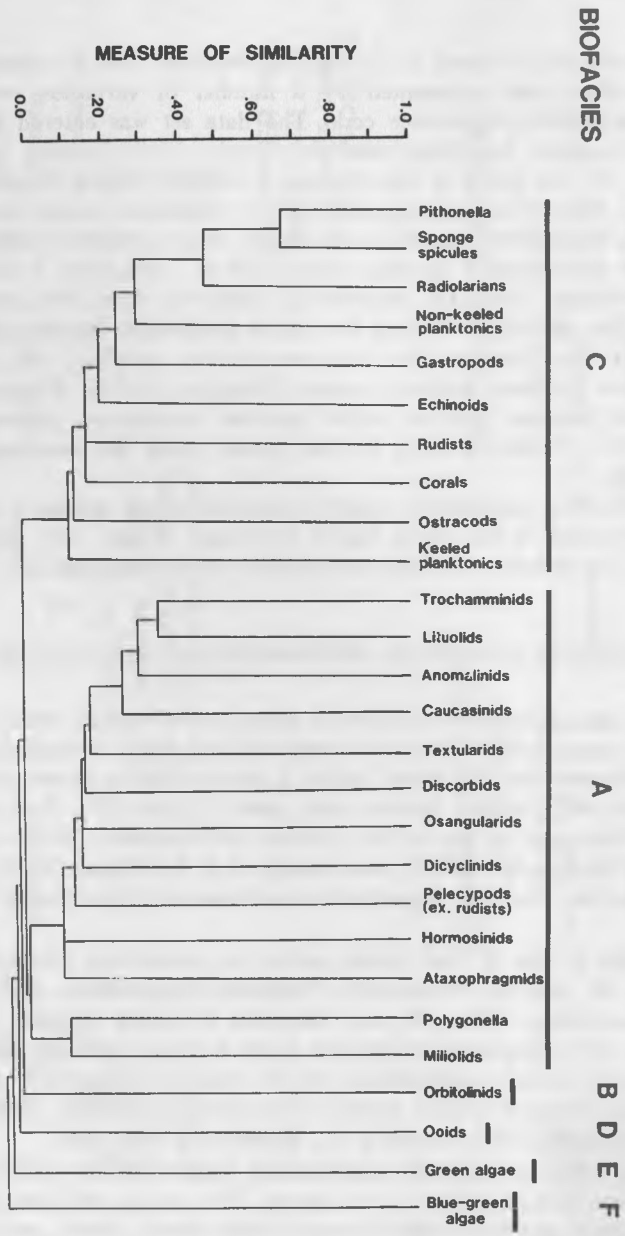


FIGURE 18.—Biofacies of the Sierra Madre Limestone.

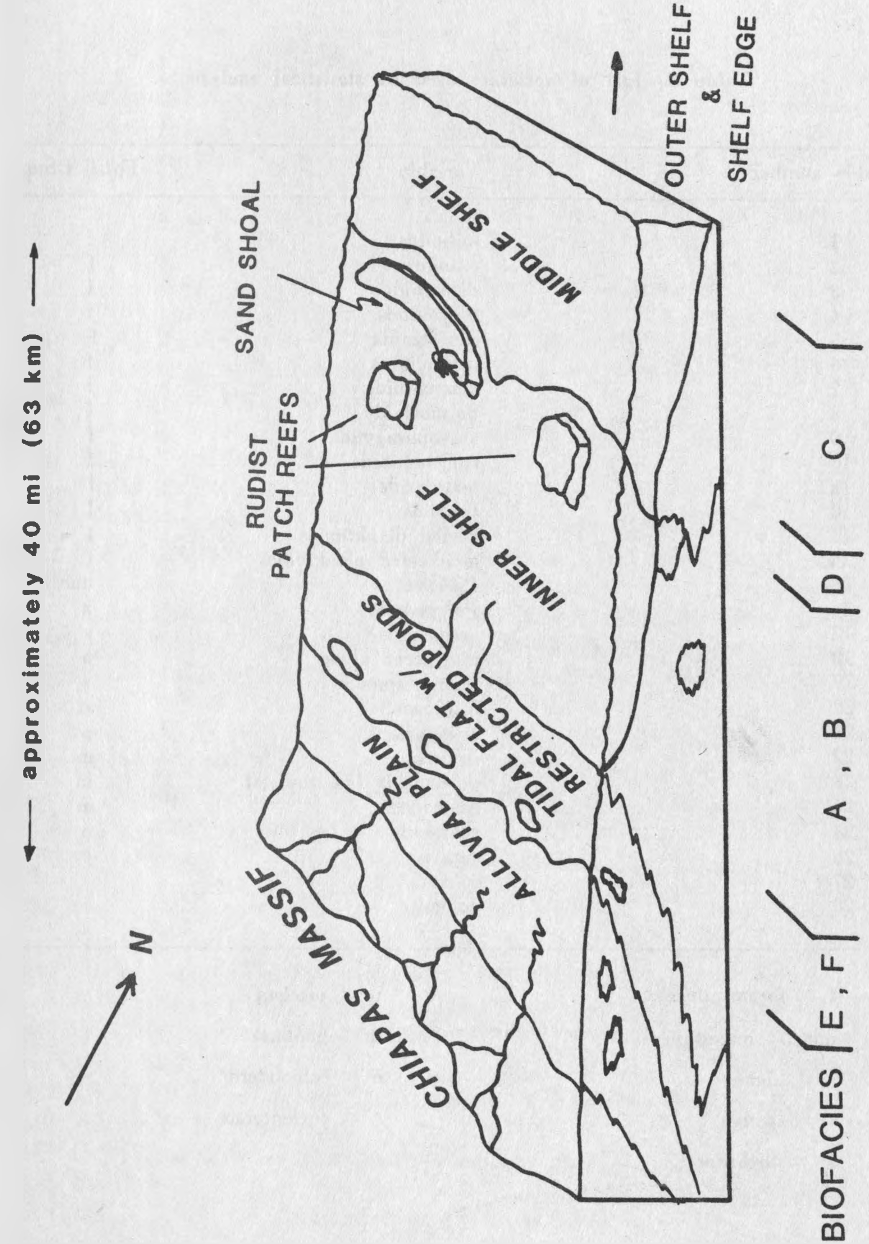


FIGURE 19.—Depositional model for the Sierra Madre Limestone in west-central Chiapas.

Table 3.—List of variables used in statistical analysis.

Variable number	Variable	Fossil Group
1	miliolids	f
2	osangularids	f
3	discorbids	f
4	dicyclinids	f
5	caucasinids	f
6	orbitolinids	f
7	anomalinids	f
8	hormosinids	f
9	ataxophragmids	f
10	trocamminids	f
11	textularids	f
12	lituolids	f
13	keeled planktonics	f
14	non-keeled planktonics	f
15	*Pithonella*	unc.
16	*Polygonella*	a
17	green algae	a
18	blue-green algae	a
19	sponge spicules	s
20	ostracods	ar
21	radiolarians	p
22	rudists	m
23	pelecypods (ex. rudists)	m
24	gastropods	m
25	echinoids	e
26	corals	c
27	ooids	
28	dolomite	

f = foraminifera
unc. = uncertain
a = algae
s = sponge
ar = arthropod
p = protista
m = mollusk
e = echinoderm
c = coelenterate

ticularly abundant in hypersaline environments (Mancini, 1981). Paleoenvironmental studies of *N. heimi* indicate shallow water depths (generally less than 5 m), and imply water temperatures between 21°C and 32°C (Conkin and Conkin, 1956). The occurrence of *Polygonella* is noted in shallow, warm water environments (Wray, 1977), as are the occurrences of low-diversity faunas of calcareous and aglutinated benthonic foraminifera (Bandy and Arnal, 1960). The occurrence of large, orbitolinid foraminifera also is indicative of warm, clear, shallow marine waters of normal salinity (Douglas, 1960).

The abundance of lime mud in this environment indicates that wave energy was very low. Water salinities probably varied between normal marine and slightly hypersaline, as indicated by changing diversities in benthonic foraminiferal populations, and the presence or absence of orbitolinid foraminifera and oysters and clams.

BIOFACIES C: THE MIDDLE SHELF ENVIRONMENT.—Biofacies C, the *Pithonella*, planktonic foraminifera, sponge spicule association, with radiolarians, corals, ostracods, echinoids, gastropods, pelecypods, rudists, and rare benthonic foraminifera (Plate 5, A) is interpreted to represent a middle shelf environment. This environment is characterized by low energy marine water with normal marine salinity and circulation. Water depths are considered to be slightly deeper (perhaps 10-30 m total) than inner shelf.

Pithonella is a small, spherical to oval fossil of uncertain affinity that is generally indicative of deeper water environments (Bonet, 1956). The planktonic foraminiferal assemblage is dominated by non-keeled, globigerinid forms which are more characteristic of Cretaceous shallow shelf environments (Sliter, 1972; Douglas and Savin, 1978; Hart, 1980). Some deeper water keeled forms such as *Praeglobotruncana stephani* are also present in the middle shelf environment. The occurrence of a highly diverse assemblage of corals, echinoids, mollusks, sponge spicules, radiolarians, and rudists is evidence of open circulation with normal marine salinities for this environment (Durham, 1966; Berquist and Coban, 1967; Perkins, 1969; J. L. Wilson, 1975). The dominance of lime mud in this environment indicates low energy conditions prevailed.

BIOFACIES D: THE PLATFORM SHOAL ENVIRONMENT.—Biofacies D, the worn skeletal grain and ooid association (Plate 5, B) is interpreted to represent a platform shoal or shallow bank environment. Very shallow water depths with high energy conditions characterize this environment. The platform shoal environment corresponds to SMF 11-15 of J. L. Wilson (1975, p. 65-66).

The skeletal fragments consist mainly of rounded, broken ostracod and pelecypod shell fragments that are highly winnowed. The occurrence of well sorted ooids indicate highly agitated waters, near or at wave base. These high energy conditions generally exclude the preservation of any other fossils, with the exception of rare benthonic foraminifera and red algae.

The platform shoal environment represents an area of small areal extent on the larger Cretaceous southern Mexican shelf that contains mud free, winnowed, high-energy grainstones. Middle to inner shelf deposits of a similar nature have been well documented in the Fredericksburg Cretaceous of central and west-central Texas (Moore and Martin, 1966; Boutte, 1969; Amsbury *et al.*, 1979) and the platform shoal deposits of the Sierra Madre Limestone are analogous to these.

BIOFACIES E: THE INTERTIDAL ENVIRONMENT.—Biofacies E includes green algae and lime mud (Plate 6, A) and is interpreted to represent an intertidal environment. The green algae are comprised mainly of the family Dasycladacea, which indicates very shallow water depths with warm, clear water of near-normal salinity (Wray, 1977). The lime mud is comprised mainly of pellets, some of which have formed lumps or aggregates. An abundance of lime mud in this environment indicates that low energy conditions prevailed. The intertidal environment most closely corresponds to SMF 22-23 of J. L. Wilson (1975, p. 69).

BIOFACIES F: THE SUPRATIDAL ENVIRONMENT.—Biofacies F includes the algal stromatolite and dolomite association (Plate 6, B) and represents a supratidal environment. Occasional rare burrows, ostracod shell fragments, molds of gastropods, and ghosts of pellets are noted in this environment. The highly restricted fauna dominated by blue-green algae indicates deposition in very shallow water, perhaps emergent at times. Extreme hypersaline waters are suggested by poor faunal diversity and the presence of fine-grained dolomite. The supratidal environment corresponds to SMF 19-20 of J. L. Wilson (1975, p. 68).

DISTRIBUTION OF BIOFACIES

Figure 20 displays the distribution of biofacies A-F throughout lithologic units 1-11. The distribution of biofacies shown in Figure 20 has been generalized from detailed occurrence and abundance charts for each unit (Waite, 1983, appendix II).

Unit 1 contains only biofacies F, indicating deposition in a highly restricted supratidal environment. Unit 2 consists of biofacies A and F, indicating two periods of inner shelf to intertidal deposition separated in time by a brief period of shallower, more restricted deposition. The depositional environment of unit 3 can not be reconstructed in the present study. Units 4 and 8 are dominated by biofacies C, indicating a deepening of water depth from inner shelf to middle shelf. Unit 5 and 9 are dominated by biofacies D, indicating deposition in a high energy shoal environment. Units 6, 7, and 10 are dominated by biofacies A, with biofacies C present in certain intervals, indicating a dominance of inner shelf deposition with occasional middle shelf influence. The lower half of unit 11 is co-dominated by biofacies A and biofacies C, indicating a stronger mixing of shallow and slightly deeper water environments. Biofacies C becomes less pronounced at the top of unit 11, indicating inner shelf deposition was occurring near the end of Sierra Madre time.

SUMMARY OF DEPOSITIONAL ENVIRONMENTS: SHALLOWING-DEEPENING CYCLES OF THE SIERRA MADRE LIMESTONE

The present study indicates that the depositional environment of the Sierra Madre Limestone in west-central Chiapas includes a wide range of sub-environments, from supratidal to middle shelf. The majority of sediments was deposited in the inner shelf environment, in warm, clear, marine waters with normal marine salinities and low energy conditions. Two high energy intervals and two deeper water intervals interrupted inner shelf deposition for relatively short periods of time.

The age and depositional environments of the Sierra Madre Limestone is west-central Chiapas verify the presence of a large carbonate body in southern Mexico during most of Cretaceous time. This carbonate platform underwent several shallowing-deepening cycles during Early Cretaceous-Late Cretaceous time. The marine cycles are preserved in the platform interior sediments, as evidenced by the Sierra Madre Limestone (Figure 21). From Albian to Coniacian-Santonian time, a total of three relatively brief marine inundations (deepening of water) can be distinguished, separated by three relatively long periods of shallow sedimentation. A complete shallowing-deepening cycle occurs once on the average of every 5-10 Ma. Causes for the cycles are probably complex and are not well understood, but may be related to a combination of carbonate production, local tectonic activity near the Chiapas massif, and local and regional sea level adjustments (J. L. Wilson, 1975). Approximately 80 Ma before present time, the prolific Cretaceous carbonate platform of southern Mexico was destroyed by regional tectonic activity in southern Mexico, which uplifted surrounding regions and provided the means for a large influx of terrigenous clastic material.

SUMMARY AND CONCLUSIONS

The Cretaceous Sierra Madre Limestone in west-central Chiapas consists of a thick sequence of dolomite breccia, dolomite, and bioclastic limestones. These sediments were deposited on the interior of a large carbonate platform

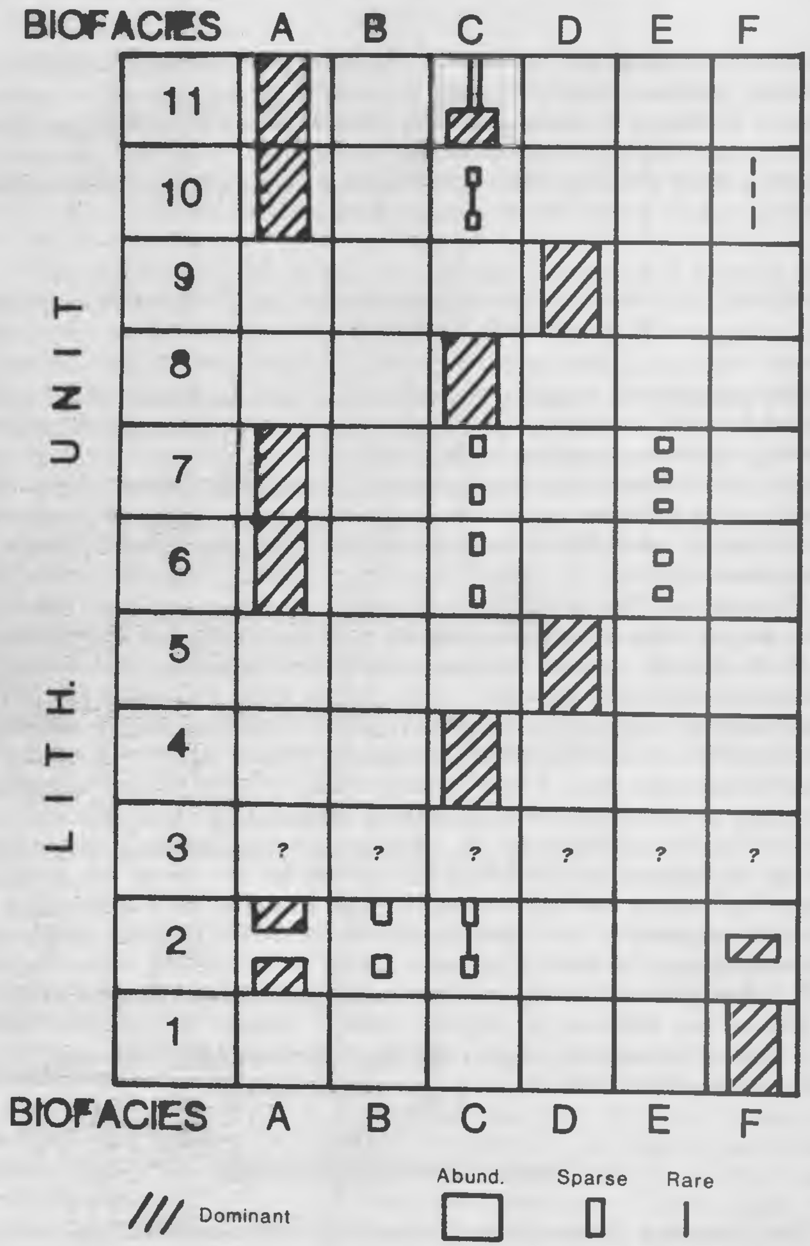


FIGURE 20.—Distribution of biofacies in the Sierra Madre Limestone.

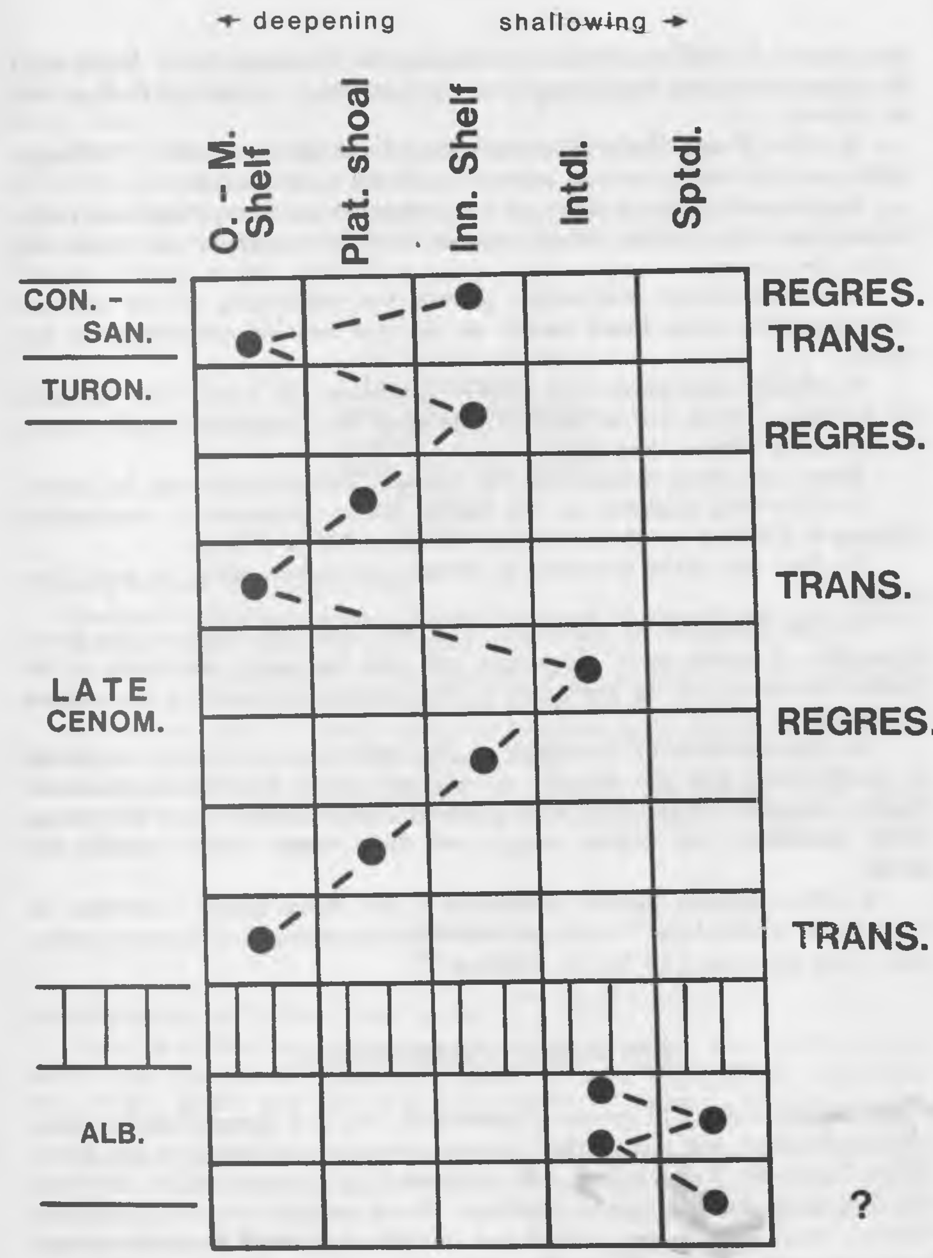


FIGURE 21.—Shallowing-deepenning cycles of the Sierra Madre Limestone.

that existed in southern Mexico during most of Cretaceous time. Based upon the observations and limitations of the present study, important findings are as follows:

1.—The Sierra Madre Limestone may be subdivided into 11 lithologic units, each of which contains a unique lithology and biota.

2.—Foraminifera and algae are the dominant biota of the limestone; radiolarians, ostracods, rudists, other mollusks, echinoids, sponges, and corals are minor components.

3.—Foraminiferal distribution permits the establishing of six informal biostratigraphic zones, based mainly on the first and last occurrences of key species.

4.—Fossil occurrences and relative abundance of fossil types delineate six biofacies, which can be used to determine the depositional environments of the Sierra Madre Limestone.

Based upon these observations, the following interpretations can be drawn:

1.—The total thickness of the Sierra Madre Limestone in west-central Chiapas is 2,590 m ± 35 m, but may be up to 900 m thicker.

2.—The age of the formation is Aptian (or slightly older) to early Santonian.

3.—The formation is correlative with the upper two-thirds of the Ixcoy Formation of northwestern Guatemala and with the upper two-thirds of the Coban Formation and the lower part of the Campur Formation of southeastern Guatemala.

4.—Environments of deposition of the formation range from supratidal to middle shelf, with the majority of sediments being deposited in the inner shelf to intertidal environment with generally open circulation and low energy water conditions; two higher energy and three deeper water intervals are noted.

5.—The platform interior carbonates of the Sierra Madre Limestone record three middle-Late Cretaceous shallowing-deepening sedimentary cycles; each cycle averages 5-10 Ma in duration.

SYSTEMATIC PALEONTOLOGY

Lithologic units 2-11 contain a moderately rich and diverse Tethyan biota, with foraminifera and algae being the most common microfossils in the Sierra Madre Limestone. Foraminifera are represented by 5 superfamilies, 20 families, and more than 40 genera. Benthonic forms predominate over planktonic forms in every unit, except units 4 and 8. Units 4, 8, and 11 contain planktonic foraminiferal assemblages that allow for accurate age determination.

Algae are represented by 16 species of Rhodophyta, Chlorophyta, and Cyanophyta. Chlorophyta are most diverse with 9 species. The most abundant species is *Polygonella*, a problematical red algae which occurs abundantly in every unit.

Minor biologic components of the Sierra Madre Limestone include radiolarians, sponges, corals, mollusks, ostracods, and serpulids (worm tubes).

The following section includes descriptive information on individual genera noted in the present study. Descriptions are taken from Loeblich and Tappan (1964) unless otherwise noted.

Phylum PROTOZOA
Class RHIZOPODA
Order FORAMINIFERIDA
Superfamily LITUOLACEA
Family TEXTULARIIDAE

Textularia sp.
(Plate 7, A)

Textularia Loeblich and Tappan, 1964.

DESCRIPTION.—Test free, elongate, biserial, compressed in plane of biseriality, chambers numerous, closely oppressed; wall agglutinated, simple.

REMARKS.—Specimens observed were generally 0.8 mm in length, 0.5 mm in breadth; specimens noted to be abundant in every unit except unit 5.

In the present study the first occurrence of *Textularia* sp. is noted in unit 2, sample 28; last occurrence is noted in unit 11, sample 509.

STRATIGRAPHIC RANGE.—Pennsylvanian-Recent (Loeblich and Tappan, 1964). Many species have been described from Albian-Maastrichtian age beds of Texas (Loeblich, 1946; Frizzell, 1954).

Spiroplectammina sp.
(Plate 7, B)

Spiroplectammina sp. Loeblich, 1946, p. 136.

DESCRIPTION.—Test free, small, flattened, periphery rounded, early portion planispirally coiled, later biserial; chambers numerous, increasing slowly in size; sutures distinct, straight, slightly depressed; well finely arenaceous; aperture a low arch at inner margin of final chamber.

REMARKS.—*Spiroplectammina* sp. differs from *Ammobaculites* sp. in having a well defined early planispiral coil, equal or greater in width than the later biserial portion; specimens were noted in units 2, 6, 7, and 10, and are slightly larger than those specimens described by Loeblich (1946).

In the present study the first occurrence of *Spiroplectammina* sp. is noted in unit 2, sample 32; last occurrence is noted in unit 10, sample 396.

STRATIGRAPHIC RANGE.—Carboniferous-Recent (Loeblich and Tappan, 1964). Many species have been described from Albian-middle Cenomanian age beds of Texas (Frizzell, 1954; Loeblich, 1946).

Pseudobolivina? sp.
(Plate 7, C)

Pseudobolivina Wiesner, Loeblich and Tappan, 1964, p. C255.

DESCRIPTION.—Test biserial, tending to become uniserial, axis slightly twisted; aperture a high narrow slit, interiomarginal in early biserial stage, becoming nearly terminal in later stages.

REMARKS.—Specimens observed average 0.5 mm in length, 0.25 mm in breadth; wall appears finely arenaceous; specimens fit general description well, but positive identification lacking due to unknown nature of aperture; specimens noted in units 2, 6, 7, 10, and 11.

In the present study the first occurrence of *Pseudobolivina*? sp. is noted in unit 2, sample 36; last occurrence is noted in unit 11, sample 506.

STRATIGRAPHIC RANGE.—Middle Jurassic-Recent (Loeblich and Tappan, 1964).

Family ATAXOPHRAGMIIDAE

Cuneolina sp., group *C. pavonia* Henson
(Plate 7, D)

Cuneolina D'Orbigny, Loeblich and Tappan, 1964, p. C285.

DESCRIPTION.—Test subcylindrical to flabelliform, trochospiral in early stage, later with arcuate biserially arranged chambers, increasing rapidly in place of biseriality; internal chambers consist of two layers of annual chambers subdivided by radial partitions into chamberlets; wall agglutinated; imperforate outer layer; aperture a series of rounded interiomarginal openings.

REMARKS.—Specimens occur rare to abundantly in every unit except units 5 and 9; specimens very abundant in units 6, 7, and 10.

In the present study the first occurrence of *Cuneolina* sp. is noted in unit 2, sample 28; last occurrence is noted in unit 11, sample 498.

STRATIGRAPHIC RANGE.—Albian-Miocene (Loeblich and Tappan, 1964; Dilley, 1973). *Cuneolina* sp. is well known from the upper Aptian-Turonian in the Mediterranean region (Saint-Marc, 1977).

Valvulammina sp.
(Plate 7, E)

Valvulammina Cushman, Loeblich and Tappan, 1964, p. C283.

DESCRIPTION.—Test low trochospiral coil, with more than three chambers to a whorl, ventral side umbilicate; wall agglutinated; aperture partially covered by a large, rounded tooth.

REMARKS.—Specimens noted to occur frequently in units 2, 4, 6, 7, 10, and 11; specimens usually fragmented, averaging 0.6 mm in height, 0.5 mm in breadth; specimens in unit 11 may be best assigned to *V. picardi* Henson, previously noted from the "Caliza Sin Nombre" of Castro-Mora and coworkers (1975).

In the present study the first occurrence of *Valvulammina* sp. is noted in unit 2, sample 39; last occurrence is noted in unit 11, sample 510.

STRATIGRAPHIC RANGE.—Cenomanian-Senonian (J. P. Beckmann, 1980, personal communication).

Pseudolituonella reicheli Marie
(Plate 7, F)

Pseudolituonella reicheli Marie, 1952, p. 117.

DESCRIPTION.—Test elongate, conical, early portion trochospiral, later uniserial, with broad, low chambers; interior of chambers with sporadic hollow interseptal pillars; wall agglutinated, calcareous imperforate; aperture cribate in center of terminal face with non-perforate marginal area.

REMARKS.—Specimens are restricted to the upper part of unit 10; this species was noted in the "Caliza Sin Nombre" of Castro-Mora and coworkers (1975).

In the present study the first occurrence of *P. reicheli* is noted in unit 10, sample 314; last occurrence is noted in unit 10, sample 376.

STRATIGRAPHIC RANGE.—Middle Albian-Turonian (Saint-Marc, 1977). Many specimens are known from the upper Cenomanian of Europe and southwestern Asia (Loeblich and Tappan, 1964).

Pseudochrysalidina? sp.
(Plate 8, A)

Pseudochrysalidina Cole, Loeblich and Tappan, 1964, p. C290.

DESCRIPTION.—Test a high trochospiral with gradual reduction in number of chambers to whorl, later portion tending to become biserial; wall agglutinated, interior with vertical pillars subdividing central area of chambers; aperture interiomarginal in early stage, cribate over terminal surface in adult.

REMARKS.—Specimens average 0.5 mm in height, 0.5 mm in breadth; positive identification lacking due to lack of well preserved specimens; specimens restricted to unit 11.

In the present study the first occurrence of *Pseudochrysalidina*? sp. is noted in unit 11, sample 482; last occurrence is noted in unit 11, sample 511.

STRATIGRAPHIC RANGE.—Lower Cretaceous-Eocene (Loeblich and Tappan, 1964).

Dorothia? sp.
(Plate 8, B)

Dorothia Plummer, Loeblich and Tappan, 1964, p. C275.

Description.—Early stage trochospiral, with four or more chambers to whorl, later stage reduced to biserial; wall agglutinated, may be of calcareous particles; aperture an interiomarginal slit.

Remarks.—Specimens average 0.7 mm in height, 0.3 mm in breadth, showing characteristic interlocking chambers; specimens noted in units 2, 4, 6, 7, and 10.

In the present study the first occurrence of *Dorothia*? sp. is noted in unit 2, sample 55; last occurrence is noted in unit 10, sample 414.

Stratigraphic range.—Albian-Recent (Loeblich and Tappan, 1964). Species have been noted in Senonian age beds in Texas (Plummer, 1931; Cushman, 1946; Frizzell, 1954).

Family ORBITOLINIDAE

Simplorbitolina sp.
(Plate 8, C)

Simplorbitolina Ciry and Rat, Douglas, 1960, p. 259.

Description.—Test small, generally less than 3 mm maximum diameter; includes forms intermediate between *Orbitolina* and *Dictyoconus*, with main partitions extending from marginal zone into central area in zig-zag manner as in *Orbitolina* but with lower part of each partition discontinuous in form of pillars as in *Dictyoconus;* marginal zone divided by main partitions and one or more series of plates.

Remarks.—Specimens noted were quite small, averaging 0.3 mm in diameter, 0.5 mm in height; specimens restricted to unit 2.

In the present study the first occurrence of *Simplorbitolina* sp. is noted in unit 2, sample 36; last occurrence is noted in unit 2, sample 61.

Stratigraphic range.—Aptian-Albian (Douglas, 1960; Dilley, 1973; Saint-Marc, 1977).

Coskinolinoides sp.
(Plate 8, D)

Coskinolinoides Keijer, Loeblich and Tappan, 1964, p. C310.

Description.—Test minute, about 0.5 mm in diameter; main partitions simple planes extending from marginal zone to central area; marginal zone divided by main partitions and one or two sets of vertical planes only.

Remarks.—Specimens noted are very poorly preserved, and are restricted to unit 2. In the present study first occurrence of *Coskinolinoides* sp. is noted in unit 2, sample 28; last occurrence is noted in unit 2, sample 35.

Stratigraphic range.—Aptian?-Albian (Dilley, 1973; Loeblich and Tappan, 1964).

Family TROCHAMMINIDAE

Trochammina? sp.
(Plate 8, E)

Trochammina Parker and Jones, Loeblich and Tappan, 1964, p. C259.

Description.—Test free, trochospiral; globular to ovate chambers increasing gradually in size: wall agglutinated; aperture low interiomarginal extraumbilical-umbilical arch which may have a narrow bordering lip.

Remarks.—Specimens show characteristic septa which in most cases are highly acute to early chambers; positive identification lacking due to unknown nature of aperture; specimens noted in units 6, 7, 10 and 11.

In the present study first occurrence of *Trochammina*? sp. is noted in unit 6, sample 90, last occurrence is noted in unit 11, sample 502.

Stratigraphic range.—Carboniferous-Recent (Loeblich and Tappan, 1964). Many species have been reported from the Cretaceous of Texas (Plummer, 1931; Cushman, 1946; Frizzell, 1954).

Family LITUOLIDAE

Pseudocyclammina sp.
(Plate 8, F)

Pseudocyclammina Yabe and Hanzawa, Loeblich and Tappan, 1964, p. C233.

Description.—Test enrolled in early stage, later uncoiling with irregular reticulate outer layer and thick, conspicuous labyrinthic inner layer in both walls and septa; aperture cribate, of irregularly spaced openings on terminal face.

Remarks.—Specimens noted are generally recrystallized so that complex inner wall structure is difficult to assess; specimens average 1.0 mm in height, 0.5 mm in width; specimens noted in units 6, 7, and 10.

In the present study the first occurrence of *Pseudocyclammina* sp. is noted in unit 6, sample 174; last occurrence is noted in unit 10, sample 390.

Stratigraphic range.—Upper Jurassic-Santonian (Loeblich and Tappan, 1964). Species have been described from Albian-Cenomanian beds of Europe (Saint-Marc, 1977).

Lituola sp.
(Plate 9, A)

Lituola Lamark, Loeblich and Tappan, 1964, p. C238.

Description.—Test large, early portion planispirally coiled, later rectilinear; wall agglutinated; simple interior walls and septa; aperture terminal, cribate.

Remarks.—Speoimens show characteristic uncoiling rectilinear chambers, which are chevron-shaped; specimens noted in units 2, 6, 7, and 10.

In the present study the first occurrence of *Lituola* sp. is noted in unit 2, sample 30; last occurrence is noted in unit 10, sample 450, STRATIGRAPHIC RANGE.—Upper Triassic-Recent (Maync, 1952; Loeblich and Tappan, 1964). Many species have been described from the Albian-Campanian of Texas (Cushman, 1946; Stead, 1951; Frizzell, 1954).

Haplophragmoides? sp.
(Plate 9, B)

Haplophragmoides Cushman, Loeblich and Tappan, 1964, p. C225.

DESCRIPTION.—Test planispirally coiled, involute; wall agglutinated, aperture an equatorial slit.

REMARKS.—Specimens show bell-shaped final chambers, similar to *H. robulus*, an Upper Cretaceous species described from Italy (Loeblich and Tappan, 1964); positive identification lacking due to unknown nature of aperture, and the fact that some specimens exhibit a loosely evolute coiling nature; specimens noted in units 2, 4, 6, 7, and 10.

In the present study the first occurrence of *Haplophragmoides*? sp. is noted in unit 2, sample 38; last occurrence is noted in unit 11, sample 487.

STRATIGRAPHIC RANGE.—Carboniferous-Recent (Maync, 1952; Loeblich and Tappan, 1964). Many species have been described from the Albian-Maastrichtian of Texas and the Cenomanian of California (Frizzell, 1954; Sliter, 1969).

Ammotium? sp.
(Plate 9, C)

Ammotium Loeblich and Tappan, 1953, p. 33.

DESCRIPTION.—Test free, compressed, ovate in outline, chambers planispirally coiled and evolute, later chambers flattened, tending to uncoil but reaching backward toward coil at inner margin; aperture simple, rounded, terminal at dorsal angle of final chamber.

REMARKS.—Specimens noted fit general description well, but positive identification lacking due to unknown nature of aperture; specimens noted in units 4, 6, 7, 10, and 11.

In the present study the first occurrence of *Ammotium?* sp. is noted in unit 4, sample 68; last occurrence is noted in unit 11, sample 502.

STRATIGRAPHIC RANGE.—Cretaceous-Recent (Loeblich and Tappan, 1964).

Flabellammina sp.
(Plate 9, D)

Flabellammina Cushman, Loeblich and Tappan, 1964, p. C244.

DESCRIPTION.—Test elongate, compressed, early stage coiled, later uniserial, with broad low, chevron-shaped chambers; wall coarsely agglutinated, simple walls and septa; aperture terminal, rounded to ovate.

REMARKS.—Specimens average 1.0 mm in height, 0.5 in width; specimens restricted to units 4, 6, and 7.

In the present study the first occurrence of *Flabellammina* sp. is noted in unit 4, sample 68; last occurrence is noted in unit 7, sample 268.

STRATIGRAPHIC RANGE.—Albian-Upper Cretaceous (Loeblich and Tappan, 1964). Many species have been described from the Cretaceous of Texas (Cushman, 1946; Stead, 1951; Frizzell, 1954).

Family HORMOSINIDAE

Cribratina sp.
(Plate 9, E)

Cribratina Sample, Loeblich and Tappan, 1964, p. C220.

DESCRIPTION.—Test free large, to 10 mm in length, elongate, uniserial and rectilinear, chambers clcsely oppressed, sutures straight, horizontal, constricted; wall agglutinated, medium to coarse-grained, with calcareous or ferriginous cement, labyrinthic; aperture terminal, cribate.

REMARKS.—Specimens average 2.0 mm in length, 0.2 mm in breadth, with coarse-grained wall; specimens noted in units 10 and 11.

In the present study the first occurrence of *Cribratina* sp. is noted in unit 10, sample 316; last occurrence is noted in unit 11, sample 509.

STRATIGRAPHIC RANGE.—Albian-Cenomanian (Frizzell, 1954; Loeblich and Tappan, 1964).

Polychasmina? sp.
(Plate 9, F)

Polychasmina Loeblich and Tappan, 1946, p. 242.

DESCRIPTION.—Test free, flattened, composed of linear series of chambers; wall thick, coarsely arenaceous; aperture terminal, consisting of a single row of elongate slits, paralleling flattened sides of test.

REMARKS.—Specimens are generally recrystallized, but a thick, coarse wall is evident; positive identification is lacking due to the unknown nature of aperture; specimens average 0.5 mm in length, 0.2 mm in width; specimens noted in units 4, 6, 7, and 8.

In the present study the first occurrence of *Polychasmina?* sp. is noted in unit 4, sample 76; last occurrence is noted in unit 8, sample 275.

STRATIGRAPHIC RANGE.—The only reference to this genus is from the Albian of Texas (Loeblich and Tappan, 1964).

Family DICYCLINIDAE

Dicyclina schlumbergeri Munier-Chalmas
(Plate 10, A-E)

Dicyclina schlumbergeri Munier-Chalmas, Loeblich and Tappan, 1964, p. C303.

DESCRIPTION.—Test free, flattened, discoidal, early planispiral chambers in two parallel layers forming raised central knob, remainder consisting of two layers of annular chambers which are subdivided by radial partitions into chamberlets; wall agglutinated;

interior subdivided by numerous, thin radial partitions perpendicular to median layer and in alignment from one primary chamber to the next, dividing primary chamber into rectangular chamberlets; aperture comprising single median row of openings in slight depression at peripheral margin.

REMARKS.—Specimens occur abundantly in units 10 and 11. In the present study the first occurrence of *D. schlumbergeri* is noted in unit 10, sample 463; last occurrence is noted in unit 11, sample 512.

STRATIGRAPHIC RANGE.—Cenomanian-Santonian (Dilley, 1973).

Superfamily DISCORBACEA
Family DISCORBINAE

Valvulineria sp.
(Plate 11, A)

Valvulineria Cushman, Loeblich and Tappan, 1964, p. C527.

DESCRIPTION.—Test free, trochospiral, umbilicate, periphery rounded: chambers increasing gradually in size; sutures radial, thickened; wall calcareous, finely perforate, radial in structure, monolamellid, surface smooth; aperture interiomarginal, with broad thin apertural flap projecting over the umbilicus.

REMARKS.—Genus is very similar to *Pfenderina* sp., but lacks axial thickening. Specimens noted in units 4, 10, and 11.

In the present study the first occurrence of *Valvulineria* sp. is noted in unit 4, sample 68; last occurrence is noted in unit 11, sample 492.

STRATIGRAPHIC RANGE.—Albian-Recent (Loeblich and Tappan, 1964). Many species have been described from the Cenomanian-Maastrichtian of Texas (Plummer, 1931; Cushman, 1946; Frizzel, 1954).

Superfamily CASSIDULINACEA

Family ANOMALINIDAE
(Plate 11, B-C)

DESCRIPTION.—Test trochospiral to nearly planispiral, evolute on one or both sides; chambers simple: wall calcareous, coarsely perforate, granular in structure, bilamellar; primary aperture interiomarginal equatorial or somewhat extending into spiral or umbilical sides, and may have additional peripheral apertures.

REMARKS.—Specimens are abundant in every unit except units 5 and 9. Due to a great variety of specimens coupled with poor preservation, identification was only carried out to the family level, many specimens can probably be best assigned to the genus *Gavelinella*. Further study of the specimens would be helpful in further classification, the results of which are not critical to the present study.

In the present study the first occurrence of Anomalinidae is noted in unit 2, sample 25; last occurrence is noted in unit 11, sample 508.

STRATIGRAPHIC RANGE.—Upper Triassic-Recent (Loeblich and Tappan, 1964).

Family CAUCASINIDAE
(Plate 11, D)

Caucasina Khalilov, Loeblich and Tappan, 1964, p. C734.

DESCRIPTION.—Test free, elongate, base bluntly rounded, early portion in low discorbine coil with up to eight chambers per whorl, later whorls becoming high-spired and reduced in number of chambers to three per whorl; early chambers low, later about equal in breadth and height and may be inflated, but extremely high or elongate; sutures distinct, depressed; wall calcareous, smooth; aperture and elongate loop at inner margin of final chamber, at right angles to sutures, with narrow lip at forward margin.

REMARKS.—Specimens average 0.5 mm in height, 0.3 mm in breadth; specimens noted in units 4 and 11.

In the present study the first occurrence of *Caucasina* sp. is noted in unit 4, sample 64; last occurrence is noted in unit 11, sample 484.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Miocene (Loeblich and Tappan, 1964).

Coryphostoma? sp.
(Plate 11, E)

Coryphostoma Loeblich and Tappan, 1962, p. 75.

DESCRIPTION.—Test free, elongate, narrow, early chambers biserial, later chambers becoming cuneiform with tendency to become uniserial; wall calcareous, finely perforate, granular in structure; aperture loop-shaped in early stage, extending from base of final chamber, becoming terminal in adult, with internal tooth plate.

REMARKS.—Specimens average 0.5 mm in height, 0.2 mm in breadth; positive identification lacking due to unknown nature of aperture and tooth plate; specimens noted in units 9, 10, 11.

In the present study the first occurrence of *Coryphostoma?* sp. is noted in unit 9, sample 286; last occurrence is noted in unit 11, sample 487.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Recent (Loeblich and Tappan, 1964).

Family OSANGULARIIDAE

Osangularia? sp.
(Plate 11, E)

Osangularia Brotzen, Loeblich and Tappan, 1964, p. C752.

DESCRIPTION.—Test free, trochospiral, lenticular, biumbonate, periphery carinate; all whorls visible on spiral side, only final whorl visible on opposite side, chambers gradually increasing in size, sutures curved and oblique on spiral side, radial and singular, bilamellar; aperture a bent opening, lying along base of final chamber on umbilical side and bending at oblique angle up apertural face, or two angles maybe separated openings, one interiomarginal, and one areal.

REMARKS.—Specimens average 0.5 mm in height, 0.4 mm in breadth; positive identification lacking due to unknown nature of aperture and overall poor preservation of specimens; specimens noted in units 6, 7, and 11.

In the present study the first occurrence of *Osangularia*? sp. is noted in unit 6, sample 131; last occurrence is noted in unit 11, sample 484.

STRATIGRAPHIC RANGE.—Lower Cretaceous-Recent (Loeblich and Tappan, 1964).

Globorotalites? sp.
(Plate 12, A)

Globorotalites Brotzen, Loeblich and Tappan, 1964, p. C752.

DESCRIPTION.—Test free, trochospiral, planoconvex, spiral side flat or slightly concave or convex, umbilical side strongly convex, periphery carinate, with poreless keel; chambers increasing gradually in size, sutures oblique, thickened on spiral side, wall calcareous, finely perforate, granular; aperture interiomarginal.

REMARKS.—Specimens average 0.3 mm in height, 0.2 mm in breadth, showing chevron-shaped chambers in final whorl; positive identification lacking due to unknown nature of aperture and keel; specimens noted to occur in units 2, 6, 7, and 11.

In the present study the first occurrence of *Globorotalites*? sp. is noted in unit 2, sample 32; last occurrence is noted in unit 11, sample 503.

STRATIGRAPHIC RANGE.—Albian-Maastrichtian (Loeblich and Tappan, 1964).

Superfamily MILIOLACEA
Family BARKERINIDAE

Nezzazzata sp.
(Plate 12, B)

Nezzazzata Omara, 1956, p. 887.

DESCRIPTION.—Test free, trochospiral, planoconvex to unequally biconvex, all whorls visible from flattened to slightly convex spiral side, only those of final whorl visible around closed umbilical region; chambers with projection at periphery; wall calcareous, imperforate, microgranular.

REMARKS.—Specimens are triangular in cross-section, and are noted in units 4, 6, 7, 10, and 11.

In the present study the first occurrence of *Nezzazzata* sp. is noted in unit 4, sample 68; last occurrence is noted in unit 11, sample 486.

STRATIGRAPHIC RANGE.—Albian-Turonian (Loeblich and Tappan, 1964: Saint-Marc, 1977).

Family NUBECULARIIDAE

Spiroloculina sp.
(Plate 12, C)

Spiroloculina D'Orbigny, Loeblich and Tappan, 1964, p. C453.

DESCRIPTION.—Test free, commonly with flattened sides and lanceolate or fusiform outline, earliest stage may consist of single chamber completely encircling proloculus, later chambers being added to whorls on alternate sides and in single plane; wall calcareous, imperforate, porcellaneous, aperture at open end of chamber, with simple or bifid tooth.

REMARKS.—Specimens show flattened to concave sides; specimens noted in unit 7 only.

In the present study the first occurrence of *Spiroloculina* sp. is noted in unit 7, sample 202; last occurrence is noted in unit 7, sample 244.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Recent (Loeblich and Tappan, 1964).

Family FISCHERINIDAE

Meandrospira sp.
(Plate 12, D)

Meandrospira Loeblich and Tappan, 1946, p. 74.

DESCRIPTION.—Test free, small, composed of proloculus followed by tubular second chamber, which spirals streptospirally and involute about proloculus in short zigzag bends; wall calcareous, imperforate; aperture simple, terminal.

REMARKS.—Specimens average 0.5 mm in diameter, and are characterized by many chambers per whorl; specimens noted in units 2, 6, 7, and 10.

In the present study the first occurrence of *Meandrospira* sp. is noted in unit 2, sample 38; last occurrence is noted in unit 10, sample 341.

STRATIGRAPHIC RANGE.—Lower Permian-Recent (Loeblich and Tappan, 1964). Many species have been described from the Albian-Cenomanian of Texas (Loeblich and Tappan, 1946; Frizzell, 1954).

Family MILIOLIDAE

Quinqueloculina sp.
(Plate 12, E)

Quinqueloculina D'Orbigny, Loeblich and Tappan, 1964, p. C458.

DESCRIPTION.—Test coiled, with chambers one-half in length and alternating regularly in five planes of coiling, 72° apart, but with successive chambers 144° apart, so that three chambers are visible from exterior on one side of test and four visible from opposite side; wall calcareous, porcellaneous, imperforate; aperture terminal, rounded, with simple bifid tooth.

REMARKS.—Specimens noted to occur in units 2, 4, 5, 6, 7, 8, 9, 10, and 11.

In the present study the first occurrence of *Quinqueloculina* sp. is noted in unit 12, sample 58; last occurrence is noted in unit 11, sample 495.

STRATIGRAPHIC RANGE.—Jurassic-Recent (Loeblich and Tappan, 1964).

Triloculina sp.
(Plate 12, F)

Triloculina D'Orbigny, Loeblich and Tappan, 1964, p. C466.

DESCRIPTION.—Test free, with chambers each one-half coil in length, early chambers in quinqueloculine arrangement, later chambers added in planes 120° apart, only final three chambers visible externally; wall calcareous, imperforate, porcellaneous, or agglutinate; aperture terminal, typically with bifid tooth.

REMARKS.—Specimens occur rarely in units 2, 6, 7, and 11. In the present study the first occurrence or *Triloculina* sp. is noted in unit 2, sample 39; last occurrence is noted in unit 11, sample 483.

STRATIGRAPHIC RANGE.—Jurassic-Recent (Loeblich and Tappan, 1964).

Nummoloculina heimi
(Plate 13, A-C)

Nummoloculina heimi Bonet, *emend.* Conkin and Conkin, 1958, p. 152.

DESCRIPTION.—Test free, biconcave to biconvex discoidal; greatest thickness one-quarter to one-half height; height ranging between 0.43-2.16 mm; test consisting of proloculus followed by 1-10 precisely arranged quinqueloculine embryonic chambers, followed by as many as seven involute, compressed planispiral whorls, divided by short septa into several chambers; wall calcareous, imperforate; aperture a low arch with small, stocky tooth.

REMARKS.—Specimens are well preserved and occur abundantly in units 2, 4, 6, and 7. Specimens average 2.0 mm in height, contain seven whorls, and average 10 septa in the sixth whorl; some specimens noted in the uppermost part of unit 7, and in units 10 and 11 might be better assigned to *N. regularis*, a middle to Upper Cretaceous form which differs slightly from *N. heimi*.

In the present study the first occurrence of *N. heimi* is noted in unit 2, sample 25; last occurrence is noted in unit 11, sample 509.

STRATIGRAPHIC RANGE.—Albian-Cenomanian (Conkin and Conkin, 1958). *N. heimi* is well known and has been described from the Edwards, Devils River and Glen Rose Limestones of Texas, and the El Abra Limestone of Mexico. Specimens have been previously described in the Sierra Madre Limestone by Chubb (1959) and by Castro-Mora and others (1975).

Miliola? sp.
(Plate 14, A)

Miliola Lamark, Loeblich and Tappan, 1964, p. C468.

DESCRIPTION.—Test with quinqueloculine chamber arrangement; aperture with trematophore (cribate).

REMARKS.—Specimens restricted to unit 11 and average 0.5 mm in height; positive identification unknown due to lack of published information and unknown nature of aperture on observed specimens; specimens very similar to the Upper Cretaceous "miliolids" of Iran (Borzorgnia, 1964, pl. LXXX) and Aquitaine (Cuvillier, 1956, pl. XXXVIII).

In the present study the first occurrence of *Miliola?* sp. is noted in unit 11, sample 479; last occurrence is noted in unit 11, sample 511.

STRATIGRAPHIC RANGE.—Cenomanian-Eocene (Borzorgnia 1964; Cuvillier, 1956; Loeblich and Tappan, 1964).

Massilina? sp.
(Plate 14, B)

Massilina Schlumberger, Loeblich and Tappan, 1964, p. C462.

DESCRIPTION.—Test free, ovate in outline, somewhat flattened, proloculus followed by chambers one-half coil in length, early ones in quinqueloculine arrangement, later chambers added in single plane, on alternate sides; wall calcareous, porcellaneous, imperforate; aperture at open end of final chamber, with bifid tooth.

REMARKS.—Specimens restricted to unit 11; specimens average 0.8 mm in height, including final chambers; positive identification lacking due to unknown nature of aperture.

In the present study the first occurrence of *Massilina* sp. is noted in unit 11, sample 484; last occurrence is noted in unit 11, sample 499.

STRATIGRAPHIC RANGE.—Lower Cretaceous-Recent (Loeblich and Tappan, 1964).

Superfamily GLOBIGERINACEA
Family HETEROHELICIDAE

Heterohelix moremani
(Plate 14, C)

Heterohelix moremani Cushman, Pessagno, 1967, p. 260-261.

DESCRIPTION (from Cushman, 1946).—Test elongate, two and one-half to three times as long as broad, gradually tapering throughout, only slightly enlarged in later portion, periphery distinctly indented throughout; sutures distinct and depressed throughout; wall smooth, finely perforate; wall lacking striae.

REMARKS.—Specimens poorly preserved, averaging 0.1 mm in height, 0.05 mm in breadth at widest part; specimens lack height of holotype as illustrated by Pessagno

(1967, pl. 89, figs. 1-2); specimens distinguished by large size and finely perforate wall; specimens noted in units 4 and 8.

In the present study the first occurrence of *H. moremani* is noted in unit 4, sample 72; last occurrence is noted in unit 8, sample 274.

STRATIGRAPHIC RANGE.—Albian?-lower Cenomanian-Turonian: *Rotalipora gandolfi-R. greenhornensis* Assemblage Zone to *Globotruncana helvetica* Assemblage Zone (Pessagno, 1967).

Heterohelix reussi
(Plate 14, D)

Heterohelix reussi Cushman, Pessagno, 1967, p. 263.

DESCRIPTION (from Cushman, 1946).—Test about one and one-half times as long as broad, rapidly tapering, greatest breadth formed by last pair of chambers; chambers globular, sutures distinctly depressed throughout; wall smooth, finely perforate.

REMARKS.—Specimens distinguished from *H. moremani* on the basis of large, globular final chambers and rapid tapering; Pessagno (1967) notes that holotypes and paratypes of *H. reussi* show the presence of fine costae, which were not observed in the present study due to poor preservation; specimens noted in units 4 and 8.

In the present study the first occurrence of *H. reussi* is noted in unit 4, sample 72; last occurrence is noted in unit 8, sample 274.

STRATIGRAPHIC RANGE.—Lower Turonian-lower Campanian (Pessagno, 1967).

Guembelitria sp.
(Plate 14, E)

Guembelitria Cushman, Pessagno, 1967, p. 258.

DESCRIPTION.—Test small, triserial; chambers spherical; sutures depressed; wall smooth, finely perforate; aperture large, semicircular, highly arched.

REMARKS.—Specimens show affinities to *G. cretacea* due to sphericity of chambers; specimens average 0.5 mm by 0.5 mm; specimens noted in units 4 and 8.

In the present study the first occurrence of *Guembelitria* sp. is noted in unit 4, sample 73; last occurrence is noted in unit 8, sample 271.

STRATIGRAPHIC RANGE.—Lower Cretaceous-Eocene (Pessagno, 1967).

Family ROTALIPORIDAE

Rotalipora cushmani
(Plate 14, F)

Rotalipora cushmani Morrow, Pessagno, 1967, p. 292-293.

DESCRIPTION (from Pessagno, 1967).—Test trochoid, dorsal side moderately convex with chambers flattened or slightly inflated, dorsal sutures roundly curving, producing scalloped periphery; ventral side strongly convex with strongly inflated chambers; sutures deeply grooved and nearly radiate.

REMARKS.—Specimens rare and poorly preserved; specimens average 0.5 mm in length, 0.2 mm in breadth.

In the present study the first occurrence of *R. cushmani* is noted in unit 4, sample 74; last occurrence is noted in unit 8, sample 281.

STRATIGRAPHIC RANGE.—Upper Cenomanian: *R. cushmani* Zone (Postuma, 1971).

Hedbergella planispira
(Plate 15, A)

Hedbergella planispira Tappan, Pessagno, 1967, p. 283-284.

DESCRIPTION (from Pessagno, 1967).—Test free, tiny, low trochospiral with two to two and one-half whorls, five to seven chambers in final whorl; sutures distinct, slightly depressed; aperture interiomarginal, extraumbilical-umbilical.

REMARKS.—Specimens noted appear slightly larger than the holotype of Loeblich and Tappan (1961), measuring 0.3 mm in length.

In the present study the first occurrence of *H. planispira* is noted in unit 4, sample 73; last occurrence is noted in unit 8, sample 271.

STRATIGRAPHIC RANGE.—Upper Albian-Coniacian (Pessagno, 1967).

Family GLOBOTRUNCANIDAE

Praeglobotruncana stephani
(Plate 15, B a-b)

Praeglobotruncana stephani Gandolfi, Pessagno, 1967, p. 287.

DESCRIPTION (from Pessagno, 1967).—Test free, trochospiral, two to three whorls with five to eignt chambers in final whorl; spiral side strongly convex, umbilical side moderately convex, wall calcareous, finely perforate, surface finely spinose; beaded peripheral keel bordering early whorls; aperture an interiomarginal arch.

REMARKS.—Specimens small, distinguished by strongly convex spiral side; keel difficult to distinguish in most specimens; specimens noted in units 4, 6, 7, and 11.

In the present study the first occurrence of *P. stephani* is noted in unit 4, sample 64; last occurrence is noted in unit 11, sample 491.

STRATIGRAPHIC RANGE.—Upper Cenomanian-Turonian (Pessagno, 1967).

Dicarinella algeriana
(Plate 15, C)

Dicarinella algeriana Caron; Lamolda, 1977, p. 387.

REMARKS.—This species is very similar to *Praeglobotruncana stephani*, but differs in that spiral side is moderately convex and umbilical side is nearly planoconvex; specimens are noted in units 4 and 8, but some specimens identified as *P. stephani* in units 6, 7, and 11 might be better assigned to *D. algeriana*.

In the present study the first occurrence of *D. algeriana* is noted in unit 4, sample 74; the last occurrence is noted in unit 8, sample 271.

STRATIGRAPHIC RANGE.—Upper Cenomanian-lower Turonian (Lamolda, 1977).

Family PLANOMALINIDAE

Globigerinelloides bentonensis
(Plate 15, D)

Globigerinelloides bentonensis Morrow, Pessagno, 1967, p. 275.

DESCRIPTION.—Test free, planispiral, involute to partially evolute, biumbilicate, six to eight chambers in final whorl; peripheral outline lobate; sutures distinct, radial, straight to gently curved; aperture a broad, low, interiomarginal, equatorial arch.

REMARKS.—Specimens noted average 0.4 mm in length; last chambers show varying degrees of flattening.

In the present study first occurrence of *G. bentonensis* is noted in unit 4, sample 73; last occurrence is noted in unit 8, sample 271.

STRATIGRAPHIC RANGE.—Cenomanian (Pessagno, 1967).

Family MARGINOTRUNCANIDAE

Marginotruncana marianosi
(Plate 15, E)

Marginotruncana marianosi Douglas, Lamolda, 1977, p. 398.

DESCRIPTION.—Test free, trochospiral, with nearly flat spiral side; umbiliconvex; equatorial periphery slightly lobate; axial periphery angular; chambers subrectangular to subtriangular, six to eight chambers in final whorl; aperture interiomarginal, extra-umbilical to umbilical.

REMARKS.—Specimens restricted to unit 11, preservation very poor.

In the present study the first occurrence of *M. marianosi* is noted in unit 11, sample 484; last occurrence is noted in unit 11, sample 490.

STRATIGRAPHIC RANGE.—Middle Turonian-upper Turonian (Lamolda, 1977).

Whiteinella baltica
(Plate 15, F)

Whiteinella baltica Douglas and Rankin, 1969, p. 197.

DESCRIPTION (from Douglas and Rankin, 1969).—Test free, low-trochospiral, equatorial periphery strongly lobate, axial periphery rounded; chambers inflated, sub-spherical, four to five in final whorl; initial chambers increase rapidly in size, final chambers increase gradually; chamber surface coarsely hispid; umbilicus shallow, wide; primary aperture extraumbilical-umbilical.

REMARKS.—Specimens large, robust; coarsely hispid chamber surface is noted.

In the present study the first occurrence of *W. baltica* is noted in unit 4, sample 74; last occurrence is noted in unit 8, sample 273.

STRATIGRAPHIC RANGE.—Middle Cenomanian-Santonian (Robaszynski and Caron, 1979).

Whiteinella archeocretacea
(Plate 16, A)

Whiteinella archeocretacea Pessagno, 1967, p. 298.

DESCRIPTION (from Pessagno, 1967).—Test lobate, low trochospiral with four to five chambers in last whorl; umbilicus shallow and wide; lacking carinae; aperture extraumbilical-umbilical.

REMARKS.—Specimens noted rarely in unit 11, with preservation very poor.

In the present study the first occurrence of *W. archeocretacea* is noted in unit 11, sample 485; last occurrence is noted in unit 11, sample 502.

STRATIGRAPHIC RANGE.—Upper Turonian-lower Santonian (Pessagno, 1967).

Family UNCERTAIN

Pithonella ovalis
(Plate 16, B)

Pithonella ovalis Kaufman, Bonet, 1956, p. 456.

DESCRIPTION (from Bonet, 1956).—Test simple, unilocular elongate oval, circular in transverse section; extremities rounded; wall laminated, imperforate, composed of radially arranged calcite; aperture simple, small, located at one extremity of test.

REMARKS.—Flood of specimens occur in units 4 and 8, preservation generally poor.

In the present study the first occurrence of *P. ovalis* is noted in unit 4, sample 73; last occurrence is noted in unit 8, sample 274.

STRATIGRAPHIC RANGE.—Albian-Maastrichtian (Bonet, 1956).

Class ACTINOPODA
Subclass RADIOLARIA
(Plate 16, C-D)

REMARKS.—Radiolarians are noted in units 4, 6, 7, 8, 10, and 11, but preservation is poor, making classification difficult; specimens can be best assigned to the orders Spumellaria and Nassellaria, based on symmetry; certain specimens show affinities to the families Actinommidae, Phacodiscidae, and Theoperidae.

In the present study the first occurrence of radiolarians is noted in unit 4, sample 63; last occurrence is noted in unit 11, sample 490.

STRATIGRAPHIC RANGE.—Actinomids, Triassic-Recent; Phacodiscids, Mesozoic-Recent; Theperids, Triassic-Recent (Kling, 1978).

Phylum RHODOPHYTA
Family SOLENOPORACEAE

Parachaetes? sp.
(Plate 16, E)

Parachaetes Wray, 1977, p. 48.

DESCRIPTION (from Wray, 1977).—Thallus consists of nodular masses which are often hemispherical; cellular tissue is compact and composed of radially arranged, rounded or polygonal filaments of cells, filaments contain well defined, regularly spaced partitions between cells, giving tissues a gridlike pattern in vertical sections; length of individual cells generally greater than cell diameter.

REMARKS.—Only one rare specimen noted, contained in unit 10, sample 304; positive identification questionable due to unknown nature of filaments in vertical section.

STRATIGRAPHIC RANGE.—Ordovician-Paleogene (Wray, 1977).

Solenopora? sp.
(Plate 16, F)

Solenopora Dybowski, Johnson, 1961, p. 74.

DESCRIPTION (from Johnson, 1961).—Thallus consisting of nodular masses; in vertical section partitions between cell within filaments are absent or inconspicuous.

REMARKS.—Specimens rare, noted in unit 2, sample 58; positive identification lacking due to rarity of specimens.

STRATIGRAPHIC RANGE.—Cambrian-Paleocene (Wray, 1977).

Family GYMNOCODIACEAE

Permocalculus sp.
(Plate 17, A)

Permocalculus Elliot, 1955, p. 83-91.
Permocalculus Elliot, Johnson, 1961, p. 81.

DESCRIPTION (from Johnson, 1961).—Thallus irregular, segmented; segments may be spherical, ovoid, barrel-shaped, elongated, irregularly finger-like, or with pinching and swelling units; pores small and cortical; sporangia cortical or medullary.

REMARKS.—Specimens common and restricted to unit 4, sample 77.

STRATIGRAPHIC RANGE.—Permian-Paleocene (Wray, 1977).

Family CORALLINACAE

Lithothamnium? sp.
(Plate 17, B)

Lithothamnium Philippi, Johnson, 1964, p. 4.

DESCRIPTION (from Johnson, 1961).—Characterized by compact tissue formed of rows of rectangular cells; thallus has well developed hypothallus and perithallus; hypothallus composed of curved rows of cells, perithallus composed of vertical rows.

REMARKS.—Specimens restricted to two samples, 311 and 315, unit 10. Positive identification lacking due to scarcity of material.

STRATIGRAPHIC RANGE.—Upper Jurassic-Recent (Wray, 1977).

Family UNCERTAIN

Polygonella sp.
(Plate 17, C)

Polygonella Elliot, 1957, p. 229.
Polygonella Johnson, 1964, p. 10.

DESCRIPTION (from Johnson, 1964).—Thallus crustose or encrusting, consisting of a single layer of large cells of polygonal-prismatic shape.

REMARKS.—Specimens occur abundantly in every unit. Some specimens can be assigned to *P. incrustacea* Elliott.

In the present study first occurrence of *Polygonella* is noted in sample 25, last occurrence is noted in sample 511.

STRATIGRAPHIC RANGE.—Upper Jurassic-Upper Cretaceous (Johnson, 1964).

Phylum CHLOROPHYTA
Family CODIACEAE

Lithocodium sp.
(Plate 17, D)

Lithocodium Elliott, 1956, p. 227-230.
Lithocodium Elliott, Johnson, 1964, p. 25.

DESCRIPTION (from Johnson, 1964).—Crustose, superimposed crusts may develop into irregular nodular masses; subdermal structure consists of inner layer consisting of very irregularly disposed coarse filaments without definite orientation, and outer layer made up of irregularly radial filaments which divide into finer filaments and may appear to reunite.

REMARKS.—Specimens appear crustose, outer wall poorly defined. Specimens occur in units 6, 7, and 11. Some specimens might be better assigned to group *L. japonicum* (Johnson, 1964, pl. 39, fig. 2).

In the present study first occurrence of *Lithocodium* sp. is noted in sample 136; last occurrence is noted in sample 508.

STRATIGRAPHIC RANGE.—Upper Jurassic-Lower Cretaceous (Johnson, 1964).

Family DASICLADACAE

Cylindroporella sp.
(Plate 17, E)

Cylindroporella Johnson, 1964, p. 117.

DESCRIPTION (from Johnson, 1964).—Thallus segmented, consisting of cylindrical segments with rounded ends; each segment contains a narrow central stem from which develop numerous whorls of six primary branches, alternating with sporangia, giving appearance of diagonal rows of sporangia in vertical sections.

REMARKS.—Specimens rare, restricted to unit 7, sample 182.

STRATIGRAPHIC RANGE.—Upper Jurassic-Upper Cretaceous (Wray, 1977).

Trinocladus? sp.
(Plate 17, F)

Trinocladus Raineri, Johnson, 1961, p. 134.

DESCRIPTION (from Johnson, 1961).—Thallus cylindrical or slender and club-shaped, central stem cylindrical, moderately large.

REMARKS.—Specimens very rare, restricted to unit 10, sample 386. Positive identification lacking due to scarcity of material.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Paleogene (Wray, 1977). Species described from Cenomanian of northern Africa (Elliott, 1955).

Neomeris sp
(Plate 18, A)

Neomeris Lamoureux, Johnson, 1961, p. 134.

DESCRIPTION (from Johnson, 1961).—Plant consists of a central stem from which arise very regular whorls of primary branches; each primary branch ends in a tuft of secondary branches which end in a terminal hair.

REMARKS.—Specimens very rare, occurring in and restricted to unit 6, sample 95.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Recent (Wray, 1977); species known from Cenomanian-Turonian of Mexico and Libya (Elliott, 1955).

Salpingoporella? sp.
(Plate 18, B)

Salpingoporella Pia, Johnson, 1964, p. 20.

DESCRIPTION (from Johnson, 1964).—Thallus small, cylindrical and unbranched, primary branches are few in number and arranged in regular whorls, small at junction with central stem enlarged toward exterior.

REMARKS.—Positive identification lacking due to small number of specimens; specimen restricted to unit 2, sample 42.

STRATIGRAPHIC RANGE.—Upper Jurassic-Lower Cretaceous (Johnson, 1964).

Acicularia sp.
(Plate 18, C)

Acicularia d'Archiac, Johnson, 1961, p. 138.

DESCRIPTION (from Johnson, 1961).—Plant consists of slender stem from which arise whorls of regularly arranged primary branches, small in size.

REMARKS.—Specimens occur sparse to commonly in units 2, 4, 6, 7, and 10.

STRATIGRAPHIC RANGE.—Upper Jurassic-Recent (Wray, 1977), with species described from the Cenomanian-Turonian of Iraq (Elliot, 1955).

Phylum CYANOPHYTA

Girvanella sp.
(Plate 18, D a-b)

Girvanella Nicholson and Etheridge, Johnson, 1961, p. 194.

DESCRIPTION (from Wray, 1977).—Characterized by flexuous, tubular filaments of uniform diameter and thick calcareous walls, tubes are unsegmented cylinders which are rarely branched; filaments may be free, but usually occur in groups, twisted together to form nodules and encrusting masses; known to occur intergrown with encrusting foraminifera.

REMARKS.—Specimens noted in units 6, 7, 10, and 11; association with encrusting foraminifera noted, but specimens usually occur as encrusting masses.

In the present study the first occurrence of *Girvanella* sp. is noted in unit 6, sample 266; last occurrence is noted in unit 11, sample 508.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Eocene (Wray, 1977).

Genera of Uncertain Affinities

Stenoporidium? sp.
(Plate 18, E)

Stenoporidium Yabe and Toyama, Johnson, 1964, p. 39.

DESCRIPTION (from Johnson, 1964).—Thallus massive, crustose to nodular; in longitudinal section structure appears as a series of closely packed, subparallel tubes more or less radially arranged; in cross-section, tubes are rounded to irregular, sometimes fusing into prolonged masses.

REMARKS.—Positive identification questionable due to unknown nature of tubes; specimens appear similar to echinoid plates, but do not go extinct under cross-nichols; specimens rare, restricted to unit 6, samples 11 and 126.

STRATIGRAPHIC RANGE.—Upper Jurassic-Lower Cretaceous (Johnson, 1964).

Phylum PORIFERA
Sponge spicules

REMARKS.—Sponge spicules are noted to occur in every unit except 5 and 9.

In the present study the first occurrence of sponge spicules is noted in unit 2, sample 59; last occurrence is noted in unit 11, sample 490.

Phylum COELENTERATA
Class ANTHOZOA
Order SCLERACTINIA
Family FAVIIDAE

Hydnophora sp.
(Plate 19, A a-b)

Hydnophora Fischer, Wells, 1956, p. F402-403.

DESCRIPTION (from Wells, 1956).—Hydnophoroid; collines discontinuous, short, conical; columella trabecular to lamellar, discontinuous, short, conical.

REMARKS.—Specimens restricted to unit 4; solitary specimens noted, averaging 1.0 mm or less in diameter; colonial specimens also noted.

In the present study the first occurrence of *Hydnophora* is noted in unit 4, sample 62; last occurrence is noted in sample 78.

STRATIGRAPHIC RANGE.—Cretaceous-Recent (Wells, 1956).

Multicolumnastraea sp.
(Plate 19, B a-b)

Multicolumnastraea Vaughan, Wells, 1956, p. F406.

DESCRIPTION (from Wells, 1956).—Massive, encrusting, or subfoliaceous, plocloid colonies, septothecate; septal margins regularly dentate; columella formed by three or four trabecular pillars.

REMARKS.—Specimens noted in units 10 and 11; individual polyps average 2-4 mm in diameter; septal margins well preserved; coenosteum not preserved; solitary and colonial specimens noted.

In the present study the first occurrence of *Multicolumnastraea* sp. is noted in unit 10, sample 463; last occurrence is noted in unit 11, sample 495.

STRATIGRAPHIC RANGE.—Upper Cretaceous (Wells, 1956).

Family ACROPORIDAE

Astreopora? sp.
(Plate 19, C)

Astreopora Blainville, Wells, 1956, p. F374.

DESCRIPTION (from Wells, 1956).—Massive or subramose; no axial corallites; coenosteum reticular, formed by outwardly inclined trabeculae, with spinose surface; dissepiments tabular; corallite walls solid.

REMARKS.—Positive identification lacking due to scarcity of material; single specimen noted in unit 11, sample 496. Individual polyps measure 2 mm in diameter.

STRATIGRAPHIC RANGE.—Upper Cretaceous-Recent (Wells, 1956).

Family STYLINIDAE

Cyathophora? sp.
(Plate 19, D)

Cyathophora Michelin, Wells, 1956, p. F375.

DESCRIPTION (from Wells, 1956).—Massive, plocoid; costate corallites united by more or less costate tabular coenosteum; septa well developed but rarely extending to corallite axis, no columella; endothecal dissepiments tabular.

REMARKS.—Positive identification lacking due to rarity of material. Single, colonial specimen noted in unit 4, sample 79. Individual polyps less than 1 mm in diameter.

STRATIGRAPHIC RANGE.—Jurassic-Cretaceous (Wells, 1956).

Phylum ARTHROPODA
Subclass OSTRACODA
Order PODOCOPIDA
Superfamily CYTHERACEA

REMARKS.—Ostracod remains are common to abundant in every lithologic unit of the Sierra Madre Limestone, ranging from sample 25 to sample 507. Occurrences are usually in the form of disarticulated valves; occasionally poorly preserved whole specimens are noted; they appear smooth and bean-shaped, oval or lenticular. Classification is difficult, but most whole specimens can be assigned to Family Cytherididae which has generic representatives from Permian to Recent.

Phylum ECHINODERMATA
Class ECHINOIDEA
Family PHYMOSOMATIDAE

Glyptocyphus sp.
(Plate 20, A a-c)

Glyptocyphus Pomel, Fell and Pawson, 1966, p. U399.

DESCRIPTION (from Fell and Pawson, 1966).—Test small, low, wheel shaped; ambilical plates polyporous, with primary tubercules reduced to single or alternating series; apical system with oculars exsert.

REMARKS.—Whole specimens abundant in marl section, unit 8.

STRATIGRAPHIC RANGE.—Upper Cretaceous (Fell and Pawson, 1966).

Family HEMIASTERIDAE

Palhemiaster sp.
(Plate 20, B III a-b)

Palhemiaster Lambert, Fell and Pawson, 1966, p. U565.

DESCRIPTION (from Fell and Pawson, 1966).—Intermediate form between *Hemiaster* and *Macraster* in having incomplete peripetalous fasciole, developed only in rear part of test.

REMARKS.—Whole specimens very abundant in marl section, unit 8.

STRATIGRAPHIC RANGE.—Aptian-Cenomanian (Fell and Pawson, 1966).

Family HEMICIDARIDAE

Pedinopsis sp.
(Plate 21, A a-c)

Pedinopsis Cotteau, Fell and Pawson, 1966, p. U388-389.

DESCRIPTION.—Test medium-sized to large, subhemispherical or subconical; ambs with porepairs biserial throughout but may be uniserial below ambitus; amb tubercules small, weakly crenulate, similar to interamb primary tubercules; interambs with numerous equal-sized tubercules, forming vertical and horizontal series.

REMARKS.—Whole specimens sparse to rare in marl section of unit 8. Specimen may be intermediate form (based on shape) between *P. texana* Cooke (Cooke, 1955, p. 90) and *P. pondi* Clark (Cooke, 1953, p. 7).

STRATIGRAPHIC RANGE.—Cenomanian-Santonian (Fell and Pawson, 1966).

Phylum MOLLUSCA
Class CEPHALOPODA
Family PLANCENTICERATIDAE

Proplacenticeras? sp.
(Plate 21, B a-b)

Proplacenticeras Spath, Arkell *et al.*, 1957, p. L390.

DESCRIPTION.—Compressed, with flat or slightly convex sides and narrow flat venter; nearly smooth, with or without slight conical umbilical tubercules and ventrolateral clavi and crescentric ribs on outer part of sides.

REMARKS.—Whole specimens very rare in marl section of unit 8; positive identification lacking due to extremely poor preservation and lack of material. Specimens very small, 40-60 mm in diameter. One vertically imbedded specimen was collected by C. I. Smith, Burke Burkart and J. G. McPherson during the summer of 1981; crescentric ribs appear absent.

STRATIGRAPHIC RANGE.—Cenomanian-Coniacian (Arkell *et al.*, 1957).

Class BIVALVIA
Order ACRICIDA
Family LIMOPSIDAE

Pectunculina sp.
(Plate 21, C a-b)

Pectunculina D'Orbigny, Cox and Newell *et al.*, 1969, p. N265.

DESCRIPTION (from Cox and Newell *et al.*, 1969).—Orbicular, nearly equatorial, commonly with slight forward obliquity, sculptured with radial costellae; inner margin crenulate.

REMARKS.—Specimens small (2.5 mm in height, 2.5 mm in breadth); whole specimens abundant in marl section of unit 8; specimens generally poorly preserved.

STRATIGRAPHIC RANGE.—Cretaceous-Recent (Cox and Newell *et al.*, 1969).

Order HIPPURITOIDA
Family RADIOLITIDAE

Radiolites
(Plate 22, A a-b)

Radiolites Lamarck, Cox and Newell *et al.*, 1969, p. N806.

DESCRIPTION (from Cox and Newell *et al.*, 1969).—Right valve conical, ornamented with strong longitudinal folds over whole valve, siphonal bands smooth accentuations of regular folds; outer wall structure coarsely reticulate.

REMARKS.—Specimens generally occur as broken shell fragments; whole specimens rare, generally less than 5 mm in diameter; specimens distinguished in thin section by regular, reticular wall structure; specimens noted in units 4, 6, 7, and 10.,

In the present study first occurrence of *Radiolites* is noted in sample 75; last occurrence is noted in sample 472.

STRATIGRAPHIC RANGE.—Cenomanian-Maastrichtian (Coogan, 1977).

Sauvagesia sp.
(Plate 23, A a-c)

Sauvagesia Choffat, Cox and Newell *et al.*, 1969, p. N810-811.

DESCRIPTION (from Cox and Newell *et al.*, 1969).—Right valve conical to cylindroconical, ornamented with longitudinal ribs; siphonal bands finely costate.

REMARKS.—Specimens generally occur whole, largest specimens measuring 7 cm in diameter; commonly bound together in growth position; specimens distinguished by characteristic polygonal wall structure in thin section; specimens observed show affinities to *S. texana* Roemer (Coogan, 1977, p. 55); specimens restricted to unit 11.

In the present study occurrence of *Sauvagesia* is noted in sample 497; last occurrence is noted in sample 508.

STRATIGRAPHIC RANGE.—Albian-Maastrichtian (Coogan, 1977).

Family REQUIENIIDAE

Toucasia sp.

Toucasia Munier-Chalmas, Cox and Newell *et al.*, 1969, p. N781.

DESCRIPTION (from Cox and Newell *et al.*, 1969).—Valves keeled, carinate, or frilled with shallow siphonal bands on posterior side of anterior valve.

REMARKS.—Specimens occur as detached valves "floating" in rock matrix; specimens distinguished from other mollusk fragments by dark brown, organic-rich color inside shell fragment; specimens noted in units 2 and 7.

In the present study first occurrence of *Toucasia* is noted in sample 28, last occurrence is noted in sample 175.

STRATIGRAPHIC RANGE.—Barremian-Cenomanian (Cox and Newell *et al.*, 1969).

Class GASTROPODA
Family PSEUDOMELANIIDAE

Tylostoma sp.
(Plate 24, A a-d)

Tylostoma sp., Perkins, 1960, p. 89.

DESCRIPTION (from Stanton, 1947).—Shell large, robust, consisting of four to five whorls; apical angle about 45°, spire elevated, equal to last whorl in height; suture conspicuous; intermediate convexity of whorl is conspicuous; aperture wide, oval, broad, throughout.

REMARKS.—Whole specimens occur rarely in marl section, unit 8; specimens average 80 mm in height, 60 mm greatest breadth.

STRATIGRAPHIC RANGE.—Barremian-Turonian (Alencáster, 1956).

Family NATICIDAE

Lunatia sp.
(Plate 24, B)

Lunatia Gray, Stanton, 1947, p. 65.

DESCRIPTION (from Stanton, 1947).—Shell small, elongate ovate, consisting of approximately six convex whorls; spire elevated; umbilicus small; aperture elongate-ovate, broadly rounded; sutures deeply impressed.

REMARKS.—Whole specimens occur rare to sparsely in marl section, unit 8; specimens average 25 mm in height, 25 mm greatest breadth.

STRATIGRAPHIC RANGE.—Cretaceous-Recent (Moore *et al.*, 1952).

Pleurotomaria? sp.
(Plate 24, C)

REMARKS.—The occurrence of one specimen is noted from the marl section, unit 8; specimen average 45 mm in height, 60 mm in breadth; shell consists of three whorls; apex missing; identification tentative due to lack of well preserved specimens.

STRATIGRAPHIC RANGE.—Unknown.

Family NERINEIDAE

Nerinea sp.
(Plate 25, A)

REMARKS.—Specimens fairly large; specimens noted to occur in units 4, 6, 7 and 11. Specimens display wide umbilicus; large outer lip and reduced inner lip noted, with little or no thickening of opposite wall.

In the present study first occurrence of *Nerinea* is noted in sample 225; last occurrence is noted in sample 482.

STRATIGRAPHIC RANGE.—Jurassic-Cretaceous (Moore *et al.*, 1952).

Family TURRITELLIDAE

Turritella? sp.

Turritella Lamark, Allison, 1955, p. 415.

DESCRIPTION.—Shell small slender, containing numerous whorls.

REMARKS.—Specimens observed were poorly preserved, so that no internal structure could be discerned. Average specimen measures 20 mm in height, 5 mm greatest breadth, and contains approximately 7 whorls. Specimens occur rare to commonly in and are restricted to unit 4.

In the present study first occurrence of *Turritella* is noted in sample 62; last ocurrence is noted in sample 77.

STRATIGRAPHIC RANGE.—Cretaceous-Recent (Moore *et al.*, 1952). Many species known from Fredricksburg (Lower Cretaceous) of Texas (Stanton, 1947).

Family ORTHOSTOMIDAE

Actaeonella sp.
(Plate 26, A)

Actaeonella D'Orbigny, 1842.

A. dolium Roemer, Stanton, 1947, p. 109.

DESCRIPTION.—Shell large, stout fusiform or subovate, convolute; greatest breadth near middle; posterior end narrow, anterior end broader.

REMARKS.—Whole specimens observed in outcrop; specimens large averaging 60 mm in length, 40 mm in breadth at widest interval. Specimens noted from units 10 and 11. At the top of unit 10 several specimens were noted and appeared to form a small biostrome.

STRATIGRAPHIC RANGE.—Cretaceous (Stanton, 1947).

Phylum ANNELIDA
Class POLYCHAETIA
Order SEDENTARIDA
Family SERPULIDAE

Serpula worm tubes
(Plate 26, B)

REMARKS.—Tubes appear as circular, oval, or elongate structures with concentric laminations.

In the present study serpula worm tubes are noted in unit 2, sample 31, and unit 11, sample 488.

STRATIGRAPHIC RANGE.—Silurian-Recent (Howell, 1962).

Phylum UNCERTAIN
Trace fossils

REMARKS.—Burrowing was noted in several samples throughout the entire Sierra Madre Limestone rock column. Most consisted of small, irregular U-shaped burrows that are filled with calcite spar. Of particular note is the presence of large, crustacean-type tracks and trails that occur abundantly in the marl section, unit 8.

REFERENCES CITED

ALENCÁSTER, GLORIA, 1956, Pelecípodos y gasterópodos del Cretácico Inferior de la región de San Juan Raya-Zapotitlán, Estado de Puebla: Univ. Nal. Autón. México, Inst. Geología, Paleontología Mexicana 2, 47 p.

ALLISON, E. C., 1955, Middle Cretaceous gastropoda from Punta China, Baja California, Mexico: Jour. Paleontology, v. 29, p. 400-432.

AMSBURY, D. L., BAY, T. A., AND LOZO, F. E., 1979, A field guide to Lower Cretaceous carbonate strata in the Moffat mound area near Lake Belton, Bell County, Texas: Soc. Econ. Mineralogists and Paleontologists Field Trip 2, A.A.P.G.-S.E.P.M., 1979, National Convention, p. 1-21.

ANDERSON, T. H., BURKART, BURKE, CLEMONS, R. E., BOHNENBERGER, O. H., AND BLOUNT, D. N., 1973, Geology of the western Altos Cuchumatanes, northwestern Guatemala: Geol. Soc. America Bull., v. 84, p. 805-826.

ARKELL, W. J., KUMMEL, BERNHARD, AND WRIGHT, C. W., 1957, Systematic descriptions: *in* Moore, R. C., ed., Treatise on invertebrate paleontology, part L (Cephalopoda, Ammonoidea). Lawrence, Univ. Kansas Press, p. L129-L490.

BANDY, O. L., 1964, General correlation of foraminiferal structure with environment: *in* Imbrie, J., and Newell, N. D., eds., Approaches to paleoecology. New York, Wiley and Sons, p. 75-90.

BANDY, O. L., AND ARNAL, R. E., 1960, Concepts of foraminiferal paleoecology: Am. Assoc. Petroleum Geologists Bull., v. 44, p. 1921-1932.

BARKER, R. W., 1944, Some larger foraminifera from the Lower Cretaceous of Texas: Jour. Paleontology, v. 18, p. 204-209.

BATHURST, R. G. C., 1976, Carbonate sediments and their diagenesis: New York, Elsevier, 658 p.

BAY, T. A., JR., 1977, Lower Cretaceous stratigraphic models from Texas and Mexico: *in* Bebout, D. G., and Loucks, R. G., eds., Cretaceous carbonates of Texas and Mexico - applications to subsurface exploration. Austin, Univ. Texas, Bur. Econ. Geology, Rept. Invest. 89, p. 12-30.

BERQUIST, H. R., AND COBBAN, W. R., 1967, Mollusks of the Cretaceous: Geol. Soc. America, Mem. 67, p. 871-884.

BISHOP, W. F., 1980, Petroleum geology of northern Central America: Jour. Petroleum Geology, v. 3, p. 3-59.

BLAIR, T. C., 1981, Alluvial fan deposits of the Todos Santos Formation of central Chiapas, Mexico: Arlington, Univ. Texas, M. Sc. thesis, 134 p. (unpublished).

BONET, FEDERICO, 1956, Zonificación microfaunística de las calizas cretácicas del este de México: Bol. Asoc. Mex. Geólogos Petroleros, v. 8, p. 389-488.

BÖSE, EMIL, 1905, Reseña acerca de la geología de Chiapas y Tabasco: Inst. Geol. México, Bol. 20, p. 5-100.

BOUTTE, A. L., 1969, Callahan carbonate-sand complex, west-central Texas: *in* Moore, C. H., Jr., ed., A guidebook to the depositional environments and depositional history, Lower Cretaceous shallow shelf carbonate sequence, west-central Texas. Dallas Geol. Soc., 1969, Ann. Meet. A.A.P.G.-S.E.P.M., p. 1-135.

BORZORGNIA, F., 1964, Microfacies and microorganisms of Paleozoic through Tertiary sediments of some parts of Iran: Tehran, National Iranian Oil Company, 20 p.

BUITRÓN, B. E., 1977, *Bellerophon crassus* Meek y Worthen (Mollusca, Gastropoda) en el Pérmico de Chiapas: Univ. Nal. Autón. México, Inst. Geología, Revista, v. 1, p. 69-73.

BURKART, BURKE, AND CLEMONS, R. E., 1972, Late Paleozoic orogeny in northwestern Guatemala: VI Conferencia Geológica del Caribe, Memorias, p. 210-213.

CASTRO-MORA, JOSÉ, SCHLAEPFER, C. J., AND MARTÍNEZ-RODRÍGUEZ, EDUARDO, 1975, Estratigrafía y microfacies del Mesozoico de la Sierra Madre del Sur, Chiapas: Bol. Asoc. Mex. Geólogos Petroleros, v. 85, p. 607-618.

CHUBB, L. J., 1959, Upper Cretaceous of central Chiapas, Mexico: Am. Assoc. Petroleum Geologists Bull, v. 43, p. 725-755.

CLEMONS, R. E., ANDERSON, T. H., BOHNENBERGER, O. H., AND BURKART, BURKE, 1974, Stratigraphic nomenclature of recognized Paleozoic and Mesozoic rocks of western Guatemala: Am. Assoc. Petroleum Geologists Bull., v. 58, p. 313-320.

CLEMONS, R. E., AND BURKART, BURKE, 1971, Stratigraphy of northwestern Guatemala: Bol. Soc. Geol. Mexicana, v. 32, p. 143-158.

CONKIN, J. E., AND CONKIN, B. M., 1956, *Nummoloculina* in Lower Cretaceous of Texas and Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 890-896.

——, 1958, Revision of the genus *Nummoloculina* and emendation of *Nummoloculina heimi* Bonet: Micropaleontology, v. 4, p. 149-158.

CONTRERAS-VÁZQUEZ, HUGO, AND CASTILLÓN-BRACHO, M. G., 1968, Domes of Isthmus of Tehuantepec: Am. Assoc. Petroleum Geologists, Mem. 8, p. 244-260.

COOGAN, A. H., 1977, Early and middle Cretaceous Hippuritacea (rudists) of the Gulf Coast: *in* Bebout, D. G., and Loucks, R. G., eds., Cretaceous carbonates of Texas and Mexico - applications to subsurface exploration. Austin, Univ. Texas, Bur. Econ. Geology, Rept. Invest. 89, p. 32-70.

COOKE, C. W., 1953, American Upper Cretaceous Echinoidea: U. S. Geol. Survey, Prof. Paper 254-A, p. 1-44.

——, 1955, Some Cretaceous echinoids from the Americas: U. S. Geol. Survey, Prof. Paper 264-E, p. 87-112.
COX, L. R., AND NEWELL, N. D. *et al.*, 1969, Systematic description: *in* Moore, R. C., ed., Treatise on invertebrate paleontology, part N, Mollusca 6 (Bivalvia), v. 1-2. Lawrence, Univ. Kansas Press, p. N255-N951.
CUSHMAN, J. A., 1946, Upper Cretaceous foraminifera of the Gulf Coast region of the United States and adjacent areas: U. S. Geol. Survey, Prof. Paper 206, 241 p.
CUVILLIER, J., 1956, Stratigraphic correlations by microfacies in western Aquitaine: *in* Clarke, W. J., Purser, P. H., and Wagner, C. W., eds., International sedimentary petrographical series. Leiden, E. J., Brill, v. II, p. 1-31.
DENGO, GABRIEL, 1975, Paleozoic and Mesozoic tectonic belts in Mexico and Central America: *in* Nairn, A. E., and Stehli, F. G., eds., Ocean basins and margins (The Gulf of Mexico and the Caribbean). New York, Plenum Press, v. 283-323.
DILLEY, F. C., 1973, Cretaceous larger foraminifera: *in* Hallam, A., ed., Atlas of paleobiogeography. New York, Elsevier, p. 403-419.
DOUGLAS, R. G., 1960, Revision of the family Orbitolinidae: Micropaleontology, v. 6, p. 249-270.
DOUGLAS, R. G., AND RANKIN, CLAY, 1969, Cretaceous planktonic foraminifera from Borhnholm and their zoogeographic significance: Lethaia, v. 2, p. 185-217.
DOUGLAS, R. G., AND SAVIN, S. M., 1978, Oxygen isotopic evidence for the depth stratification of Tertiary and Cretaceous planktonic foraminifera: Marine Micropaleontology, v. 3, p. 175-196.
DUNHAM, R. J., 1962, Classification of carbonate rocks according to depositional texture: *in* Classification of carbonate rocks - a symposium. Am. Assoc. Petroleum Geologists, Mem. 1, p. 108-121.
DURHAM, J. W., 1966, Ecology and paleoecology: *in* Moore, R. C., ed., Treatise on invertebrate paleontology, part U (Echinodermata 3), v. 1. Lawrence, Univ. Kansas Press, p. U257-P265.
EICHER, D. L., 1969, Paleobathymetry of Cretaceous Greenhorn Sea in eastern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 53, p. 1075-1090.
ELLIOTT, G. F., 1955, Fossil calcareous algae from the Middle East: Micropaleontology, v. 1, p. 125-131.
——, 1956, Further records of fossil calcareous algae from the Middle East: Micropaleontology, v. 2, p. 327-334.
——, 1957, New calcareous algae from the Arabian Peninsula: Micropaleontology, v. 3, p. 227-230.
ENOS, PAUL, 1974, Reefs, platforms, and basins of middle Cretaceous in northeast Mexico: Am. Assoc. Petroleum Geologists Bull., v. 58, p. 800-809.
FELL, H. B., AND PAWSON, D. L., 1966, Echinacea: *in* Moore, R. C., ed., Treatise on invertebrate paleontology, part U (Echinodermata 3), v. 2. Lawrence, Univ. Kansas Press, p. U367-U695.
FRIZZELL, D. L., 1954, Handbook of Cretaceous foraminifera of Texas: Austin, Univ. Texas, Bur. Econ. Geology, Rept. Invest. 22, p. 1-232.
FROST, S. H., AND LANGENHEIM, R. L., JR., 1974, Cenozoic reef biofacies: DeKalb, Northern Illinois Univ. Press, 388 p.
GUTIÉRREZ-GIL, ROBERTO, 1956, Geología del Mesozoico y estratigrafía pérmica del Estado de Chiapas: México, D. F., Cong. Geol. Internal., 20, Excursión C-15, p. 1-82.
GUZMÁN, E. J., AND CSERNA, ZOLTAN DE, 1963, Tectonic history of Mexico: *in* Childs, O. E., and Beebe, B. W., eds., Backbone of the Americas: tectonic history from pole to pole. Am. Assoc. Petroleum Geologists, Mem. 2, p. 113-129.

HANCOCK, J. M., 1975, The sequence of facies in the Upper Cretaceous of northern Europe compared with that in the Western Interior: Geol. Assoc. Canada, Spec. Paper 13, p. 83-118.
HARBAUGH, J. W., AND MERRIAM, D. F., 1969, Computer applications in stratigraphic analysis: New York, Wiley and Sons, 282 p.
HART, M. B., 1980, A water depth model for the evolution of planktonic Foraminiferida: Nature, v. 286, p. 252-254.
HARTIGAN, J., 1979, Cluster analysis of variables: *in* Dixon, W. J., and Brown, M. B., eds., Biomedical computer programs P-series. Berkeley, Univ. California Press, p. 623-632.
HOWELL, B. F., 1962, Miscellanea-worms: *in* Moore, R. C., ed., Treatise on invertebrate paleontology, part W (Miscellanea). Lawrence, Univ. Kansas Press, p. W144-W171.
IMLAY, R. W., 1944, Cretaceous formations of Central America and Mexico: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 1077-1195.
JOHNSON, J. H., 1961, Limestone-building algae and algal limestones: Golden, Colorado School of Mines, 297 p.
——, 1964, The Jurassic algae: Colorado School of Mines, Quarterly, v. 59, p. 1-129.
KAESLER, R. L., 1959, Aspects of quantitative distributional paleoecology: *in* Merriam, D. F., ed., Computer applications in the earth sciences. New York, Plenum Press, p. 99-120.
KLING, S. A., 1987, Radiolaria: *in* Haq, B. U., and Boersma, Anne, Introduction to marine micropaleontology. New York, Elsevier, p. 203-204.
KONISHI, K., AND EPIS, R. C., 1962, Some Early Cretaceous calcareous algae from Cochise County, Arizona: Micropaleontology, v. 8, p. 67-76.
LAMOLDA, M. A., 1977, Los Marginotruncaninae del Turoniense vasco-cantábrico: Revista Española de Micropaleontología, v. 9, p. 381-410.
LITKE, G. R., 1975, The stratigraphy and sedimentation of Barillas quadrangle, Department of Huehuetenango, Guatemala, C. A.: Arlington, Univ. Texas, M. Sc. thesis, (unpublished).
LOEBLICH, A. R., JR., 1946, Foraminifera from the type Pepper Shale of Texas: Jour. Paleontology, v. 20, p. 130-139.
LOEBLICH, A. R., JR., AND TAPPAN, HELEN, 1946, New Washita foraminifera: Jour. Paleontology, v. 20. p. 238-258.
——, 1953, Studies of Arctic foraminifera: Smithsonian Misc. Coll., v. 121, n. 7, 150 p.
——, 1961, Cretaceous planktonic foraminifera; part I - Cenomanian: Micropaleontology, v. 7, p. 257-304.
——, 1962, Six new generic names in the Mycetozoidea (Trichiidae) and Foraminiferida (Fischerinidae, Bulliminidae, Caucasinidae and Pleurostomellidae), and a redescription of *Loxostomum* (Loxostomidae, new family): Proc. Biol. Soc. Washington, v. 75, p. 107-113.
——, 1964, Sarcodina chiefly "Theocampebians" and Foraminiferida: *in* Moore, R. C., ed., Treatise of invertebrate paleontology, part C, (Protista 2). Lawrence, Univ. Kansas Press, v. 1-2, p. C1-C900.
LÓPEZ-RAMOS, ERNESTO, 1969, Geología del sureste de México y norte de Guatemala: *in* Trabajos técnicos presentados en la segunda reunión de geólogos de América Central. Publ. Geol. ICAITI, v. 2, p. 57-67.
——, 1975, Geological summary of the Yucatán Peninsula: *in* Nairn, A. E., and Stehli. F. G., eds., Ocean basins and margins (The Gulf of Mexico and the Caribbean). New York, Plenum Press, v. 3, p. 257-282.
LOWENSTAM, H. A., AND EPSTEIN, S., 1956, Cretaceous paleo-temperatures as determined

by the oxygen isotope method, their relations to the nature of rudistid reefs: México, D. F., Cong. Geol. Internal., 20, p. 65-76.

Mancini, E. A., 1981, Foraminiferal paleoecology of the Grayson Formation (Upper Cretaceous) of north-central Texas: Gulf Coast Assoc. Geol. Societies, Trans., v. 28, p. 295-311.

Mandelbaum, H., and Sanford, J. T., 1952, Table for computing thickness of strata measured in a traverse or encountered in a bore hole: Geol. Soc. America Bull., v. 63, p. 765-776.

Marie, Pierre, 1952 (1954), Quelques genres nouveaux de foraminifères du Crétacé a facies récifal: Algiers, Cong. Geol. Internal., 19, Proc., sec. 13, fasc. 15, p. 117-124.

Maync, Wolf, 1952, Critical taxonomic study and nomenclatural revision of the Lituolidae based upon the prototype of the family, *Lituola nautiloidea* Lamarck, 1804: Contrib. Cushman Found. Foram. Research, v. 3, pt. 2, p. 35-56.

Moore, C. H., Jr., and Martin, K. G., 1966, Comparison of quartz and carbonate shallow marine sandstones, Fredericksburg Cretaceous, Central Texas: Am. Assoc. Petroleum Geologists Bull., v. 50, p. 981-1000.

Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: New York, McGraw-Hill, 766 p.

Moravec, D. L., 1983, Study of the Concordia fault system near Jerico, Chiapas, Mexico: Arlington, Univ. Texas, M. Sc. thesis, 155 p. (unpublished).

Müllerried, F. K. G., 1942, The Mesozoic of Mexico and northwestern Central America: Washington, D. C., Am. Sci. Congress, 8, Proc., v. 4, p. 125-147

Murray, G. E., 1961, Geology of the Atlantic and Gulf Coast province of North America: New York, Harper and Brothers, 692 p.

Norton, R. D., 1930, Ecologic relations of some foraminifera: Univ. California, Scripps Inst. Oceanography, Tech. Ser., v. 2, p. 331-388.

Omara, S., 1956, New foraminifera from the Cenomanian of Sinai, Egypt: Jour. Paleontology, v. 30, p. 883-890.

Perkins, B. F., 1960, Biostratigraphic studies in the Comanche (Cretaceous) Series of northern Mexico and Texas: Geol. Soc. America, Mem. 83, p. 1-138.

——, 1969, Rudist faunas in the Comanche Cretaceous of Texas: Shreveport Geol. Soc. Guidebook, Spring Field Trip, p. 121-137.

Pessagno, E. A., Jr., 1967, Upper Cretaceous planktonic foraminifera from the western Gulf Coast plain: Palaentographica Americana, v. 37, p. 245-445.

Pindell, J., and Dewey, J. F., 1982. Permo-Triassic reconstruction of western Pangea and the evolution of the Gulf of Mexico/Caribbean region: Tectonics, v. 1, p. 179-211.

Plummer, H. J., 1931, Cretaceous foraminifera in Texas: Austin, Univ. Texas, Bull. 3101, p. 109-203.

Postuma, J. A. 1971, Manual of planktonic foraminifera: New York, Elsevier, 397 p.

Purdy, E. G., 1963, Recent calcium carbonate facies of the Great Bahama Bank; 1. Petrography and reaction groups: Jour. Geology, v. 71, p. 334-355.

Richards, H. G., 1963. Stratigraphy of earliest Mesozoic sediments in southeastern Mexico and western Guatemala: Am. Assoc. Petroleum Geologists Bull., v. 47, p. 1861-1870.

Robaszynski. F., and Carons M., 1979, Atlas de foraminiferes planctoniques du Crétacé moyen (mer Boreales et Tethys): Cahiers de Micropaléontologie, C.N.R.S., v. 1, 185 p.

Saint-Marc, Pierre, 1977, Repartition stratigraphique de grands foraminifères benthiques de l'Aptien, de l'Albien, du Cenomanian et du Turonien dans les regions Mediteranées: Revista Española de Micropaleontología, v. 9, p. 317-325.

Sapper, Karl, 1894, Informe sobre la geografía física y la geología de los estados de Chiapas y Tabasco: Bol. Agric. Miner. e Industr., v. 3, p. 187-211.

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

Sliter, W. V., 1969, Upper Cretaceous foraminifera from southern California and northwestern Baja California, Mexico: Univ. Kansas Paleont. Contr., Serial Number 49, Protozoa, Art. 7, p. 1-141.

——, 1972, Cretaceous foraminifers - depth habitats and their origin: Nature, v. 239, p. 514-515.

Stanton, T. W., 1947, Studies of some Comanche pelecypods and gastropods: U. S. Geol. Survey Prof. Paper 211, p. 1-256.

Stead, F. L., 1951, Foraminifera of the Glen Rose Formation (Lower Cretaceous) of central Texas: Texas Jour. Science, n. 4, p. 577-605.

Steele, D. R., 1982, Physical stratigraphy and petrology of the Cretaceous Sierra Madre Limestone, west-central Chiapas, Mexico: Arlington, Univ. Texas, M. Sc. thesis, 174 p. (unpublished).

Tappan, Helen, 1940, Foraminifera from the Grayson Formation of northern Texas: Jour. Paleontology, v. 14, p. 93-126.

Van Hinte, J. E., 1976, A Jurassic and Cretaceous time scale: Am. Assoc. Petroleum Geologists Bull., v. 60, p. 489-516.

Viniegra-Osorio, Francisco, 1971, Age and evolution of salt basins of southeastern Mexico: Am. Assoc. Petroleum Geologists Bull., v. 55, p. 478-494.

——, 1981, Great carbonate bank of Yucatán, southern Mexico: Jour. Petroleum Geology, v. 3, p. 247-278.

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

Waite, L. E., 1983, Biostratigraphy and paleoenvironmental analysis of the Sierra Madre Limestone (Cretaceous), Chiapas, Mexico: Arlington, Univ. Texas, M. Sc. thesis, 192 p. (unpublished).

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

Wells, J. W., 1956, Scleractinia: *in* Moore, R. C., ed., Treatise of invertebrate paleontology, part. F (Coelenterata). Lawrence, Univ. Kansas Press, p. F329-F444.

Wilson, H. H., 1974, Cretaceous sedimentation and orogeny in nuclear Central America: Am. Assoc. Petroleum Geologists Bul., v. 58, p. 1348-1396.

Wilson, J. L., 1974, Characteristics of carbonate-platform margins: Am. Assoc. Petroleum Geologists Bull., v. 58, p. 810-824.

——, 1975, Carbonate facies in geologic history: New York, Springer, 471 p.

Wray, J. L., 1977, Calcareous algae: New York, Elsevier, 185 p.

Zavala-Moreno, J. M., 1971, Estudio geológico del proyecto hidroeléctrico Cañón del Sumidero, Río Grijalva, Estado de Chiapas: Bol. Asoc. Mex. Geólogos Petroleros, v. 23, p. 1-117.

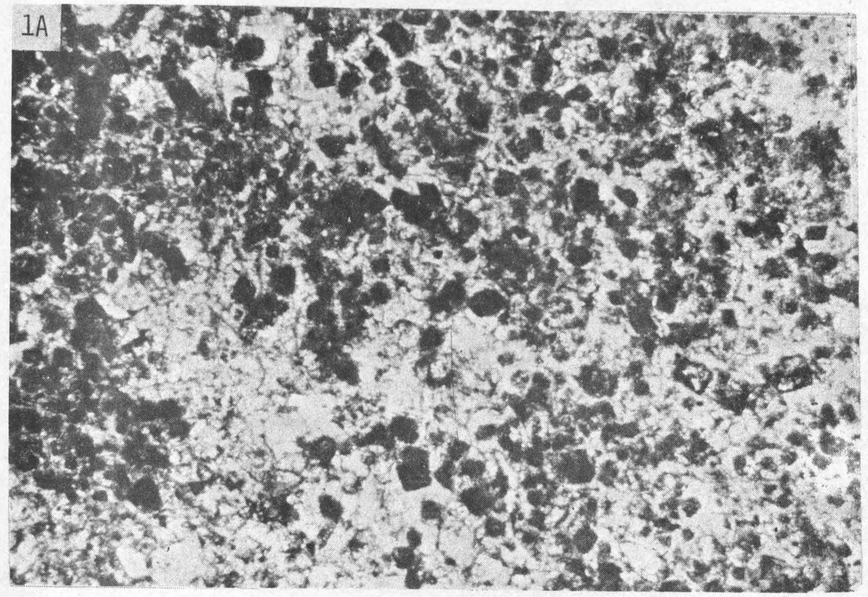
PLATES 1-26

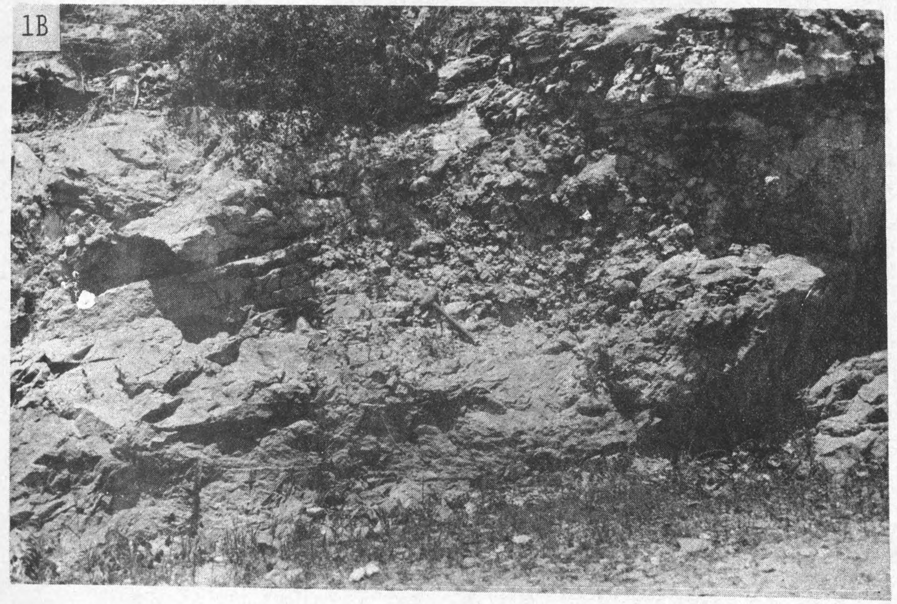
PLATE 1

TEXTURE AND TEPEE STRUCTURE IN DOLOMITE

1A — Photomicrograph of coarse-grained dolomite. Note large euhedral rhombs (unit 1, sample 15).

1B — Photograph of tepee structure in dolomite unit (measured section IV, Cascada El Aguacero).





TEXTURE AND TEPEE STRUCTURE IN DOLOMITE

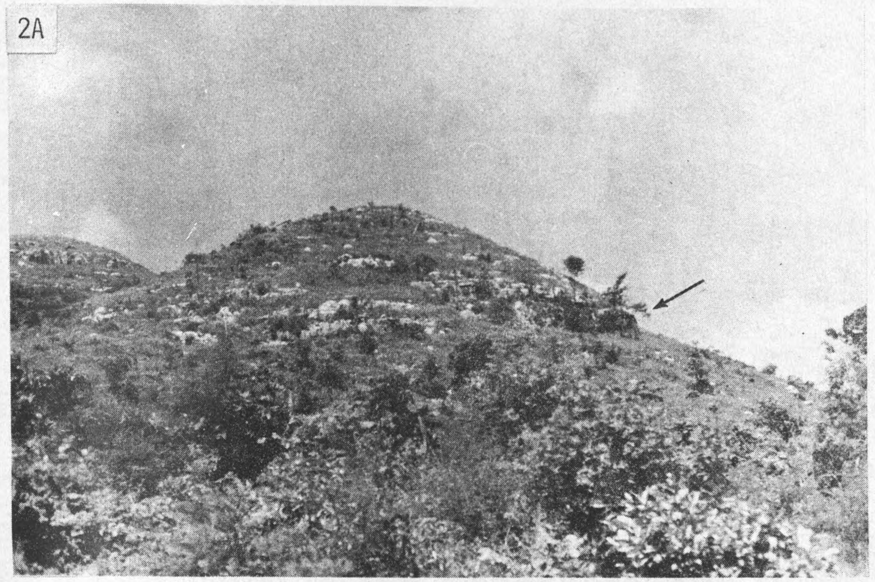
PLATE 2

FIELD EXPOSURES OF MOUND STRUCTURE AND INACCESSIBLE UNMEASURED SECTION

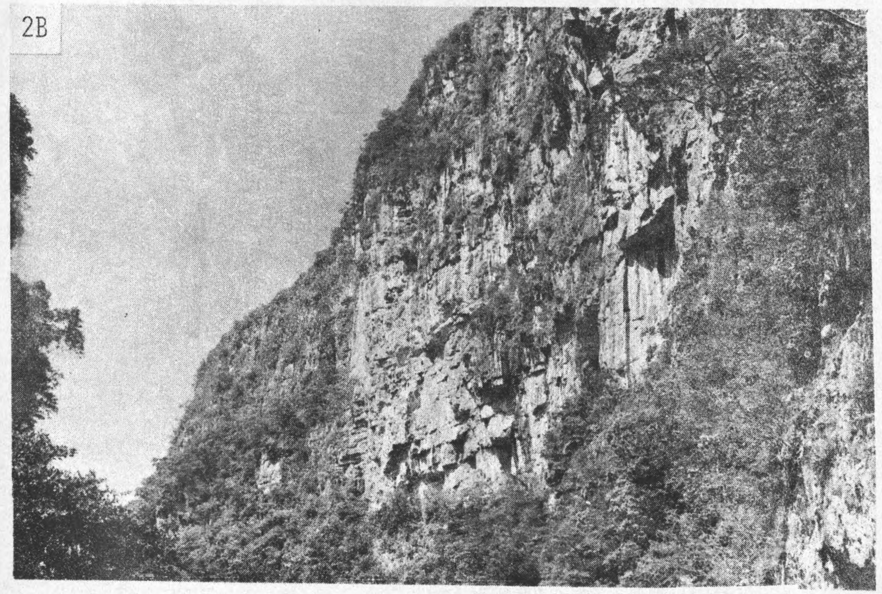
2A — Photograph of mound structure (shown by arrow) of probable biologic origin (measured section V, "miliolid hills").

2B — Photograph of inaccessible exposures of the unmeasured section (unit 3, sheer cliffs along Río Venta).

2A



2B

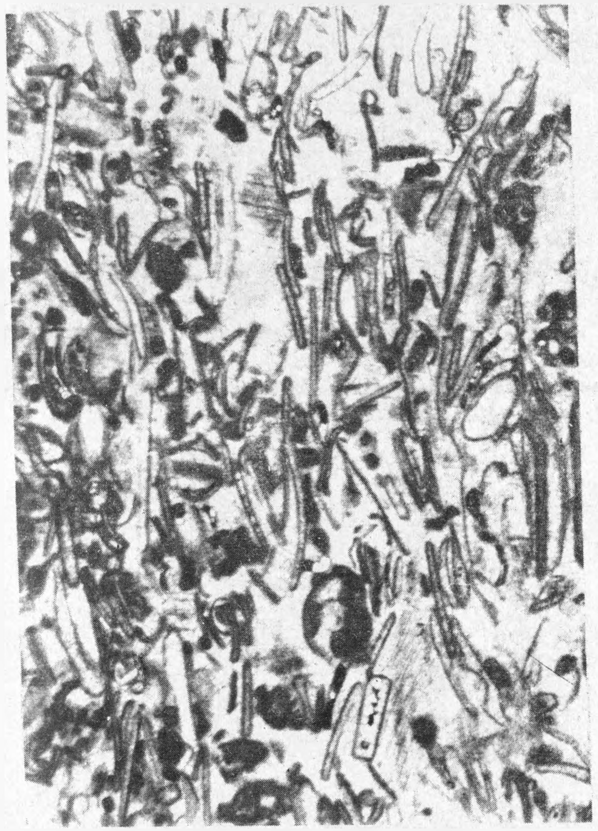


FIELD EXPOSURES OF MOUND STRUCTURE AND INACCESSIBLE UNMEASURED SECTION

PLATE 3

PHOTOMICROGRAPH OF OOID-BEARING, WORN SKELETAL FRAGMENT GRAINSTONE

(unit 9, sample 284)



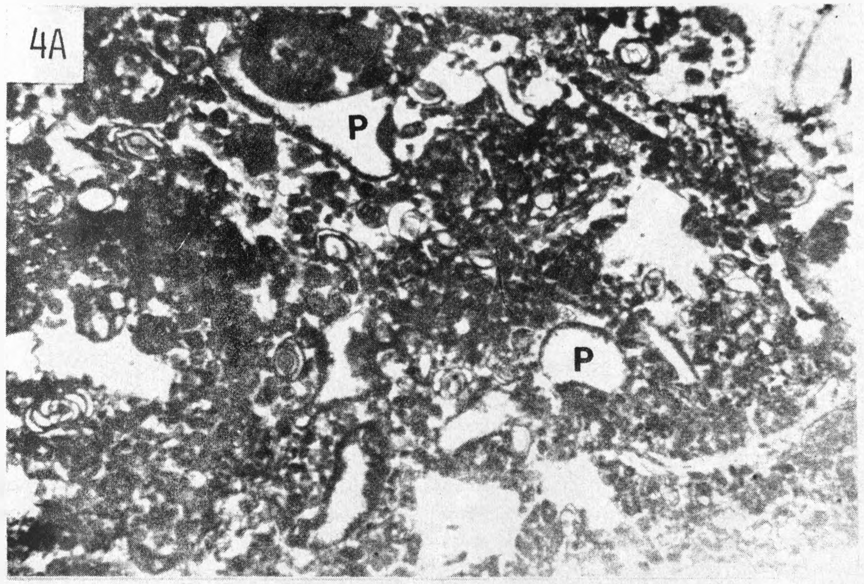
PHOTOMICROGRAPH OF OOID-BEARING, WORN SKELETAL FRAGMENT GRAINSTONE

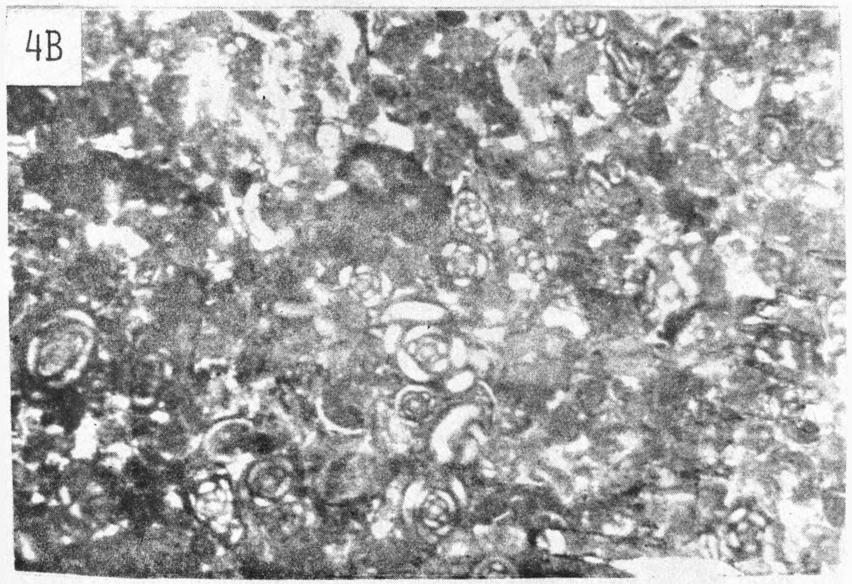
PLATE 4

PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES A AND B

4A — Miliolid algal pellet packstone; P = *Polygonella* (unit 10, sample 318); bar = 0.5 mm.

4B — Miliolid-pellet packstone with rare benthonic foraminifera and ostracod fragments (unit 7, sample 103); bar = 0.5 mm.





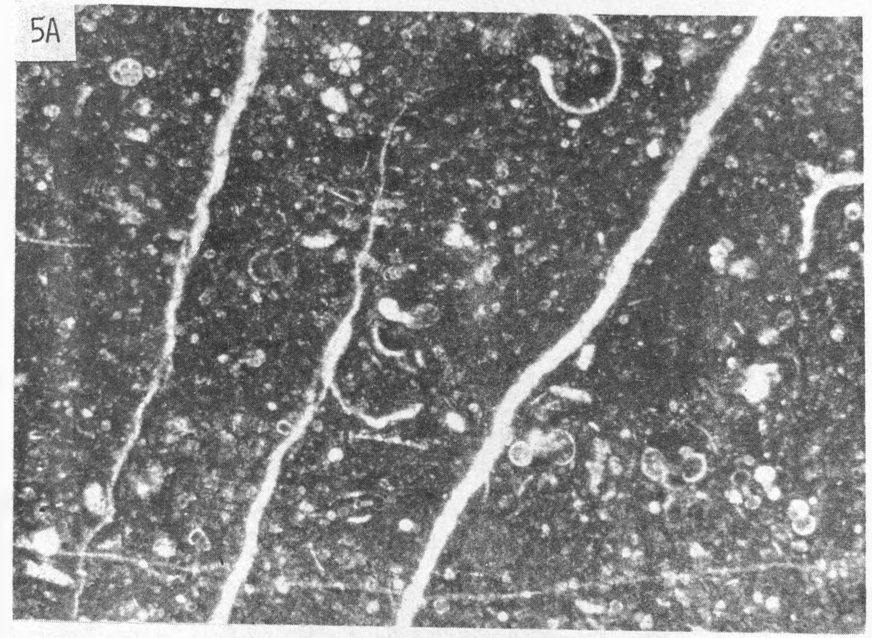
PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES A AND B

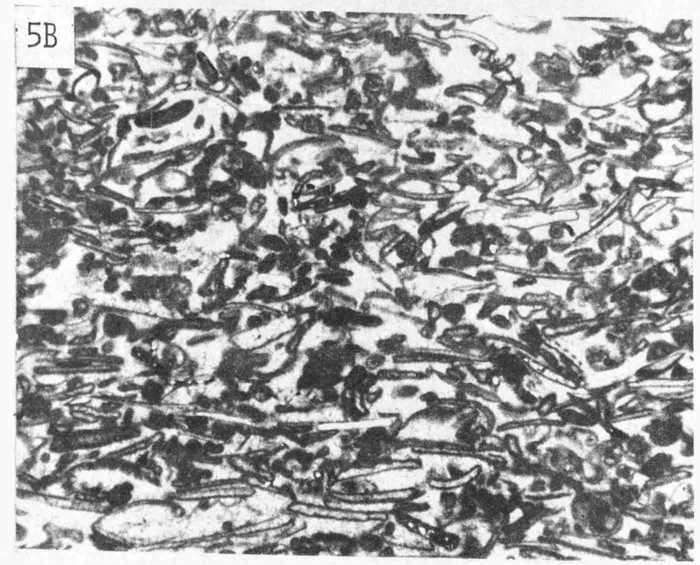
PLATE 5

PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES C AND D

5A — Photomicrograph of sample from biofacies C (unit 8, sample 273). *Phitonella*-planktonic foraminifera wackestone with molluscan and echinoid shell débris. Note large, calcite-filled fractures; bar = 0.5 mm.

5B — Photomicrograph of sample from biofacies D (unit 9, sample 284). Highly winnowed, oolitic-worn shell fragment grainstone; bar = 0.5 mm.





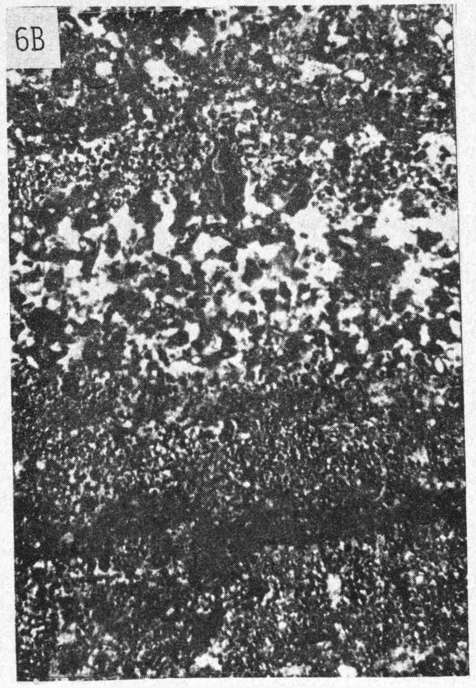
PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES C AND D

PLATE 6

PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES E AND F

6A — Photomicrograph of sample from biofacies E (unit 4, sample 154). *Acicularia*-pellet packstone; note aggregated grains at top-center of photograph; bar = 0.5 mm.

6B — Photomicrograph of sample from biofacies F (unit 2, sample 44). Blue-green algal boundstone; bar = 0.5 mm.

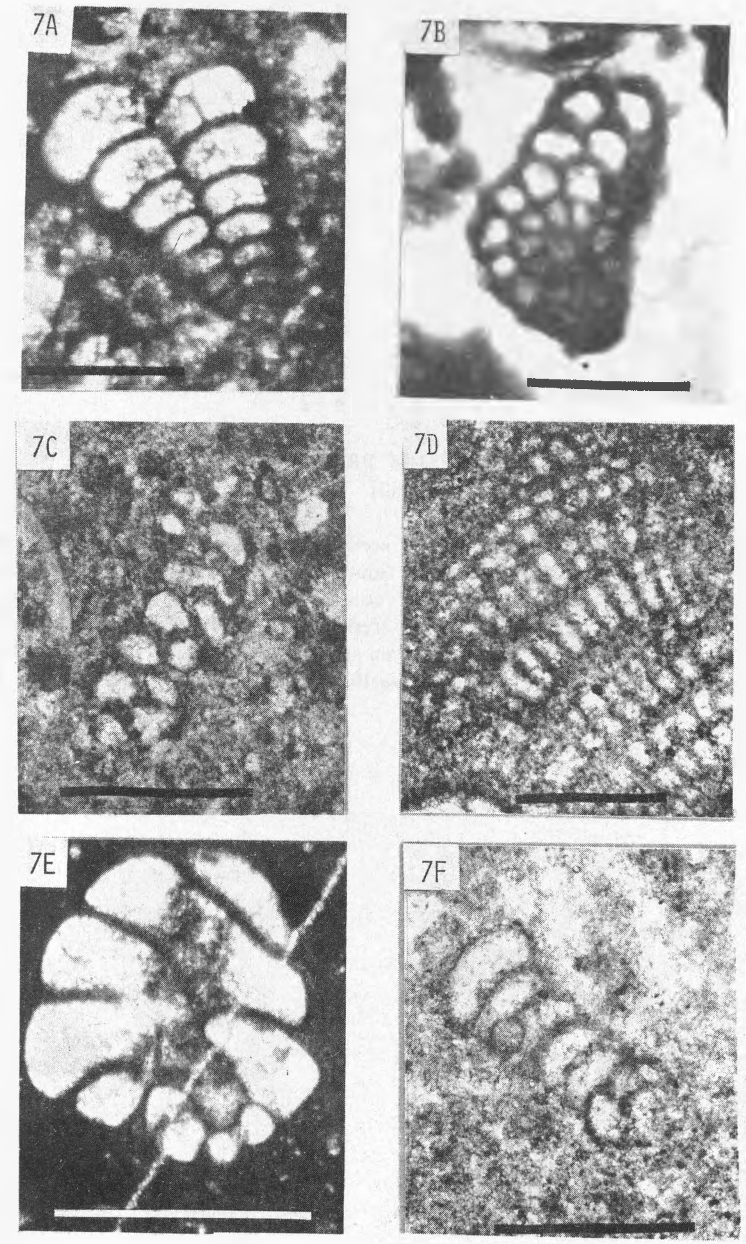


PHOTOMICROGRAPHS OF SAMPLES FROM BIOFACIES E AND F

P L A T E 7

PHYLUM PROTOZOA
Superfamily Lituolacea

7A — *Textularia* sp.; equatorial section (unit 4, sample 237); bar = 0.5 mm.
7B — *Spiroplectammina* sp.; equatorial section (unit 3, sample 208); bar = 0.5 mm.
7C — *Pseudobolivina*? sp.; equatorial section (unit 7, sample 506); bar = 0.5 mm.
7D — *Cuneolina* sp., group *C. pavonia* Henson; partial axial section (unit 3, sample 254); bar = 0.5 mm.
7E — *Valvulammina* sp.; equatorial section (unit 3, sample 253); bar = 0.5 mm.
7F — *Pseudolituonella reicheli* Marie; equatorial section (unit 3, sample 199); bar = 0.5 mm.

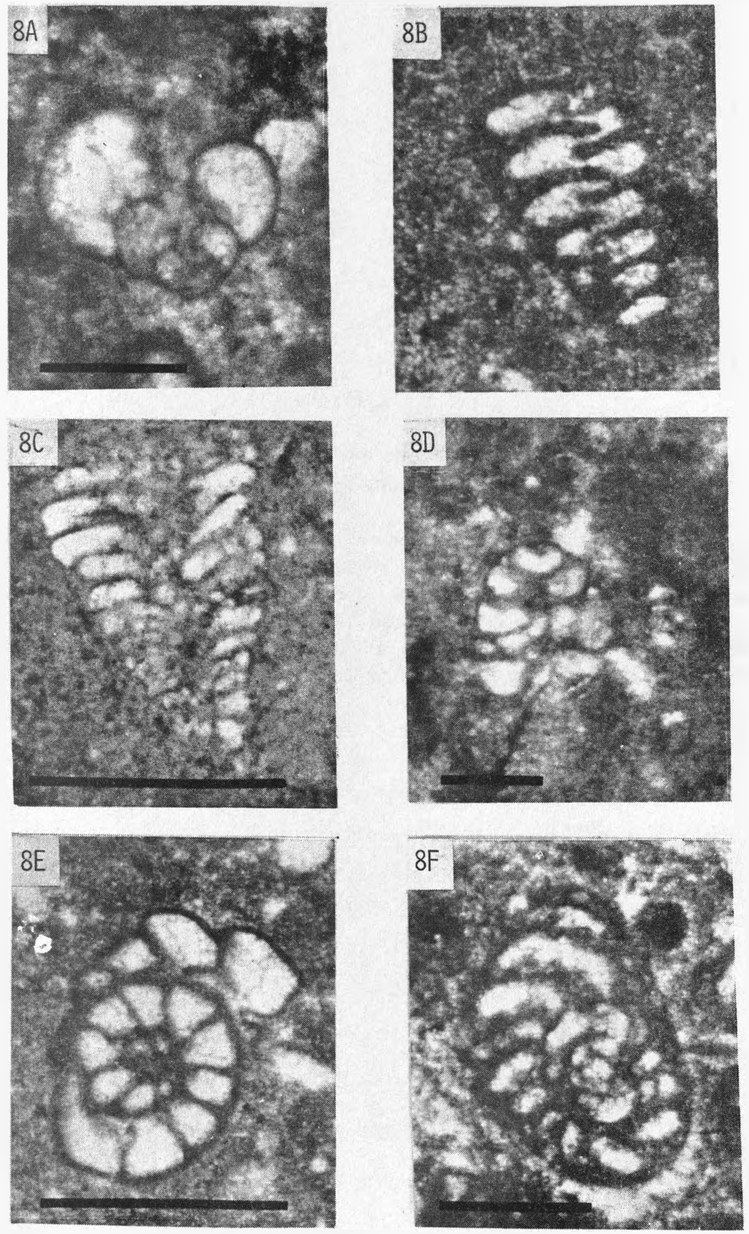


PHYLUM PROTOZOA
Superfamily Lituolacea

PLATE 8

PHYLUM PROTOZOA
Superfamily Lituolacea

8A — *Pseudochrysalidina?* sp.; equatorial section (unit 7, sample 511); bar = 0.1 mm.
8B — *Dorothia?* sp.; equatorial section (unit 3, sample 252); bar = 0.5 mm.
8C — *Simplorbitolina* sp.; axial section (unit 1, sample 58); bar = 0.5 mm.
8D — *Coskinolinoides?* sp.; partial axial section (unit 1, sample 28); bar = 0.1 mm.
8E — *Trochammina?* sp.; equatorial section (unit 3, sample 251); bar = 0.5 mm.
8F — *Pseudocyclammina* sp.; equatorial section (unit 3, sample 205); bar = 0.5 mm.

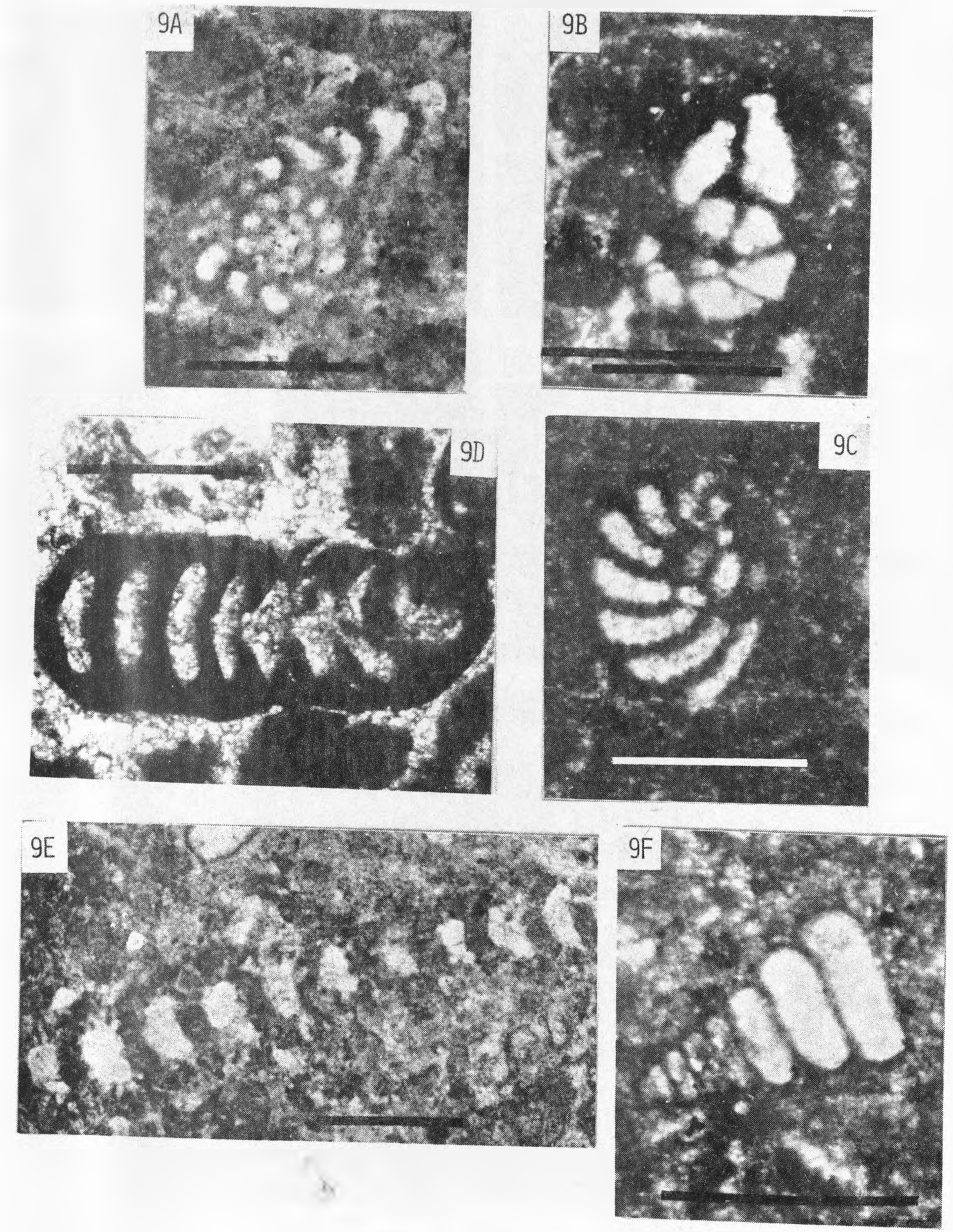


PHYLUM PROTOZOA
Superfamily Lituolacea

PLATE 9

PHYLUM PROTOZOA
Superfamily Lituolacea

9A — *Lituola* sp.; equatorial section (unit 3, sample 112); bar = 0.5 mm.
9B — *Haplophragmoides*? sp.; equatorial section (unit 1, sample 38); bar = 0.5 mm.
9C — *Ammotium*? sp.; equatorial section (unit 3, sample 123); bar = 0.5 mm.
9D — *Flabellammina* sp.; equatorial section (unit 2, sample 68); bar = 0.5 mm.
9E — *Cribratina* sp.; equatorial section (unit 7, sample 507); bar = 0.5 mm.
9F — *Polychasmina*? sp.; equatorial section (unit 2, sample 76); bar = 0.5 mm.

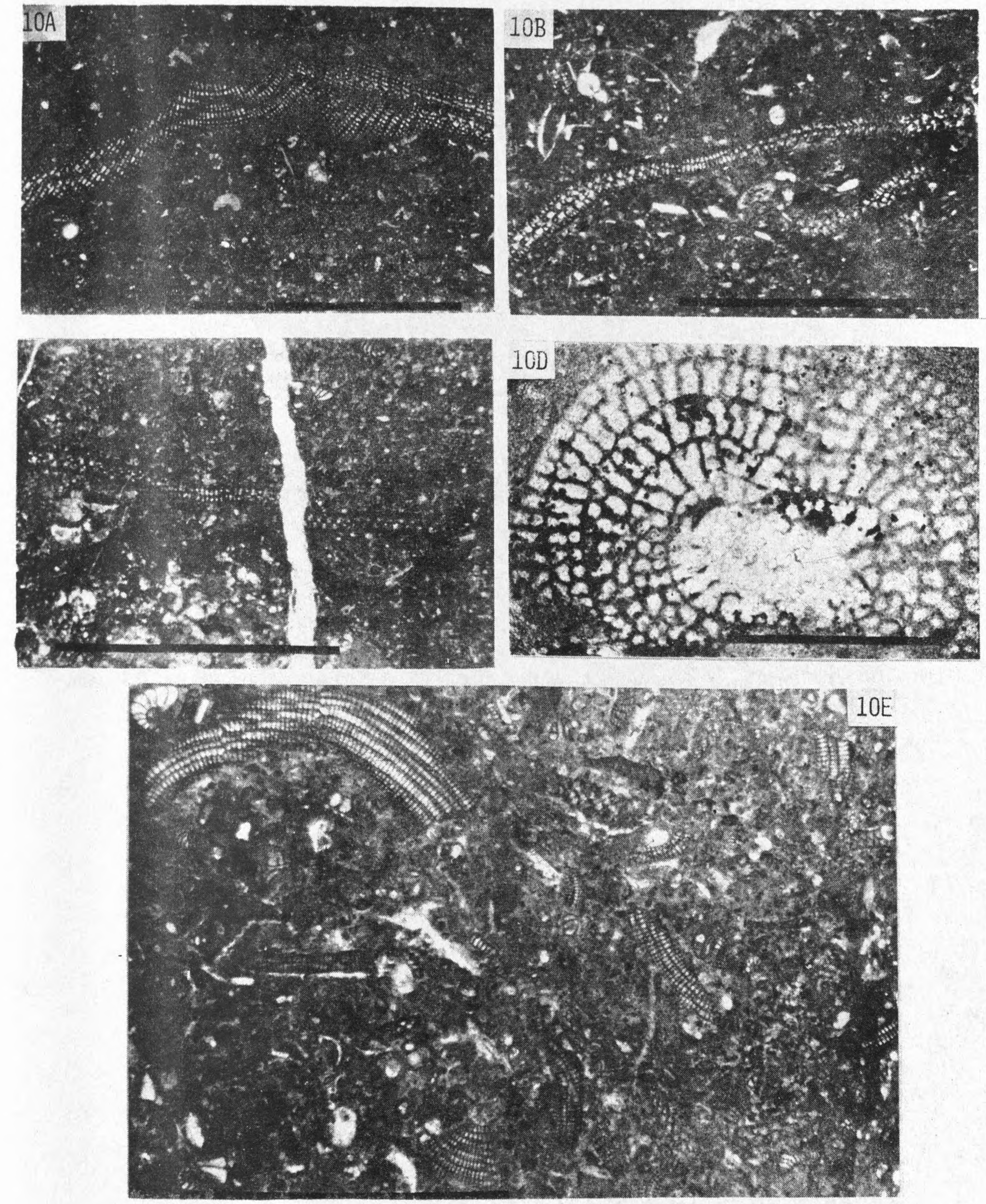


PHYLUM PROTOZOA
Superfamily Lituolacea

PLATE 10

PHYLUM PROTOZOA
Superfamily Lituolacea

10A — *Dicyclina schlumbergeri* Munier-Chalmas; partial axial section (unit 7, sample 487); bar = 5.0 mm.
10B — *Dicyclina schlumbergeri* Munier-Chalmas; vertical section (unit 7, sample 484); bar = 5.0 mm.
10C — *Dicyclina schlumbergeri* Munier-Chalmas; vertical section, offset by fracture (unit 6, sample 472); bar = 5.0 mm.
10D — *Dicyclina schlumbergeri* Munier-Chalmas; partial horizontal section (unit 7, sample 481); bar = 1.0 mm.
10E — *Dicyclina* wackestone (unit 6, sample 463); bar = 5.0 mm.

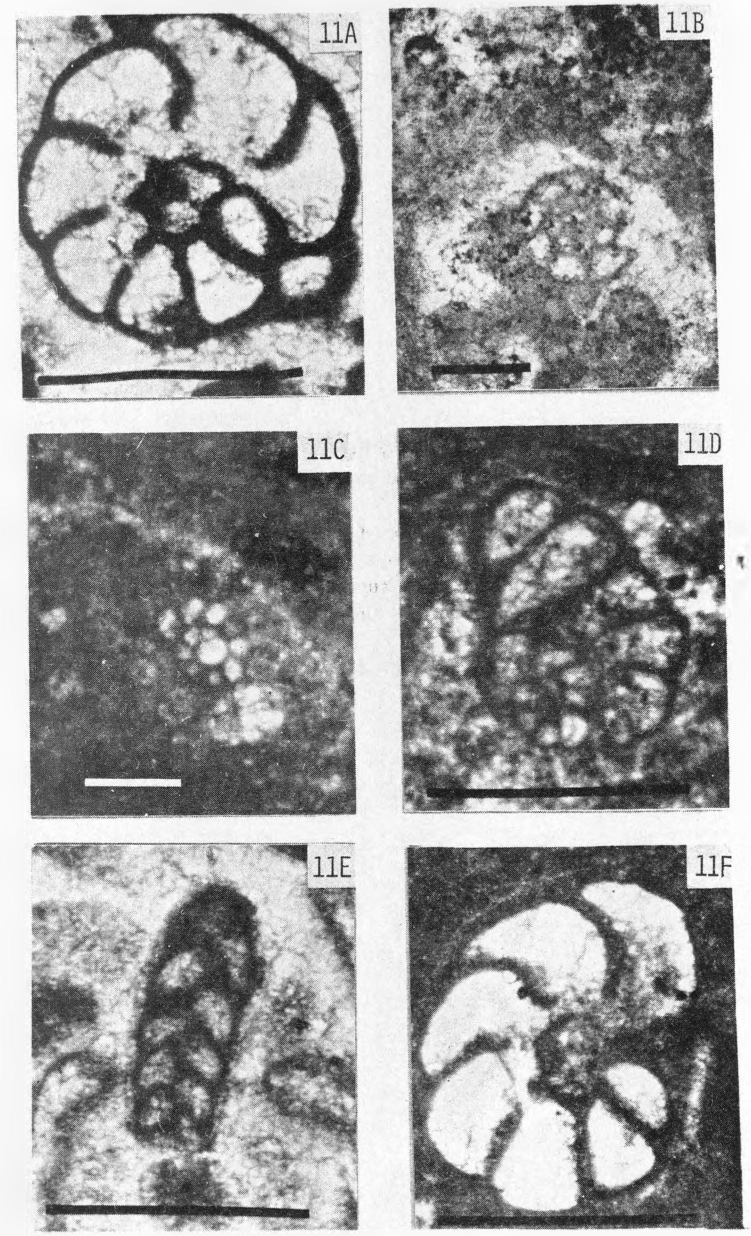


PHYLUM PROTOZOA
Superfamily Lituolacea

PLATE 11

PHYLUM PROTOZOA
Superfamilies Discorbacea and Cassidulinacea

11A — *Valvulineria* sp.; equatorial section (unit 2, sample 68); bar = 0.5 mm.
11B — Anomalinidae; equatorial section (unit 6, sample 318); bar = 0.3 mm.
11C — Anomalinidae; equatorial section (unit 6, sample 318); bar = 0.3 mm.
11D — *Caucasina* sp.; equatorial section (unit 3, sample 149); bar = 0.5 mm.
11E — *Coryphostoma*? sp.; equatorial section (unit 5, sample 286); bar = 0.5 mm.
11F — *Osangularia*? sp.; equatorial section (unit 3, sample 252); bar = 0.5 mm.

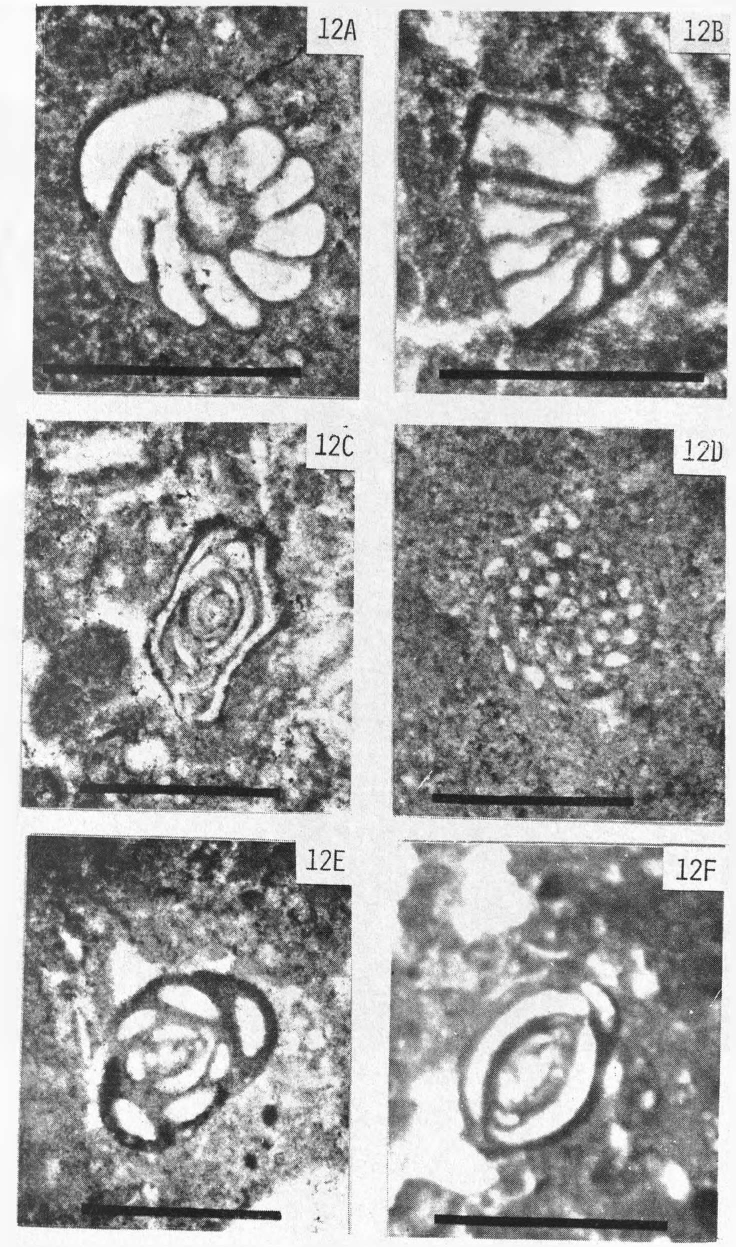


PHYLUM PROTOZOA
Superfamilies Discorbacea and Cassidulinacea

PLATE 12

PHYLUM PROTOZOA
Superfamilies Cassidulinacea and Miliolacea

12A — *Globorotalites* sp.; equatorial section (unit 6, sample 469); bar = 0.5 mm.
12B — *Nezzazata* sp.; equatorial section (unit 3, sample 253); bar = 0.5 mm.
12C — *Spiroloculina* sp.; sagittal section (unit 3, sample 190); bar = 0.5 mm.
12D — *Meandrospira* sp.; equatorial section (unit 3, sample 203); bar = 0.5 mm.
12E — *Quinqueloculina* sp.; sagittal section (unit 3, sample 254); bar = 0.5 mm.
12F — *Triloculina* sp.; sagittal section (unit 3, sample 208); bar = 0.5 mm.

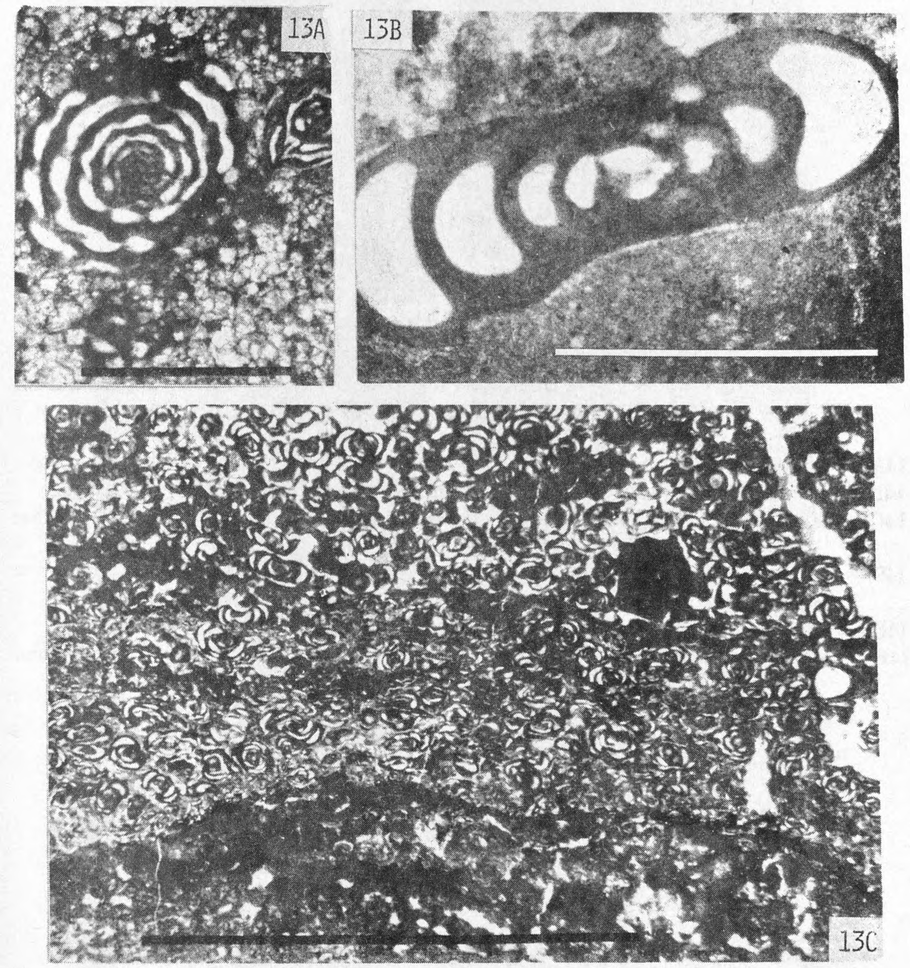


PHYLUM PROTOZOA
Superfamilies Cassidulinacea and Miliolacea

P L A T E 13

PHYLUM PROTOZOA
Superfamily Miliolacea

13A — *Nummoloculina heimi* Bonet; sagittal section (unit 1, sample 43); note dolomite matrix; bar = 1.0 mm.
13B — *N. heimi;* axial section (unit 3, sample 177); bar = 1.0 mm.
13C — *N. heimi* packstone (unit 3, sample 215); some specimens appear deformed; bar = 10.0 mm.

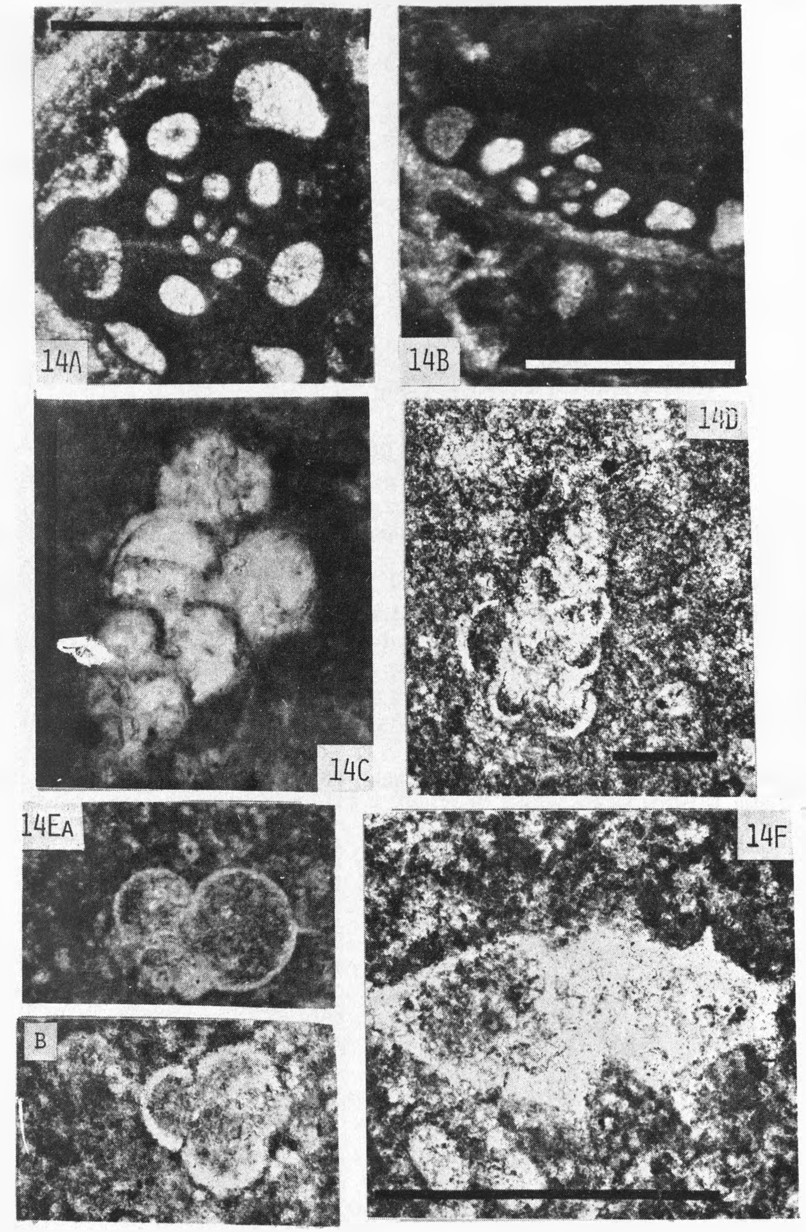


PHYLUM PROTOZOA
Superfamily Miliolacea

PLATE 14

PHYLUM PROTOZOA
Superfamilies Miliolacea and Globigerinacea

14A — *Miliola?* sp.; sagittal section (unit 7, sample 499); bar = 0.5 mm.
14B — *Massilina?* sp.; sagittal section (unit 7, sample 484); bar = 0.5 mm.
14C — *Heterohelix moremani* Cushman; equatorial section (unit 4, sample 271); bar = 0.1 mm.
14D — *Heterohelix reussi* Cushman; equatorial section (unit 4, sample 271); bar = 0.1 mm.
14E — *Guembelitria* sp.; equatorial section (unit 2, sample 73); bar = 0.1 mm.
14F — *Rotalipora* cf. *R. cushmani*: axial section (unit 2, sample 75); bar = 0.5 mm.



PHYLUM PROTOZOA
Superfamilies Miliolacea and Globigerinacea

PLATE 15

PHYLUM PROTOZOA
Superfamily Globigerinacea

15A — *Hedbergella planispira* Tappan; equatorial section (unit 4, sample 271); bar = 0.5 mm.

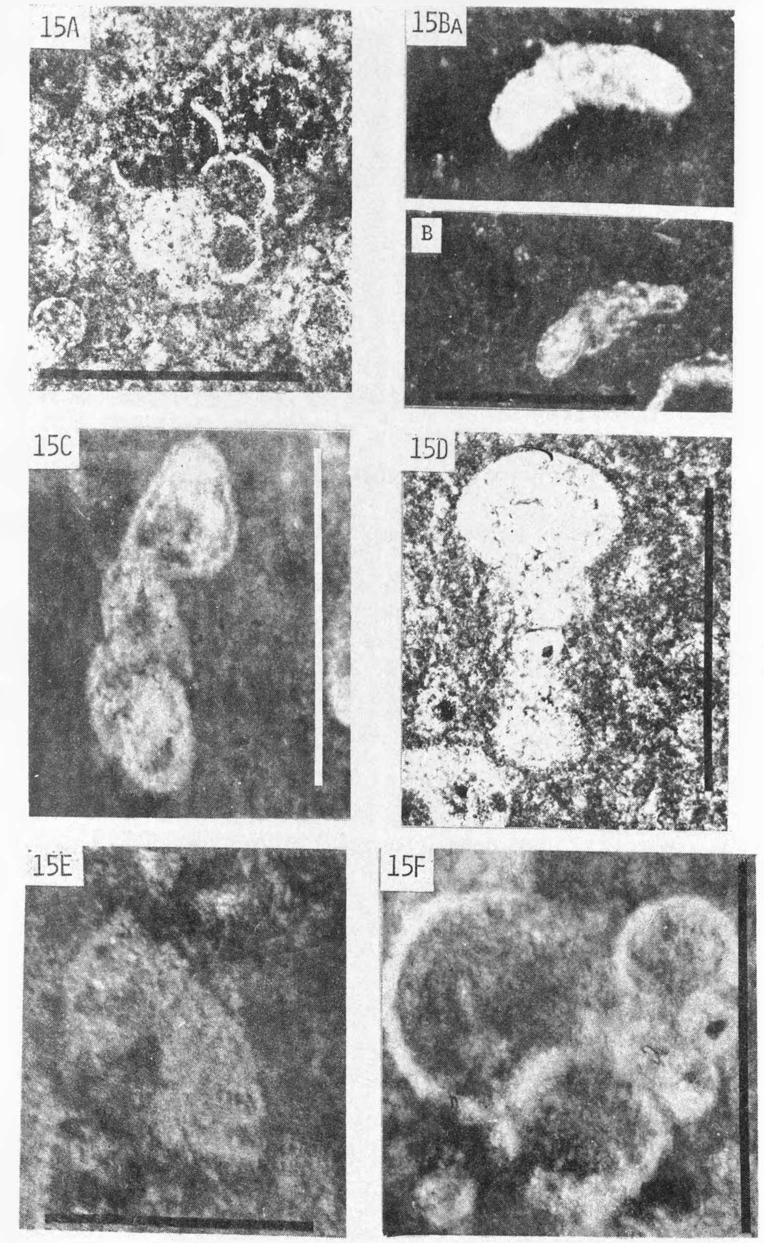
15B — *Praeglobotruncana stephani* Gandolfi; (a) axial section (unit 6, sample 312); (b) axial section (unit 6, sample 312); bar = 0.5 mm.

15C — *Dicarinella algeriana* Caron; axial section (unit 4, sample 271); bar = 0.5 mm.

15D — *Globigerinelloides bentonensis* Borrow; axial section (dnit 1, sample 490); bar = 0.5 mm.

15E — *Marginotruncana marianosi* Douglas: axial section (unit 7, sample 490); bar = 0.5 mm.

15F — *Whiteinella baltica* Douglas and Rankin: axial section (unit 4, sample 271); bar = 0.5 mm.

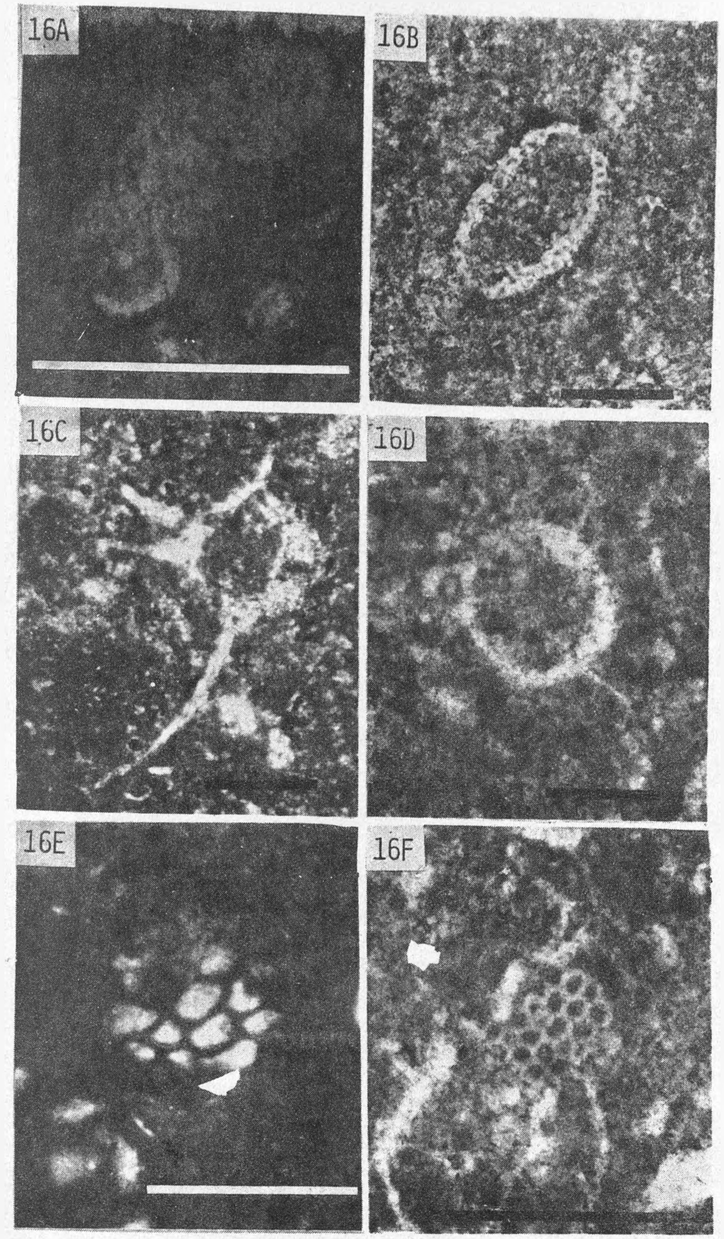


PHYLUM PROTOZOA
Superfamily Globigerinacea

PLATE 16

PHYLUM PROTOZOA AND DIVISION RHODOPHYTA

16A — *Whiteinella archeocretacea* Pessagno; axial section (unit 7, sample 487); bar = 0.5 mm.
16B — *Pithonella ovalis* Kaufmann (unit 4, sample 271); bar = 0.1 mm.
16C — Radiolaria; Order Nassellaria (unit 4, sample 274); bar = 0.1 mm.
16D — Radiolaria; Order Spumellaria (unit 7, sample 484); bar = 0.1 mm.
16E — *Parachaetes?* sp.; transverse section (unit 6, sample 304); bar = 0.5 mm.
16F — *Solenopora* sp.; transverse section (unit 1, sample 58); bar = 0.5 mm.

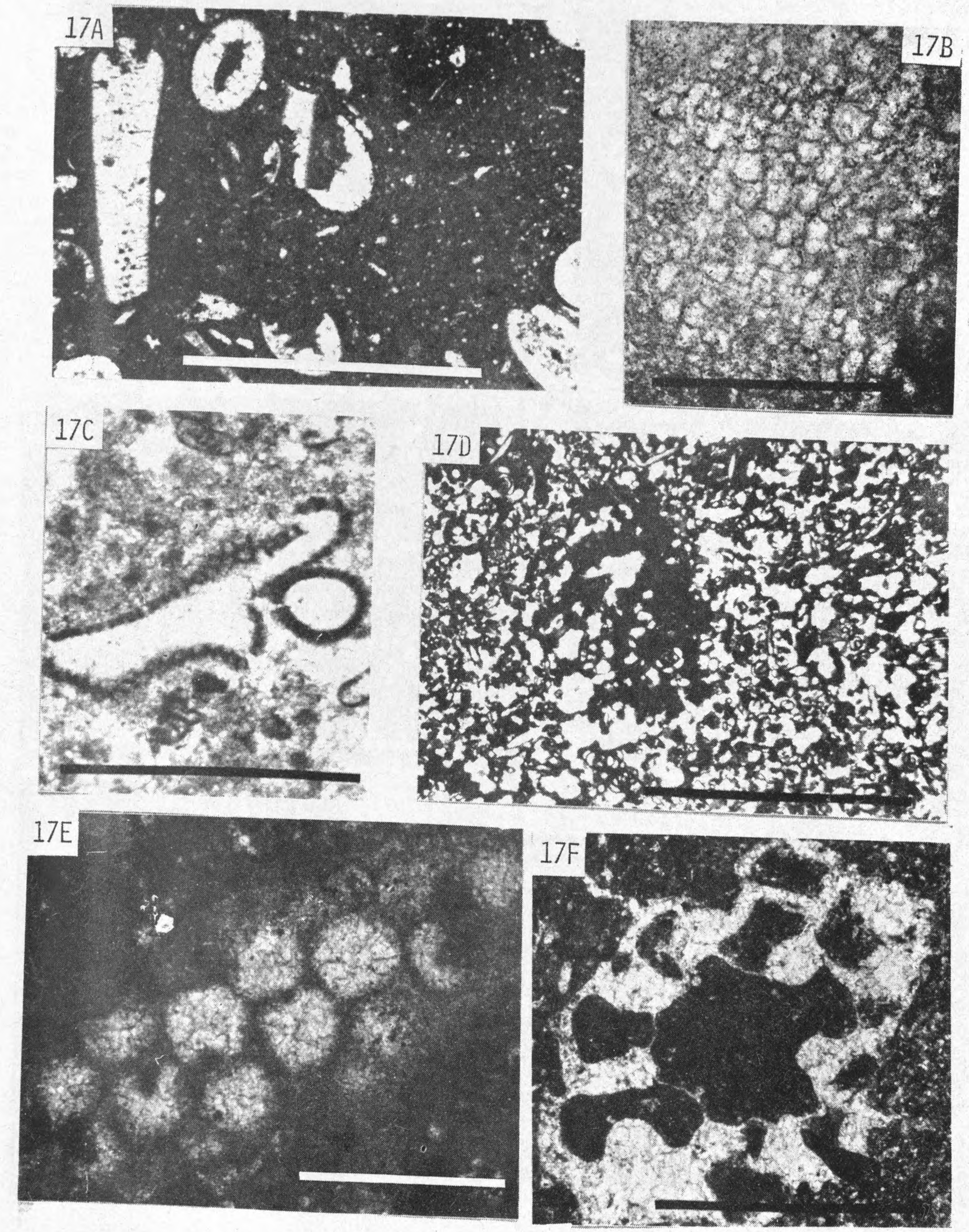


PHYLUM PROTOZOA AND DIVISION RHODOPHYTA

PLATE 17

DIVISIONS RHODOPHYTA AND CHLOROPHYTA

17A — *Permocalculus* sp.; transverse sections (unit 2, sample 77); bar = 0.5 mm.
17B — *Lithothamnium?* sp.; longitudinal section (unit 6, sample 311); bar = 0.5 mm.
17C — *Polygonella* sp.; transverse section (unit 3, sample 178): bar = 0.5 mm.
17D — *Lithocodium* sp.; general view, showing crustose form (unit 3, sample 248); bar = 0.5 mm.
17E — *Cylindroporella* sp.; oblique vertical section (unit 3, sample 182); bar = 0.5 mm.
17F — *Trinocladus?* sp.; transverse section (unit 6, sample 386); bar = 0.5 mm.

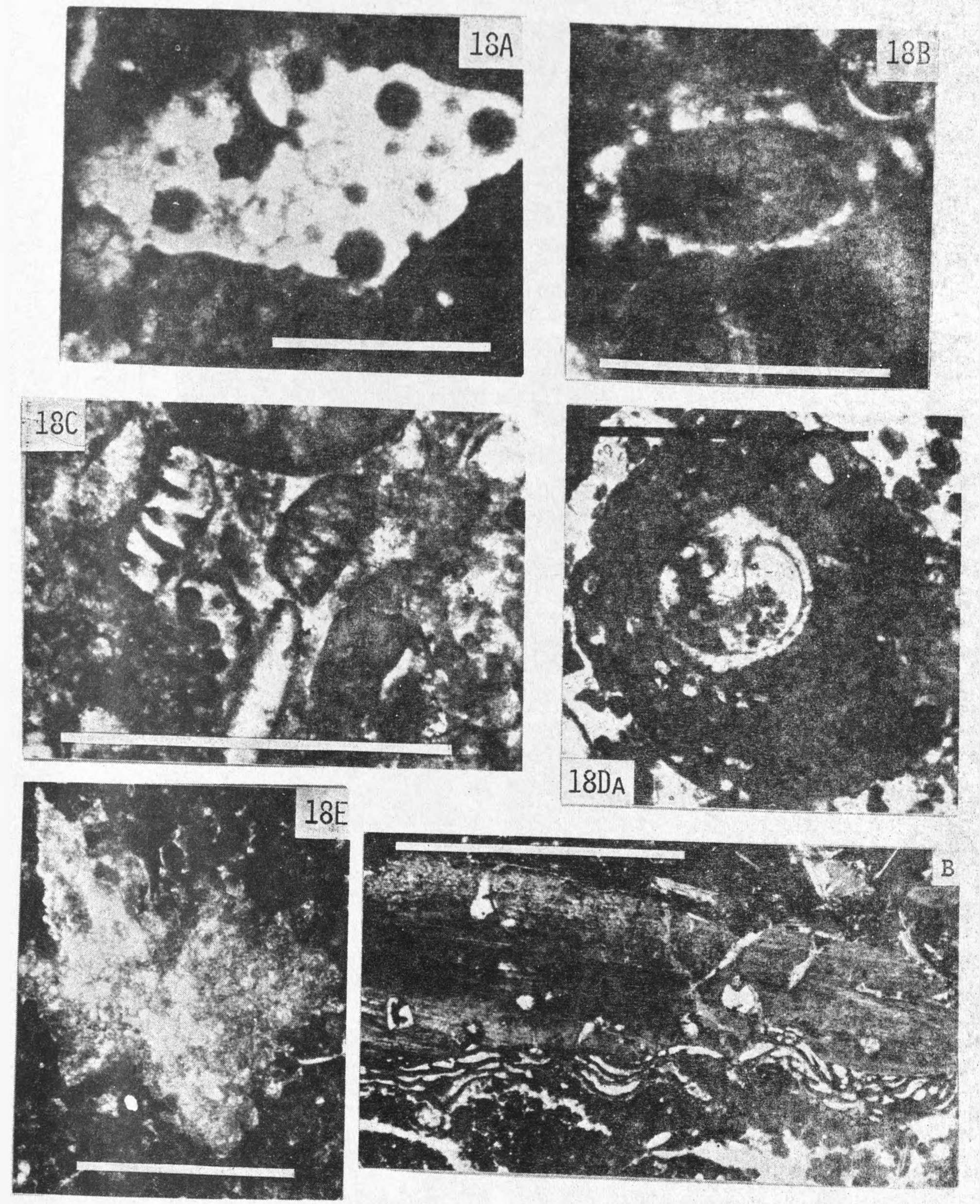


DIVISIONS RHODOPHYTA AND CHLOROPHYTA

PLATE 18

DIVISIONS CHLOROPHYTA AND CYANOPHYTA AND PHYLUM PORIFERA

18A — *Neomeris* sp.; transverse section (unit 3, sample 95); bar = 0.5 mm.
18B — *Salpingoporella?* sp.; transverse section (unit 1, sample 42); bar = 1.0 mm.
18C — *Acicularia* sp.; transverse sections; (unit 2, sample 62); bar = 1.0 mm.
18D — *Girvanella* sp.; transverse sections (a) encrusting mass (unit 6, sample 329); bar = 2.0 mm, (b) association with encrusting foraminiferids (unit 3, sample 259); bar = 0.5 mm.
18E — *Stenoporidium?* sp.; longitudinal section (unit 3, sample 111); bar = 0.5 mm.



DIVISIONS CHLOROPHYTA AND CYANOPHYTA AND PHYLUM PORIFERA

PLATE 19

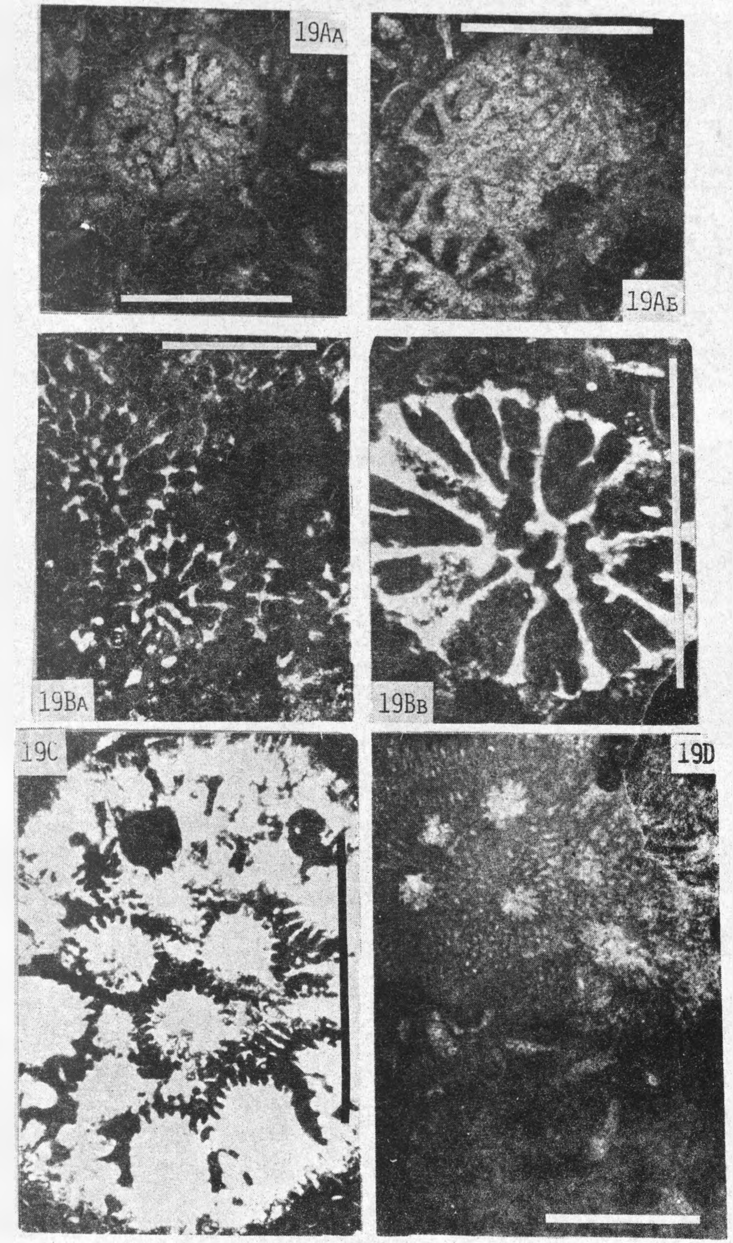
PHYLA COELENTERATA AND ARTHROPODA

19A — *Hydnophora* sp.; (a) solitary specimen (unit 2, sample 62); bar = 2.0 mm; (b) colonial specimens (unit 2, sample 62); bar = 4.0 mm.

19B — *Multicolumnastraea* sp.; (a) colonial association (unit 7, sample 495); bar = 2.0 mm; (b) close-up of individual polyp (unit 7, sample 495); bar = 2.0 mm.

19C — *Astreopora*? sp.; colonial association (unit 7, sample 496); bar = 4.0 mm.

19D — *Cyathophora*? sp.; colonial association (unit 2, sample 78); bar = 2.0 mm.



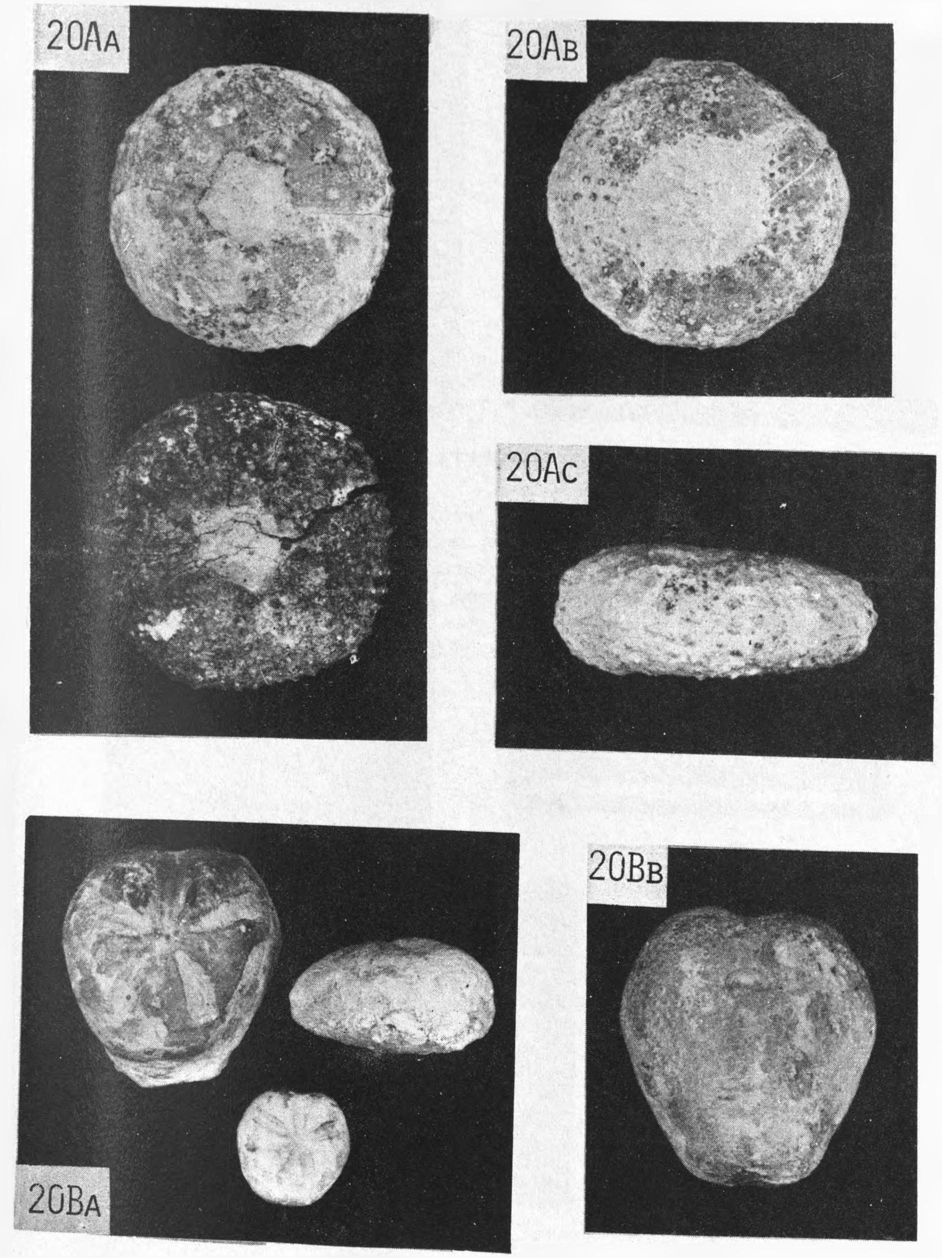
PHYLA COELENTERATA AND ARTHROPODA

P L A T E 20

PHYLUM ECHINODERMATA

20A — *Glyptocyphus* sp.; whole specimens; (a) top view; (b) bottom view; (c) side view; (unit 4, weathered out from marl); bar = 30.0 mm.

20B — *Palhemiaster* sp.; whole specimens; (a) top and side view; (b) bottom view; (unit 4, weathered out from marl); bar = 30.0 mm.



PHYLUM ECHINODERMATA

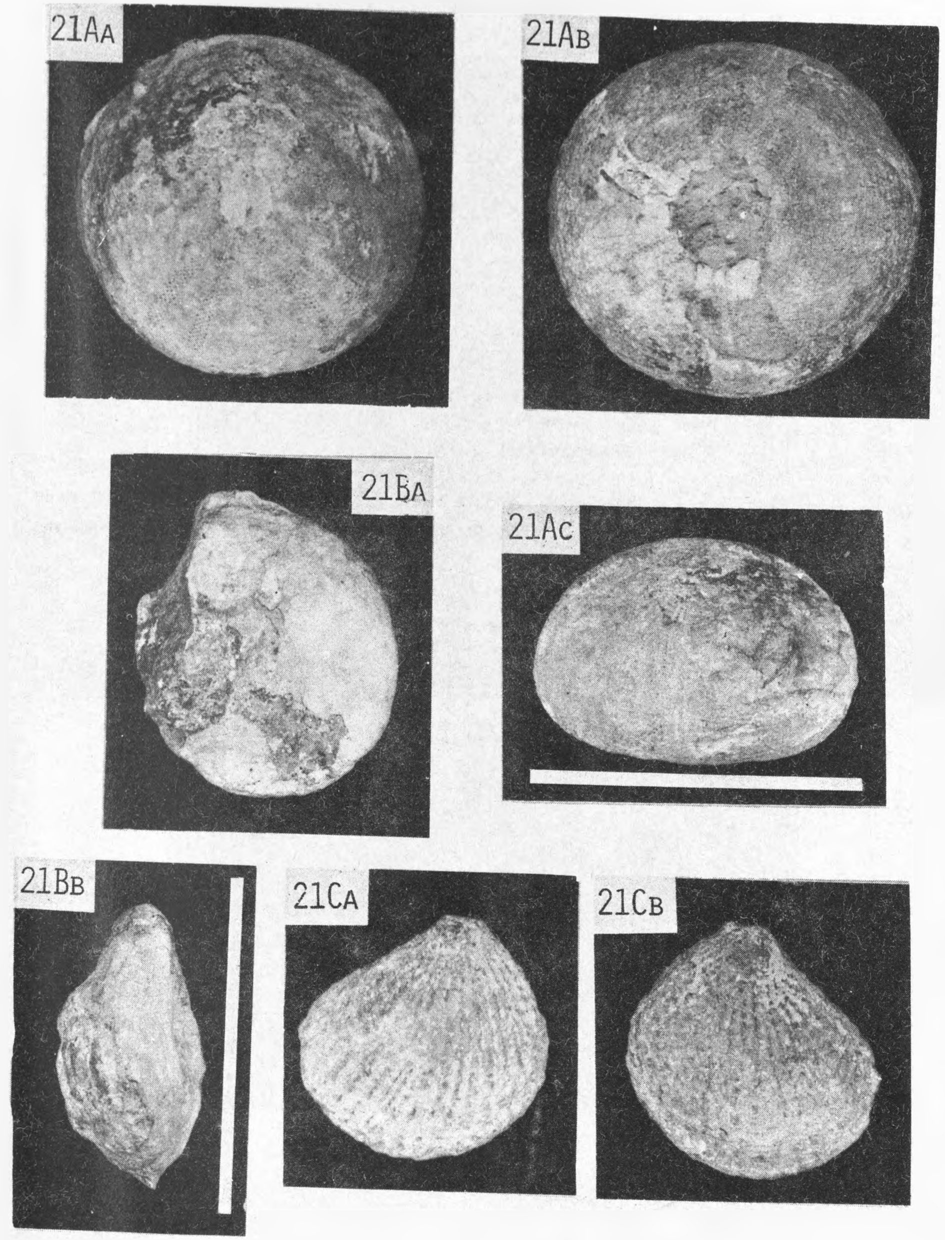
PLATE 21

PHYLA ECHINODERMATA AND MOLLUSCA

21A — *Pedinopsis* sp.; whole specimens; (a) top view; (b) bottom view; (c) side view; (unit 4, weathered out from marl); bar = 50.0 mm.

21B — *Proplacenticeras*? sp.; whole specimens; (a) side view; (b) axial view, note concavity (unit 4, weathered out from marl); bar = 50.0 mm.

21C — *Pectunculina* sp.; whole specimen; (a) right valve; (b) left valve; (unit 4, weathered out from marl); bar = 25.0 mm.

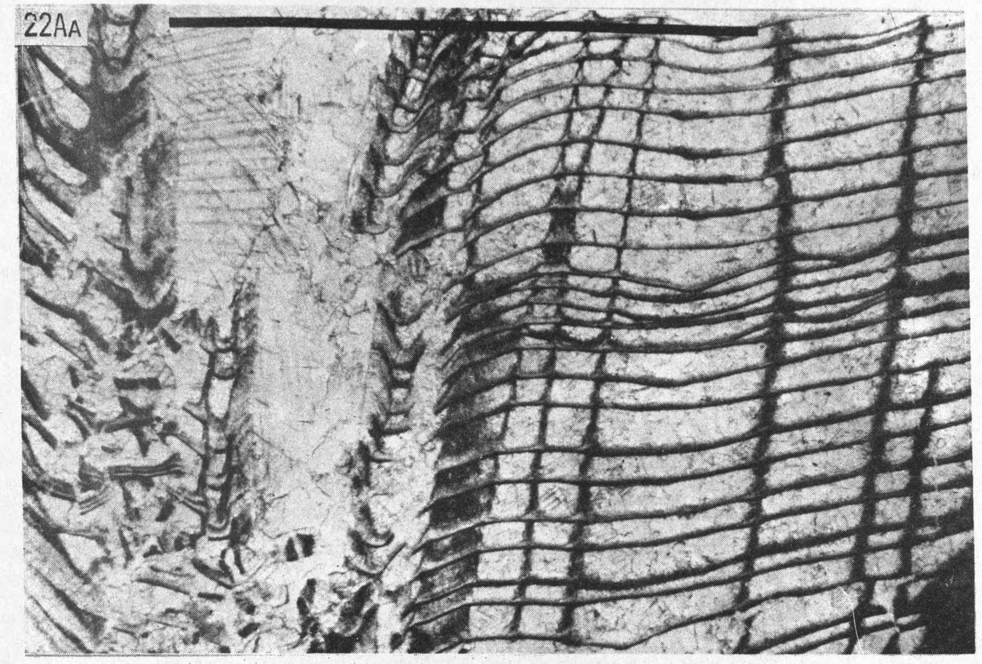


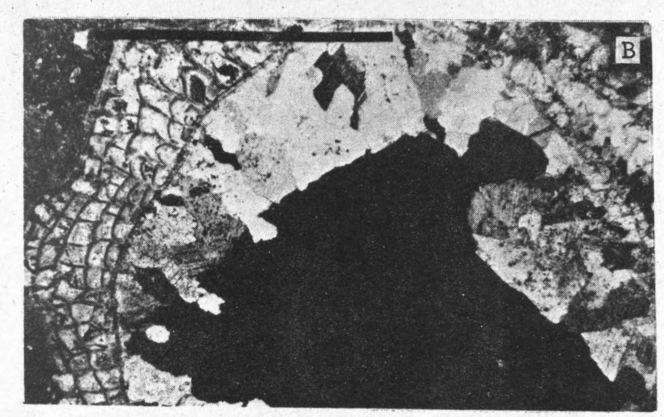
PHYLA ECHINODERMATA AND MOLLUSCA

P L A T E 22

PHYLUM MOLLUSCA

22A — *Radiolites* sp.; (a) transverse section (unit 3, sample 194); bar = 3.0 mm; (b) cross section showing development of secondary porosity (unit 6, sample 472); bar = 3.0 mm.



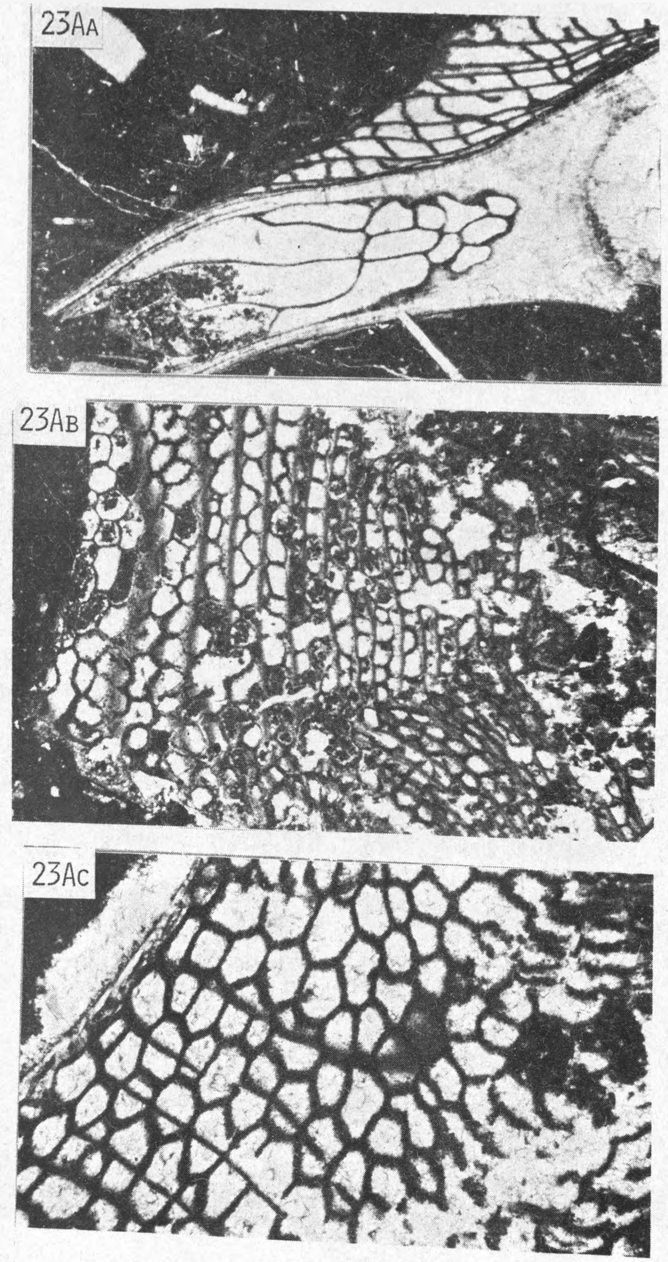


PHYLUM MOLLUSCA

PLATE 23

PHYLUM MOLLUSCA

23A — *Sauvagesia* sp.; transverse sections; (a) unit 7, sample 497; bar = 3.0 mm; (b) unit 7, sample 502; bar = 3.0 mm; (c) unit 7, sample 502; bar = 3.0 mm.



PHYLUM MOLLUSCA

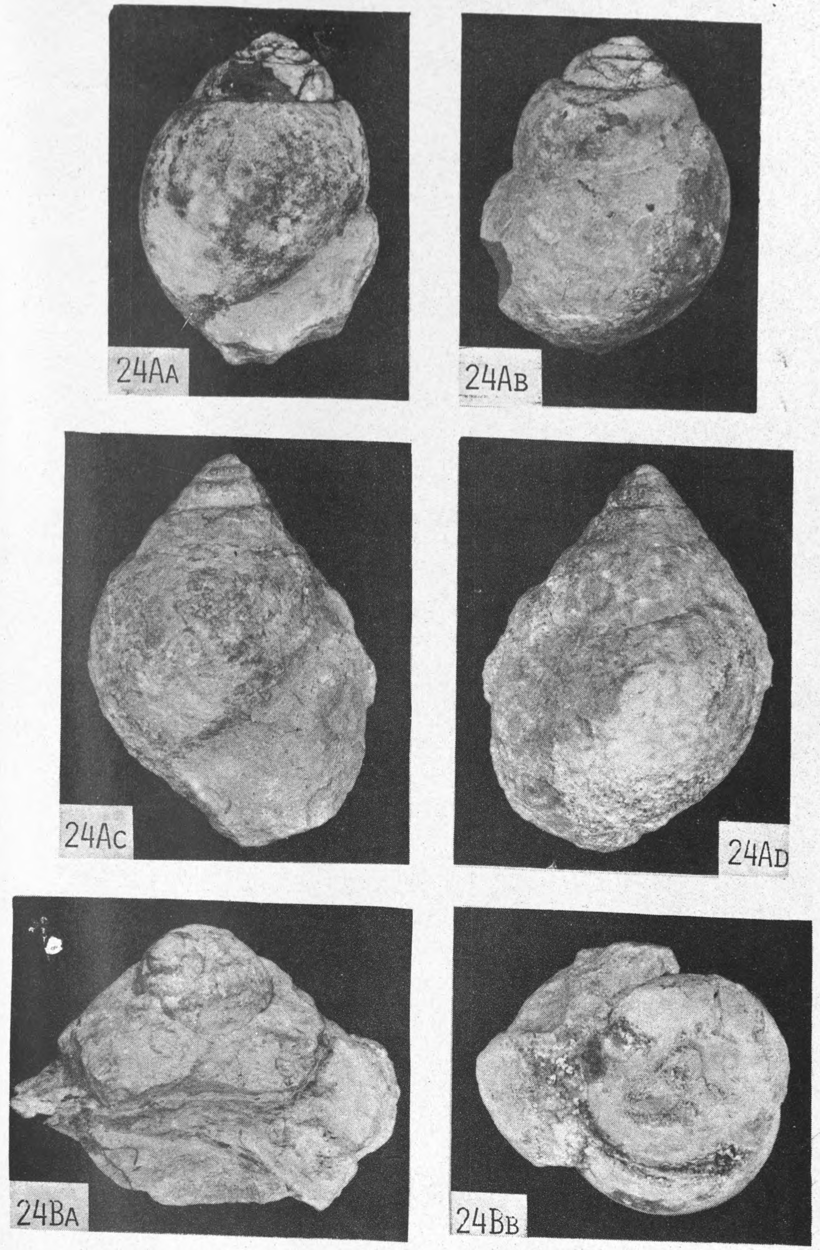
PLATE 24

PHYLUM MOLLUSCA

24A — *Tylostoma* sp.; whole specimens; (a), (b), dextrial coil; bar = 60.0 mm; (c), (d), dextrial coil; bar = 50.0 mm (both specimens from unit 4, weathered out from marl).

24B — *Lunatia* sp.; whole specimen (unit 4, weathered out from marl); bar = 20.0 mm.

24C — *Pleurotomaria*? sp.; whole specimen (unit 4, weathered out from marl); bar = 60.0 mm.

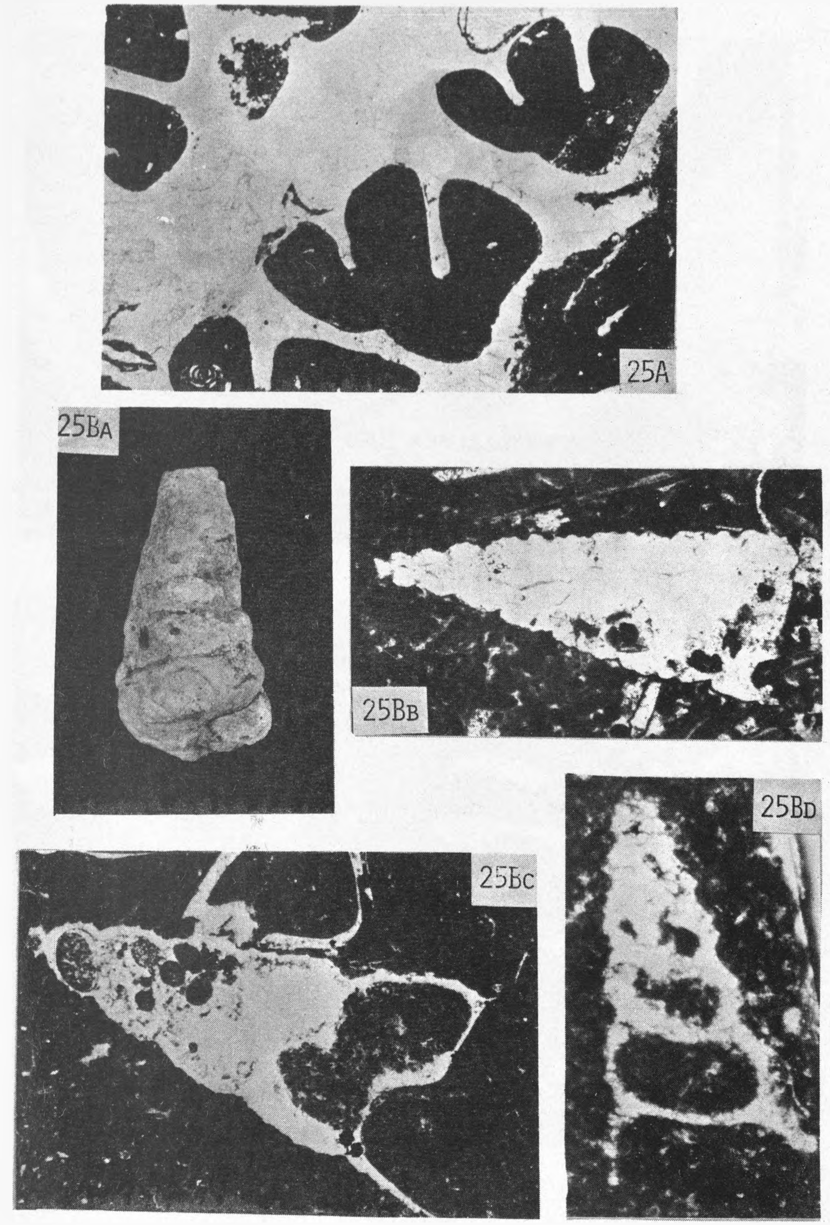


PHYLUM MOLLUSCA

PLATE 25

PHYLUM MOLLUSCA

25A — *Nerinea* sp.; transverse section (unit 3, sample 254); bar = 0.5 mm.
25B — *Turritella?* sp.; (a) whole specimen (unit 4, weathered out from marl); bar = 90.0 mm; (b), (c), (d) several transverse sections of possible genera; bar = 1.0 mm.

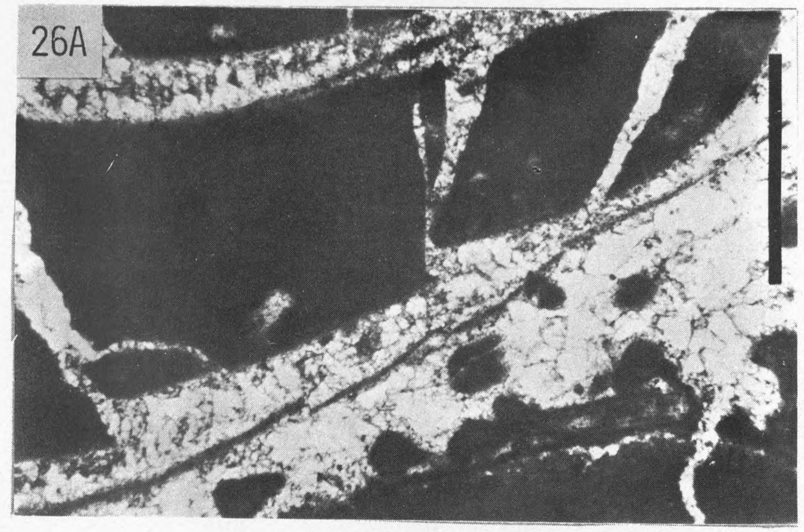


PHYLUM MOLLUSCA

PLATE 26

PHYLA MOLLUSCA AND ANNELIDA

26A — *Actaeonella* sp.; transverse section (unit 6, sample 451); bar = 0.5 mm.
26B — Serpula worm tubes; transverse section (unit 1, sample 31); bar = 0.5 mm.

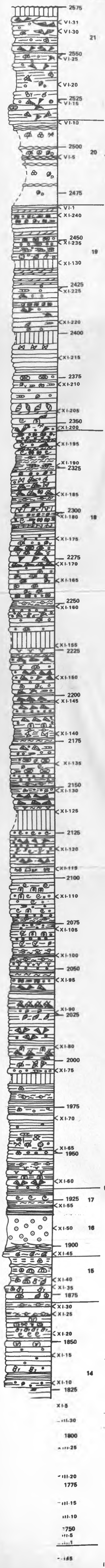


PHYLA MOLLUSCA AND ANNELIDA

Boletín 102 del Instituto de Geología. *Contributions to the Statigraphy of the Sierra Madre Limestone (Cretaceoua) of Chiapas*, editado por la Dirección General de Publicaciones, se terminó de imprimir en la Editorial Libros de México, S. A., el 25 de marzo de 1987. Su composición se hizo en tipo Bodoni de 8 y 10 puntos. La edición consta de 1,200 ejemplares.

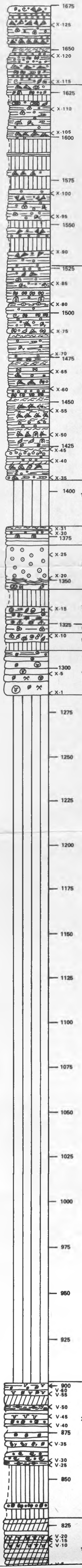
OCOZOCUAUTLA FORMATION

SIERRA MADRE LIMESTONE

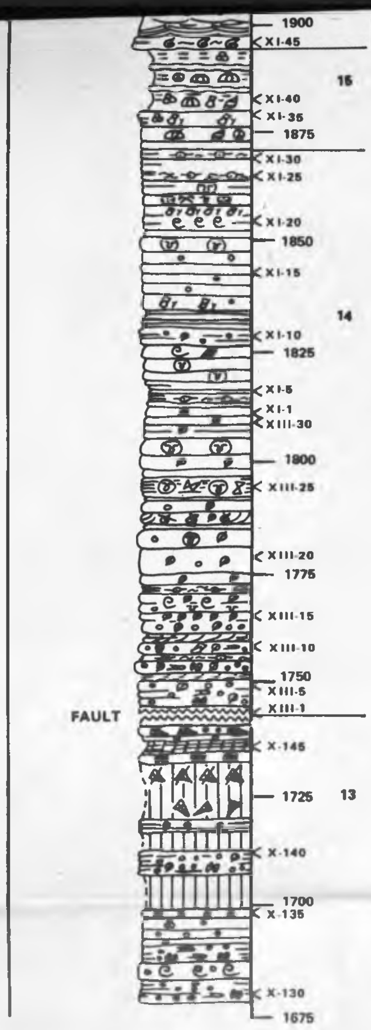


UNIT		METERS
21	Whole radiolitid rudist, pellet lime wackestone with sparse planktonic foraminifers, solitary corals, echinoid fragments, and sponge spicules, light colored; 0.4m to 0.6m thick beds. Allochems heavily bored, micritized, unabraded, some oncolitically coated . . .	60.0m
	. . . from 2,560m to 2,574.7m associations and clusters of large sauvagessid rudists in growth position and laterally equivalent biostrome thickets of Distefanella? sp.	
	. . . from 2,520m to 2,522m abraded colonial coral fragments.	
	. . . contact with the Ocozocuautla Formation covered, reported as disconformable.	
20	Nodular, planktonic foraminifer and Dicyclina schlumbergi bearing lime wackestone with blue chert nodules, Nerinea sp., calcispheres, and fine fragments of echinoids, rudists, and solitary corals; yellowish to reddish-brown; nodular beds, 10cm to 40cm thick, lumpy and thicker bedding at the top of the unit	46.5m
	. . . contact with unit 19 conformable but apparently abrupt	
19	Lime mudstone and pellet wackestone with sparse stromatoporoids and requieniid and radiolitid rudists at the base; light colored and porcellaneous	
	. . . from 2,422m to 2,468.2m (top of unit) thin (10cm to 20cm), interbedded, reddish-orange, pellet-intraclast grainstone with siderite spherulites and hematite stain, mudstone to pellet packstone and Thaumatoporella sp. boundstone	122.5m
	. . . at 2,390.5m packstone of large (1cm to 3cm) intraclasts to lithoclasts.	
	. . . at 2,357m biostromes of large gastropods, primarily Trochacteon?	
18	Undifferentiable, interbedded, radiolitid rudist fragment lime packstone; wackestone of miliolids, pellets, and whole requieniid and radiolitid rudists; and thin-bedded fenestral stromatolites. Allochems are extensively bored, micritized and algally coated; sparse echinoid fragments and planktonic foraminifers occur throughout the unit; bedding is poorly exposed	413.0m
	. . . contact with unit 17 is arbitrarily chosen at the first occurence of radiolitid rudists.	
17	Dolomitic, laminated, fenestral lime mudstone interbedded with slightly burrowed lime mudstone with ostracods and sparse benthonic and planktonic foraminifers; light colored; thin (10cm to 20cm) beds	15.5m
16	Cross bedded, worn, coated, skeletal fragmant, ooid lime grainstone; light colored to reddish-orange; 20cm to 30cm thick trough cross-bedding; weathers with a nodular appearance	28.0m
	. . . from 1,889.5m to 1,892.5m nodular, fine, worn, coated, skeletal fragment packstone with large fossil fragments. Forms a prominent ledge.	
15	Nodular, planktonic foraminifer bearing, echinoid and mollusc lime wackestone interbedded with fossiliferous marl; yellowish-brown to reddish nodules; crustacean? burrows common; echinoids, gastropods, and pelecypods abundent; wackestone matrix rich in calcispheres and planktonic foraminifers	17.0m
	. . . at 1,886.5m two poorly preserved ammonites	
14	Thick (0.5m to 2.0m) beds of pellet-intraclast lime packstone, lime mudstone and lime wackestone with miliolids and requieniid rudists interbedded with thin (10cm to 20cm) beds of stromatolites and miliolid lime grainstone; light colored. Large tubular fenestrae (spar-filled burrows) are common in thick bedded miliolid bearing lime mudstone	128.5m
	. . . at 1,863m? dense laminoid caliche crust.	
	. . . at 1,856.5m oyster biostrome, 0.5m to 1.5m thick.	
	FAULT	
13	Interbedded radiolitid rudist fragment lime packstone, pellet-intraclast packstone, pellet wackestone to packstone and occasional stromatolites; light colored; 20cm to 30cm thick beds with occasional 1.0m thick beds. Skeletal fragments are bored, micritized and algally-encrusted. Both radiolitid and requieniid rudist occur. Top of the unit is faulted, minimum thickness	113.5m
	. . . from 1,698m to 1,732m cover and rubbly exposures with fine to	

SIERRA MADRE LIMESTONE



UNIT		METERS
12	Whole radiolitid rudist lime wackestone and planktonic foraminifer bearing, pellet lime wackestone with grumeleuse texture and sparse echinoid fragments; light colored; flaggy, 20cm to 30cm thick beds with occasional 50cm thick beds. Allochems show little micritization or algal encrustation	104.0m
	. . . from 1,568m to 1,598m mostly cover with abundant radiolitid rudist wackestone and packstone float	
11	Alternating pellet-intraclast lime packstone, bioclastic radiolitid rudist fragment packstone and vaguely laminated stromatolites; light colored; flaggy 20cm to 30cm thick beds. Skeletal fragments are heavily bored, micritized and algally coated	119.0m
	. . . from 1,407m to 1,425m thin beds alternating with 1.0m to 1.5m thick beds of pellet-intraclast, radiolitid rudist fragment packstone.	
	. . . at 1,466.5m lithoclastic caliche.	
	. . . at 1,472.5m celestite cemented algal, intraclast packstone.	
10	Undescribed interval	25.0m
	Lime mudstone, laminated lime mudstone, and pellet wackestone to packstone; light colored; 0.5m to 1.5m thick beds	12.0m
	. . . from 1,378m to 1,382m oncolitically-coated, bored-lithoclast wackestone capped by laminated fenestral stromatolites.	
9	Worn skeletal fragment, ooid lime grainstone; light colored to reddish-orange, particularly at base.	25.3m
	. . . from 1,346m to 1,352m 0.3m to 0.6m thick low angle trough cross-bedding weathering with a nodular appearance.	
8	. . . at 1,345m skeletal packstone with colonial corals in growth position and large gastropods.	
	. . . from 1,363m to 1,371m grading into thin bedded mudstones and crudely-laminated, algal-coated gastropod packstones-grainstones.	
7	Planktonic foraminifer bearing oyster, mollusc fragment lime wackestone with echinoid fragments; matrix calcisphere rich; light colored; bedding 0.5m to 1.5m, heavy bioturbation with some surface mottling. Mollusc fragments partially silicified	10.0m
	. . . from 1,335m to 1,344.7m rubbly covered beds	9.7m
6	Planktonic foraminifer lime mudstone to wackestone, light colored; vaguely laminated, slightly burrowed, 0.5m to 1.0m thick beds . .	4.0m
5	Planktonic foraminifer bearing, oyster and mollusc fragment, pellet lime wackestone with echinoid fragments and calcispheres; light colored; 0.5m to 1.0m thick beds	10.0m
4	Pellet and miliolid bearing, sponge spicule lime mudstone to wackestone; light colored; intensely bioturbated, 1.0m to 2.5m thick beds at the base, 0.2m to 0.5m at the top	25.0m
	. . . from 1,286m to 1,296m large tubular fenestrae (spar-filled burrows).	
3	Undescribed interval; thickness estimated	384.0m
2	Interbedded lime mudstone, pellet miliolid lime wackestone; and requieniid lime wackestone; brown to light colored; 0.5m to 1.0m thick beds. Weathered exposures alternating with covered intervals superficially resemble bioherms	73.9m
	. . . from 882m to 893m dolomite; fine to medium crystalline, gray to brown, mottled, 0.5m to 4.0m thick beds.	
	. . . at 868m oyster wackestone overlying a thin packstone bed of large rounded intraclasts.	
	. . . from 828m to 859m cover; pellet, miliolid wackestones with sparse miliolid grainstones are laterally equivalent.	
1	Dolomite; medium to coarsely crystalline, vuggy, sucrosic; light colored to gray; thin beds of fenestral stromatolites, fossil molds of high-spired gastropods, burrow structures and small channel structures are common. Evaporite solution collapse breccias are common in the lower 355m. The unit is largely undescribed	828.3m



... from 1,889.5m to 1,892.5m nodular, fine, worn, coated, skeletal fragment packstone with large fossil fragments. Forms a prominent ledge.

15 Nodular, planktonic foraminifer bearing, echinoid and mollusc lime wackestone interbedded with fossiliferous marl; yellowish-brown to reddish nodules; crustacean? burrows common; echinoids, gastropods, and pelecypods abundant; wackestone matrix rich in calcispheres and planktonic foraminifers 17.0m

... at 1,886.5m two poorly preserved ammonites

14 Thick (0.5m to 2.0m) beds of pellet-intraclast lime packstone, lime mudstone and lime wackestone with miliolids and requieniid rudists interbedded with thin (10cm to 20cm) beds of stromatolites and miliolid lime grainstone; light colored. Large tubular fenestrae (spar-filled burrows) are common in thick bedded miliolid bearing lime mudstone 128.5m

... at 1,863m? dense laminoid caliche crust.

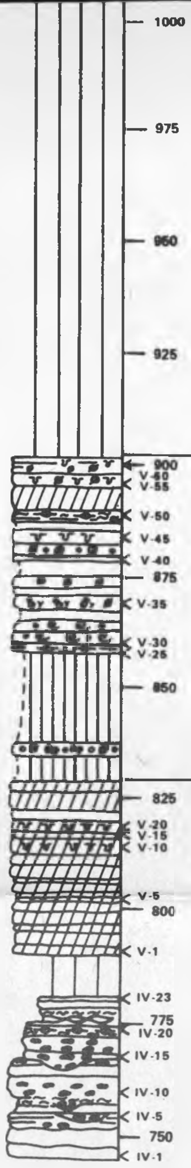
... at 1,856.5m oyster biostrome, 0.5m to 1.5m thick.

FAULT

13 Interbedded radiolitid rudist fragment lime packstone, pellet-intraclast packstone, pellet wackestone to packstone and occasional stromatolites; light colored; 20cm to 30cm thick beds with occasional 1.0m thick beds. Skeletal fragments are bored, micritized and algally-encrusted. Both radiolitid and requieniid rudist occur. Top of the unit is faulted, minimum thickness 113.5m

... from 1,698m to 1,732m cover and rubbly exposures with fine to medium crystalline dolomitic pelletal limestone.

... at 1,694m planktonic foraminifer bearing pellet wackestone.



2 Interbedded lime mudstone, pellet miliolid lime wackestone; and requieniid lime wackestone; brown to light colored; 0.5m to 1.0m thick beds. Weathered exposures alternating with covered intervals superficially resemble bioherms 73.9m

... from 882m to 893m dolomite; fine to medium crystalline, gray to brown, mottled, 0.5m to 4.0m thick beds.

... at 868m oyster wackestone overlying a thin packstone bed of large rounded intraclasts.

... from 828m to 859m cover; pellet, miliolid wackestones with sparse miliolid grainstones are laterally equivalent.

1 Dolomite; medium to coarsely crystalline, vuggy, sucrosic; light colored to gray; thin beds of fenestral stromatolites, fossil molds of high-spired gastropods, burrow structures and small channel structures are common. Evaporite solution collapse breccias are common in the lower 355m. The unit is largely undescribed 828.3m

... lower 150m of the unit is finely crystalline dolomite.

... base to 50m massive evaporite solution collapse breccia.

... at 775m irregular lenticular beds with calcareous clay separations.

... at 771m well developed stromatolites laterally grading into a brecciated supratidal crust.

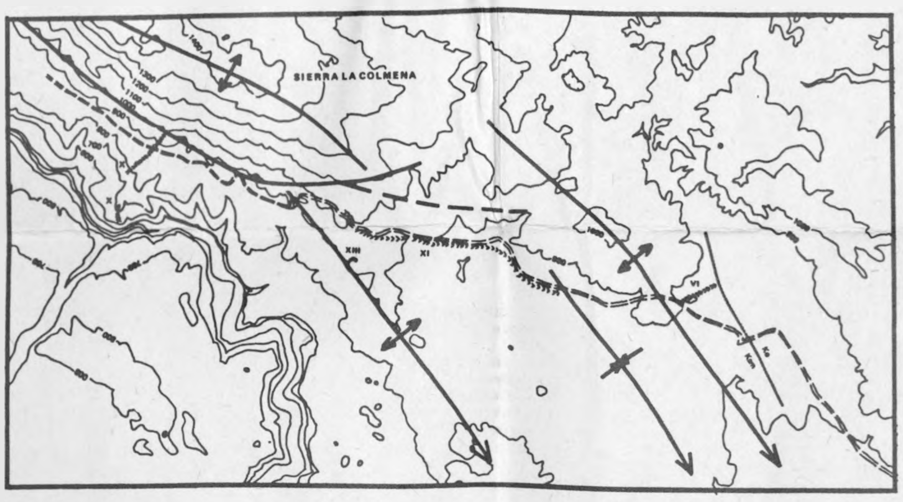
... at 758m 15cm bed of red calcareous clay.

... lower contact with the San Ricardo Formation poorly exposed, appears conformable.

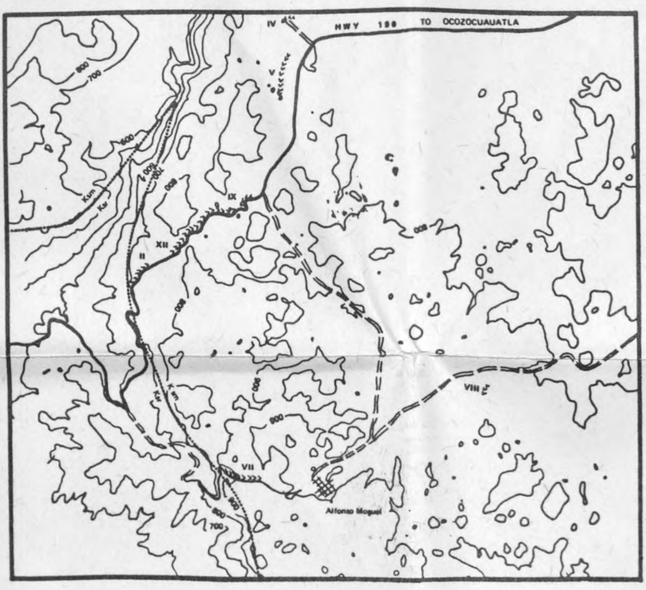
Measured By: D. R. Steele and L. E. Waite. 1980.

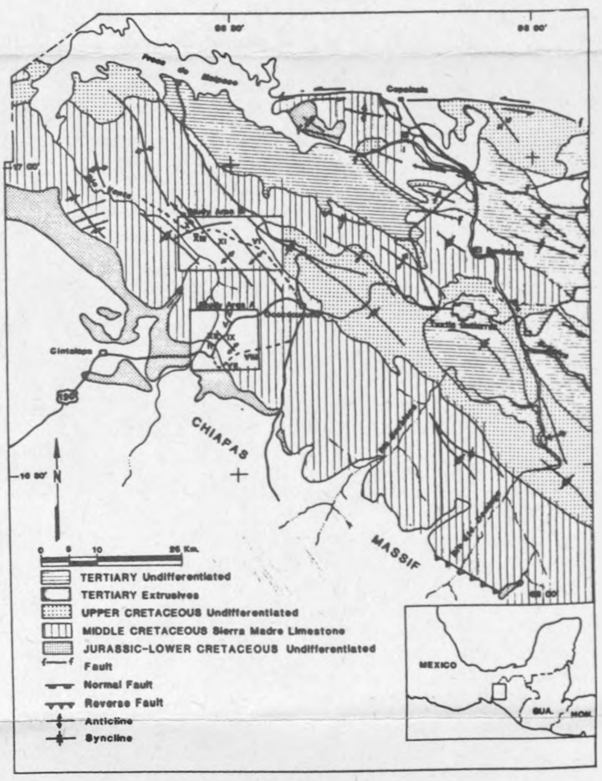
OCOZOCUAUTLA REGION COMPOSITE

STUDY AREA B



STUDY AREA A





EXPLANATION

ROCK TYPES

- Lime Mudstone
- Lime Wackestone
- Lime Grainstone or Packstone
- Marl
- Chert
- Dolomite
- Covered
- Undescribed

SEDIMENTARY PARTICLES

- Pellets
- Ooids
- Intraclasts
- Lithoclasts

SAMPLE COLLECTION CODE

Example

V1-5 { V1 - Locality; 5 - Sample Number }

SEDIMENTARY FEATURES

- Tubular Fenestrae (spar-filled burrows)
- Planar Fenestrae
- Vugs (Dolomite)
- Burrows
- Channel
- Cross-bedding
- Cross-lamination
- Nodular Bedding
- Thick Beds > 50cm
- Thin Beds < 50cm

FOSSILS

ALGAE

- Stromatolites
- Red (Solenoporacean) – as a Boundstone
- Green (Dasycladacean)
- Rhodolites
- Oncolites
- Calcispheres
- Corals
- Echinoids
- Radiolarians
- Sponge Spicules
- Sponge
- Stromatoporoids

FORAMINIFERS

- Miliolids
- Benthonic (V) Valvulammina (D) Dicyclina
- Planktonics

MOLLUSCS

- Cephalopods
- Oysters
- Pelecypods
- Radiolitids
- Requieniids
- Undifferentiated Macrofossils
- Denotes Fragments