

Micropaleontological study of Lower Cretaceous rocks (Barremian-Albian) near La Soledad, Nuevo León, northeastern Mexico

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Abstract

A micropaleontological study was conducted to provide information about the microfossil fauna in the Lower Cretaceous rocks of the Cupido, La Peña, and Cuesta del Cura formations cropping out near the town of La Soledad, southern of Nuevo León state. For the Cupido Formation were recognized the Barremian-middle Aptian *Globigerinelloides blowi*, *Hedbergella sigali*, *H. similis*, *H. roblesae*, and *Hedbergella* sp. For the La Peña Formation the association comprises the late Aptian *Globigerinelloides ferreolensis*, *Paraticinella rohri* (= *Ticinella bejaouaensis*), *Hedbergella* sp., *H. sigali*; and other pelagic microfossils such as *Microcalamoides diversus* and *Colomiella recta*. In the Cuesta del Cura Limestone we recorded *Muricohedbergella delrioensis*, *Bishopella ornelasae*, *B. alata*, *Ticinella* sp., and *Favusella washitensis*, Albian in age, in association with calcareous-hyaline calcispheres and *Microcalamoides diversus*. The micropaleontological analysis allows clarifying the stratigraphy of the study area. The information presented will contribute to a better known of the microfauna studied and therefore of paleoenvironmental conditions, under which these rocks were deposited. In addition, this study will allow correlations to local and regional level.

Keywords: Microfossils, Barremian-Albian, Nuevo León, Mexico.

Resumen

Se realizó un estudio micropaleontológico para proporcionar información sobre los microfósiles presentes en las rocas del Cretácico Inferior de las formaciones Cupido, La Peña y Cuesta del Cura; expuestas cerca de La Soledad, al sur del estado de Nuevo León. Para la Formación Cupido se reconocieron *Globigerinelloides blowi*, *Hedbergella sigali*, *H. similis*, *H. roblesae* y *Hedbergella* sp. del Barremiano-Aptiano medio. Para la Formación La Peña la asociación comprende *Globigerinelloides ferreolensis*, *Paraticinella rohri* (= *Ticinella bejaouaensis*), *Hedbergella* sp., *H. sigali*; y otros microfósiles pelágicos como *Microcalamoides diversus* y *Colomiella recta*, correspondientes al Aptiano tardío. En la Caliza Cuesta del Cura se registraron *Muricohedbergella delrioensis*, *Bishopella ornelasae*, *B. alata*, *Ticinella* sp. y *Favusella washitensis*, del Albiano; asociadas a calcisferas hialinas calcáreas. El análisis micropaleontológico permite aclarar la estratigrafía del área de estudio. La información presentada aquí, contribuirá a una mejor comprensión de la microfauna y, por lo tanto, de las condiciones paleoambientales bajo las cuales se depositaron estas rocas, además de permitir establecer correlaciones a nivel local y regional.

Palabras clave: Microfósiles, Barremiano-Albiano, Nuevo León, México.

1. Introduction

In Mexico, Lower Cretaceous rocks are outstanding from the stratigraphic and paleontological point of view. Due to their extensive outcrops and rich fossil content, these rocks allow performing detailed studies on their fauna. The recognition of the stratigraphic distribution of these fossil-bearing units is very useful for accurate determination of the age of the rocks. In particular, the simultaneous use of different groups increases the resolution and reliability of the geological and paleontological interpretations, and therefore the global and regional biostratigraphic correlations. For chronostratigraphic purposes, planktonic foraminifers are among the most important groups of microfossils used in biostratigraphic studies. In the south-central portion of the state of Nuevo León, Lower Cretaceous rocks have been the subject of stratigraphic and paleontological studies, highlighting among the latter those carried out by Méndez-Franco (2003), Barragán-Manzo and Méndez-Franco (2005), and Ángeles-Villeda *et al.* (2005). Ángeles-Villeda *et al.* (2005) recognized the Cupido, Tamaulipas Superior, Cuesta del Cura, Agua Nueva, and San Felipe formations based on the microfacies and the micropaleontological associations, identified a platform, upper slope, and basin paleoenvironments with abundant benthic foraminifers, rudists, ostracods, echinoderms and algae; slope with predominance of planktonic foraminifers, radiolarians, ostracods; and basin with planktonic foraminifers, radiolarians, echinoderms and mollusks. Around six years ago, a field campaign was carried out by geological field survey mappers from the Mexican Geological Survey (SGM by its Spanish initials) where the microfossils herein studied were collected. The rock for thin-sections collection was performed without bed by bed sampling control. However, the samples were taken considering the position within the Cupido, La Peña, and Cuesta del Cura formations, such as lower, middle, and upper parts of each studied unit. Despite the lack of bed by bed sampling control, the microfossil herein studied are interesting for several reasons among them: the first time that planktonic microfossils are reported in the studied area, their presence allowed to corroborate chronostratigraphically the age of the lithological units, and furthermore, this age control will provide baseline data for forthcoming micropaleontological studies. The purpose of this work was to identify the microfossil fauna present in the outcrops of the Cupido, La Peña, and Cuesta del Cura formations exposed at Los Mimbres, southeastern Nuevo León state. The biostratigraphic information obtained from this microfauna, besides the geological framework established in the studied units, will be useful for subsequent correlation with other areas, as well as in paleogeographic reconstructions.

2. Study area

The study area is located in a mountain range in the southern part of the Nuevo León state, northeastern Mexico, between 24°02'13"-24°02'16" North and 100°02'54"-100°03'16" West. The studied rocks are exposed at Los Mimbres locality, placed in the neighborhood of La Soledad town, approximately 1100 m to the south of Los Mimbres stream (Figure 1). Geologically, it belongs to the physiographic sub-province of the Sierras Bajas, which is part of the Sierra Madre Oriental Province (Raisz, 1964).

3. Materials and methods

The material analyzed come from 3 stratigraphic outcrops measured and sampled in Los Mimbres, Nuevo León. The 15 rock hand samples were collected from each section, exercising caution of the lithological features and stratigraphical relations among sequences. The micropaleontological study was carried out on 30 thin sections from limestone samples. These thin sections were prepared by SGM's staff at Centro Experimental Oaxaca and later examined using a petrographic microscope in order to determine its micropaleontological content. In this study, we followed the criteria of Caron (1985), Sliter (1989), Premoli-Silva and Verga (2004), Huber and Leckie (2011), and Ando *et al.* (2013) for Cretaceous planktonic foraminifers. In the case of colomieliids, we followed Trejo (1975, 1980); while for calcisphaerulids and Microcalamoides we adopt Trejo (1983).

4. Results

4.1. Lithostratigraphy

Geological units exposed in the studied area correspond to the Cupido, La Peña, and Cuesta del Cura formations (Figure 2).

The Cupido Formation. Imlay (1937) named the Cupido limestone from later Hauterivian-Barremian rocks in the middle and west parts of the Sierra de Parras, Coahuila. Humphrey (1949) included Imlay's lower limestone member of the La Peña Formation within this unit, and Humphrey and Díaz (2003) redefined it as the Cupido Formation. Based on the stratigraphic position of this formation, Mayer-Pérez (1967) and Humphrey and Díaz (2003) proposed a Barremian-early Aptian, and Hauterivian-late Aptian age, respectively. According to its paleontological content, Hauterivian-Aptian age has been assigned by PEMEX (1988) and Ángeles-Villeda *et al.* (2005); while Barragán-Manzo and Díaz-Otero (2004) assigned a Barremian-early Aptian age. At Los Mimbres,

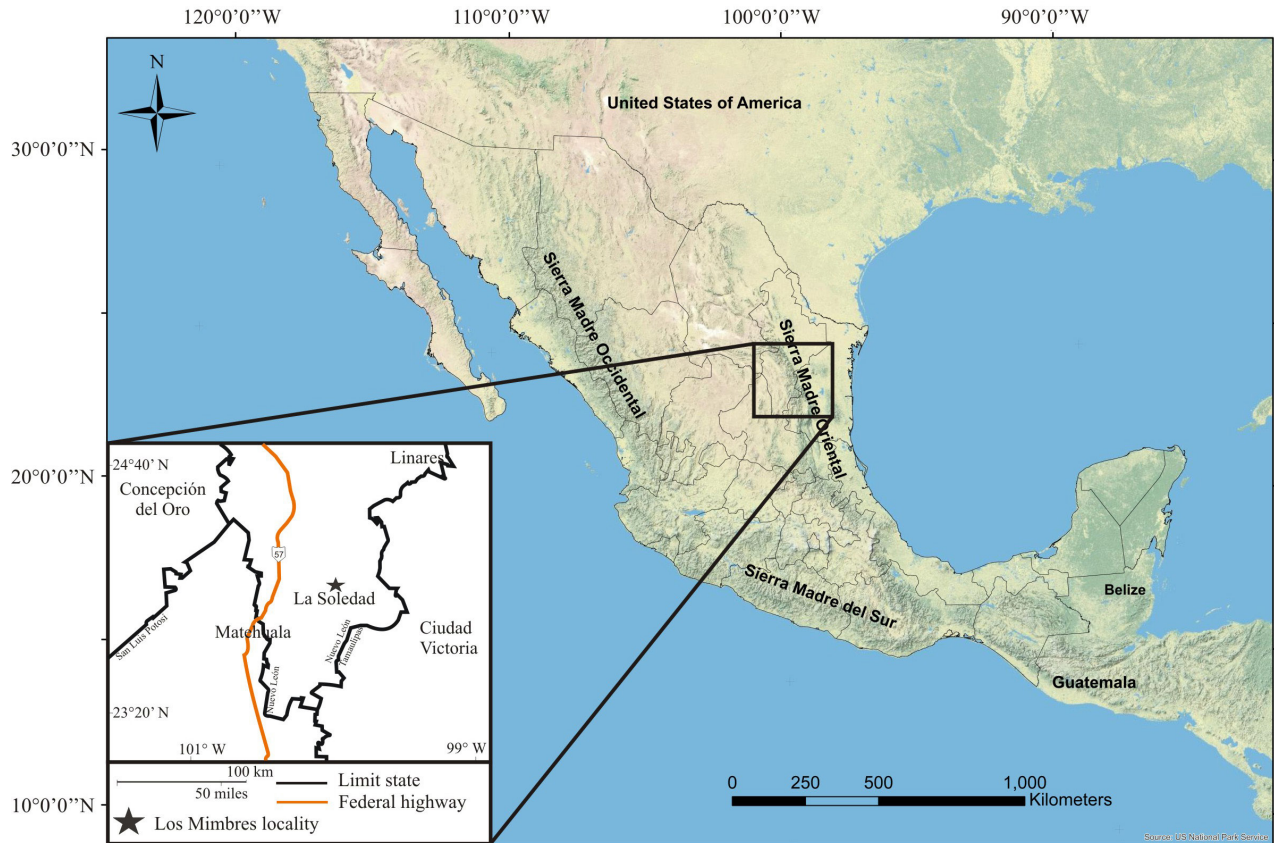


Figure 1. Geographical location. Location of the study area in the Sierra Madre Oriental, at Los Mimbres locality, near of La Soledad, southern of Nuevo León. (Taken from Geo Info Mex. <http://mapasims.sgm.gob.mx/GeoInfoMexDb/>).

the Cupido Formation about 50 m thick, conformably underlies the La Peña Formation (Figure 3 A), and consists of light gray argillaceous limestone in fresh sample and light-white-yellowish gray in weathering sample, with mudstone-wackestone texture in sets of thin-to-medium beds which thickness is in a range of 0.05 m to 0.50 m (Figure 3 B). Occasionally, laminar argillaceous limestone beds with stylolites, light gray to dark gray chert nodules and lenses, calcite stringers and veins, as well as hematite nodules, can be found. Five hand samples were taken from the limestone layers of this unit to prepare thin sections for micropaleontological analysis.

The La Peña Formation. The La Peña Formation was originally described by Imlay (1936) from an upper Aptian outcrop in the Sierra de Parras, Coahuila, conformed by a lower unit of limestone and an upper shale unit. Humphrey (1949) restricted the term La Peña Formation to the upper shale unit and included the lower limestone within the Cupido Formation. Barragán-Manzo and Méndez-Franco (2005) according to ammonite vertical distribution in this unit, established an age corresponding to the uppermost part of the early to late Aptian. In Los Mimbres this formation, about 20 m thick, consists of gray limestone in fresh sample, that weathers to light-reddish-pinkish

limestone, with mudstone or mudstone-wackestone texture in beds from 0.10 m to 0.40 m thick, alternating with laminar reddish limestone. Dark gray chert occurs in nodules and bands (Figure 3 C). Interbedding shale and laminar argillaceous limestone, as well as stylolites, calcite stringers and veins, and nodules of hematite are present. For micropaleontological study, six rock hand samples were collected from this formation.

The Cuesta del Cura Limestone. The term Cuesta del Cura Limestone was proposed by Imlay (1936) to describe an Albian rocks exposed in Sierra de Parras, Coahuila, constituted by interbedded limestone, clay and chert bands. Based on its stratigraphic position, the age of this unit was restricted to upper part of the Albian (Imlay, 1937), but several subsequent works focused on its paleontological content determined an Albian-Cenomanian age (Gandolfi, 1942 in Ángeles-Villeda *et al.*, 2005; Pantoja-Alor, 1962; Tardy *et al.*, 1975; Bacon, 1978; Stinnesbeck, 1983; PEMEX, 1988; Barboza-Gudiño *et al.*, 2004; Arvizu-Gutiérrez, 2006; Villarreal-Fuentes, 2007), and Albian-Turonian age (Pérez-Rul, 1967). Locally, the Cuesta del Cura Limestone, 80 m thick, is constituted by gray limestone in fresh samples that weathers to light-white gray colors with mudstone-wackestone texture. Calcite veins and oxides

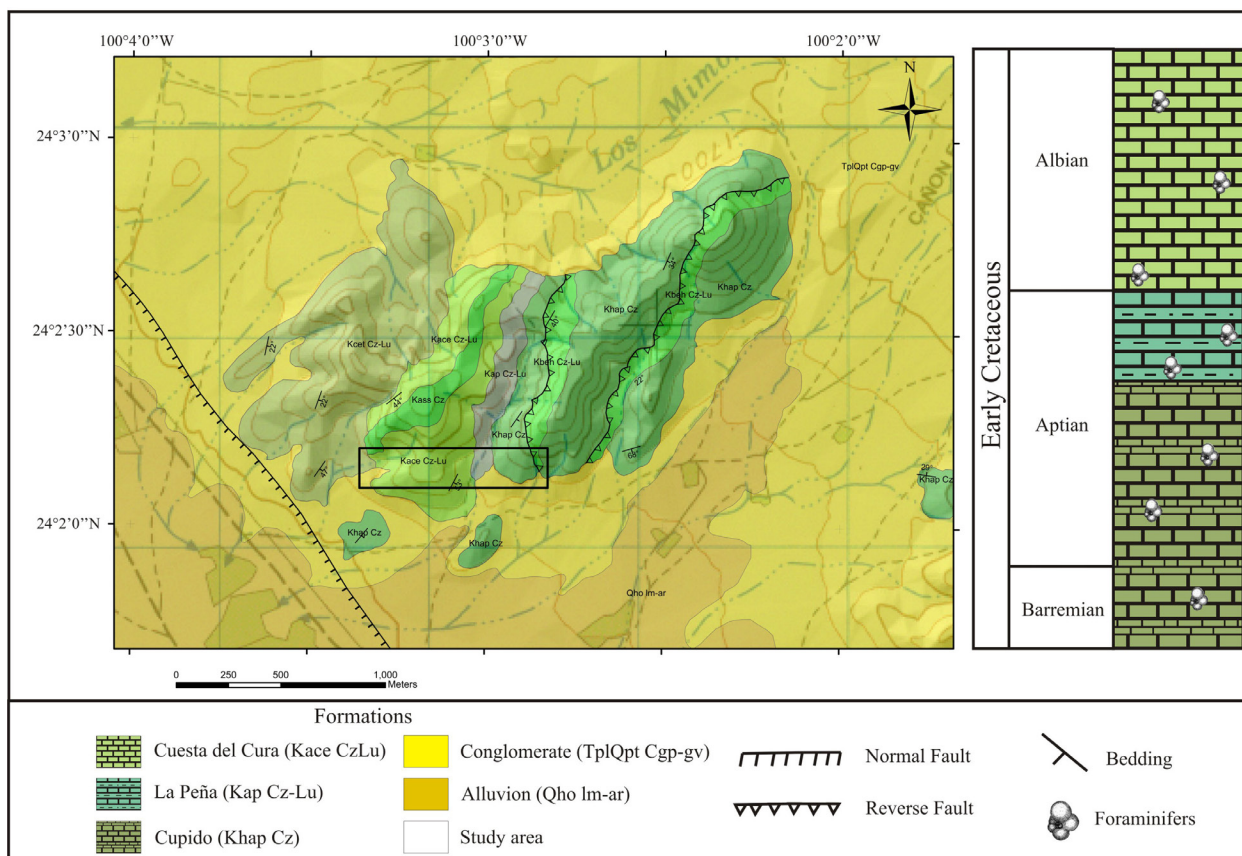


Figure 2. Geological map and generalized stratigraphic column in the studied region. Modified from Romo-Ramírez and Padilla-Islas (2012).

dissemination are present. Medium-to-thick beds from 0.10 m to 0.60 m conformed by dark gray chert nodules and bands, as well as laminar argillaceous limestone interbedded with reddish shale can be observed (Figure 3 D). For micropaleontological analysis, four rock hand samples were collected from the limestone layers of this unit.

4.2. Systematic Paleontology

Order Foraminiferida Eichwald, 1830

Suborden Globigerinina Delage and Hérouard, 1896

Superfamily Planomalina Bolli, Loeblich and Tappan, 1957

Family Globigerinelloididae Longoria, 1974

Subfamily Globigerinelloidinae Longoria, 1974

Genus *Globigerinelloides* Cushman and Ten Dam, 1948

Type species. *Globigerinelloides algeriana* Cushman and Ten Dam, 1948.

Diagnosis. Test planispirally enrolled, biumbilicate, involute to evolute, lobulate in outline, chambers globular to somewhat elongate in partially evolute species, sutures depressed; wall calcareous, perforate, optically radial; aperture equatorial and interiomarginal, bordered by a narrow imperforate lip, broad and low to moderately arched, the lateral portians remaining open as relict supplementary

apertures around the umbilicus when new chambers are added.

Globigerinelloides blowi (Bolli, 1959)

(Figure 4 A)

1959 *Planomalina blowi* Bolli, p. 260, pl. 20, figs. 2–6.

1974 *Globigerinelloides blowi* (Bolli); Longoria, p. 82, pl. 4, figs. 4, 7, 11–13.

1978 *Globigerinelloides blowi* (Bolli); Caron, p. 658, pl. 6, figs. 11, 12.

1979 *Globigerinelloides blowi* (Bolli); Butt, p. 258, pl. 3, figs. 14–17.

1981 *Globigerinelloides? blowi* (Bolli); Tronchetti, p. 121, pl. 32, figs. 1–2.

1988 *Blowiella blowi* (Bolli); Banner and Desai, p. 170, pl. 4, figs. 5–8.

1992 *Globigerinelloides blowi* (Bolli); Sliter, fig. 6.4.

1999 *Globigerinelloides blowi* (Bolli); Sliter, p. 334, pl. 2, fig. 2.

2004 *Globigerinelloides blowi* (Bolli); Premoli-Silva and Verga, p. 239, pl. 9, figs. 9–10.

2005 *Globigerinelloides blowi* (Bolli); Omaña, González-Arreola and Ramírez-Garza, p. 93, fig. 3.6.



Figure 3. Outcrops of Lower Cretaceous rocks at Los Mimbres locality, Nuevo León. A) Contac between the Cupido and La Peña formations, B) Light gray argillaceous limestone in thin-to-medium strata with interbedded shale horizons of the Cupido Formation, C-D) Dark gray limestone with medium-to-thick beds of the Cuesta del Cura Limestone.

Description. Test small with planispiral coiling; globular to sphaerical chambers in final whorl, increasing rapidly in size; wall calcareous.

Occurrence. Sample PSJ-246, the Cupido Formation, Los Mimbres locality.

Stratigraphic range. Aptian (Caron, 1985; Sliter, 1989); late Barremian to uppermost Aptian (Premoli-Silva and Verga, 2004); early Barremian to Aptian (Huber and Petrizzo, 2016).

Globigerinelloides ferreolensis (Moullade, 1961)
(Figure 4 B)

1961 *Biticinella ferreolensis* Moullade, p. 214, pl. 1, figs. 1–5.

1974 *Globigerinelloides ferreolensis* (Moullade); Longoria, pl. 5, figs. 7, 8; pl. 8, figs. 1–3, 8–15; pl. 14, figs. 7, 8; pl. 27, figs. 3, 5, 12.

1975 *Globigerinelloides ferreolensis* (Moullade); Longoria, pl. 1, fig. 7.

1985 *Globigerinelloides ferreolensis* (Moullade); Caron, p. 47, figs. 29.12–13; 10, 12, 15.

1992 *Globigerinelloides ferreolensis* (Moullade); Sliter, figs. 6.5, 6.6.

2004 *Globigerinelloides ferreolensis* (Bolli); Premoli-Silva and Verga, p. 239, pl. 9, figs. 13–15.

2009 *Globigerinelloides ferreolensis* (Moullade); Longoria and Monreal, p. 282.

2017 *Globigerinelloides ferreolensis* (Moullade); Brovina, p. 524, pl. 1, fig. 7.

Description. In axial view, medium sized and planispiral test, slightly thick wall with smooth surface. Globular chambers are visible; the last one increased in size with respect to the others. Inside the visible chambers, a dark layer inside the wall. Moderately preserved specimen.

Occurrence. Sample PSJ-242, the La Peña Formation, Los Mimbres locality.

Stratigraphic range. Aptian (Sliter, 1989; Premoli-Silva and Verga, 2004; Huber and Petrizzo, 2016); late Aptian (Caron, 1985; BouDagher-Fadel, 2015).

Superfamily Rotaliporacea Sigal, 1958

Family Hedbergellidae Loeblich and Tappan, 1961

Subfamily Hedbergellinae Loeblich and Tappan, 1961

Genus *Hedbergella* Brönnimann and Brow, 1958

Type species. *Anomalina lorneiana*, d'Orbigny var. *trochoidea* Gandolfi, 1942.

Diagnosis. Test with globular and gradually enlarging chambers in a low trochospiral coil, narrow umbilicus on the umbilical side, sutures radial, depressed; wall calcareous, finely perforate optically radial, surface smooth to hispid, without a poreless margin; aperture an interiomarginal, umbilical-extraumbilical arch, with a narrow lip or flap.

Hedbergella sigali Moullade, 1966

(Figure 4 C)

1966 *Hedbergella sigali* Moullade, p. 87, pl. 7, figs. 20–25.

1985 *Hedbergella sigali* Moullade; Bolli, Saunders and Perch-Nielsen, p. 59, figs. 25.21–22; 10, 12, 15.

1992 *Hedbergella sigali* Moullade; Sliter, figs. 7.1–2.

1999 *Hedbergella sigali* Moullade; Sliter, p. 333, pl. 1, figs. 2–3.

2002 *Hedbergella sigali* Moullade; Moullade, Bellier and Tronchetti, p. 128.

2004 *Hedbergella sigali* Moullade; Premoli-Silva and Verga, p. 251, pl. 21, fig. 12.

2005 *Hedbergella* gr. *sigali* Moullade; Omaña, González-Arreola and Ramírez-Garza, p. 93, fig. 3.3.

Description. Test small, trochospiral, in equatorial section, with 4 – 4½ globular to reniform chambers in final whorl; final chamber globular to slightly ovate.

Occurrence. Sample PSJ-246, PSJ-247, the Cupido Formation, Los Mimbres locality.

Stratigraphic range. Early Cretaceous, Barremian-early Aptian (Caron, 1985), Barremian to Albian (Sliter, 1989); late Valanginian to early Albian (Premoli-Silva and Verga, 2004); and late Valanginian to uppermost Aptian (Huber and Petrizzo, 2016).

Hedbergella similis Longoria, 1974

(Figure 4 D)

1974 *Hedbergella similis* Longoria, p. 68, pl. 16, figs. 10–21; pl. 18, figs. 12, 13; pl. 23, figs. 14–16.

1988 *Lilliputianella similis* (Longoria); Banner and Desai, p. 169, pl. 8, figs. 8, 9.

1999 *Hedbergella similis* Longoria; Michalík, Reháková, Lintnerová, Boorová, Halásová, Kotulová, Soták, Peterěáková, Hladíková and Skupien, p. 177, pl. 4, fig. 3.

1999 *Hedbergella similis* Longoria; Sliter, p. 335, pl. 3, figs. 6, 13.

2005 *Hedbergella similis* Longoria; Omaña, González-Arreola and Ramírez-Garza, p. 93, figs. 3.1a, 3.1b.

2014 *Hedbergella similis* Longoria; Mweneinda, p. 125, pl. 3.6, figs. 3a–d.

Description. Test medium, trochospiral, in equatorial section with 5 globular chambers in the final whorl. The final chamber is ovate to slightly elongated.

Occurrence. Sample PSJ-247, the Cupido Formation, Los Mimbres locality.

Stratigraphic range. Aptian (Sliter, 1989); early Barremian to late Aptian (Premoli-Silva and Verga, 2004); late Hauterivian to Aptian (Huber and Petrizzo, 2016).

Hedbergella roblesae (Obregón de la Parra, 1959)

(Figure 4 E)

1959 *Globigerina roblesae* Obregón de la Parra, p. 149, pl. 4, fig. 4.

1974 *Hedbergella roblesae* (Obregón de la Parra); Longoria, p. 65–66, pl. 16, figs. 1–3, 4–6; pl. 20, figs. 10, 11.

1997 *Lilliputianella roblesae* (Obregón de la Parra); BouDagher-Fadel, Banner, Whittaker, and Simmons, 173, pl. 9.3, figs. 1–7.

1998 *Praehedbergella roblesae* (Obregón de la Parra); Moullade, Tronchetti, Kuhnt and Masse, p. 208.

2002 *Praehedbergella roblesae* (Obregón de la Parra); Moullade, Bellier and Tronchetti, p. 128.

2013–2014 *Lilliputianella roblesae* (Obregón de la Parra); Barchetta, p. 79, pl. 4, figs. 3a–b.

Description. Test medium sized, in equatorial section, trochospirally coiled with 5 chambers in outer whorl; chambers initiality globular to subglobular, the last three elongate. Wall calcareous and smooth.

Remarks. The equatorial section of this species is comparable with the illustration of Premoli-Silva and Verga (2004).

Occurrence. Sample PSJ-246, the Cupido Formation, Los Mimbres locality.

Stratigraphic range. Barremian to uppermost Aptian (Premoli-Silva and Verga, 2004); late Hauterivian to Aptian (Huber and Petrizzo, 2016).

Hedbergella spp.

(Figure 4 F)

Description. Test medium sized and trochospiral in axial view. Wall thin and finely perforate. Chambers globular to subglobular. Umbilical area narrow and deep. Moderately preserved specimen.

Occurrence. Sample PSJ-243, the La Peña Formation; Sample PSJ-247, the Cupido Formation, Los Mimbres locality.

Stratigraphic range. Early Barremian-early Santonian (Caron, 1985), late Valanginian-late Aptian (Premoli-Silva

and Verga, 2004), late Aptian-Paleocene (BouDagher-Fadel, 2015), late Valanginian-late Albian (Huber and Petrizzo, 2016).

Genus *Muricohedbergella* Huber and Leckie, 2011

Type species. *Muricohedbergella delrioensis* (Carsey, 1926).

Diagnosis. Test wall moderately thick, multilamellar, finely perforate, wall pores variably spaced in adult

chambers, surface moderately to coarsely muricate or pustulose, never with a keel, raised sutures or imperforate peripheral margin. Test small to moderate in size, coiled in a very low to low trochospire, spiral side evolute, umbilical side mostly involute; chambers globular, never elongated radially, increasing slowly to moderately in size, with 4.5–7 in the final whorl; aperture a low interiomarginal, umbilical-extraumbilical arch that is bordered by a thick lip or flap that may extend partly into the umbilical region.

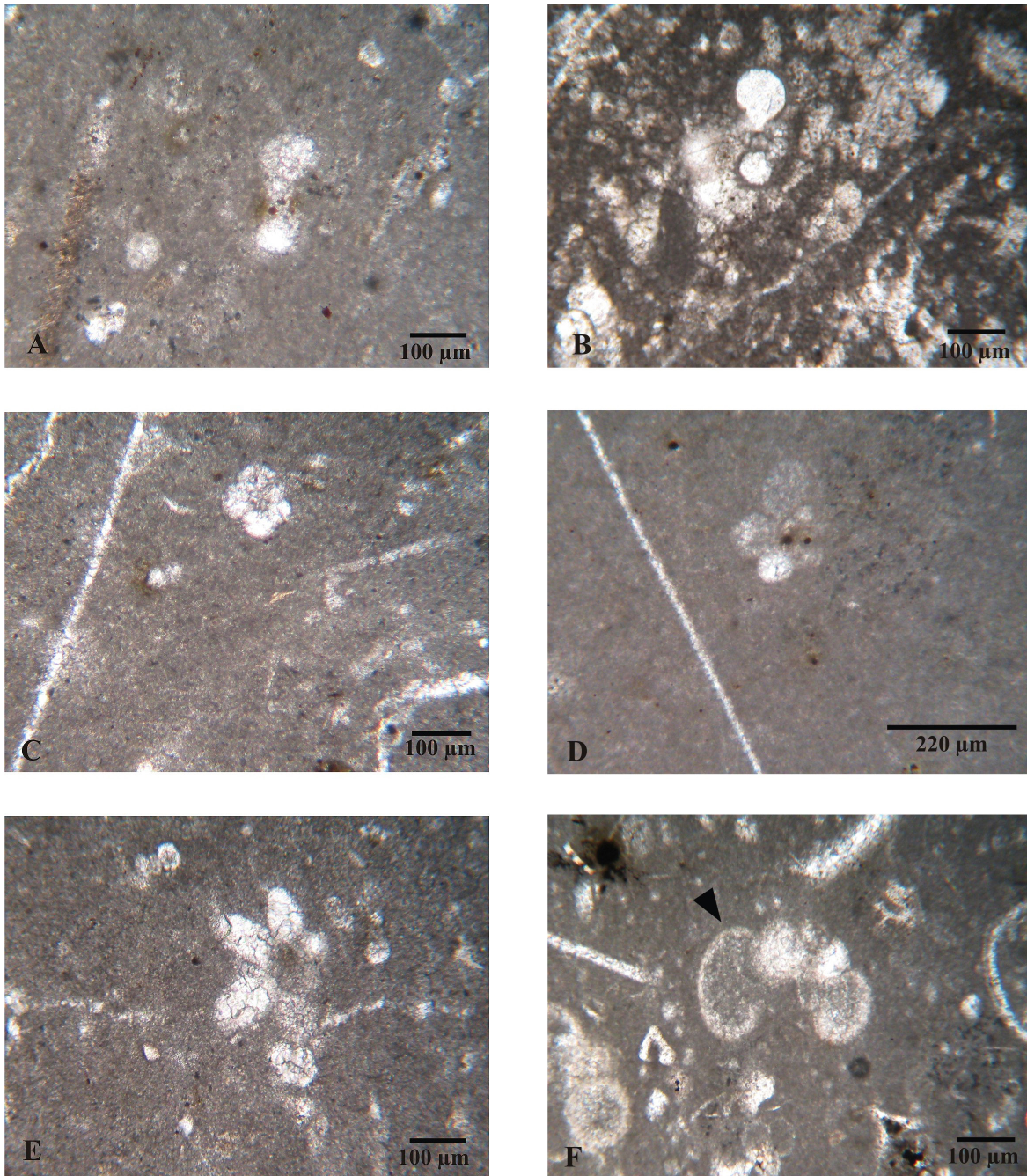


Figure 4. A) *Globigerinelloides blowi* (Bolli), axial section; B) *Globigerinelloides ferreolensis* (Moullade), axial section; C) *Hedbergella sigali* Moullade, equatorial section; D) *Hedbergella similis* Longoria, equatorial section; E) *Hedbergella robesae* (Obregón de la Parra), equatorial section; F) *Hedbergella* sp., axial section.

Remarks. According to Huber and Leckie (2011) the “murico” definition is added to pre-existing *Hedbergella* genus, because of the presence of moderate to thick pustules or muricas on test surface.

Muricohedbergella delrioensis (Carsey, 1926)
(Figure 5 A)

- 1926 *Globigerina cretacea* d'Orbigny var. *delrioensis* n. var. Carsey, p. 43.
 1937 *Globigerina infracretacea* Glaessner, p. 28, text-fig. 1.
 1966 *Hedbergella delrioensis* (Carsey); Butt, p. 173–174, pl. 2, figs. 1–8.
 1967 *Hedbergella delrioensis* (Carsey); Pessagno, p. 282–283, pl. 48, figs. 1, 2, 3–5.
 1970 *Hedbergella delrioensis* (Carsey); Eicher and Worstell, p. 302, pl. 9, figs. 10, 11a–b.
 1971 *Hedbergella delrioensis* (Carsey); El-Naggar, pl. 6, figs. a–c, 37.
 1972 *Hedbergella delrioensis* (Carsey); Barr, p. 13, pl. 2, fig. 1a.
 1973 *Hedbergella delrioensis* (Carsey); Dailey, p. 82, pl. 17: a.
 1974 *Hedbergella delrioensis* (Carsey); Herb, p. 752, pl. 3, figs. 15–18.
 1974 *Hedbergella delrioensis* (Carsey); Longoria, pl. 10, figs. 1–3.
 1975 *Hedbergella delrioensis* (Carsey); North and Caldwell, pl. 4, figs. 16a, 18a–c.
 1975 *Hedbergella delrioensis* (Carsey); Luterbacher, pl. 1, fig. 8.
 1975 *Hedbergella delrioensis* (Carsey); Heller, pl. 2, fig. 12.
 1976 *Hedbergella delrioensis* (Carsey); Masters, p. 328, pl. 2, figs. 1–3.
 1979 *Hedbergella delrioensis* (Carsey); Robaszynski, Caron and others, p. 123, pl. 22, figs. 1–2; pl. 23, figs. 1–3.
 1980 *Hedbergella delrioensis* (Carsey); Peryt, p. 54, pl. 10: 1a–c.
 1983 *Hedbergella delrioensis* (Carsey); Belford, p. 15, pl. 5, figs. 11–16.
 1983 *Hedbergella delrioensis* (Carsey); Peryt, p. 447, pl. 30: 8, 10.
 1984 *Hedbergella delrioensis* (Carsey); Leckie, p. 598, pl. 1, fig. 12; pl. 9, figs. 1–4, 8.
 1985 *Hedbergella delrioensis* (Carsey); Caron, p. 57, figs. 25.6–7.
 2006 *Hedbergella delrioensis* (Carsey); Petrizzo and Huber, p. 185, pl. 7, figs. 3–4.
 2011 *Muricohedbergella delrioensis* (Carsey); Huber and Leckie, p. 84.
 2013 *Muricohedbergella delrioensis* (Carsey); Egger, Mohamed and Rögl, p. 100, figs. 10/8–9.

2017 *Muricohedbergella delrioensis* (Carsey); Flores-Cadenas, p. 36–38, fig. 8D.

Description. Test small to medium, low trochospiral, globular to subglobular chambers; wall calcareous and thin.

Occurrence. Sample PSJ-243, the La Peña Formation, Los Mimbres locality.

Stratigraphic range. The stratigraphic range varies depending the criterious of each autor, for example, Barremian to Campanian (Master, 1977); early Aptian to Coniacian (Caron, 1985); early Aptian to early Santonian (Sliter, 1989); late Albian to early Santonian (Patterson *et al.*, 2004); early Albian to late Coniacian (Premoli-Silva and Verga, 2004); Albian to Turonian (Loeblich and Tappan, 1961; Salaj and Samuel, 1966; Longoria, 1974; Pflamann and Krashennikov, 1977; Chronos, 2006); late Albian to early Turonian (Huber and Petrizzo, 2016).

Family Favusellidae Longoria 1974

Genus *Favusella* Michael 1972

Type species. *Globigerina washitensis* Carsey, 1926.

Diagnosis. Test trochospirally coiled, globular chambers rapidly enlarging, 4–5 in each of the 2–3 whorls, sutures radial, depressed; wall calcareous, perforate, without keels, surface with a distinct honeycomblike pattern of costellae.

Favusella washitensis (Carsey, 1926)
(Figure 5 B1)

- 1926 *Globigerina washitensis* Carsey, p. 44, pl. 7, fig. 10.
 1931 *Globigerina washitensis* Carsey; Plummer, p. 193, pl. 13, figs. 12a–b.
 1972 non *Favusella washitensis* (Carsey); Michael, p. 61, pl. 4, figs. 7–9.
 1974 *Favusella washitensis* (Carsey); Longoria, pl. 26, figs. 4–6.
 1985 *Favusella washitensis* (Carsey); Bolli, Saunders and Perch-Nielsen, p. 45, figs. 25.25–26, 10, 12, 15.
 2009 *Favusella washitensis* (Carsey); Longoria and Monreal, p. 281, pl. 2, fig. 7.
 2013 *Favusella washitensis* (Carsey); Soleimani, Bahadori and Meng, p. 1168, fig. 4.6.
 2016 *Favusella washitensis* (Carsey); Omaña, Alencaster and Buitrón, p. 485, fig. 5g.

Description. Test high with trochospiral coil. Chambers spherical to subspherical. Wall calcareous ornamented.

Occurrence. Sample PSJ-241, the Cuesta del Cura Limestone, Los Mimbres locality.

Stratigraphic range. According to Caron (1985) and Premoli-Silva and Verga (2004) the age is Lower Cretaceous (Albian) to Upper Cretaceous (lower Cenomanian); while Longoria and Monreal (2009), BouDagher-Fadel (2015), and Huber and Petrizzo (2016) assigned from Early Cretaceous (late Aptian) to Late Cretaceous (Cenomanian).

Family Rotaliporidae Sigal, 1958
 Subfamily Ticinellinae Longoria 1974

Genus *Ticinella* Reichel, 1950

Type species. *Anomalina roberti* Gandolfi, 1942.

Diagnosis. Test trochospiral, biconvex to planoconvex, umbilicate, chambers globular to ovate, sutures curved on the spiral side, radial on the umbilical side, depressed,

periphery rounded and without a keel or poreless margin, peripheral outline lobulate; wall calcareous, optically radial, surface smooth, finely perforate, secondary lamellae emphasizing the surface rugosity and obscuring some pores but enlarging others.

Ticinella sp.
 (Figure 5 C1)

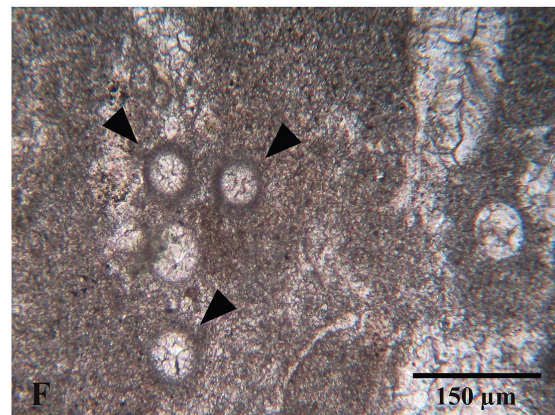
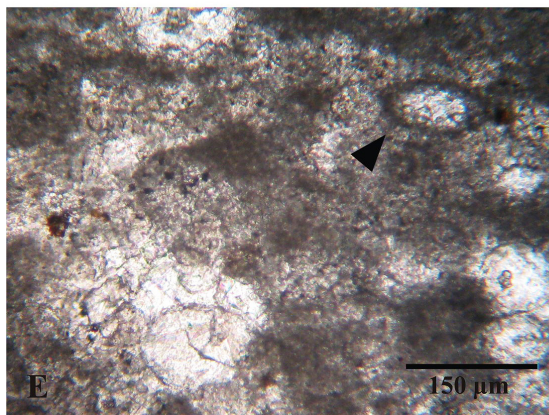
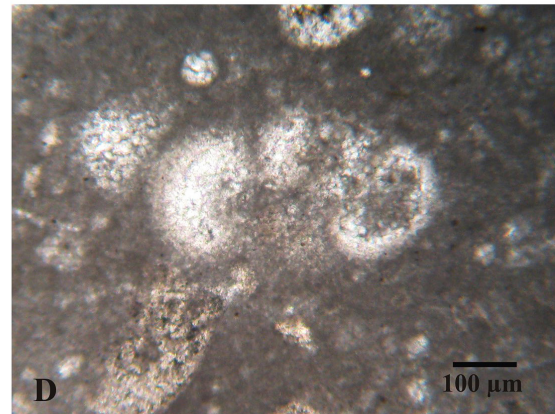
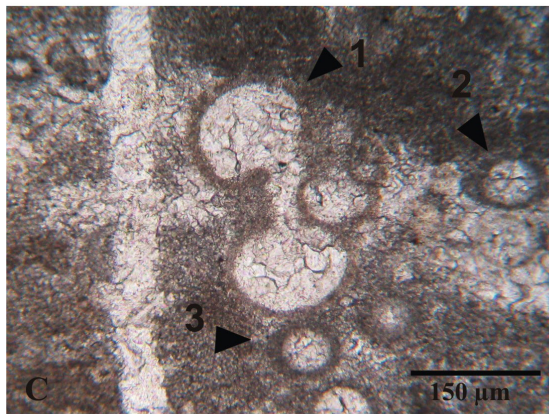
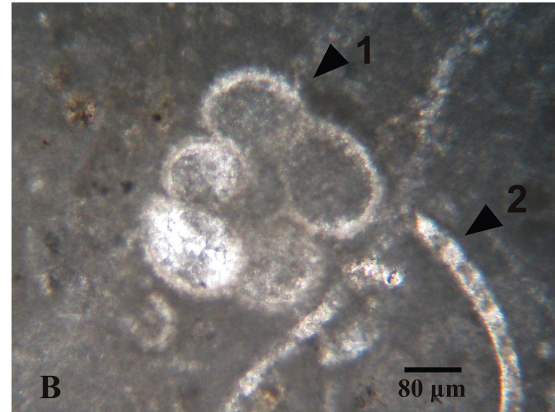
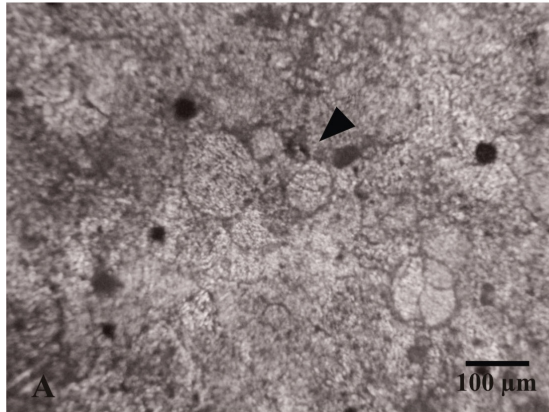


Figure 5. A) *Muricohedbergella delrioensis* (Carsey), axial section; B) *Favusella washitensis* (Carsey), equatorial section (1), *Microcalamoides diversus* Bonet (2); C) *Ticinella* sp., axial section (1), *Bishopella alata* (2), *Bishopella ornelasae* (3); D) *Paraticinella rohri* (Bolli), axial section; E) *Bishopella alata* Trejo; F) *Bishopella ornelasae* Trejo.

Description. Test trochospiral, chambers globular to ovate, periphery rounded without keels; wall calcareous, surface smooth, finely perforate.

Occurrence. Sample PSJ-240, the Cuesta del Cura Limestone, Los Mimbres locality.

Stratigraphic range. Late Aptian to late Albian (Caron, 1985); Aptian to early Cenomanian (Loeblich and Tappan, 1988); Albian (Sliter, 1989; Premoli-Silva and Verga, 2004; Huber and Petrizzo, 2016).

Genus *Paraticinella* Premoli-Silva, Caron, Leckie, Petrizzo, Soldan and Verga, 2009

Type species. *Ticinella eubejaouaensis* Randrianasolo and Anglada, 1988, and *Ticinella bejaouaensis* as emended by Moullade 1966.

Diagnosis. Low trochospiral, generally slightly lobate in outline, numerous chambers (7–11) in the last whorl, globular, sutures straight and depressed on both sides; wall finely perforate; wall surface rugose to smooth, with rugosities masking the inner whorl, then covering the first chambers of the last whorl, frequently organized in irregularly sized ridges that may cover the pores and run parallel to the spiral suture; surface of later-formed chambers may bear volcano-like perforation cones that progressively attenuate toward the ultimate chamber; shallow umbilical area moderate to large in size; umbilical area may be covered, at least partially, by large flaps from the ultimate and penultimate chambers that fuse along a slightly depressed line forming a cover-plate; primary aperture an interiomarginal arch, umbilical-extraumbilical extending toward the periphery; may have one to two small, weakly developed umbilical accessory (infralaminal) apertures in the last chambers.

Paraticinella rohri (Bolli, 1959)
(Figure 5 D)

- 1959 *Praeglobotruncana rohri* Bolli, p. 267–268, pl. 22, figs. 6 (holotype), 7 (paratype) (non pl. 22, fig. 5).
1966 *Ticinella roberti* var. *bejaouaensis* Sigal, p. 207–208, pl. 5, figs. 8, 9 (non pl. 5, figs. 5–7).
1966 *Ticinella bejaouaensis* Sigal; Moullade, p. 103, pl. 9, figs. 4–5.
1971 *Ticinella bejaouaensis* Sigal; Risch, p. 50–51, pl. 5, figs. 1–9.
1974 *Ticinella bejaouaensis* Sigal; Longoria, p. 94, pl. 18, figs. 1–2; pl. 19, figs. 9–16; pl. 21, figs. 12–13.
1979 “*Hedbergella*” aff. *Ticinella bejaouaensis* Sigal; Sigal, pl. 3, figs. 14–15.
1984 *Ticinella roberti* s.l. (Gandolfi); Leckie, p. 600–601, pl. 5, figs. 5–12 (non pl. 5, figs. 1–4).
1984 *Ticinella bejaouaensis* Sigal; Premoli-Silva and McNulty, pl. 2, figs. 1–3.

- 1985 *Ticinella bejaouaensis* (Sigal); Caron, p. 76–77, figs. 36.1–3, 10, 12, 15.
1985 *Ticinella roberti* (Gandolfi); Bellier, p. 10, pl. 1, figs. 1–3.
1986 *Ticinella bejaouaensis* Sigal; Premoli-Silva and Sliter, pl. 1, figs. 3–5.
1992 *Ticinella bejaouaensis* Sigal; Sliter, figs. 7.8–7.11.
1993 *Ticinella* (?) *bejaouaensis* Sigal; Sliter and Leckie, pl. 5, figs. 1–2.
1998 *Ticinella eubejaouaensis* Randrianasolo and Anglada, p. 28.
1999 *Ticinella bejaouaensis* Sigal; Aguado, Castro, Guillén, figs. 10.24–10.27.
2000 *Ticinella bejaouaensis* Sigal; Lipson-Benitah and Almogi-Labin, p. 12, pl. 1, figs. 1–5.
2002 *Ticinella eubejaouaensis* Randrianasolo and Anglada; Bellier and Moullade, p. 19–20, pl. 1, figs. 13–15.
2009 *Paraticinella eubejaouaensis* (Randrianasolo and Anglada); Premoli-Silva, Caron, Leckie, Petrizzo, Soldan and Verga, p. 131–132, 135, pl. 1, figs. 5a–b, 6a–b; pl. 2, figs. 1a–d, 2–6.
2009 *Ticinella bejaouaensis* (Sigal); Longoria and Monreal, p. 281, pl. 1, figs. 1, 2.
2010 *Paraticinella rohri* (Bolli); Georgescu, text-figs. 1.1–1.3.
2011 *Paraticinella eubejaouaensis* (Randrianasolo and Anglada); Huber and Leckie, p. 85, figs. 10.4, 10.6.
2012 *Paraticinella eubejaouaensis* (Randrianasolo and Anglada); Petrizzo, Huber, Gale, Barchetta, and Jenkyns, pl. 4, figs. 2–3.
2013 *Paraticinella rohri* (Bolli); Ando, Huber, Premoli-Silva, p. 282, figs. 2A, 2B.

Description. Test low, almost flat trochospire; globular chambers; wall calcareous, surface rugose; umbilicus deep.
Occurrence. Sample PSJ-243, the La Peña Formation, Los Mimbres locality.

Stratigraphic range. Late Aptian (Premoli-Silva *et al.*, 2009; BouDagher-Fadel, 2015; Huber and Petrizzo, 2016).

Subphylum Sarcodina Hertwig and Lesser, 1874
Clase Rhizopoda von Siebold, 1845
Orden Foraminiferida Eichwal, 1830
Incerta sedis

Genus *Bishopella* Trejo, 1983

Type species. *Bishopella alata* Trejo, 1983.

Diagnosis. Test monothalamic and micritical, hallow or filled with spatic calcite. Shape of test is sphaerical to lenticular, with a conical face of rounded apex and other slightly convexo or flat. Wall thick, crossed by regular pores with radial orientation.

Bishopella alata Trejo, 1983
(Figures 5 C2, 5 E)

1983 *Bishopella alata* Trejo, p. 12, pl. 26, figs. 2–12; pl. 27, figs. 1, 2, 5, 8; text-fig. 1.

Description. Test monothalamic, filled with spatic calcite; 140 to 200 in diameter. These specimens have an edge formed by the union between oral face slightly convex and aboral face conical redounded. Wall thick and micritical.

Occurrence. Sample PSJ-239, PSJ-240, the Cuesta del Cura Limestone, Los Mimbres locality.

Stratigraphic range. Middle Albian to late Albian (Trejo, 1983).

Bishopella ornelasae Trejo, 1983
(Figures 5 C3, 5 F)

1983 *Bishopella ornelasae* Trejo, p. 13, pl. 21–34.

Description. Test sphaerical; 150 to 200 μm in diameter. Wall micritical and thick.

Occurrence. Sample PSJ-239, PSJ-240, the Cuesta del Cura Limestone, Los Mimbres locality.

Stratigraphic range. Middle Albian to late Albian (Trejo, 1983).

Phylum Protozoa Goldfuss, 1818 emend. Von Siebold, 1845

Class Ciliatea Perty, 1852

Order Tintinnida Corliss, 1955

Superfamily Tintinnidea Bonet, 1956

Family Colomiellidae Bonet, 1956

Genus *Colomiella* Bonet, 1956

Type species. *Colomiella mexicana* Bonet, 1956.

Diagnosis. Colomiellidae with a cylindrical collar and with one or more cylindrical anular rings.

Colomiella recta Bonet, 1956
(Figure 6 A)

1956 *Colomiella recta* Bonet, p. 431, pl. 21.

1989 *Colomiella recta* Bonet; Rosales-Domínguez, fig. 7A.

2009 *Colomiella recta* Bonet; Longoria and Monreal, p. 273, pl. 1, figs. 3, 4, 7, 8.

2012 *Colomiella recta* Bonet; Núñez-Useche and Barragán, fig. 6d.

2017 *Colomiella recta* Bonet; Caetano-Filho, Dias-Brito, Rodrigues and Acevedo, figs. 7C–D, 8B–C, F.

Description. Test thin and hemisphaerical, large necklace. The necklace is separated from test body; thick wall at the necklace base.

Occurrence. Sample PSJ-244, the La Peña Formation, Los Mimbres locality.

Stratigraphic range. Barremian to uppermost Aptian (Bonet, 1956); Barremian to early Albian (Longoria, 1973).

Phylum Arthropoda Latreille, 1829

Subphylum Mandibulata Clairville, 1798

Class Crustacea Pennant, 1777

Subclass Ostracoda Latreille, 1806

Genus *Microcalamoides* Bonet, 1956

Type species. *Microcalamoides diversus* Bonet, 1956.

Diagnosis. Calcitic remains of cylindrical shape, about $\frac{1}{4}$ to 1 mm in diameter, length unknown. Outer surface with longitudinal furrows. It is ignored if both ends are closed or open, as well as the length of the cylinders. The conserved parts look like fragments of a calcitic skeleton.

Microcalamoides diversus Bonet, 1956
(Figures 5 B2, 6 B)

1956 *Microcalamoides diversus* Bonet, p. 433–436, pls. 27, 29, 30.

1960 *Microcalamoides diversus* Bonet; Trejo, p. 264, 267, 268.

1971 *Microcalamoides diversus* Bonet; Ramírez del Pozo, p. 309–310, pls. 38–2, 45–2, 49–2.

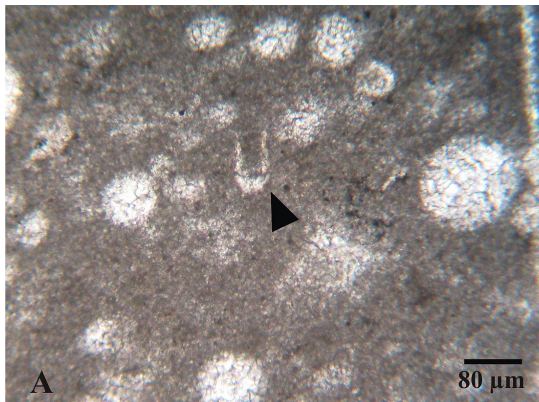


Figure 6. A) *Colomiella recta* Bonet; B) *Microcalamoides diversus* Bonet.

- 1974 *Microcalamoides diversus* Bonet; O'Neil and Waite, p. 39, pl. 23, figs a–c.
 1974 *Microcalamoides diversus* Bonet; Prestat, p.3, pl. 7, figs. 6–8.
 1975 *Microcalamoides diversus* Bonet; Trejo, p. 15, 16.
 1983 *Microcalamoides diversus* Bonet; Trejo, p. 15, pl. 18, figs. 1–2.
 1989 *Microcalamoides diversus* Bonet; Rosales-Domínguez, fig. 8.
 2017 *Microcalamoides diversus* Bonet; Caetano-Filho, Dias-Brito, Rodrigues and Acevedo, figs. 8B–C, H.

Description. Calcitic skeletal remains similar to a keq with large dimensions. Probably these remains correspond to globose shells of ostracods. Generally they have arch shape in thin section. Wall thin; external surface has longitudinal grooves.

Occurrence. Sample PSJ-241, the Cuesta del Cura Limestone, Sample PSJ-242, La Peña Formation, Los Mimbres locality.

Stratigraphic range. Late Valanginian to middle Albian (Bonet, 1956).

4.3. Biostratigraphic results and paleoenvironment considerations

The microfauna analyzed is mostly represented by planktonic and benthic foraminifers, calcisphaerulids, bioclasts of mollusks, echinoid spines, among other unidentified planktonic and benthic microfossils.

4.3.1. The Cupido Formation

At the base of the Cupido Formation, two microfossil associations were found. The first, characterized by poorly preserved chambers of globigerinids, *Hedbergella* sp., co-occurring with some small textulariid benthic foraminifers, indicating a Barremian-middle Albian age. The second association is distinguished by spicules of sponges replaced by calcite, together with scarce and recrystallized planktonic foraminifers as *Hedbergella similis* Longoria, which testifies an early Barremian-Aptian age (Sliter, 1989; Omaña *et al.*, 2005); as well as *Hedbergella* sp. Both associations indicate an age from Barremian to Maastrichtian (Caron, 1985; Sliter, 1989). For the middle-upper part of the Cupido Formation, microfauna is represented by *Globigerinelloides blowi* (Bolli), which indicates a late Barremian-Aptian age, *Hedbergella sigali* Moullade, from Barremian to middle Aptian, and *Hedbergella roblesae* (Obregón de la Parra), Barremian-late Aptian (see Range Chart 2 presented by Premoli-Silva and Verga, 2004). The latter is considered by Sliter (1989) from Aptian age. Textulariid benthic foraminifers and bioclasts of mollusks also were recognized. For this studied section, a Barremian-middle Aptian age is suggested based on the first appearance of *Hedbergella similis* Longoria and the last presence of *Globigerinelloides blowi* (Bolli). All this microfaunal assemblage and the

sedimentological features in this formation document the presence of a low energy and slightly oxygenated marine setting (shelf).

4.3.2. The La Peña Formation

This unit contains abundant planktonic foraminifers as *Globigerinelloides ferreolensis* (Moullade), *Paraticinella rohri* (Bolli) (= *Ticinella bejaouaensis*) and *Hedbergella* sp., co-occurring with *Microcalamoides diversus* Bonet, roveacrinids, crinoid fragments, scarce benthic foraminifers and undetermined microfossils. A second association for the La Peña Formation is represented by *Hedbergella* sp., *Muricohedbergella delrioensis* (Carsey), and undetermined globigerinids. In the uppermost part of the La Peña Formation, *Hedbergella sigali* is co-occurring with *Colomiella recta* Bonet, whose stratigraphic range in Mexico has been considered from the uppermost late Aptian to early Albian. Also spumellarids and nassellarids radiolarians, and scarce roveacrinids were found. Considering the fossil association identified, a late Aptian age is assigned to this unit at Los Mimbres. The micropaleontological data reveal a low energy, oxygenated deep-sea environment, from the outer shelf to bathyal zones.

4.3.3. The Cuesta del Cura Limestone

At the base of this unit, planktonic foraminiferal assemblage consists of *Muricohedbergella delrioensis*, *Favusella washitensis* (Carsey), unidentified globigerinids, associated with *Microcalamoides diversus* Bonet, crinoidal fragments, mollusks, and undetermined small benthic foraminifers. A middle Albian age was given to this section on the basis of the first occurrence *Favusella washitensis* Carsey (Premoli-Silva and Verga, 2004) and the last appearance of *Microcalamoides diversus* Bonet. For the middle part of this unit, two microfaunistic associations were identified. The first one consists mostly of *Bishopella ornelasae* Trejo and in lower proportion of *Bishopella alata* Trejo, both of middle-late Albian; *Ticinella* sp., undetermined poorly preserved planktonic foraminifers, and calcified spumellarid radiolarian. The second one is characterized by *Bishopella ornelasae* Trejo, *B. alata* Trejo, poorly preserved calcisphaerulids together with bioclasts of mollusks and unidentified textulariid foraminifers. According to the aforementioned micropaleontological association, the deposition of this unit took place in a shallow marine environment of the neritic region.

5. Conclusions

The carbonated rocks of the Cupido, La Peña, and Cuesta del Cura formations are well exposed at Los Mimbres locality. The micropaleontological study allowed to identify an assemblage composed of seven species of planktonic foraminifers, four species of pelagic microfossils, as well as bishopelids, and bioclasts of echinoderms and mollusks.

This microfauna indicates an age from early Barremian to late Albian for the rocks studied. The analyzed microfauna and the lithology suggest a depositional environment characterized by oxygenated, low energy deep-water, belonging to pelagic marine setting (from outer platform to bathyal zone). The present finds shed more light on the Early Cretaceous micropaleontological associations from Nuevo León State and provide valuable information that could be used in future biostratigraphic works from this area and elsewhere in northeastern Mexico.

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