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MICROPALEONTOLOGY AND PALEOGEOGRAPHY OF THE UPPER MURAL LIMESTONE OF SOUTHEASTERN ARIZONA AND NORTHERN SONORA.

by

Maria del Carmen Rosales Dominguez

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

The University of Arizona

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STATEMENT BY AUTHOR

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ABSTRACT

The upper Mural Limestone is a carbonate rock sequence of early and mid-Cretaceous age that crops out in southeastern Arizona and northern Sonora. It was deposited at the northern margin of the Chihuahua Trough during the peak of a major marine transgression, followed by a regression and a less extensive second transgression.

Four stratigraphic sections were studied. They form a NW-SE transect that runs along the axis of the Bisbee Basin. Six different facies were recognized based on micropaleontologic studies: 1) biomicrite with Orbitolina; 2) biomicrite with Colomiella; 3) quartz sandstone; 4) oomicrite with biogenic fragments; 5) biomicrite with Dictyoconus, and 6) biomicrite with Nummoloculina. The facies represent a mosaic of environments that range from inner carbonate shelf to shelf basin deposits.

The age of the upper Mural Limestone is tentatively considered as Albian-Lower Cenomanian, based on the presence of tintinnids and foraminiferal index fossils. Paleogeographic maps for the Lower, Middle, and Upper Albian based on correlation with adjacent areas are included.

CHAPTER 1

INTRODUCTION

The Bisbee Group is a conformable sequence of nonmarine and marine sedimentary rocks that occurs throughout southeastern Arizona and northern Sonora. It was deposited in a NW-trending extensional depression known as the Chihuahua Trough (Fig. 1). Most deposition occurred during Early Cretaceous time. The sequence is a transgressive-regressive cycle and includes more than 3500 m of shale, sandstone, limestone and conglomerate (Hayes, 1970a) (Fig. 2). Ransome (1904) named the Mural Limestone of the Bisbee Group for Mural Hill in the Mule Mountains, where he recognized a lower and an upper member. Since then, the upper member has been extensively studied -mainly for its abundant fossil content- which is the main focus of this study.

Upper Mural strata were deposited during the peak of a maximum marine transgression into the area and minor regressions (Warzeski, 1986; Hayes, 1970b). These rocks represent a variety of depositional environments that range from inner carbonate shelf to shelf basin deposits (Scott, 1979; Warzeski, 1983). The upper Mural crops out in most mountain ranges of southeastern Arizona, and

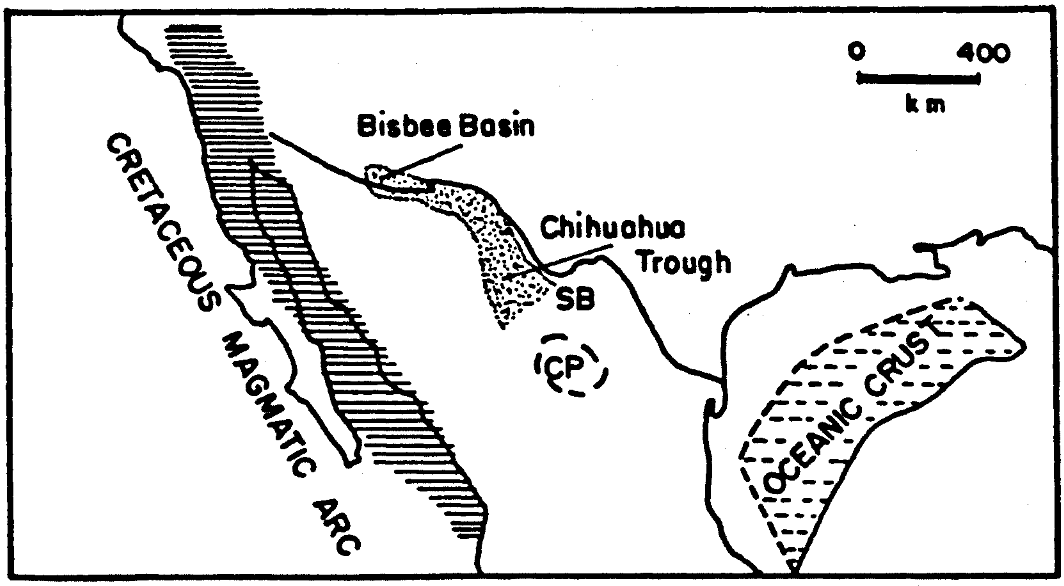


Fig. 1.- CRETACEOUS TECTONIC SETTING.
Modified from Dickinson and others, 1986. Abbreviations: CP, Coahuila Platform; SB, Sabinas Basin.

ALBIAN	BISBEE GROUP	CINTURA FORMATION		PINKISH-GRAY TO PALE RED FELDSPATHIC SANDSTONE AND GRAYISH RED SILTSTONES AND MUDSTONES.
		MURAL LIMESTONE	UPPER	MADE UP OF THICK BEDS OF GRAY LIMESTONE THAT YIELD A STRONLGY FETID ODOR WHEN FRESHLY BROKEN,SOME BEDS RICH IN *ORBITOLINA*.
			LOWER	MADE UP OF CALCAREOUS MUDSTONE, IMPURE FOSSILIFEROUS LIMESTONES AND FRIABLE CALCAREOUS SILTSTONES AND SANDSTONES.
APTIAN		MORITA FORMATION		MADE UP MOSTLY OF REPEATED SEQUENCES OF PINKISH-GRAY FELDSPATHIC SANDSTONES THAT GRADE UPWARD INTO MASSIVE GRAYISH-RED SILTSTONES AND MUDSTONES.
		GLANCE CONGLOMERATE		MADE UP OF POORLY SORTED AND POORLY ROUNDED COBBLES AND PEBBLES BOUND IN A MATRIX OF REDDISH-BROWN SANDY AND SILTY MUDSTONE.

Fig. 2.- Stratigraphy and generalized lithology of the Bisbee Group in southeastern Arizona and northern Sonora (According to Hayes, 1970a).

correlative strata extend to New Mexico and northern Mexico (Fig. 3). The strata consist ..."almost entirely of medium-light gray weathering limestone in relatively thick beds that hold up resistant cliffs or ridges... The limestone is mostly medium dark gray on fresh fracture and typically yields a strongly fetid odor when freshly broken" (Hayes, 1970a).

The thickness of the upper Mural varies enormously, but there is an indisputable thickening southward (Imlay, 1939; Hayes, 1970a, 1970b; Warzeski, 1983,1987). It is 54 m thick at Abbott Canyon, in the northern Mule Mountains, 64 m thick at Paul Spur, 290 m at Sierra del Caloso in Sonora (Warzeski, 1987), and 155 m thick at the Culantrillo section in Sonora.

The geologic contacts vary slightly. According to Hayes (1970a), the lower Mural-upper Mural contact is conformable but sharp. He placed it where the nonresistant calcareous sandstones and siltstones and impure limestones of the lower member give way to the more resistant relatively pure limestone of the upper member. The upper Mural-Cintura contact is gradational, and is placed at the "top of a limestone bed above which sandstone is dominant over limestone and below which limestone is dominant over sandstone" (Hayes, 1970a).

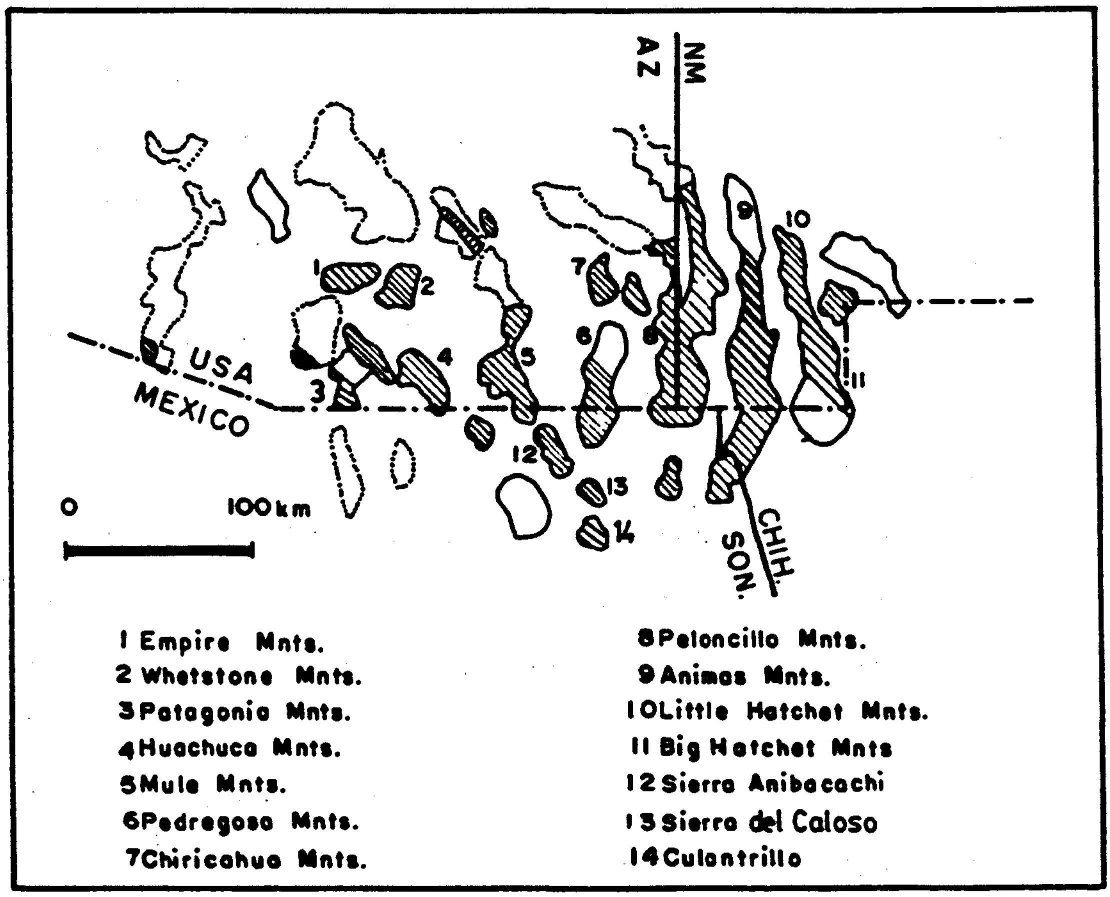


Fig. 3.- Map showing the different mountain ranges where the upper Mural strata crop out.

PREVIOUS WORK

Since the pioneer work of Ransome (1904), the upper Mural has been the focus of many studies. Fossils in the Mural Limestone have been used to date important geologic events in Arizona and northern Sonora. Paleogeographic reconstructions based on the Mural Limestone and the other units that form the Bisbee Group have helped to better understand the geologic history of the region.

Among the workers who have studied the upper Mural Limestone is Stoyanow (1949), who made exhaustive fossil collections from the unit. He also proposed some refinements in the Bisbee Group stratigraphy, although his units were later found unsuitable for mapping (Hayes and Landis, 1961).

In 1970, Hayes described the Mural Limestone, as well as the other formations that form the Bisbee Group. He established the age and conditions of deposition of the group as a whole (Hayes, 1970a). The Bisbee Group was then considered mostly Aptian and Albian in age. His fossil evidence, Serpula sp., Ostrea sp., Trigonia sp., and the benthic foraminifera Orbitolina sp., indicated that the upper Mural Limestone was late Trinity in age (Lower Albian), and that its uppermost part could be as young as the Fredericksburg Group of Texas (Middle Albian).

Scott (1979) defined and described the lithofacies of the upper member of the Mural Limestone in southeastern Arizona. He constructed a depositional model of Early Cretaceous coral-algal-rudist reefs, which has served as a solid base for later paleobiologic studies.

More recently, Scott (1987) studied the stratigraphy and correlation of the Mural Limestone in Arizona and Sonora. He used graphic correlation techniques to identify stadial and substage boundaries as defined in British reference sections. Rudist bivalves, ammonites and benthic foraminifera were the groups used in his study. In this way, the Aptian-Albian boundary falls within the basal part of the upper Mural Limestone.

Warzeski (1983) conducted a detailed study of the facies patterns and diagenesis of Cretaceous carbonate shelf deposits in northeastern Sonora and southeastern Arizona. He divided Ransome's (1904) informal upper Mural member into five new formal members in the Mexican localities. From base to the top, these five members are: the Canova, El Caloso, Angostura, La Aguja, and Agua Prieta members. He based his divisions on his observation of ..."lateral facies changes across the border, and to the appearance of several, new, lithologically distinct, mappable units within the Mural in Sonora"...(Warzeski, 1987).

Many Master of Science theses and doctoral dissertations in the Department of Geosciences at the University of Arizona have also focussed on the Mural Limestone and the Bisbee Group as a whole. Some are especially relevant to this study, although all of them contribute to a better knowledge and refinement of the Bisbee Group stratigraphy and sedimentology.

Archibald (1982) studied the stratigraphy and sedimentology of the Bisbee Group in the Whetstone Mountains in western Cochise County of southeastern Arizona. He found marginal-lacustrine, fluvial-deltaic and marine deposits within the Shellenberger Canyon Formation. These deposits were interpreted as a northwesternmost extension of marine waters in the Bisbee-Chihuahua Embayment, and correlated in part with the Mural Limestone. The sandstone and siltstone bodies of the overlying Turney Ranch Formation were found extensively bioturbated. For this and other reasons they were interpreted as being deposited in an upper estuarine setting, and correlated with an Albian-Cenomanian marine interval in the Mojado Formation of New Mexico noted by Zeller (1965).

Lindberg (1982) conducted a study of the Cretaceous rocks in the Rucker Canyon area in Cochise County. He described the upper Mural of this region as a massive carbonate unit about 75 m thick, consisting of at least three shoaling-upward cycles of deposition. He also found that the overlying Cintura Formation, the uppermost unit of the Bisbee Group, appears to have a concordant contact with the Upper Cretaceous Fort Crittenden Formation, although ..."the contact probably represents a hiatus of several million years" (Lindberg, 1987).

Klute (1987) studied the sandstone petrofacies in the Bisbee Basin of southeastern Arizona. She discerns different northwestern and southeastern lithofacies, which indicate the coexistence of different depositional regimes within the basin. The northwestern facies is almost entirely nonmarine, with exception of the shoreface and estuarine deposits of the Turney Ranch Formation. Klute also mentions the possibility that these facies may represent a mid-Cretaceous marine transgression into southeastern Arizona recorded in the northwestern facies of the Bisbee Group.

In Sonora, studies of the Mural Limestone have focussed on geologic and stratigraphic problems. Many units equivalent to its upper member have received different names, such as El Macho Formation, Sahuaro Formation (Gonzalez, 1978), Espinazo del Diablo Formation (Herrera y Bartolini, 1983), middle member of the Arroyo Sasabe Formation (Jacques, 1987), and many others. The micropaleontology of these units has not been studied in detail. Biostratigraphic work needs to be integrated in order to better understand the complicated stratigraphy and paleogeography of the region. The area has been exposed to severe faulting and folding during and after the Cretaceous due to the Laramide Orogeny (Rangin, 1977), the mid-Tertiary Orogeny, and the Basin and Range Disturbance (Damon, et al., 1964).

With few exceptions, very little integration of the Bisbee Group stratigraphy and its correlatives has been done. This is mainly due to poor age control in most of the formations that form the sequence. Those exceptions have been possible mainly through the fossil content in the Mural Limestone and equivalent units. Figure 4 shows the Bisbee Group correlation chart based on studies of different authors in southeastern Arizona and southwestern New Mexico.

Some of the previous studies (Archibald, 1982; Klute, 1987) indicate a mid-Cretaceous marine transgression (Upper Albian-Cenomanian) into the northwestern facies of the Bisbee Group. Nevertheless, most authors who have studied the paleontology of the upper Mural still contend that this member records only a single marine transgression in the area during Lower Cretaceous time (Warzeski, 1986; Scott, 1987). The presence of the

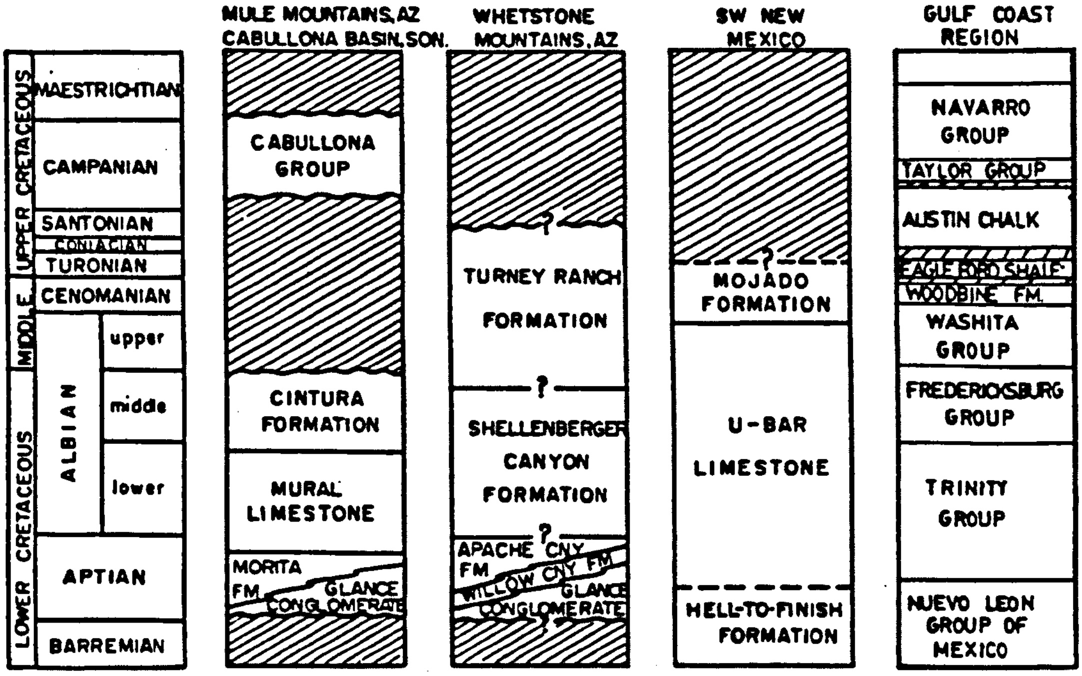


Fig. 4.- Correlation chart of the Bisbee Group in southeastern Arizona and southwestern New Mexico, showing its inferred time relations with Cretaceous strata of the Gulf coast region. Column of the Mule Mountains and Cabullona Basin from Hayes (1970a); column of the Whetstone Mountains from Archibald (1982); column of southwestern New Mexico from Sandidge (1985); and column of the Gulf coast region from Hayes (1970b).

foraminiferal index fossil <u>Nummoloculina heimi</u> Bonet close to the top of the upper Mural Limestone could indicate even a Late Albian-Early Cenomanian age (Ornelas, 1984; Ornelas et al., 1985; Cantu, 1989, personal communication) for the uppermost part of the unit. Such an age would be evidence for a second marine transgression during mid-Cretaceous time also recorded in the southeastern facies of the Bisbee Group.

OBJECTIVE

The objective of this study is a detailed micropaleontologic examination of the fossiliferous limestones of the Bisbee Group from geologic sections in southeastern Arizona and northern Sonora. The stratigraphic ranges of index fossils will be reviewed. Available biostratigraphic information will be integrated to clarify the stratigraphy of the Bisbee Group and correlatives. The paleogeography of the upper Mural Limestone will be interpreted from strata preserved in southeastern Arizona, northern Sonora, and adjacent areas.

CHAPTER 2

METHODS

GEOLOGIC SECTIONS

Four measured stratigraphic sections were selected for this study. They form a NW-SE transect along the axis of the Bisbee basin. They are the Abbott Canyon section, the Paul Spur section, the Sierra del Caloso section, and the Culantrillo section (Fig. 5).

The Abbott Canyon section was measured by Warzeski (1983) in the Mule Mountains of southeastern Arizona. It is a 74 m thick section that begins at the Morita-Mural contact, where calcareous quartz sandstone with small scale ripple-cross laminations gives way to a pelletoid-miliolid-packstone. Six samples were collected from this section.

The Paul Spur section was studied by Scott (1979). It is taken as the reference section for reefs in southeastern Arizona. No samples for this study were collected from this locality.

The Sierra del Caloso section was measured by Warzeski (1983) on the east bank of Rio de Agua Prieta, in Sonora. It is a 290 m thick section that begins at the top of the

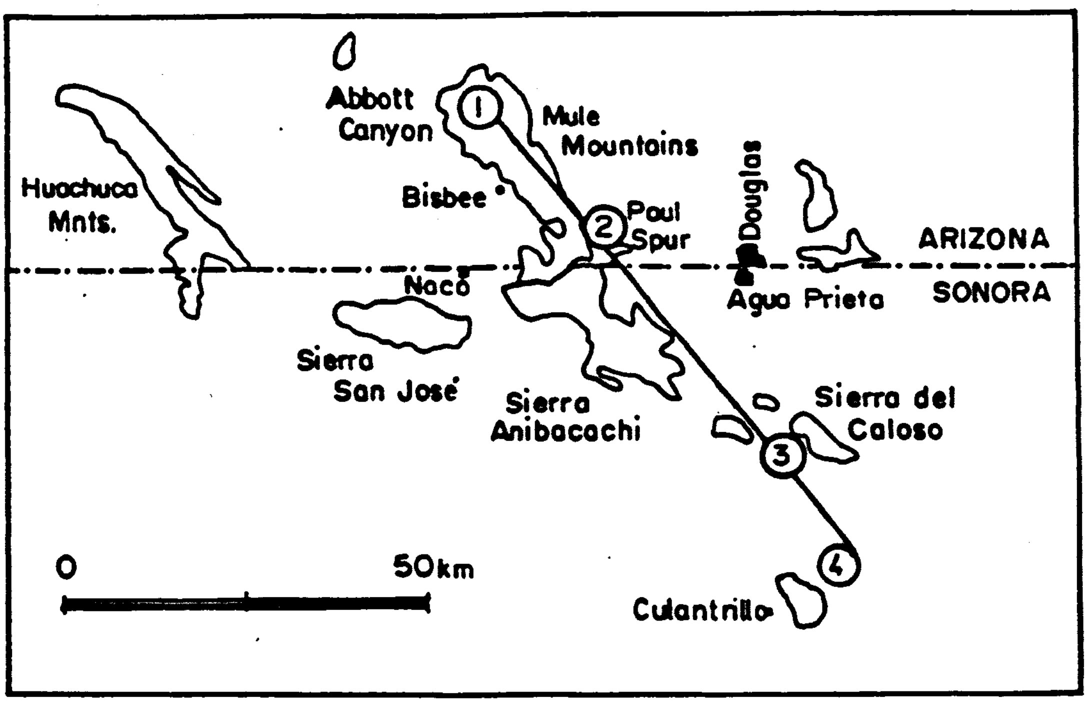


Fig. 5.- Map showing the location of studied stratigraphic sections along the axis of the Bisbee Basin.

lower Mural Limestone and ends at the base of the Cintura Formation. I did not collect any samples from this section. However, 19 thin sections were kindly made available to this author by Warzeski.

The Culantrillo section in northern Sonora is 2015 m thick (Plate I, in pocket). The sequence is formed by the Glance Conglomerate, the Morita Formation, and the Mural Limestone. 15 samples were collected from the upper Mural Limestone in this section.

Many other samples collected from different localities were studied for comparative purposes. Margaret Klute, Carlos Gonzalez, Robert Warzeski, Cesar Jacques, and Pat Hartshorne contributed thin sections of the upper Mural Limestone from Arizona and Sonora localities.

THIN SECTIONS

The thin sections were studied under the petrographic microscope. The lithology was not described in detail.

.Identification of the microfossils was based mainly on the work of Ornelas (1978) on globigerinids; by Trejo (1975) in the case of tintinnids; and by Bonet (1956) for the benthic foraminifera.

Facies were named based on the most common fossil in the faunal assemblage.

Stratigraphic ranges of the index fossils were determined by reference to Bonet (1956), Trejo (1975), Trejo y Bautista (1977), Rosales (1983), Coogan (1977), Ornelas (1984), and Ornelas et al. (1985).

CHAPTER 3

MICROPALEONTOLOGY

ABBOTT CANYON SECTION.- The Abbott Canyon samples studied here form the biomicrite with Orbitolina. This faunal association contains abundant Orbitolina sp. (Fig. 6) and rare Colomiella recta. For this section, Warzeski (1983) also reports the molluscs Monopleura, Toucasia, Acteonella, and Nerinea. The abundance of Orbitolina, the presence of the tintinnid Colomiella recta, and that of diverse mollusc fauna suggest an open marine platform environment with moderate circulation for the Abbott Canyon samples. These environments are located in straits, open lagoons and bays behind the outer platform edge. Water depth is a few tens of meters deep at most (Wilson, 1975).

PAUL SPUR SECTION.- No thin sections were studied from this locality. However, its paleontology and paleoecology were studied by Scott (Section 7929 in Scott, 1979). He described a coral-stromatolite-rudist facies and a coral-rudist fragment facies.

The coral-stromatolite-rudist facies is made of corals (Actinastrea), algae (Microsolena), and rudists (Coalcomana and Petalodontia). The growth of this

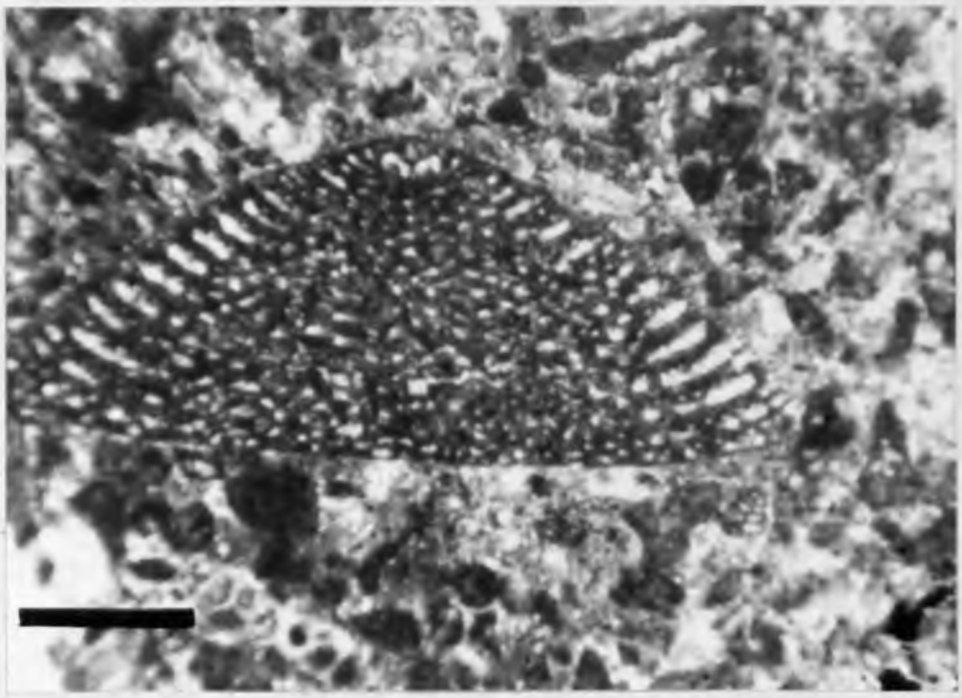


Fig. 6.- Photomicrograph of Orbitolina sp..
Abbott Canyon section, Biomicrite with
Orbitolina facies. Thin section, plane
polarized light. Scale bar is 500 microns.

community formed the reef core. According to Scott (1979), the rock fabric, facies relations, and the epibiotic encrusting habitat of the community suggest a high energy environment.

The coral-rudist fragment facies represents the reef-flank environment. It is present around the margins of the reef core. Abundant rounded, micritized grains of corals and rudists are present. Orbitolina, the algae Permocalculus, ostracods, serpulids, and tintinnids are also reported. This facies was deposited in an environment with energy conditions capable of moving and abrading shell fragments (Scott, 1979).

The caprinids Coalcomana ramosa and Caprinuloidea gracilis are reported from the reef facies and the reef flank facies (Scott, 1979).

SIERRA DEL CALOSO SECTION.- The Sierra del Caloso thin sections contain abundant microfossils. They form characteristic faunal associations very common throughout the Lower and middle Cretaceous. They are grouped in this study as follows:

- Biomicrite with Colomiella. This faunal association is preserved in a micrite matrix that contains diverse tintinnids and globigerinids, as well as other microfossils. The most common are Colomiella recta, C. coahuilensis, Calpionellopsella sp., Hedbergella sp., H.

planispira, H. gorbachiki (?), H. delrioensis, Favusella sp., F. washitensis (Fig. 7), and Microcalamoides diversus (Fig. 8). It is represented by samples WOR2-12 to WOR2-38. The lime mudstone sediment and the presence within this matrix of abundant pelagic microfossils indicates deposition in a deep, calm water, open marine environment (Wilson, 1975). The biomicrite with Colomiella corresponds to the Canova and Angostura Members of Warzeski (1987).

- Quartz sandstone. This facies is represented only by two samples, WOR2-50 and 51. They are formed exclusively of quartz (Fig. 9a). This facies corresponds to the La Aguja Member of Warzeski (1987).

- Oomicrite with biogenic fragments. This facies contains well preserved oolites (Fig. 9b), some of them with surficial coatings typical of moderately agitated waters. It also contains gastropods, echinoderm, pelecypod and algae fragments. It is represented by samples WOR2-52 to 54. It is equivalent to the base of the Agua Prieta Member of Warzeski 1987).

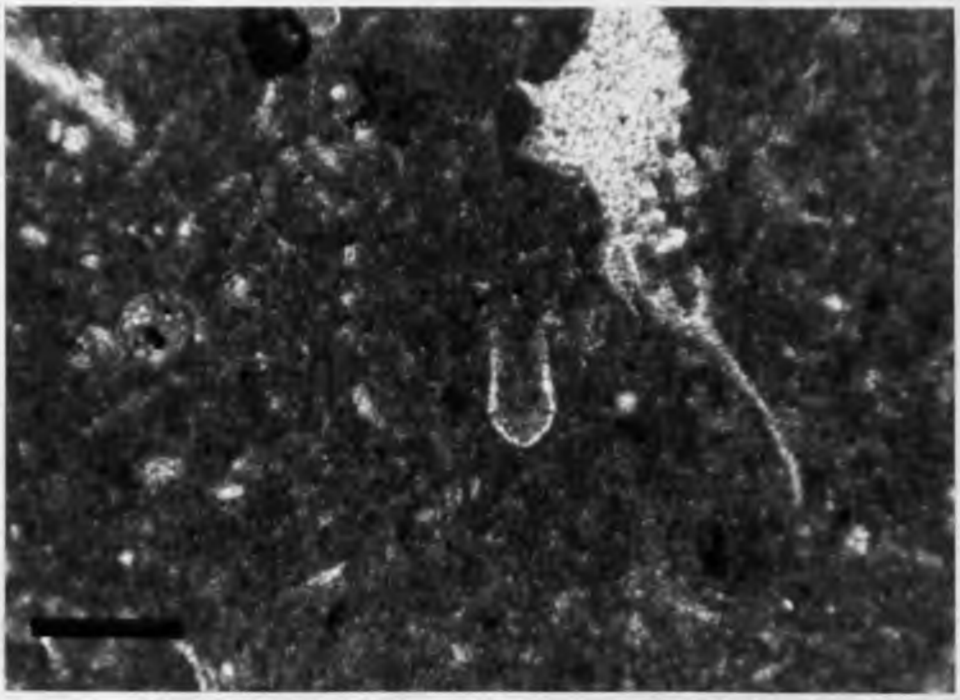
- Biomicrite with Dictyoconus. This facies contains abundant benthic foraminifera typical of reef facies or in calcarenites originating near rudist banks (Bonet, 1956). The most common microfossils are Dictyoconus walnutensis (Fig. 10a), Coskinolina sp., and Cuneolina sp.. Abundant

FIGURE 7

BIOMICRITE WITH *COLOMIELLA* FACIES.
SIERRA DEL CALOSO SECTION.

A. Photomicrograph of *Colomiella recta*.
Thin section, plane polarized light.
Scale bar is 100 microns.

B. Photomicrograph of *Ticinella* sp.?
Thin section, plane polarized light.
Scale bar is 150 microns.



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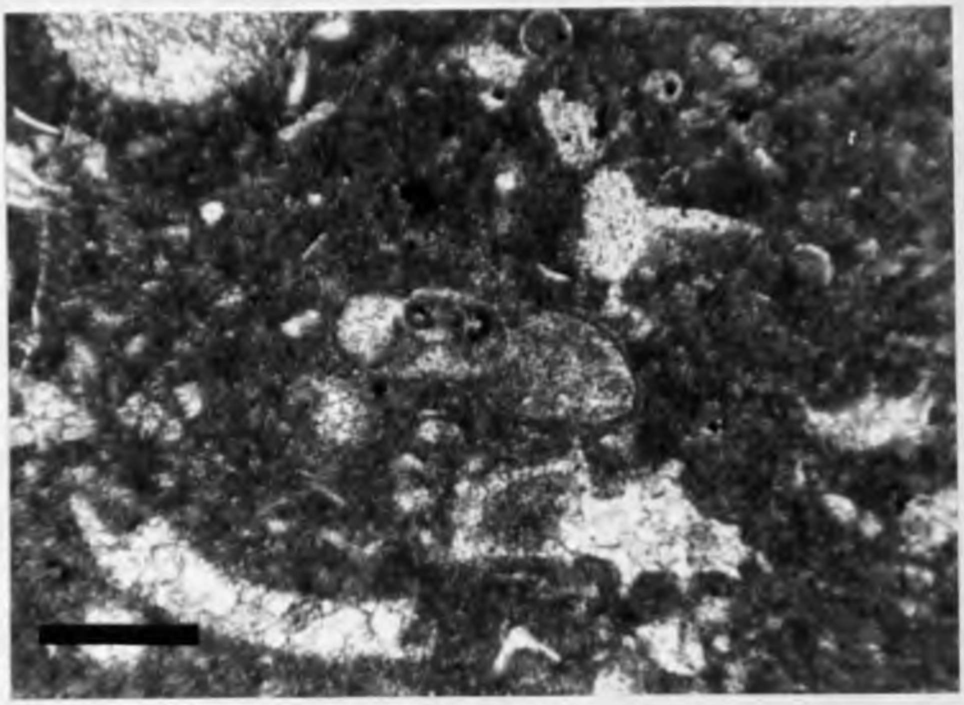


B

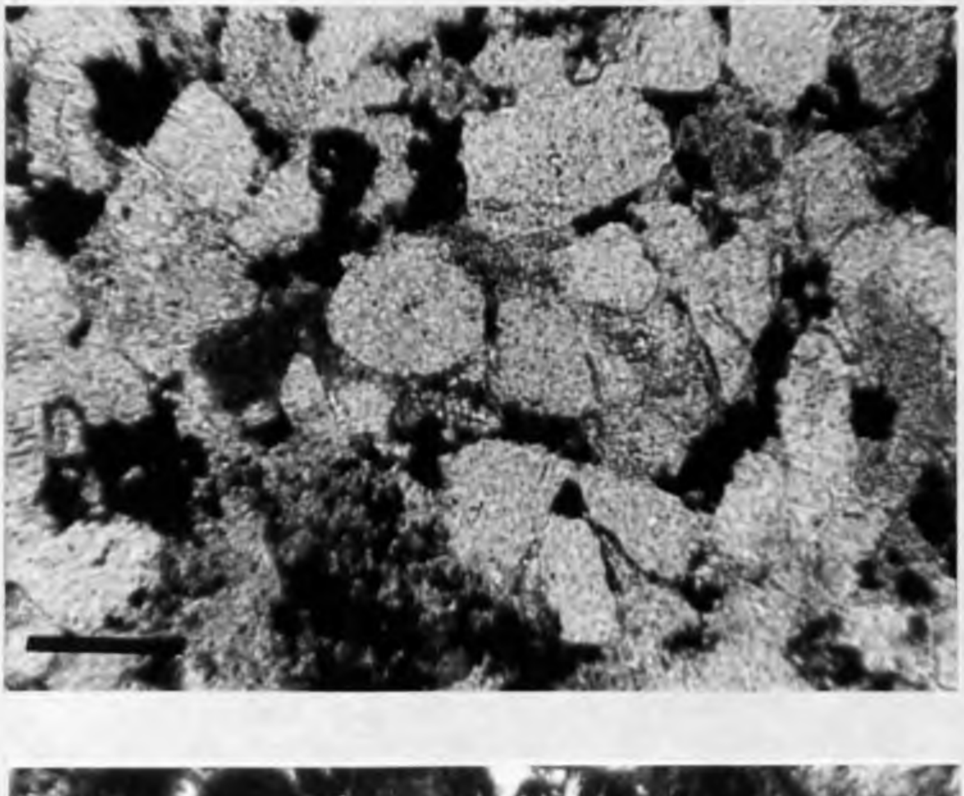
FIGURE 7

Fig. 8.- Photomicrograph of Microcalamoides diversus. Sierra del Caloso section, Biomicrite with Colomiella facies. Thin section, plane polarized light. Scale bar is 125 microns.

FIGURE 9

A. Photomicrograph of quartz sandstone. Sierra del Caloso section. Thin section, plane polarized light. Scale bar is 100 microns.

B. Photomicrograph of oolitic facies. Sierra del Caloso section. Thin section, plane polarized light. Scale bar is 500 microns.



A

B

FIGURE 9

fragments of algae, echinoderm, textularids, bryozoans, gastropods and other molluscs are commonly found. Biogenic fragments are often heavily encrusted by foraminifera. The presence of Dictyoconus walnutensis has been reported from several sections of central Mexico and the Gulf region (Bonet, 1956; Adams, 1985; Coogan, 1977; Ornelas, 1984; Ornelas et al., 1985). This facies is represented by samples WOR2-60 and 61. It is equivalent to the lower and middle part of the Agua Prieta Member of Warzeski (1987).

- Biomicrite with Nummoloculina. This association consists of abundant Nummoloculina heimi (Fig. 10 b and 11a) and rare Dicyclina (Fig. 11 b). Also present are Quinqueloculina sp., Cuneolina sp., and other benthic foraminifera; Diplopora sp. (?) and other algae; gastropod, textularids, and echinoderm fragments. The presence of this biota indicates deposition in an environment of restricted circulation on marine platforms, which form lagoons and bays with extremely variable conditions (Wilson, 1975; Bonet, 1956). It is represented by samples WOR2-63 to 67. It corresponds to the uppermost part of the Agua Prieta Member of Warzeski (1987).

CULANTRILLO SECTION.- The Culantrillo thin sections also contain abundant microfossils. However, with one exception, the faunal associations described for the Sierra del Caloso section are absent here. The only faunal

FIGURE 10

A. Photomicrograph of Dictyoconus walnutensis. Biomicrite with Dictyoconus facies, Sierra del Caloso section. Thin section, plane polarized light. Scale bar is 400 microns.

B. Photomicrograph of Nummoloculina heimi. Biomicrite with Nummoloculina facies, Sierra del Caloso section. Thin section, plane polarized light. Scale bar is 200 microns.

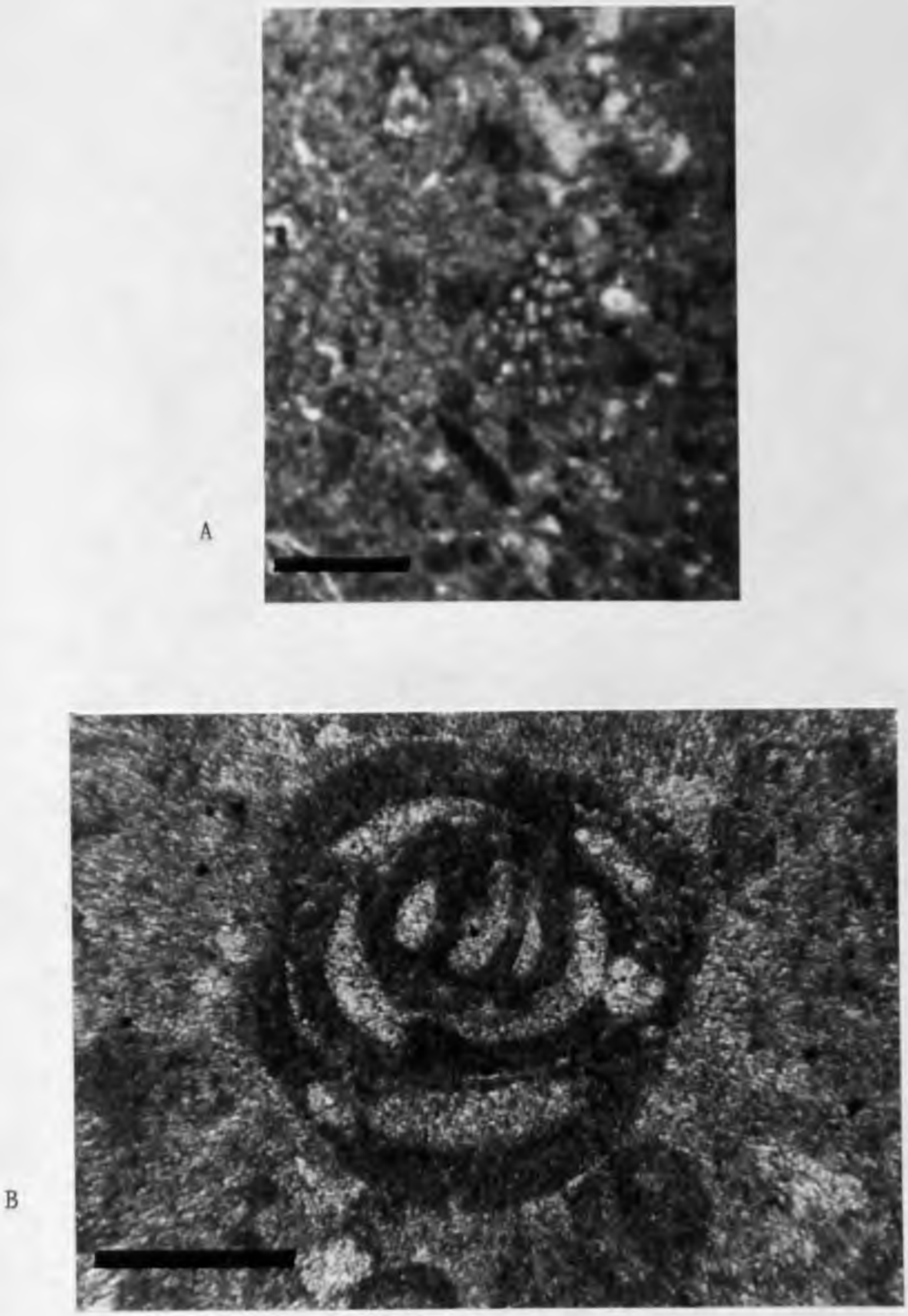


FIGURE 10

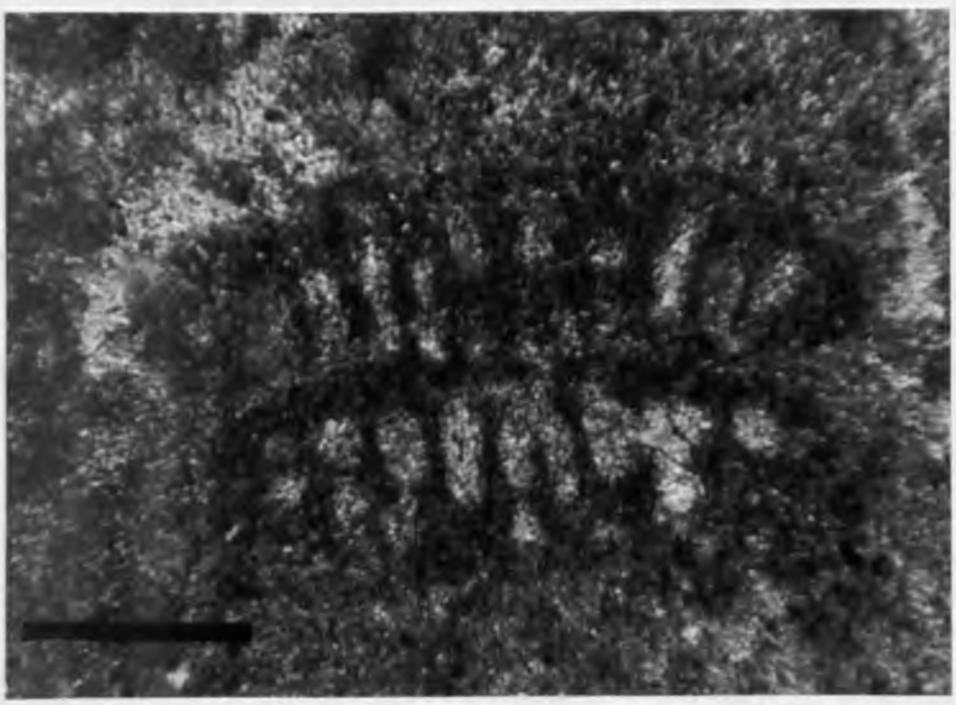
FIGURE 11

BIOMICRITE WITH NUMMOLOCULINA FACIES.
SIERRA DEL CALOSO SECTION.

A. *Nummoloculina heimi*. Thin section, plane polarized light. Scale bar is 200 microns.

B. *Dicyclina schlumbergeri*. Thin section, plane polarized light. Scale bar is 200 microns.

A



B

FIGURE 11

association in the Culantrillo section is the Biomicrite with Colomiella. It is represented by samples MG/CR-24 to 33.

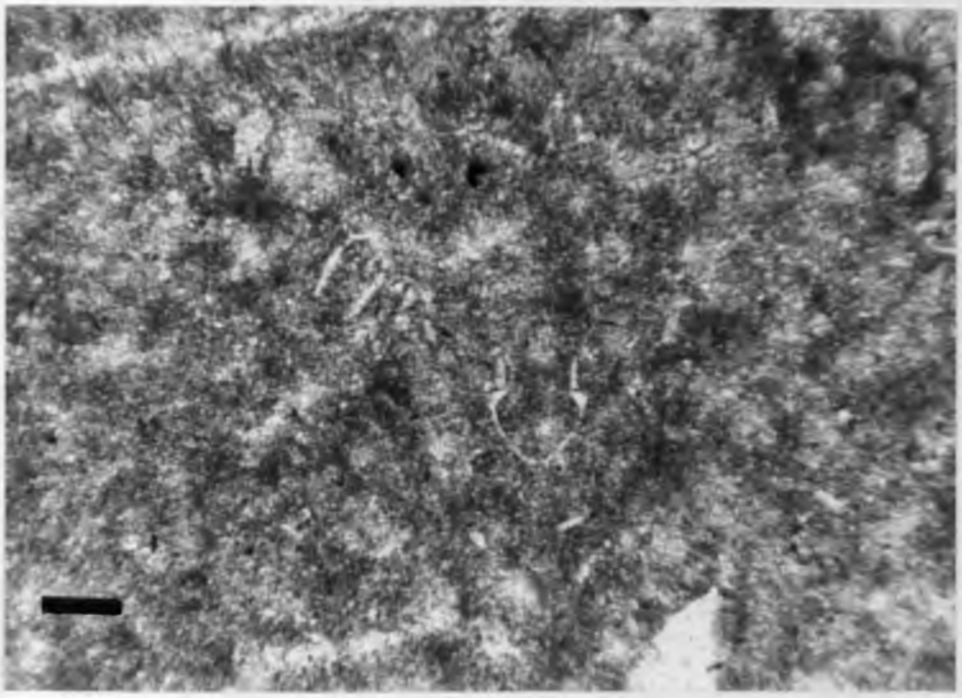
The biomicrite with Colomiella in the Culantrillo section commonly contains Colomiella recta. Also present are Hedbergella sp., H. delrioensis, Favusella sp., F. uashitensis and other small globigerinids, rare Microcalamoides diversus, echinoderm and mollusc fragments, rare miliolids and algae fragments. As well as in the Sierra del Caloso samples, this facies represents deposition in an open marine environment. However, there are some small differences in their fossil content: a) The biomicrite with Colomiella in the Culantrillo section contains Colomiella mexicana (Fig. 12a), which is absent in the Sierra del Caloso section. b) Microcalamoides diversus (Fig. 12b) is less abundant in the Culantrillo samples. c) The uppermost samples in the Culantrillo section contain thick-walled small globigerinids that are absent in the Sierra del Caloso section.

FIGURE 12

BIOMICRITE WITH *COLOMIELLA* FACIES.
CULANTRILLO SECTION.

A. *Colomiella mexicana* and *Colomiella recta*. Thin section, plane polarized light. Scale bar is 65 microns.

B. *Microcalamoides diversus*. Thin section, plane polarized light. Scale bar is 15Ø microns.



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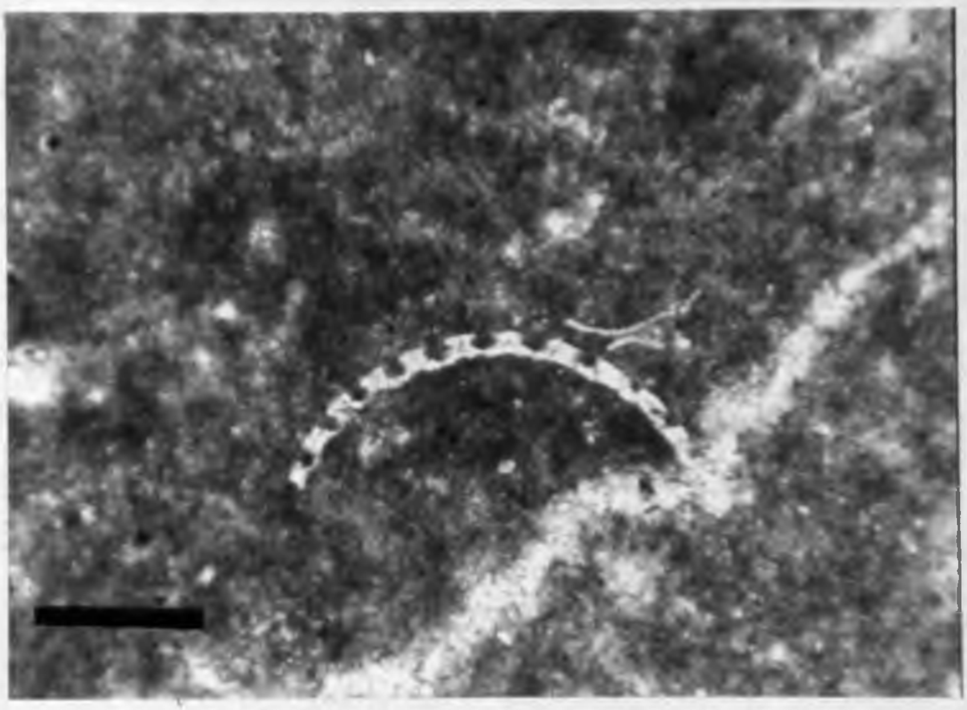


B

FIGURE 12

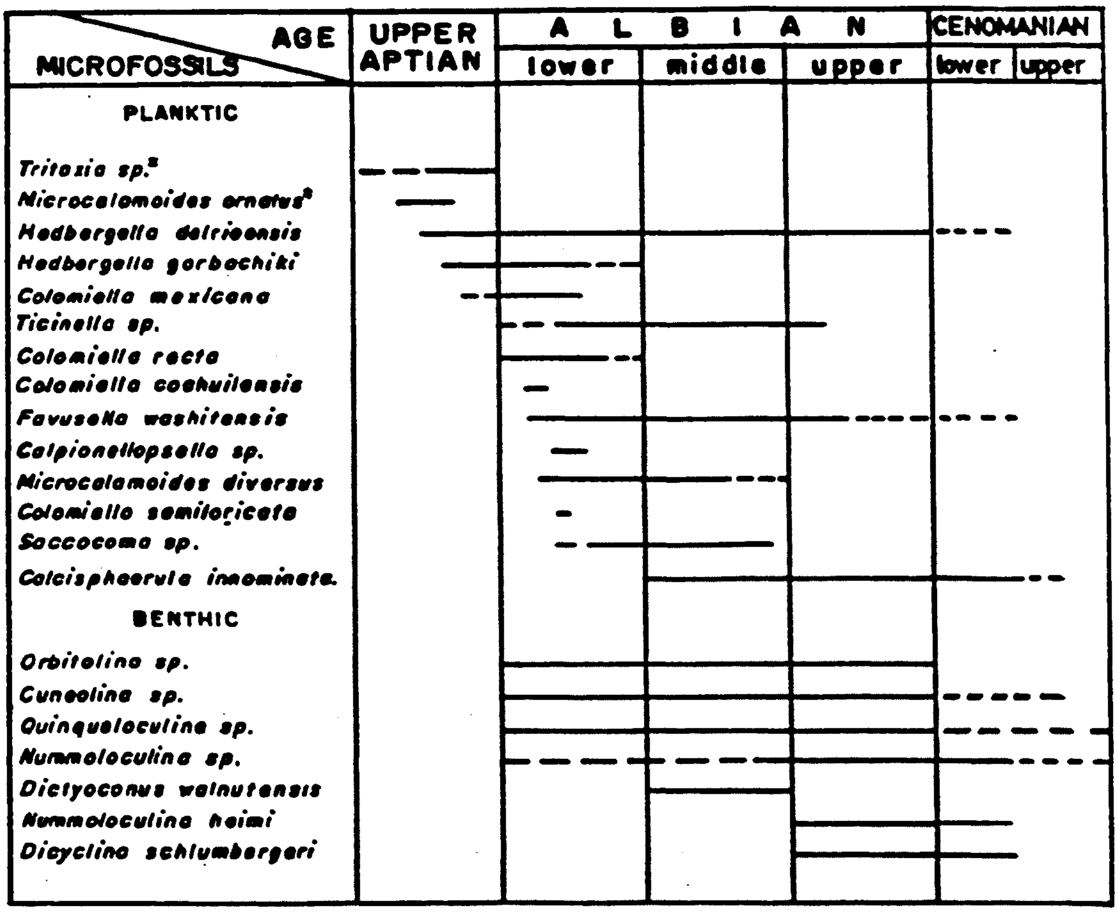
CHAPTER 4

BIOSTRATIGRAPHY

Faunal elements in the Mural Limestone ranging from early Trinity to Washita age (Upper Aptian to Cenomanian) permitted Hayes to constrain the age of this unit. A Late Trinity to Fredericksburg age (Upper Aptian to Middle Albian), however, seemed most probable to him because of the presence in the lower member of the pelecypod *Trigonia*, an ammonite that resembled *Parahoplites*, as well as *Orbitolina*, *Dictyoconus floridanus*, *Caprinella* (?) and *Exogyra arietana* in the upper member (Hayes, 1970a).

Micropaleontologic studies in this report reveal that the upper Mural Limestone could possibly extend from Albian to early Cenomanian times. Figure 13 shows the generalized stratigraphic ranges of the upper Mural Limestone microfossils reported here.

The first appearance of the tintinnid *Colomiella recta* marks the Aptian-Albian boundary (Trejo, 1980). In the upper Mural Limestone, *Colomiella recta* is present along with *Calpionellopsella maldonadoi*, *Favusella washitensis* and *Microcalamoides diversus* in the El Caloso and Culantrillo sections in Sonora. These fossils all together form a typical pelagic association often found in early



* in lower Mural

Fig. 13.- Stratigraphic ranges of the microfossils present in the upper Mural Limestone, southeastern Arizona and northern Sonora.

Albian basinal deposits (Trejo, 1975; Trejo y Bautista, 1977; Rosales, 1983; Ornelas, 1984; Ornelas et al., 1985).

According to Douglass (1960), the maximum range of the benthic foraminifera Orbitolina in the Tethys realm is from Neocomian to Cenomanian, but in North America this genus is apparently confined to the Albian. In the samples studied here, the genus Orbitolina is abundant in the Abbott Canyon samples, common in the Paul Spur section (Scott, 1979), rare in the Sierra del Caloso section, and very rare in the Culantrillo section. Thus, the presence of Orbitolina throughout the upper Mural gives an Albian age to this unit. However, it is important to note that all of the specimens reported here are in the lower half of the member. In the Abbott Canyon samples, Orbitolina is present along with Colomiella recta, which would indicate a Lower Albian age.

Dictyoconus cf. D. walnutensis was found in the Sierra del Caloso section above the Oomicrite with biogenic fragment facies. Dictyoconus walnutensis is considered as a Middle Albian index fossil (Coogan, 1977).

The miliolid Nummoloculina heimi was found in the uppermost samples of the Sierra del Caloso section. This fossil has been previously reported for mid-Cretaceous strata of the Gulf Basin (Bonet, 1956), central Mexico (Bonet, 1956; Ornelas, 1984; Ornelas et al., 1985), and east-central Sonora (Scott and Gonzalez, in press). Sometimes *Nummoloculina heimi* constitutes pure populations as is the case of El Abra Formation in central Mexico (Ornelas et al., 1985). The presence of *N. heimi* and its coexistence with *Dicyclina*, a larger foraminifera that first appears in Late Albian time and continues into the Cenomanian (Coogan, 1977; Ornelas, 1984), indicates an Upper Albian-Lower Cenomanian age for the uppermost upper Mural in the Sierra del Caloso section. Similar ages have been assigned to *Nummoloculina heimi* bearing strata in the Tepalcatepec and Morelos Formations in Jalisco, Mexico (Ornelas, 1984); and to strata in northern Mexico (Cantu, 1989, personal communication).

In short, the upper Mural Limestone spans the Albian stage, and possibly the Lower Cenomanian. In the Abbott Canyon section, the upper Mural Limestone can be considered as Lower Albian because of the presence of *Orbitolina* and *Colomiella recta*. The upper Mural Limestone in the Paul Spur section is considered in this study as Lower to Middle Albian in age for the occurrence of tintinnids and *Orbitolina*, and the overlapping of *Coalcomana* and *Caprinuloidea* (Scott and Brenckle, 1977; Young, 1984), respectively. The Sierra del Caloso section ranges from Albian to Lower Cenomanian. This is shown by the occurrence of *Colomiella recta* of the Lower Albian, *Dictyoconus walnutensis* of the Middle Albian, and *Nummoloculina heimi*, considered as an Upper Albian-Lower Cenomanian index fossil. The Culantrillo section is tentatively assigned to Lower-Middle Albian? time because of the presence of *Colomiella recta* and *Calcisphaerula innominata*?.

CHAPTER 5

CORRELATION

Upper Mural strata are present in southeastern Arizona and northern Sonora (Imlay, 1939; Hayes, 1970b; Warzeski, 1983). Correlative strata have been studied by Hayes (1970b), Archibald (1982, 1987), Klute (1987), Warzeski (1983, 1987), Zeller (1965), Sandidge (1985), Herrera y Bartolini (1983), Gonzalez 1978), and Jacques (1987), among others.

Hayes (1970b) correlated the upper Mural Limestone of the Mule and Huachuca Mountains with rocks in the Pedregosa-Southern Chiricahua Mountains to the east, based upon *Orbitolina*-bearing rocks.

The correlation of the upper Mural with the U-Bar Limestone in the Big Hatchet Mountains of southwestern New Mexico was based on lithologic similarities and age (Hayes, 1970b). The reef facies in the U-Bar Limestone contains *Ostrea*-type bivalves, rudist bivalves, abundant orbitolinids, colonial corals and coralline algae. Rudist bivalves from this group suggest an age between Lower and Middle Albian (Sandidge, 1985). Beds of marine origin were reported near the top of the overlying Mojado Formation (Zeller, 1965).

Archibald (1982, 1987) correlated the Mural Limestone with the marine interval of the Shellenberger Canyon Formation in the Whetstone Mountains. His correlation is supported by the occurrence of fish teeth of the Family Pycnodontidae in the oyster coquina marker bed. A possible Albian to Cenomanian age has been assigned to the overlying Turney Ranch Formation (Tyrrell, 1957, and Hayes, 1970, in Archibald, 1982). Archibald (1982) ..."believes that at least some of the Turney Ranch Formation is younger than Cenomanian". There are not any fossils that could establish the age of this unit; however, many portions of the Turney Ranch Formation are lithologically compatible with marine depositional environment models (see Archibald, 1982, pp. 105-114 for details). Archibald speculates that the second transgression event that occurred during mid-Cretaceous time and is recorded at the top of the Mojado Formation in southwestern New Mexico might be associated with the deposition of the Turney Ranch Formation in southeastern Arizona (Archibald, 1982, 1987; Klute, 1987).

In the Lampazos area, in east-central Sonora, Scott and Gonzalez (in press) report among others the Lower Albian foraminifera *Orbitolina texana* in the Lampazos Formation (Gonzalez y Buitron, 1984); the Middle Albian *Dictyoconus walnutensis* and *Orbitolina subconcava* in the

Espinazo del Diablo Formation; and rudists that support a Middle Albian age in the Espinazo del Diablo and Nogal Formations. However, they also describe an ammonite assemblage that consists of *Engonoceras stolleyi*, *E. belviderense*, *Protengonoceras* sp., *Parengonoceras* sp., *Hoplites* sp., and *Beudanticeras* sp., among others (Gonzalez y Buitron, 1984; Gonzalez, 1987; Herrera et al., 1984) in member 3 of the Nogal Formation. The authors suggest a tentative correlation of this member 3 with Middle to basal Upper Albian ammonite zones. This ammonite also occurs in the Kiowa Formation of Kansas and Oklahoma (Scott, 1970b). The Kiowa Formation has been correlated with the Washita Group in Texas (Upper Albian- Cenomanian) (Cobban and Reeside, 1952, *in* Scott, 1970b).

Figure 14 shows the correlation chart proposed in this study for the upper Mural Limestone. Upper Mural correlative strata might be the Shellenberger Canyon Formation and part of the Turney Ranch Formation in the Whetstone Mountains; the U-Bar Limestone and part of the Mojado Formation in southwestern New Mexico; and the Lampazos, Espinazo del Diablo, and Nogal Formations in east-central Sonora. These correlations assume the following: 1) the age of the upper Mural Limestone is Albian-Lower Cenomanian; 2) the marine interval in the Shellenberger Canyon Formation correlates with the upper

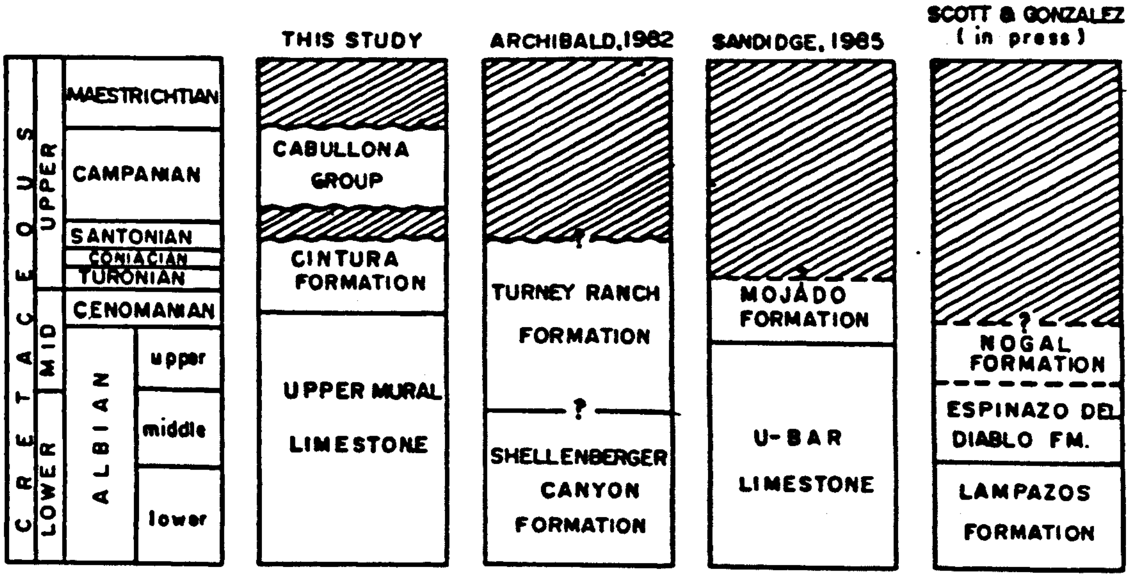


Fig. 14.- Chart showing the correlation proposed in this study for the upper Mural Limestone.

Mural Limestone (Archibald, 1982, 1987; Klute, 1987); 3) the Turney Ranch Formation is a marine deposit as previously reported by Archibald (1982); 4) the U-Bar Limestone in southwestern New Mexico correlates with the upper Mural Limestone (Hayes, 1970b; Sandidge, 1985); 5) that "marine" deposits of the Turney Ranch Formation might be correlative with the mid-Cretaceous marine beds at the top of the Mojado Formation in southwestern New Mexico, as proposed by Archibald (1982, 1987). This would be evidence of a second marine transgression into the area during Upper Albian-Lower Cenomanian time; and 6) that the ammonite assemblage reported by Scott and Gonzalez (in press) is Upper Albian in age and might be the basinal facies equivalent in time to the *Nummoloculina heimi* facies at the top of the upper Mural Limestone in the Sierra del Caloso section.

The age and correlation of the Cintura Formation shown in Figure 14 is based on stratigraphic position. This unit has been previously correlated largely with the Mojado Formation in the Big Hatchet Mountains, with the Shellenberger Canyon Formation, with the Turney Ranch Formation in the Whetstone, Empire and Santa Rita Mountains (Hayes, 1970b), and with the Fredericksburg Group of Texas (Middle Albian). However, some authors believe that the Cintura Formation could be as young as the Washita Group (Upper Albian-Cenomanian) (Hayes, 1970b). In this respect, it is considered important to note the fact that Lindberg (1987) reports an apparent concordant contact of the Cintura Formation with the Upper Cretaceous Fort Crittenden Formation in the Rucker Canyon area, Cochise County of southeastern Arizona.

The upper Mural correlation presented here is tentative. It is based on the fossil data available, micropaleontologic studies carried out in this study, and previous correlations. Better correlations of the Bisbee Group as a whole should be possible with more detailed micropaleontologic study of the carbonate units and lithologic studies of the terrigenous facies.

CHAPTER 6

PALEOGEOGRAPHY

Late Jurassic to Cretaceous paleogeographic reconstruction in southeastern Arizona and northern Sonora has been possible throughout the study of the Bisbee Group units and their correlatives. The Glance Conglomerate, the Morita Formation, the Mural Limestone, and the Cintura Formation deposits record a transgressive-regressive event in the southeastern facies of the Bisbee Group.

The Glance Conglomerate is a syntectonic deposit of Late Jurassic to Early Cretaceous age that represents deposition during regional rift tectonism in and around Arizona (Bilodeau et al., 1987). The basal clasts lithology in this unit reflects the nature of the underlying bedrock. It includes earlier Mesozoic volcanics, Jurassic granitic rocks, Paleozoic sedimentary rocks, and Precambrian crystalline rocks (Hayes, 1970a).

The Morita Formation represents deposition on a slowly subsiding subaerial deltaic plain. The upper part of this unit contains thin impure oyster-bearing limestone beds deposited in brackish waters. These waters are believed to have flooded intermittently the delta plain in southeastern Arizona and northern Sonora from an advancing sea to the southeast during Lower Aptian (?) time (Hayes, 1970a). In areas to the northwest, middle and distal facies of the alluvial fan system were deposited (Bilodeau, 1979). They are represented by the Willow Canyon Formation which contains few lacustrine or marginal lacustrine deposits (Archibald, 1982).

Mixed and interbedded terrigenous sediments and carbonates of the lower Mural Limestone represent the pulsating northwestward sea advance over the deltaic plain complex during Upper Aptian time (Hayes, 1970a).

Based on index fossils and the correlations with adjacent areas proposed here, the paleogeographic setting indicates that during the Lower Albian marine waters from the Gulf of Mexico region flooded, at a maximum, southeastern Arizona and northern Sonora (Fig. 15). The sediments formed an extensive carbonate platform that dipped toward the south, creating a diverse mosaic of facies now preserved in the upper Mural Limestone and equivalent units. At this time, the Abbott Canyon area was an open marine platform environment with moderate circulation, as indicated by the presence of the benthic foraminifera *Orbitolina* and the tintinnid *Colomiella recta*. It was during this time that the Paul Spur reef was formed by corals, algae and rudists. This fauna is characteristic of shallow and clear waters. In areas to

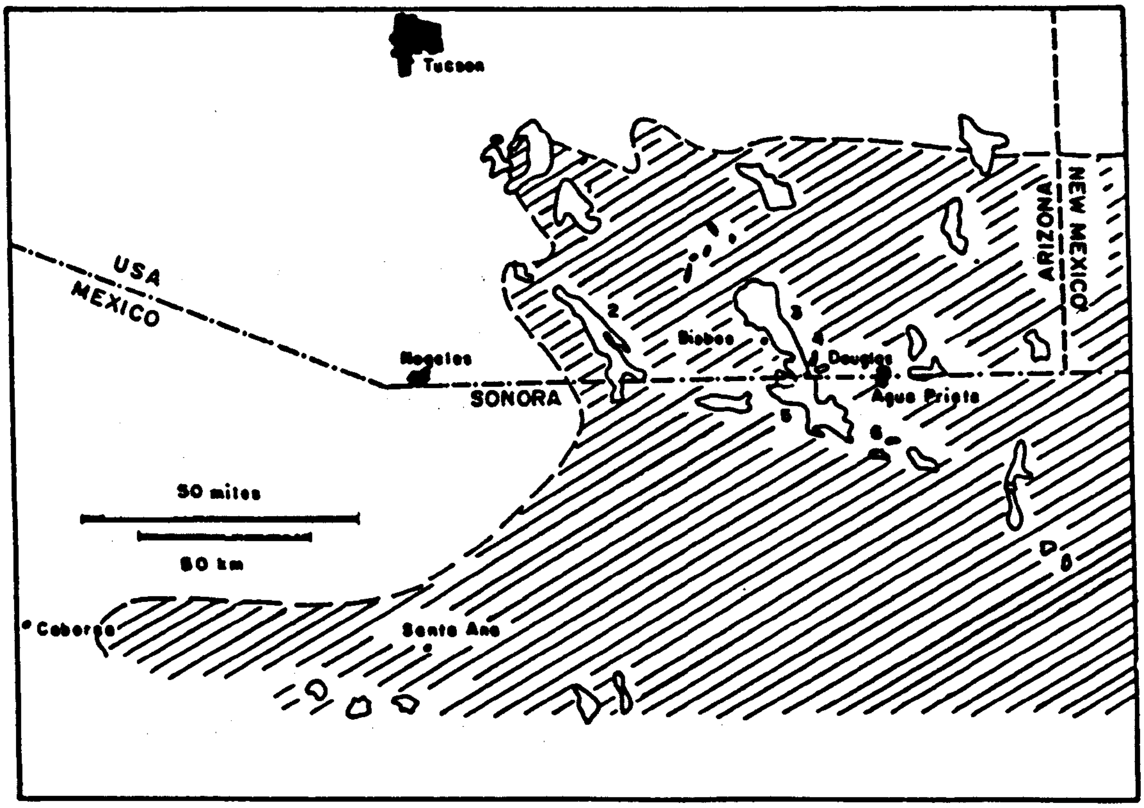


Fig. 15.- Paleogeography of the upper Mural Limestone during Lower Albian time (modified from Hayes, 1970b). Locations: 1, Whetstone Mountains; 2, Huachuca Mountains; 3, Mule Mountains; 4, Paul Spur; 5, Sierra Anibacachi; 6, Sierra del Caloso.

approximate limit of marine facies

the south, basinal facies were being deposited as demonstrated by the presence of abundant planktic organisms such as tintinnids and globigerinids in the Sierra del Caloso and the Culantrillo regions. At this time, in southwestern New Mexico, the sediments of the limestone-shale member of the U-Bar Limestone were deposited (Sandidge, 1985). In areas to the southwest, in Sierra del Chanate in Sonora, lagoonal deposits of the middle member of the Arroyo Sasabe Formation (Jacques, 1987) were being deposited.

A minor regression occurred during Middle Albian time (Fig. 16). This shallowing is recorded in the upper Mural strata: basinal facies gave way to shallower deposits. In the Sierra del Caloso section, the presence of <u>Dictyoconus walnutensis</u>, a benthic foraminifera typical of shallow waters indicates this regression. In southwestern New Mexico, the reef limestone member records the presence of abundant <u>Ostrea</u>-type bivalves, rudists, and abundant orbitolinids (Sandidge, 1985). In east-central Sonora, the presence of caprinids, requienids, colonial corals and algae shows shallow water conditions for the region.

A second marine transgression into southeastern Arizona and northern Sonora during Upper Albian-Lower Cenomanian times (Fig. 17) is recorded at the top of the upper Mural Limestone in the Sierra del Caloso section.

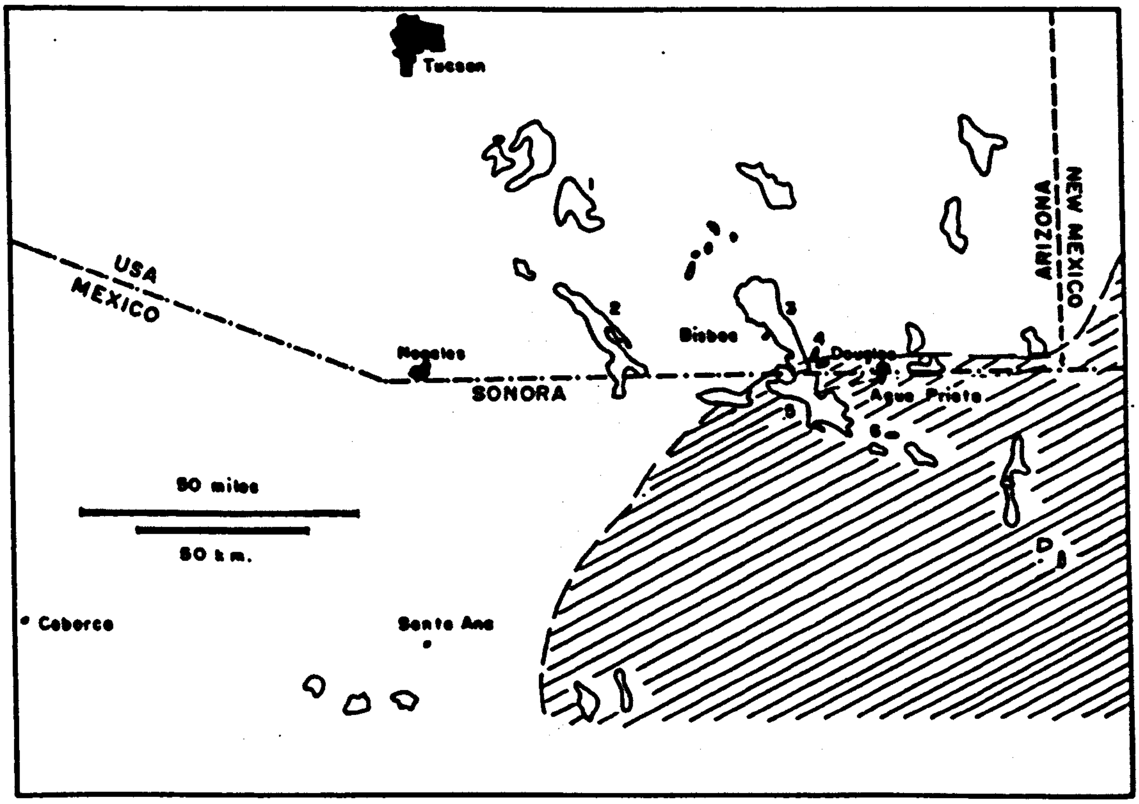
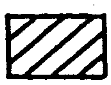


Fig. 16.- Paleogeography of the upper Mural Limestone during Middle Albian time. Locations: 1, Whetstone Mountains; 2, Huachuca Mountains; 3, Mule Mountains; 4, Paul Spur; 5, Sierra Anibacachi; 6, Sierra del Caloso.

 approximate limit of marine facies

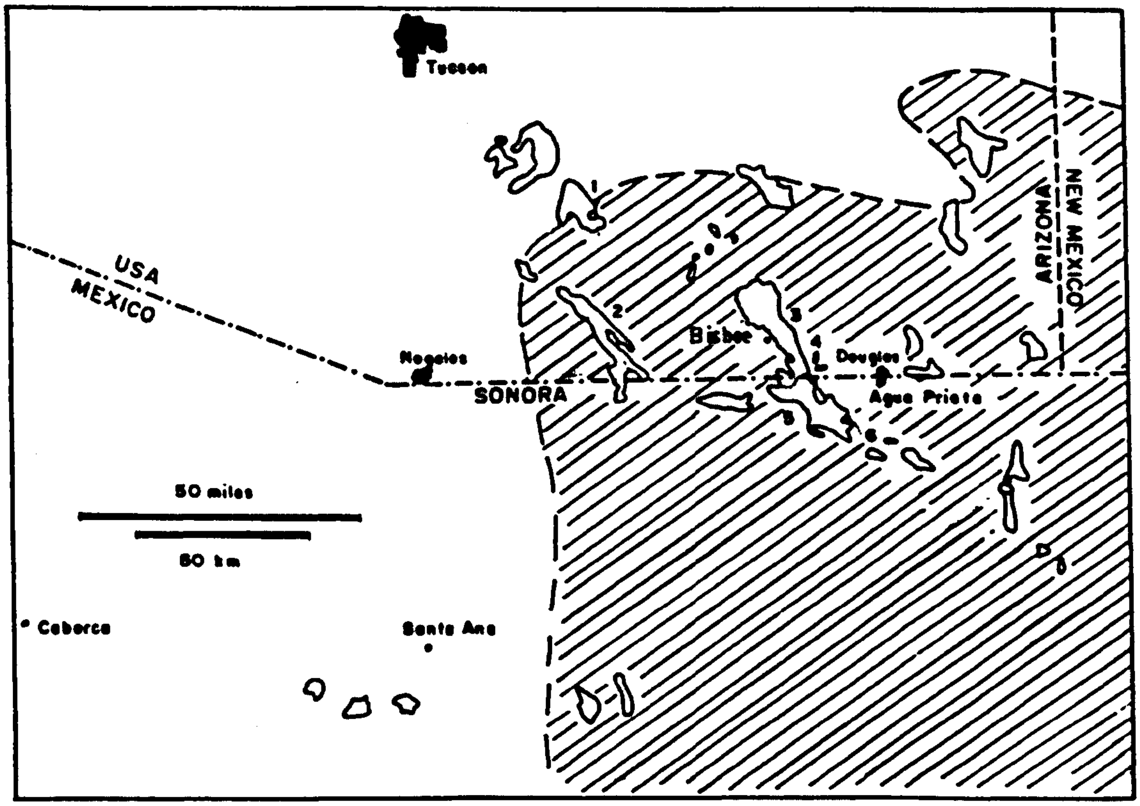


Fig. 17.- Paleogeography of the upper Mural Limestone during Upper Albian-Lower Cenomanian time. Locations: 1, Whetstone Mountains; 2, Huachuca Mountains; 3, Mule Mountains; 4, Paul Spur; 5, Sierra Anibacachi; 6, Sierra del Caloso.

approximate limit of marine facies

This is shown by the presence of *Nummoloculina heimi* and *Dicyclina*, index fossils of this age. Further evidence includes nearshore marine sediments of the Turney Ranch Formation in the Whetstone Mountains (Archibald, 1982), and those of the Lower Transitional Unit in the Santa Rita Mountains reported by Inman (1987). At this time, sediments of marine origin were also being deposited in southwestern New Mexico (Zeller, 1965; Sandidge, 1985). Time equivalent basinal facies in the Culantrillo section were not found. In this section, the upper contact of the upper Mural Limestone is covered by volcanics. However, in the Lampazos region, in east-central Sonora, there is a sequence with fossiliferous limestone beds that contains well preserved upper Albian ammonites (Scott and Gonzalez, in press).

After that time, a final regression occurred to give way to the deltaic deposits of the Cintura Formation, the uppermost unit of the Bisbee Group.

CHAPTER 7

SUMMARY

The upper Mural Limestone of the Bisbee Group was deposited at the northwestern end of the Chihuahua Trough during a maximum marine transgression, which included smaller regressions, into southeastern Arizona and northern Sonora (Warzeski, 1983, 1987; Bilodeau and Lindberg, 1983), as well as a minor second transgression. The sediments formed an extensive carbonate platform that dipped southward (Hayes, 1970b; Warzeski, 1987).

The sections studied in this paper form a NW-SE transect that coincides along the axis of the Bisbee Basin. The presence of different microfossils such as algae, miliolids and other benthic foraminifera, tintinnids, and globigerinids reveals a marked change of facies from north to south.

The age of the upper Mural Limestone ranges from Albian to Lower Cenomanian and is shown by the presence of *Colomiella recta* of the Lower Albian, *Dictyoconus walnutensis* of the Middle Albian, and *Nummoloculina heimi* and *Dicyclina* of the Upper Albian-Lower Cenomanian.

Correlative strata of the upper Mural Limestone may include the Shellenberger Canyon Formation and part of the

Turney Ranch Formation in the Whetstone Mountains; the U-Bar Limestone and part of the Mojado Formation in southwestern New Mexico, and the Lampazos, Espinazo del Diablo, and Nogal Formations in east-central Sonora.

Micropaleontologic and biostratigraphic studies suggest that upper Mural Limestone strata record the maximum flooding of a first major marine transgression into southeastern Arizona and northern Sonora, which was followed by small regressions and a second less extensive marine transgression. This second marine transgression is recorded at least in the Sierra del Caloso section in northern Sonora and shown by the presence of the Upper Albian-Lower Cenomanian foraminifera Nummoloculina heimi. These findings in the southeastern facies of the Bisbee Group support the evidence of an Albian-Cenomanian transgression into the area recorded in the northwestern facies of the Bisbee Group as suggested by Archibald (1982, 1987).

More detailed micropaleontologic studies of the carbonate units of the Bisbee Group and a more integrated approach to the stratigraphy of the group as a whole is necessary to better clarify the key aspects of the evolution of the Bisbee Basin strata and correlatives.

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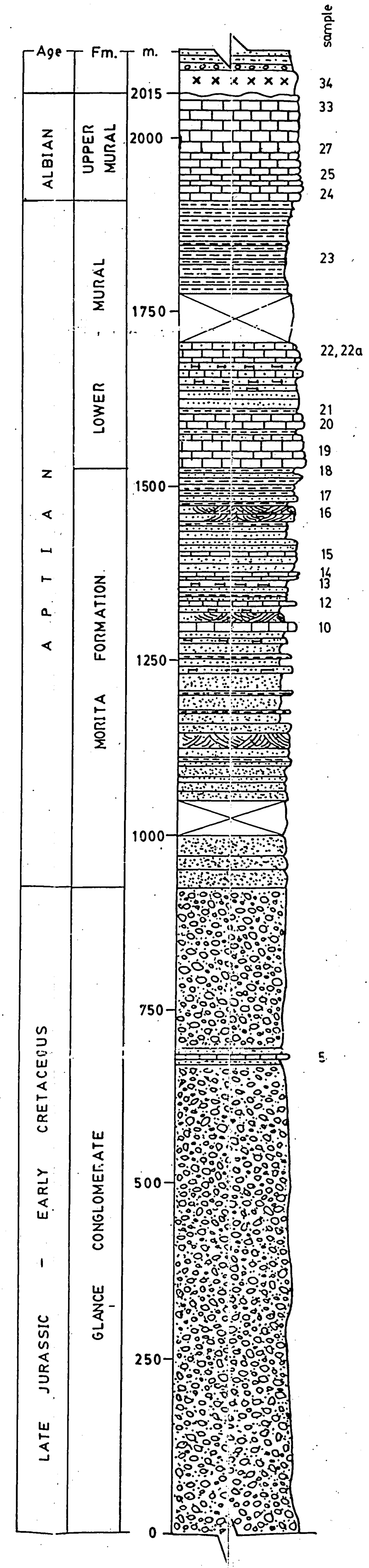
UNIT DESCRIPTION



Andesite flow overlapped by reddish conglomerate and sandstone.

Limestone, medium bedded, gray in color. It contains echinoids and abundant microfossils. Colomiella recta, C. mexicana, Hedbergella sp., and rare Orbitolina sp..

Calcareous mudstone, yellowish in color.

Covered

Sandy limestone with intercalated calcareous mudstone. It contains oysters and pelecypods.**
Yellowish calcareous sandstone. Oysters.

Calcareous mudstone, yellow in color.
Sandy gray limestone. It contains abundant oysters and ammonites.*
Ctenostreon sp. ?
Medium bedded limestone with abundant oysters.

Reddish mudstone.
Sandstone intercalated with gray limestone and reddish and greenish mudstone, and crossbedded sandstones.
Gray limestone with abundant charophyte oogonia.

Crossbedded sandstone.
Limestone, thick bedded; abundant algae
Dolomitic limestone

Pinkish arkosic sandstone interbedded with greenish mudstone.

Crossbedded arcosic sandstone.

Pale-yellow to pinkish subarkosic sandstone.

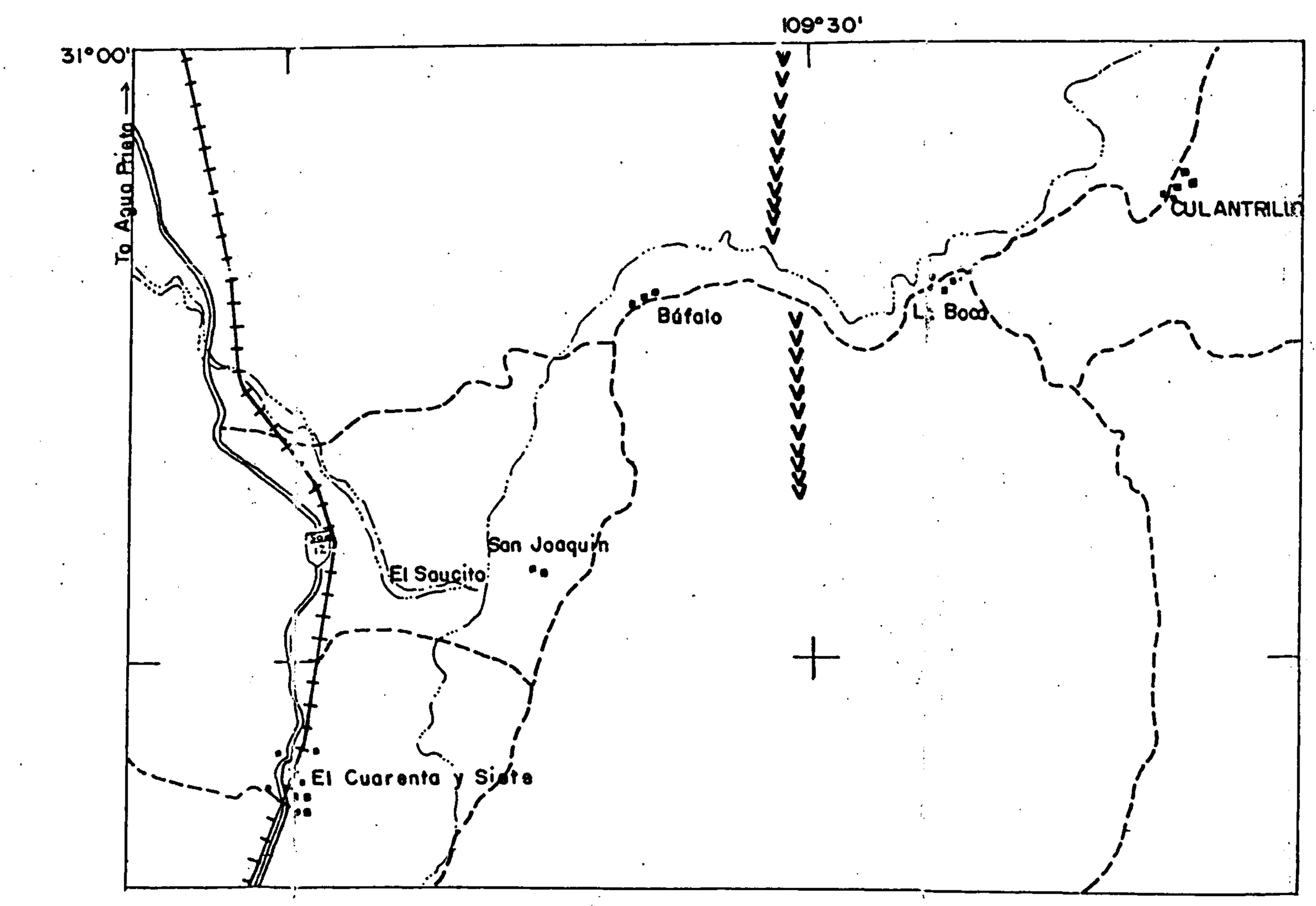
Poorly sorted granitic-clasts conglomerate. Composed of granitic fragments (Pre-Cambrian?) set in a reddish feldspathic sandy matrix. Rare thin limestone lenses toward the top. They contain ostracods.

* Sample 20:
Hypacanthoplites sp., H. milletoides, H. sp. cf. H. shepherdi, Cucullaea sp., Protocardia sp..

** Sample 22:
Camptonectes (Camptonectes) sp., Exogyra sp. cf. E. quitmanensis.

** Sample 22a:
Yaadia (Quadritrigonia) sp.
Trigonia sp.

Macrofossil identification by A.B. Villaseñor and M.E. Gomez (Instituto Mexicano del Petroleo).



Map showing location of the Culantrillo Section.

0 500 1000 2000 m

SCALE 1: 50,000

PLATE .- Location map and stratigraphic column of the Culantrillo section.

THE UNIVERSITY OF ARIZONA
DEPARTMENT OF GEOSCIENCES
MASTER OF SCIENCE THESIS
1989

Maria del Carmen Rosales Dominguez