Revista Mexicana de Ciencias Geológicas, volumen 15, número 1, 1998, p. 46-56.
Universidad Nacional Autónoma de México, Instituto de Geología; y Sociedad Geológica Mexicana, México, D.F.

# LATE CENOMANIAN FOSSIL ASSOCIATION FROM MORELOS, MEXICO—STRATIGRAPHIC IMPLICATIONS

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## ABSTRACT

The fossil content of a limestone succession of the Cuautla Formation, from the central part of the State of Morelos, indicates a late Cenomanian age. Amongst the fossils that were identified, those that do not show reworking include the calcareous algae *Permocalculus irenae, P. budaensis, Heteroporella lepina, Dissocladella* sp. cf. *D. undulata, Boueina pygmaea, Neomeris cretacea, Salpingoporella milovanovici* and *Acicularia endoi,* and the benthic foraminifera *Praechrysalidina* sp. cf. *P infracretacea* and *Cuneolina pavonia parva.* This association indicates a late Cenomanian age. Besides these fossils, the rocks contain calcisphaerulids, fragments of echinoderms, rudists and gastropods, rotaliids, some miliolids, planktic foraminifera and radiolaria. There is also a type of nerineid gastropod *(Nerinella* sp. cf. *Nerinea dupiniana)* that seems to be characteristic of this level.

Previous works have reported an unconformity separating the lower Cenomanian (Morelos Formation) from the lower Turonian (Cuautla Formation). This has led to suggestions that a period of non deposition or erosion occurred in the Guerrero-Morelos Platform during the middle and late Cenomanian. The late Cenomanian age of the rocks here described restricts the duration of this event in this area to the middle Cenomanian-early late Cenomanian, if this area was actually affected.

Key words: Stratigraphy, Cenomanian, Guerrero-Morelos Platform, calcareous algae, Morelos, Mexico.

## RESUMEN

El contenido fósil de un paquete de calizas pertenecientes a la Formación Cuautla, de la parte central del estado de Morelos, indica una edad cenomaniana tardía. Entre los fósiles que no muestran retrabajo, se identificó las algas calcáreas *Permocalculus irenae, P. budaensis, Heteroporella lepina, Dissocladella* sp. cf. *D. undulata, Boueina pygmaea, Neomeris cretacea, Salpingoporella milovanovici* y *Acicularia endoi,* y los foraminíferos bentónicos *Praechrysalidina infracretacea* y *Cuneolina pavonia parva.* Esta asociación indica una edad cenomaniana tardía. Además de estos fósiles, las rocas contienen calcisferúlidos, fragmentos de equinodermos, rudistas y gasterópodos, rotálidos, algunos miliólidos, foraminíferos planctónicos y radiolarios. También hay un tipo de gasterópodo nerineido *(Nerinella* sp. cf. *Nerinea dupiniana)* que parece ser característico de este nivel estratigráfico.

En estudios anteriores se ha consignado una discordancia separando el Cenomaniano inferior (Formación Morelos) del Turoniano inferior (Formación Cuautla). Se ha sugerido que un periodo de no depósito o erosión ocurriera en la Plataforma Guerrero-Morelos durante el Cenomaniano medio y tardío. La edad cenomaniana tardía de las rocas descritas aquí restringe la duración de este evento al Cenomaniano medio-inicios del Cenomaniano tardío, si es que en realidad esta área fue afectada.

Palabras clave: Estratigrafía, Cenomaniano, plataforma Guerrero-Morelos, algas calcáreas, Morelos, México.

## INTRODUCTION

The studies of fossils from the northern half of Mexico started toward the end of the past century by Mexican and foreign scientists, such as Emil Böse from Germany. The contributions of Böse to the geology of many regions of Mexico have been outstanding, but he also reported for the first time Upper Cretaceous invertebrate faunas from Cárdenas (State of San Luis Potosí), Cerro de Muleros (State of Chihuahua) and La Encantada (State of Chihuahua and surrounding regions of the State of Coahuila). These studies served as a basis for later investigations.

The Albian-Turonian shallow-marine limestones that crop out in the states of Morelos and Guerrero (Figures 1 and 2) were described as two separate formations by Fries (1960). The older unit, the Morelos Formation, was described as a succession of limestone and dolomite beds 20–60 cm thick, composed of peloids, abundant large benthic foraminifera (particularly miliolids), rudists and gastropods. The thickness of this unit varies from 600 to more than 1,000 m and it has extensive outcrops in the region (Fries, 1960). This makes it the most characteristic unit of what has been called the Guerrero-

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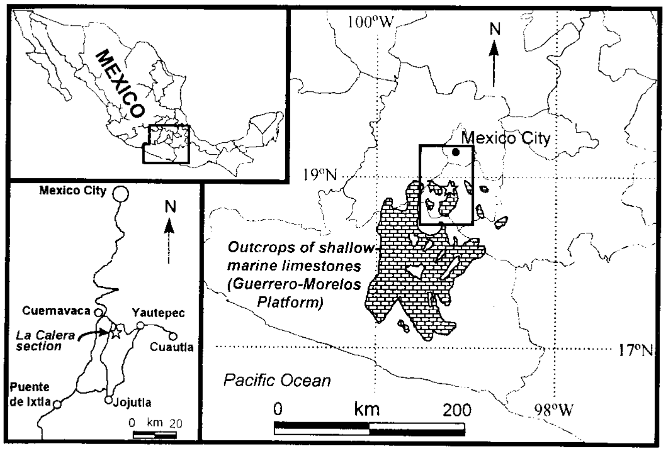


Figure 1. Location of the outcrops of the Guerrero-Morelos Platform. La Calera section (star) is located in one of the northernmost outcrops of the shallow marine limestones of this area.

Morelos Platform. Considering the fossils and stratigraphic relationships this author observed, he assigned an Albian-early Cenomanian age to this unit (Fries, 1960).

Overlying the Morelos Formation, Fries (1960) described a succession of limestone beds of variable thickness composed by "clastic detrital grains of limestone and dolomite,

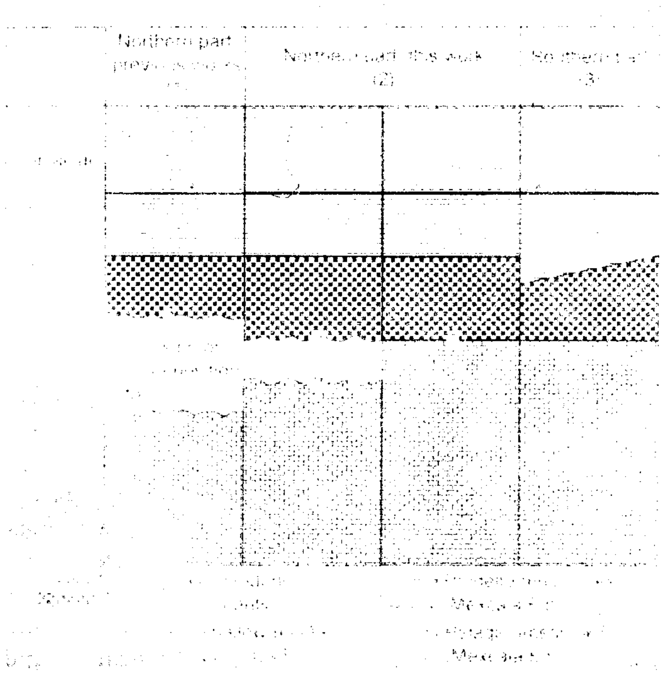

Figure 2. Albian-Coniacian lithostratigraphic units of the eastern part of the Guerrero-Morelos Basin. 1, Stratigraphy originally proposed by Fries (1960) for Morelos and northern Guerrero, in the northern part of the Guerrero-Morelos Platform; 2, two possible stratigraphic columns for central Morelos showing a more restricted erosion or non deposition event according to our data (see discussion for explanation); 3, stratigraphic column and conformable relationships found in central Guerrero, in the southern and eastern part of the Guerrero-Morelos Platform (Salinas-Prieto, 1986; Hernández-Romano, 1995; Aguilera-Franco, 1995; Hernández-Romano *et al.*, 1997).

mixed with chert grains and abraded large foraminifera (miliolids), all of them derived from the underlying Morelos Formation". Other fossils that he reported for these rocks were rudists, gastropods, corals, echinoids, green algae, calcisphaerulids and some benthic and planktic foraminifera. Fries (*op. cit.*) noted the scarcity of miliolids in these rocks, feature that contrasted with their abundance in the Morelos Formation. He assigned an early Turonian age to this unit, but suggested that the basal calcarenitic beds be late Cenomanian. The difference in age between these rocks and the underlying Morelos Formation, together with the presence of clastic beds at the base of the Cuautla Formation, led Fries (*op. cit.*) to propose a period of erosion or non-deposition for the middle and late Cenomanian. He did notice, however, that there was no angular relationship between the beds of those units. The rocks of the Cuautla Formation grade upwards to pelagic limestones and terrigenous-clastic rocks of the Mexcala Formation (Fries, 1960).

More recent studies have gathered stratigraphic evidence that indicates that there is no significant hiatus nor unconformity between the Morelos Formation and rocks with the characteristics of the Cuautla Formation (Salinas-Prieto, 1986; Aguilera-Franco, 1995; Hernández-Romano *et al.*, 1997). A conformable contact has also been observed between the Morelos and the Mexcala formations, where the Cuautla is not present (Ontiveros-Tarango, 1973; Sabanero-Sosa, 1990; González-Pacheco, 1991; Martínez-Medrano, 1994; Hernández-Romano, 1995). However, most of these studies were done in Guerrero, to the south of the area, where the units and their unconformable relationship were first described.

In this paper, it is presented a biostratigraphic study of a limestone succession from the State of Morelos that further restricts the duration and areal extent of the erosional gap or hiatus. If subaerial or submarine erosion or non-deposition occurred in the Guerrero-Morelos platform during the middle and late Cenomanian, it affected a much more restricted area than originally suggested.

## LOCATION AND GEOLOGIC SETTING

The studied section is located in the north-central part of the State of Morelos, approximately 13 km southeastward from Cuernavaca, close to the western end of Cañón de Lobos (Figure 1). Cretaceous limestones in this area crop out along north-south oriented anticlines produced during the Late Cretaceous-Early Tertiary Laramide Orogeny. The studied outcrop lies in the western flank of one of these structures. The shallow-marine limestones have been thrusted westwards over Upper Cretaceous flyschoid rocks of the Mexcala Formation.

The studied rocks represent one of the northernmost outcrops of the Cretaceous shallow-marine limestones of the Guerrero-Morelos Platform. The limestones are in turn part of a succession of Cretaceous sedimentary rocks that define the Guerrero-Morelos Basin. These rocks are covered to the north by Tertiary and Quaternary volcanic rocks of the Trans-Mexican Volcanic Belt.

## LA CALERA SECTION

The studied outcrop is a 13-m succession of light-grey, 0.7 to 3-m-thick limestone beds. It consists of an intercalation of bioclastic, peloidal and intraclastic wackestone and packstone (Figures 3 and 4). The bioclastic fraction is dominated by calcisphaerulids, calcareous algae (dasycladacean, gymnocodiacean and udoteacean), benthic foraminifera (biserial lituolids and rotaliids), and fragments of echinoderms, rudists and gastropods. Gymnocodiacean and udoteacean algae (*Permocalculus* and *Boueina;* Figures 5–7) are particularly common in these rocks. Accompanying these fossils, some intervals have also some corals, brachiopods, ostracods, radiolarians, planktic foraminifera, roveacrinids, and other types of benthic foraminifera such as miliolids and other lituolids (Figures 4–8).

In the upper part of the section, there is a particular type of nerineid gastropod that is locally common. They have long and slender shells of up to 7-cm long (Figure 8*C–G*). The wall of the shell is thin and the whorl section has one labral fold and one columellar fold. This type of gastropod was identified as *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny and seems to be characteristic of this interval.

Peloids and intraclasts are the main components in some intervals (Figures 3 and 4). Some of the bioclasts (miliolids and mollusc fragments) have micrite stuck to them indicating that they are actually intraclasts (Figures 4*B*, *D*). In other cases the test appears completely clean, with no significant abrasion, an indication that at least some are indigenous (non-reworked) bioclasts (Figures 4*B*, *C*). It is common to observe thick micritic envelopes on mollusc shells and other bioclasts (Figure 4*D*). It is important to note that particles with unequivocal features of extraclasts or lithoclasts (particles derived from previously lithified, older rocks) are difficult to find in these rocks. Most seem to derive from partially lithified sediments from which fossils are easily released and the host soft matrix is washed away. Hard fossil fragments generally protrude from the intraclast surface (Figure 4*D*).

Intense burrowing and incipient nodular aspect are characteristic of some beds. Silicified mollusc shells and white chert nodules are scattered in the succession. No dolomite was observed in any thin section. The characteristics observed in these rocks correspond to those assigned by Fries (1960) to the bank facies of the Cuautla Formation.

## BIOSTRATIGRAPHY

There are several lines of evidence that indicate a late Cenomanian age for the rocks of La Calera section. They contain a number of fossils that do not show signs of reworking and which have only been reported from pre-Turonian rocks

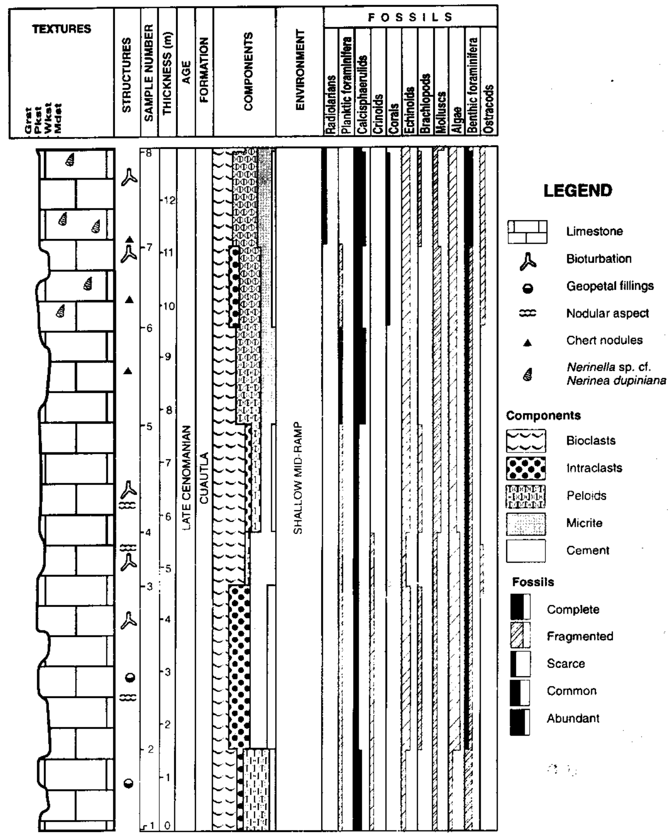


Figure 3. Characteristics of La Calera section.

(Tables 1 and 2). They include the species of calcareous algae *Salpingoporella milovanovici* Radoicic (Pls. 2A, 2F, 4A, 4B), *Permocalculus irenae* Elliot (Pls. 2E, 3B), *Neomeris cretacea* Steinmann (Pl. 3F) and *Acicularia* sp. cf. *A. endoi* Praturlon (Pl. 2B), and the benthic foraminifera *Praechrysalidina* sp. cf. *P. infracretacea* Luperto Sinni (Pl. 4D) and *Cuneolina pavonia parva* Henson (Pl. 3E). The calcareous algae *Heteroporella lepina* Praturlon (Pl. 4E) and *Dissocladella* sp. cf. *D. undulata* Raineri (Pl. 2C) have only been reported from upper Cenomanian and lower Turonian rocks, while *Permocalculus budaensis* Johnson (Pls. 2D, 3A) has been reported in upper Albian to lower Turonian rocks (Table 2).

Despite the presence of several species of benthic foraminifera, these rocks do not show the diversity and abundance of this group of fossils that is characteristic of the underlying Morelos Formation (Hernández-Romano *et al.*, 1997). Biostratigraphic studies in other parts of the platform (Aguilera-Franco *et al.*, 1997; Aguilera-Franco and Hernández-Romano, in press; Aguilera-Franco *et al.*, in press) indicate that most large benthic foraminifera disappear in the upper Cenomanian, at a level that closely corresponds to the base of the *Whiteinella archaeocretacea* planktic foraminiferal zone. Rocks of the upper Cenomanian that overlie this level show first a drastic increase in calcareous algae (*Permocalculus*, *Acicularia* and *Boueina*) followed by a reduction and disappearance of these fossils by the beginning of the

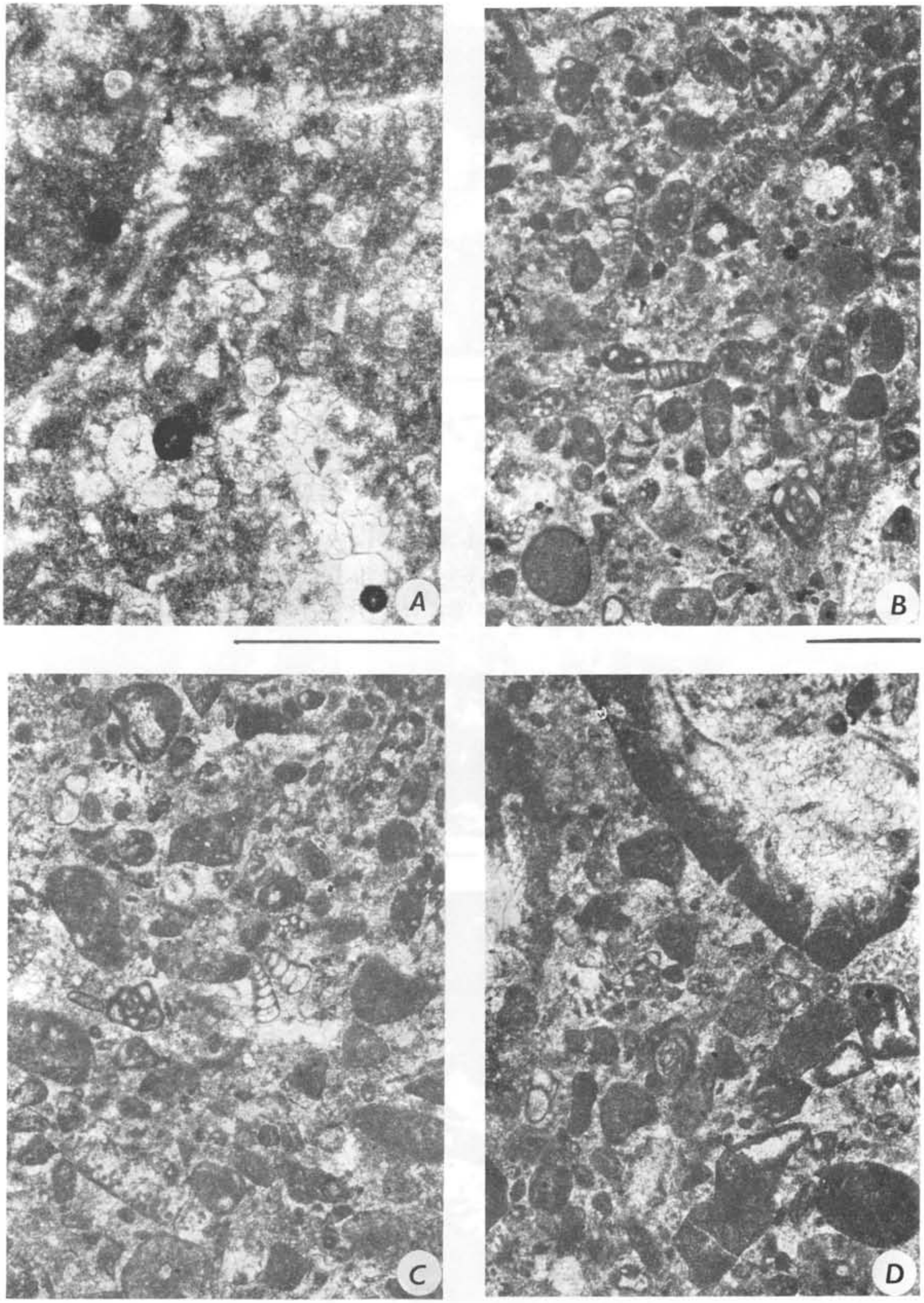


Figure 4. *A*, Peloidal/bioclastic packstone with calcisphaerulids and fragments of green algae, sample 7; *B*, intraclastic/bioclastic packstone. Some biserial lituolids, miliolids, calcisphaerulids, planktic foraminifera and green algae fragments are visible, sample 2; *C*, intraclastic/bioclastic packstone. Biserial lituolids, miliolids and green algae fragments are visible, sample 6; *D*, intraclastic bioclastic packstone. Large mollusc fragments with thick micritic envelopes. Intraclast with miliolid. Scale bars: A = 0.25 mm; B, C and D = 0.5 mm.

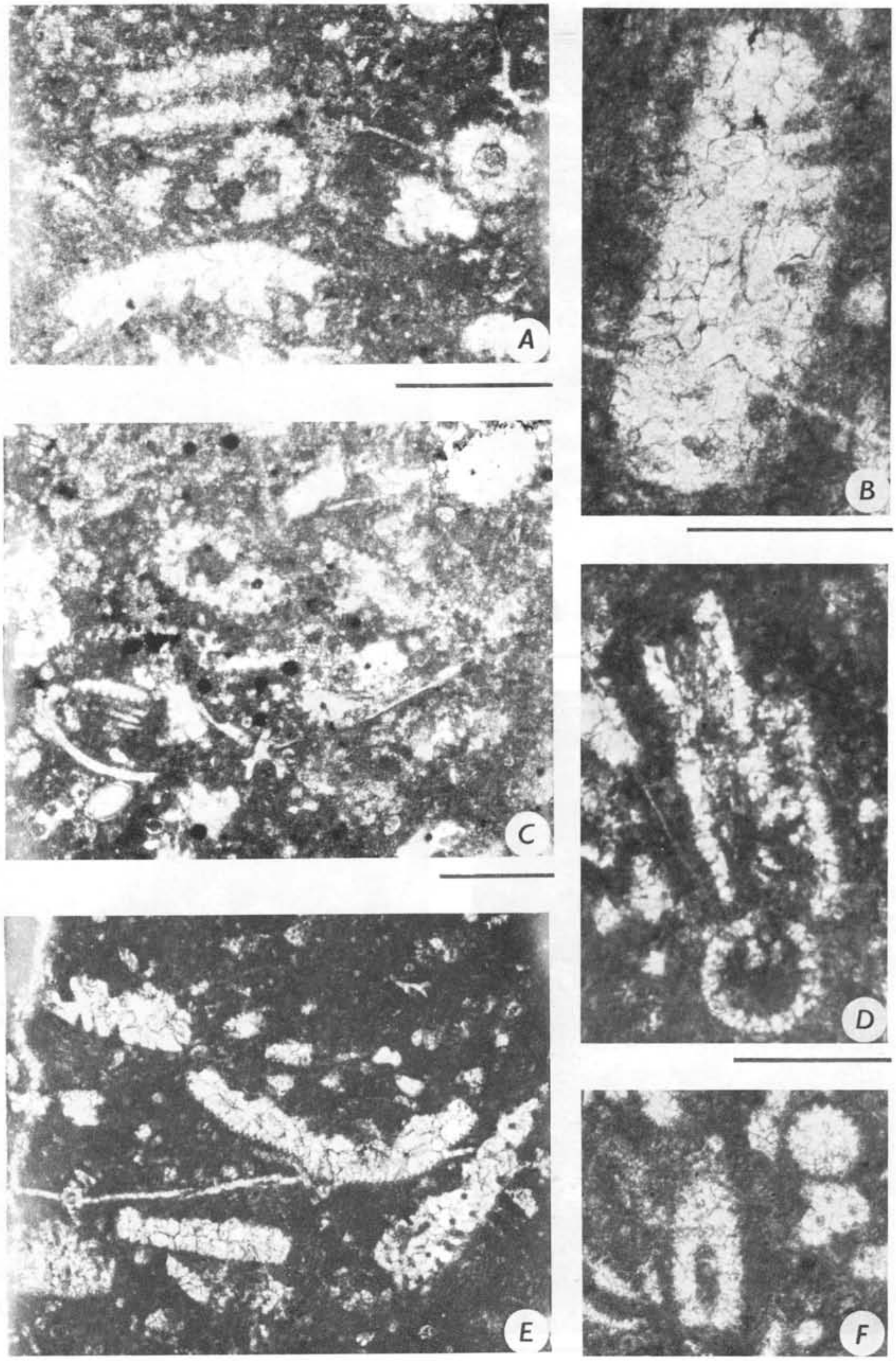


Figure 5. **A**, *Salpingoporella milovanovici* Radoicic, sample 3; **B**, *Acicularia* sp. cf. *A. endoi* Praturlon, sample 3; **C**, *Dissocladella* sp. cf. *D. undulata* Raineri, sample 1; **D**, *Permocalculus budaensis* Johnson, sample 5; **E**, *Permocalculus irenae* Elliot, sample 1; **F**, *Salpingoporella milovanovici* Radoicic, sample 3. Scale bars: A, C, D, E and F = 0.5 mm; B = 0.25 mm.

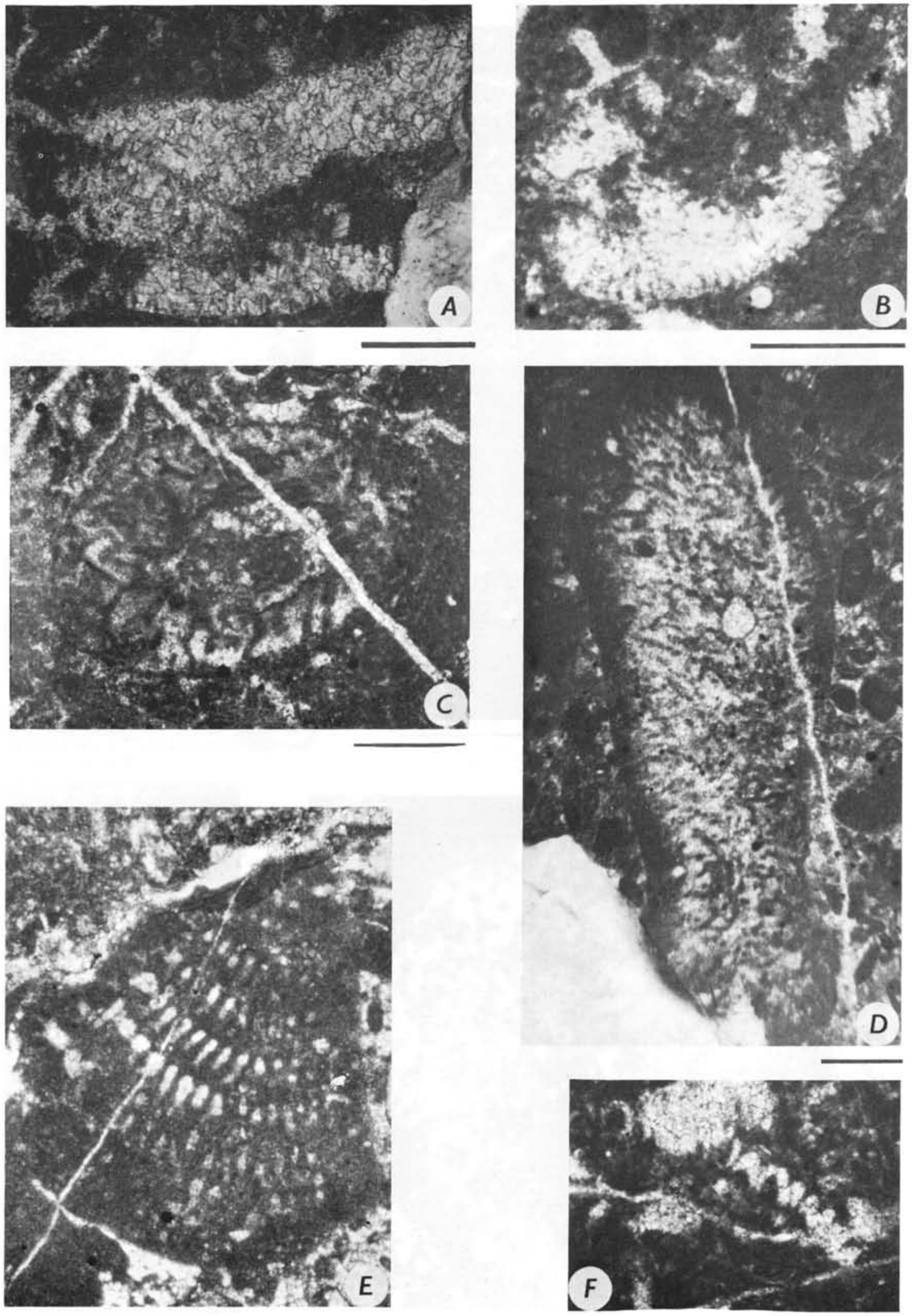

Figure 6. **A**, *Permocalculus budaensis* Johnson, sample 3; **B**; *Permocalculus irenae* Elliot, sample 2; **C**, *Boueina pygmaea* Pia, sample 2; **D**, *Boueina pygmaea* Pia, sample 2; **E**, *Cuneolina pavonia parva* Henson, sample 6; **F**, *Neomeris cretacea* Steinmann, sample 3. Scale bars = 0.5 mm.

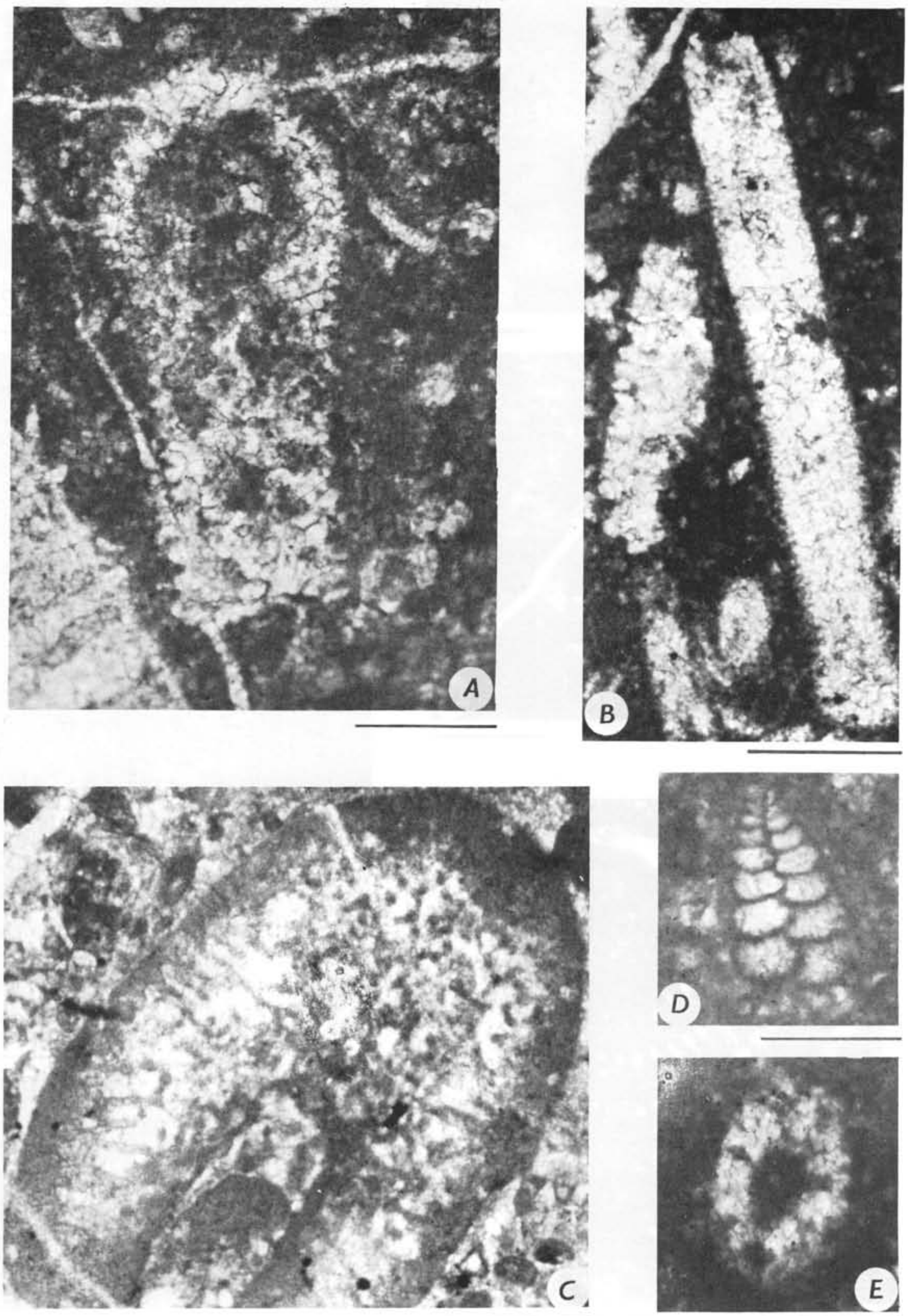


Figure 7. **A**, *Salpingoporella milovanovici* Radoicic, sample 5; **B**, *Salpingoporella milovanovici* Radoicic and *Permocalculus irenae* Elliot on the left, sample 3; **C**, *Boueina pygmaea* Pia, sample 2; **D**, *Praechrysalidina infracretacea* Luperto Sinni, sample 2; **E**, *Heteroporella lepina* Praturlon, sample 2. Scale bars: A, D, E = 0.25 mm; B and C = 0.5 mm.

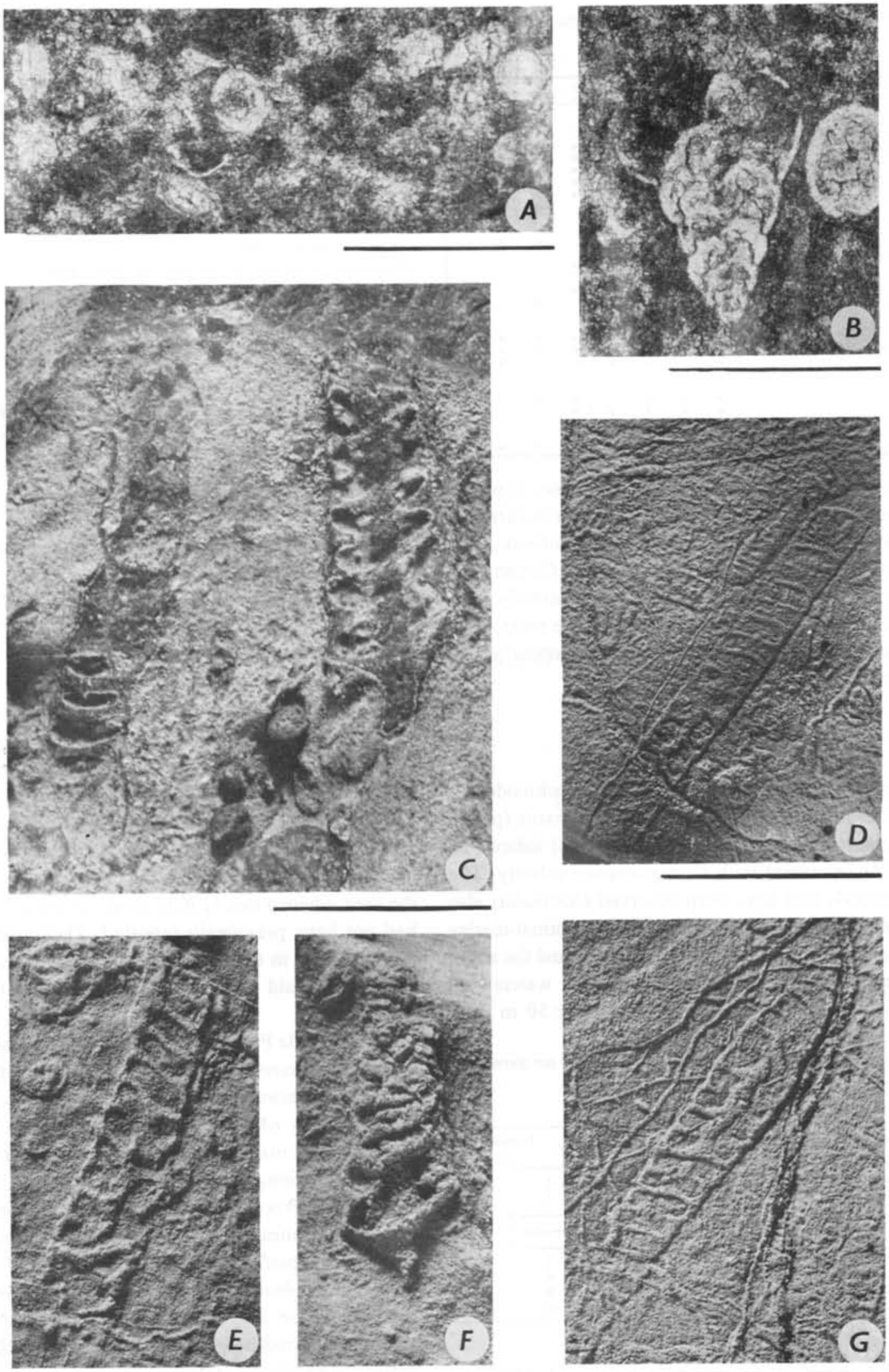


Figure 8. **A**, Calcisphaerulids, sample 5; **B**, *Heterohelix* sp., sample 3; **C**, *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny, sample 2; **D**, *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny, sample SB 116; **E**, *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny, sample SB114; **F**, *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny, sample 2; **G**, *Nerinella* sp. cf. *Nerinea dupiniana* d'Orbigny, sample SB 115. Scale bars: A and B = 0.25 mm; C = 2.5 cm; D = 3.5 cm; E = 2.0 cm; F = 1.5 cm; G = 3.0 cm.

Table 1. Distribution of genera and species identified in the samples of La Calera section.

| Fossils | Samples 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **CALCAREOUS ALGAE** | | | | | | | | |
| *Acicularia* sp. cf. *A. endoi* | • | • | | • | | | | |
| *Heteroporella lepina* | | • | • | | | | | • |
| *Permocalculus irenae* | • | • | • | • | • | • | • | • |
| *Dissocladella* sp. cf. *D. undulata* | • | • | • | • | • | | • | • |
| *Salpingoporella* sp. | | • | • | • | • | | • | • |
| *Boueina pygmaea* | | • | | • | • | • | | • |
| *Permocalculus* sp. | | | • | • | • | • | | • |
| *Neomeris cretacea* | • | | • | • | | • | • | |
| **BENTHIC FORAMINIFERA** | | | | | | | | |
| *Praechrysalidina infracretacea* | • | • | • | • | | • | • | |
| *Dicyclina schlumbergeri* | • | | • | | | | | |
| *Quinqueloculina* sp. | | • | | | • | | | |
| *Spiroloculina* sp. | | • | | | | | | |
| *Nezzazata* sp. | | • | | | • | | | |
| *Cuneolina pavonia parva* | | | | | | • | | |
| **CALCISPHAERULIDS** | | | | | | | | |
| *Pithonella ovalis* | • | • | • | | • | • | • | • |
| *Calcisphaerula innominata* | • | • | • | | • | • | • | |
| *Stomiosphaera sphaerica* | • | | • | • | | • | • | • |
| **PLANKTIC FORAMINIFERA** | | | | | | | | |
| *Heterohelix* sp. | • | • | • | | • | • | | |
| *Hedbergella* sp. | • | • | • | • | • | | | |
| **GASTROPODS** | | | | | | | | |
| *Nerinella* sp. cf. *Nerinea dupiniana* | | | | | | • | • | • |

Turonian (Aguilera-Franco and Hernández-Romano, in press). It is very likely that this succession of bioevents occurred at almost the same time in the northern part of the platform.

In conclusion, the presence of well-preserved Cenomanian fossils, the scarcity of benthic foraminifera (particularly miliolids) and the abundance of calcareous algae in the rocks of La Calera indicate that these rocks correspond to the upper part of the upper Cenomanian.

## ENVIRONMENTAL INTERPRETATION

The presence of corals, codiacean algae, echinoderms, and brachiopods together with typically pelagic fossils (planktic foraminifera, radiolarians, and calcisphaerulids) indicate an open marine environment with normal-marine salinity. The nerineid gastropods that have been observed (*Nerinella*) also seem to be characteristic of environments with normal-marine salinity (Vaughan, 1988). The presence of corals and the abundance of green algae also indicates very shallow waters well within the photic zone, probably in the upper 50 m (e.g. Banner and Simmons, 1994). However, the presence of lime-mud in most of the rocks indicates deposition below the fair-weather wave base (>10–15 m in open-marine settings, Flügel, 1982). Putting this information into context with what has been reported from other parts of the Guerrero-Morelos Platform (Hernández-Romano, 1995; Hernández-Romano *et al.*, 1997), it is likely that these rocks were deposited in the shallow part of a mid ramp, at water depths between 10 and 50 m.

The large benthic foraminifera that are occasionally observed as bioclasts or part of intraclasts are more characteristic of restricted conditions. Their presence suggests that a zone with more restricted sedimentation existed at the same time, probably in the innermost parts of the ramp. Since some specimens of this group of fossils are abraded, it is also possible that some degree of reworking of pre-deposited sediments occurred.

Table 2. Cenomanian fossils found in La Calera section that do not show signs of reworking.

| Fossils | Albian | Cenomanian | Turonian |
|---|---|---|---|
| *Permocalculus budaensis* | — (upper part) | — | — 1 |
| *Permocalculus irenae* | | — | 2 |
| *Salpingoporella milovanovici* | | — | 3 |
| *Heteroporella lepina* | | — (upper part) | — 4 |
| *Dissocladella* sp. cf. *D. undulata* | | — (upper part) | — 5 |
| *Boueina pygmaea* | | — | — 6 |
| *Neomeris cretacea* | | — | 7 |
| *Acicularia* sp. cf. *A. endoi* | | — | 8 |
| *Praechrysalidina* sp. cf. *P. infracretacea* | — | — | 9 |
| *Cuneolina pavonia parva* | | — | 10 |

1: Deloffre, 1992. 2: Berthou, 1973; Elliot, 1960; Deloffre, 1992. 3: Radoicic, 1978. 4: Berthou, 1973; Saint-Marc, 1975; Bassoullet *et al.*, 1978. 5: Pia, 1936; Berthou, 1973; Saint-Marc, 1975; Bassoullet *et al.*, 1978. 6: Elliot, 1960; Praturlon, 1963; Basson and Edgell, 1971; Bilotte, 1984. 7: Elliot, 1958; Basson and Edgell, 1971. 8: Basson and Edgell; 1971; Deloffre, 1992. 9:Loeblich and Tappan, 1988. 10: Saint-Marc, 1975; Bilotte, 1984.

## STRATIGRAPHIC IMPLICATIONS

As more stratigraphic information is being collected in the area of the Guerrero-Morelos Platform, it is becoming evident that the erosion or non-deposition event proposed by Fries (1960) for the middle-late Cenomanian did not have the duration nor the areal extent that was originally suggested.

From previous studies it is evident that the southern, western and central parts of the Guerrero-Morelos Platform did not undergo significant erosion or non-deposition during the Cenomanian (Ontiveros-Tarango, 1973; Salinas-Prieto, 1986; Sabanero-Sosa, 1990; González-Pacheco, 1991; Martínez-Medrano, 1994; Aguilera-Franco, 1995; Hernández-Romano, 1995; Hernández-Romano *et al.*, 1997). However, middle to late Cenomanian rocks from the northern part of the platform, the area where Fries (1960) observed the erosional features, had not been previously reported. The suggestion of Fries (1960, p. 70) in the sense that the basal beds of the Cuautla Formation could be of late Cenomanian age is confirmed by this report.

The Cuautla Formation or rocks with similar characteristics have been commonly reported in the basal part of a deepening upward succession that culminates in the pelagic rocks of the lower facies of the Mexcala Formation (Fries, 1960; Hernández-Romano, 1995). The succession reflects the progressive drowning of the platform and one of the first expressions of this process is the open marine influence in the shallow marine limestones. In this context, the open marine character of the fossil association of the rocks of La Calera suggests that the drowning process had already started by the latest Cenomanian. Any erosion episode therefore, is more likely to have occurred before these rocks were deposited, that is, during the middle Cenomanian or early late Cenomanian.

There are however, some other aspects that may further restrict the duration of the erosion event. In a nearby quarry, around 500 m west-northwest from the studied outcrop, there are limestones of the Morelos Formation containing abundant benthic foraminifera, particularly miliolids. Amongst the foraminifera, it is possible to recognise numerous specimens of the soritid *Pseudorhapydionina*. These fossils are characteristic of the middle and upper Cenomanian (Saint-Marc, 1975; Chiocchini *et al.*, 1979; Schroeder and Neumann, 1985), although some species have been reported from the lower Turonian of Europe (Sartorio and Venturini, 1988). In most of the Guerrero-Morelos Platform, *Pseudorhapydionina* sp. and most of the other large benthic foraminifera disappeared during the late Cenomanian (Aguilera-Franco *et al.*, 1997; Aguilera-Franco and Hernández-Romano, in press). It is possible therefore, that in this area there are also middle or early late Cenomanian rocks, in this case corresponding to the Morelos Formation.

The present authors believe that if an erosional gap or hiatus exists between the Morelos and the Cuautla formations in this area, the section missing should be of latest middle Cenomanian or early late Cenomanian age. There is also the possibility that erosion or interruption of deposition did not occur in this area and the Cenomanian section is complete (Figure 2). More studies are needed to know the relationships between the Morelos and Cuautla formations in this and other areas of the Guerrero-Morelos Platform.

## ACKNOWLEDGMENTS

The authors wish to express their gratitude to Dr. Christian Spaeth, of the University of Hamburg, and Dr. J.E. Aguayo-Camargo, of the Universidad Nacional Autónoma de México, for the critical review of this paper. Also, the authors appreciate the help of Dr. Raoul Deloffre (Pau, France) who kindly identified some species of calcareous algae. This is PRIS contribution No. 747.

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