Barremian planktonic foraminiferal events correlated with the ammonite zones from the San Lucas Formation, Michoacán (SW Mexico)

Lourdes Omaña*, Celestina González-Arreola, and Blanca Margarita Ramírez-Garza

Instituto de Geología, Universidad Nacional Autonóma de México,
Ciudad Universitaria, Delegación Coyoacán, 04510, México, D.F., Mexico.
** lomanya@geologia.unam.mx*

ABSTRACT

We studied the Tiringueo section from the San Lucas Formation, located in the state of Michoacán, SW Mexico. The section is a flysch sequence consisting of a rhythmic deposit of shale, siltstone, and fine to medium graded sandstone interbedded with limestone. The sequence contains ammonites, foraminifera and radiolarians.

The biostratigraphic analysis, based on the planktonic foraminifera and ammonites, permitted the recognition of the biostratigraphic units established on both fossil groups, for first time in SW Mexico. Although the planktonic foraminifera are scarce and poorly preserved, some important events such as the first occurrence of Hedbergella similis, Globigerinelloides blowi and Globigerinelloides aptiensis were correlated with the ammonite zones. By means of these foraminiferal events, the Zones of Hedbergella similis and Globigerinelloides blowi partim (early and late Barremian) were identified. The faunal assemblage and distinctive lithological characteristics suggest that the San Lucas Barremian sequence was deposited in pelagic conditions.

Key words: planktonic foraminifera, Barremian, San Lucas Formation, Michoacán, Mexico.

RESUMEN

La sección Tiringueo de la Formación San Lucas, localizada en el Estado de Michoacán, es una secuencia de tipo flysch que consiste en un depósito rítmico de lutita, limolita, y arenisca gradada de media a fina, interestratificada con caliza. Esta secuencia contiene amonites, foraminíferos y radiolarios.

El análisis bioestratigráfico basado en el estudio de los foraminíferos planctónicos y amonites permitió reconocer las unidades bioestratigráficas de ambos grupos fósiles por primera vez en el Sureste de México. Aunque los foraminíferos planctónicos son escasos y pobremente conservados algunos importantes eventos como la primera aparición de Hedbergella similis, Globigerinelloides blowi y Globigerinelloides aptiensis fueron correlacionados con las zonas de amonites. Por medio de estos eventos las Zonas de Hedbergella similis y Globigerinelloides blowi partim (Barremiano temprano y tardío) fueron identificadas. La asociación faunística y las características litológicas sugieren que la Formación San Lucas (Barremiano) fue depositada en un ambiente pelágico.

Palabras clave: foraminíferos planctónicos, Barremiano, Formación San Lucas, Michoacán, México.

INTRODUCTION

Most of southwest Mexico belongs to the Guerrero Terrain, characterised by magmatic, volcanic, and sedimentary sequences typical of island arcs. The San Lucas Formation is a complex volcano-sedimentary succession of Early Cretaceous age constituted in its lower part mostly of shale, sandstone, conglomerate, and limestone, while its upper part contains volcaniclastic material (Pantoja-Alor, 1990). This formation crops out around the San Lucas town, in Michoacán State, SW Mexico (Figure 1)-, where the Tiringueo section (100º 55', 100º 45'W and 18º 40', 18º 30'N) was sampled principally to study ammonites. The same samples were used for the foraminiferal analysis reported in this work.

Early Cretaceous planktonic foraminifera are rarely reported, mainly due to the fact that samples of that age consist mainly of hard limestone which can be studied only in thin sections. The few softer samples found interbedded with hard limestone are generally rich in organic matter and pyrite, in which planktonic foraminifera are poorly preserved. Few Early Cretaceous (Barremian) planktonic foraminifera have been observed in Mexico, although Longoria (1977) in his zonal scheme for Mexico recorded the first appearance of *Globigerinelloides duboisi*, *G. blowi*, *Hedbergella excelsa*, *H. semielongata* and *H. sigali* - the upper part of the CI-5 Zone (*Nannoconus wasalli*/ *Nannoconus colomi*) in the Barremian. Besides, Omaña *et al.* (2003) reported on the Barremian planktonic foraminifera from the San Lucas Formation in Michoacán.

Studies of pre-Aptian planktonic foraminifera species have been reported by Moullade (1966) from the Lower Cretaceous in the Vocontian Basin. These microfossils appeared in the upper Hauterivian (*P. angulicostata* Zone) and continue until the base of the Aptian. *Clavihedbergella eocretacea* occurs with *H. sigali* in the upper part of the lower Barremian. Fuchs (1971) reported a more diversified fauna from the mid-Barremian including deformed specimens. Neagu (1975) recorded in Romania *Clavihedbergella eocretacea* associated with *H. sigali* from the lower Barremian and *H. aptica* from the upper Barremian based on ammonite ages and a species close to *H. similis* at the top of the Barremian

Sigal (1977), in his zonal scheme for the Tethyan Cretaceous, dated the first occurrence of the planktonic foraminifer *Favusella hauterivica* as Hauterivian, followed by undetermined species of *Hedbergella* in the upper Hauterivian (*P. angulicostata* Zone), then by *H. sigali* at the base of the Barremian, and *C. eocretacea,* which identifies a total range zone in the late early Barremian and the schackoinids in the latest part of the early Barremian.

A good record of Early Cretaceous sediments was obtained from an offshore DSDP hole drilled in Morocco (Pflaumann and Krasheninnikov, 1978). At this site, 370 individuals of *Hedbergella sigali*, *H. planispira*, *H.* aff. *gorbachikae*, *H.* aff. *infracretacea*, *Globgerinelloides aptiensis*, *G. ultramicrus*, *G. gottisi*, *Gubkinella graysonensis* and *Loeblichella moulladei* were recorded. The benthic component of the foraminiferal fauna included calcareous forms such as *Gyroidina*, *Cibicides*, lagenids and spirillinids.

Grigelis and Gorbatchik (1980) review the taxonomy of Jurassic and Early Cretaceous globigerine-like foraminifera and give a modified and amended description of the Family Favusellidae and of the genera incorporated. The range of the family is defined more precisely from the Middle Jurassic up to early Cenomanian. Salaj (1980, 1984) in Tunisia recorded *Favusella hauterivica* as the only species in the Hauterivian, but a more diversified assemblage from the Barremian was observed. Aguado *et al*. (1992) recorded a few planktonic foraminifera from the Barremian in the Betic Cordillera. Banner *et al*. (1993) described and illustrated several planktonic foraminifera of early Barremian and late Aptian ages from bore holes drilled in the central North Sea. Cecca *et al.* (1994) reported a correlation between ammonites, calcareous nannofossils, planktonic foraminifera and magnetic chrons in the upper Hauterivian–Barremian interval from the Umbría–Marche area (Central Italy). A study on the Early Cretaceous from the Río Argos in Spain (Coccioni and Premoli-Silva, 1994) demonstrated that the abundance and diversity of the planktonic foraminifera began much earlier than previously considered.

The objective of this paper is to record the foraminiferal assemblage in the lower part of the San Lucas Formation (Figure 2), in order to obtain an accurate dating of this interval. The significance of this study lies in the calibration of the Barremian planktonic foraminiferal events with the ammonite zones.

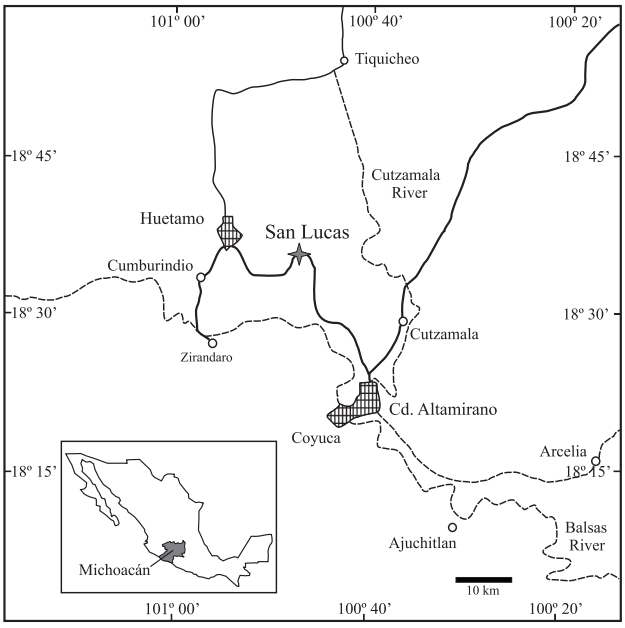

Figure 1. Geographic setting of the studied Tiringueo section, near the town San Lucas.

Geological setting and local stratigraphy

The area studied comprises a Lower Cretaceous sequence which crops out near the town of San Lucas in the south-eastern part of the state of Michoacán (Figure 1). This area belongs to the tectonostratigraphic Guerrero Terrain (Campa and Coney, 1983). The Lower Cretaceous deposit was developed within a magmatic island arc in an active margin as result of a complex process of uplift and drop of tectonic blocks affected by volcanic construction (endogenous processes), and the aerial erosion (Pantoja-Alor, 1990).

Pantoja-Alor (1959) proposed the name the San Lucas Formation for a flysch sequence composed of shale, sandstone and conglomerate, deposited over the Upper Jurassic sediments (the Zirándaro Formation), which crops out in the San Lucas Anticlinorium. The San Lucas Formation was subdivided into two parts (Pantoja-Alor, 1990). The

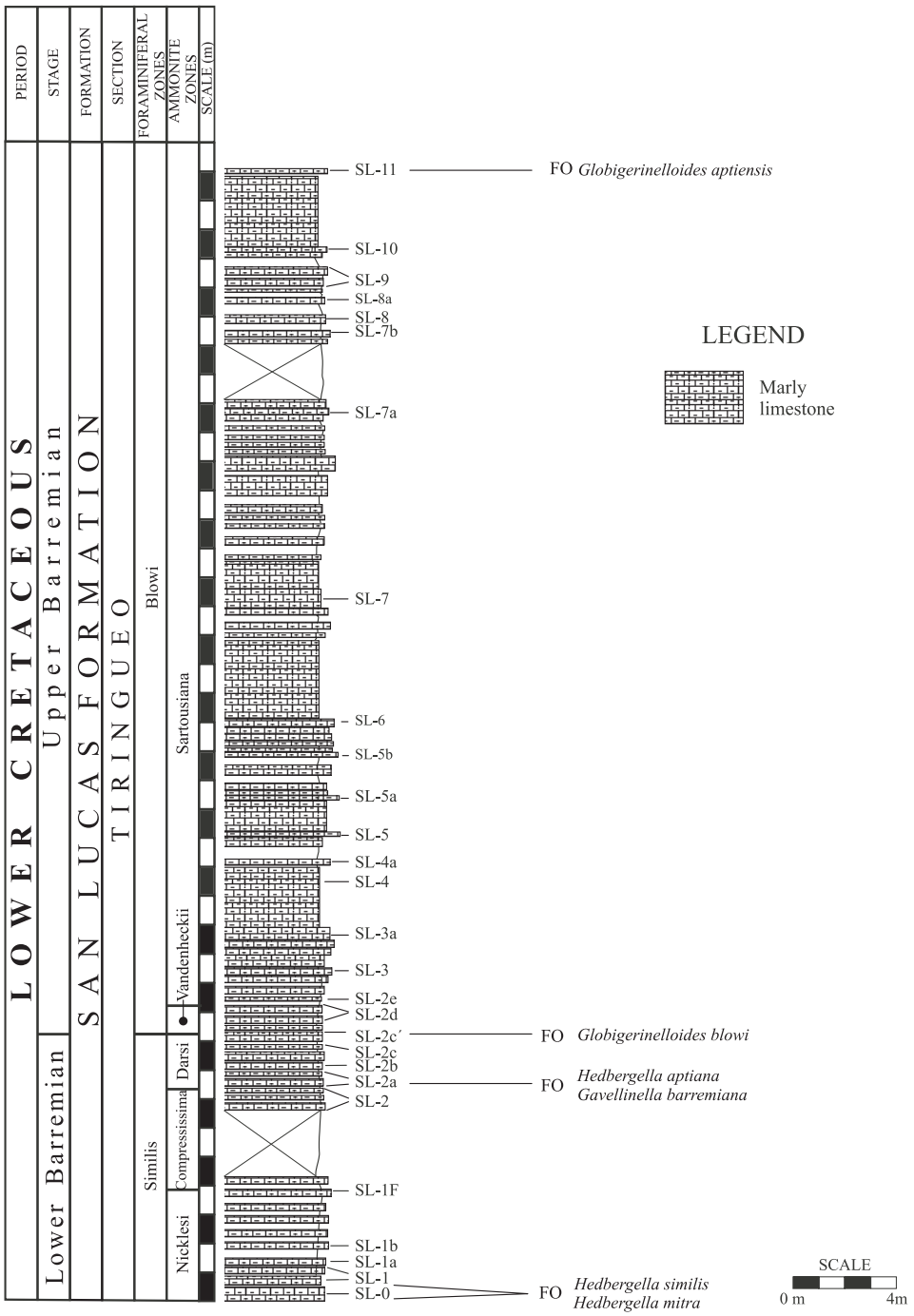

Figure 2. Stratigraphic column of the San Lucas Formation in the Tiringueo section.

lower member, Terrero Prieto, consists of shale, calcareous, fine to medium graded sandstone and conglomerate (turbidites) with biostrom rudist banks at the top. In some outcrops, a few layers of explosive volcanics and lava flows are observed, and in other beds there is evidence of soft sediment deformation, such as syndepositional slumping, convolute bedding, and flame-like structures. In the lower part of this member, ammonite and aptychi of Valanginian age have been studied. Ammonites of Barremian age have been reported from the middle part of the member (Gómez-Luna *et al.*, 1993).

The upper member, Las Fraguas, is composed of thick to massive bedded volcanic, feldspathic, and lithic sandstone with interbedded siltstone and finely grained conglomerate, which represent distal deltaic fan deposits with some turbiditic facies (Pantoja-Alor, 1990).

MATERIALS AND METHODS

The material collected from the lower part of the San Lucas Formation consists of 15 samples of calcarenites, calcareous siltstone, marly limestone and limestone (Figure 2). The samples contain ammonites and a microfaunal assemblage that consists mostly of planktonic foraminifera and radiolarians, but benthic foraminifera were also observed.

The analyses were carried out on thin sections from the limestone samples. These show a discontinuous presence of foraminifera, which are scarce and poorly preserved. Identification was difficult, but the marker species were identified, and some planktonic foraminiferal events were recorded. The textural features of the limestone were evaluated.

SYSTEMATIC PALEONTOLOGY

The identification of the species is based on morphological characteristics observed in two-dimensional axial or transverse sections. In general, the studied planktonic foraminiferal assemblage contains trochospiral hedbergellids forms which are the most important components of the association. Depending on the species, they have four to six chambers in the last whorl. Some important *Globigerinelloides* species and benthonic foraminifera are present. The described species are housed in the Paleontology Collection of the Institute of Geology (UNAM).

Planktonic Foraminifera

***Favusella hoterivica* (Subbotina)**
Figure 3.11

Globigerina hoterivica Subbotina, 1953, p. 50, pl. 1, figs. 1-4.
Caucasella hoterivica (Subbotina). Longoria, 1974, p.49, pl. 11, figs. 9-11, 14-16
Globuligerina hoterivica (Subbotina). Sliter, 1999, p. 33, pl. 1, fig. 1.
Favusella hoterivica (Subbotina). Premoli-Silva and Sliter, 2002, p. 394, pl. 157, fig. 1.

Description. Test small globigeriniform trochospiral, 2– 2.5 whorls of globular chambers; 3.5–4 chambers in the last whorl, increasing rapidly in size except the last chamber which displays almost the same size as the penultimate one; equatorial periphery compact slightly lobate; sutures radial and depressed on both sides.

Remarks. The illustrated specimen from San Lucas Formation is comparable to the Calera Limestone (Sliter, 1999).

***Hedbergella aptiana* Bartenstein**
Figure 3.5

Hedbergella aptiana Bartenstein, 1965, p. 337, text-figs. 4–6. Sliter, 1999, p. 333, pl. 1, fig. 4.

Description. Test small with low trochospire, nearly planispiral with 5–5.5 moderately enlarging subglobular chambers in the last whorl, periphery lobulate.

Remarks. *Hedbergella aptiana* differs from *H. delrioensis* by having a depressed inner spire; a lower growth rate in the last chambers, and more depressed sutures perpendicular to the inner spire.

***Hedbergella excelsa* Longoria**
Figure 3.2

Hedbergella excelsa Longoria, 1974, p. 55, pl. 18, figs. 6–8, 9–11, 14–16.

Description. Test small to medium size with high trochospire, generally six globular chambers in the last whorl increasing gradually in size; earlier chambers in higher plane than the ultimate whorl.

Remarks. *Hedbergella excelsa* is differentiated from *Hedbergella aptiana* by having a higher inner spire.

***Hedbergella mitra* (Banner and Dessai)**
Figure 3.4

Blefuscuiana mitra Banner and Dessai, 1988, p. 157, pl. 3, fig. 10, pl. 4, figs. 1–4.
Hedbergella mitra (Banner and Dessai). Premoli-Silva and Verga, 2004, p. 239, pl. 9, fig. 6.

Description. Test small, low to depressed trochospire with 6 chambers in the last whorl; globular chambers very

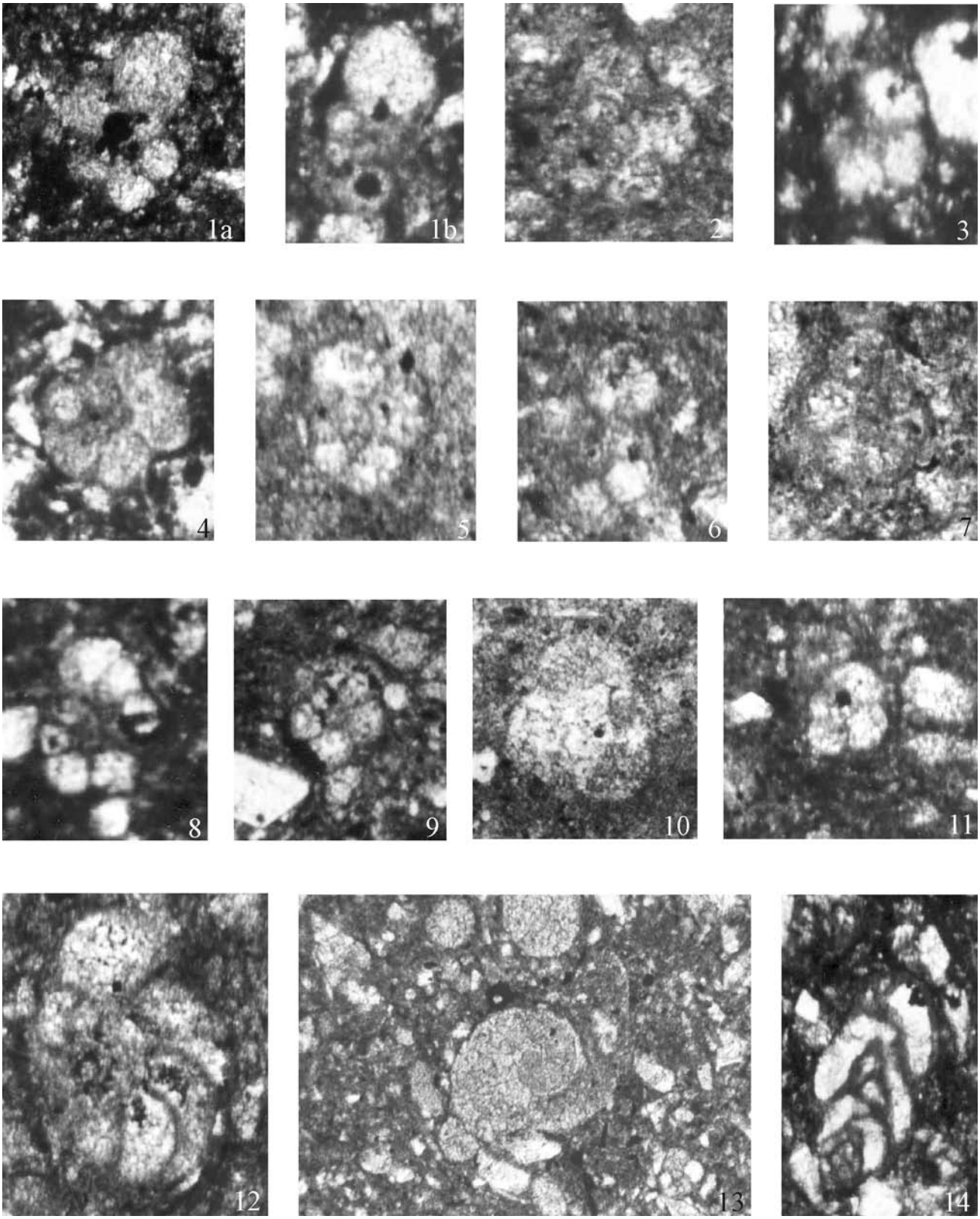

Figure 3. Barremian planktonic foraminifera from the San Lucas Formation. 1a, 1b: *Hedbergella similis* Longoria (SL-0), 160X; 2: *Hedbergella excelsa* Longoria (SL-11), 163X; 3: *Hedbergella* gr. *sigali* Moullade (SL-0), 175X; 4: *Hedbergella mitra* (Banner and Dessai) (SL-0), 175X; 5: *Hedbergella aptiana* Bartenstein (SL-2A), 200X; 6: *Globigerinelloides blowi* Longoria (SL-2C'), 175X; 7: *Globigerinelloides aptiensis* Longoria (SL-11), 140X; 8: *Globigerinelloides paragottisi* Verga and Premoli-Silva (SL-0), 240X; 9: *Globigerinelloides* sp. (SL-0), 220X; 10: *Gorbachikella* sp. (SL-11), 100X; 11: *Favusella hoterivica* (Subbotina) (SL-2A); 12: *Gavellinella barremiana* Bettenstaedt (SL-2A), 160X; 13: Ammonite, foraminiferal and radiolarian assemblage (SL-0), 80X; 14: Benthonic foraminifer (SL-0), 160X.

gradually and slowly increasing in size as added, sutures radial straight and depressed.

Remarks. *Hedbergella mitra* differs from *H. similis* for possessing a more depressed inner spire and less lobate periphery.

***Hedbergella* gr. *sigali* Moullade**
Figure 3.3

Hedbergella sigali Moullade, 1966, p. 87, pl. 7, figs. 20–25. Sliter, 1999, p. 333, pl. 1, fig. 2–3; Premoli-Silva and Verga, 2004, p. 251, pl. 21, fig. 12.

Description. Test small with 4 to 4.5 globular chambers in the last whorl increasing gradually in size as added, periphery broadly rounded, umbilicus narrow; sutures radial and straight on spiral and umbilical sides; primary aperture a low arch, extraumbilical bordered by a lip.

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

***Hedbergella similis* Longoria**
Figures 3.1a, 3.1b

Hedbergella similis Longoria, 1974, p. 68, pl. 16, figs. 10–21, pl. 18, figs. 12, 13, pl. 23, figs. 14–16. Sliter, 1999 p. 335, pl. 3, figs. 6, 13.

Description. Test small to medium low trochospiral, with five to six chambers in the last whorl initially globular then elongate gradually increasing in size as added, peripheral margin lobate, ovoid in peripheral view; sutures radial, slightly curved, depressed on both umbilical and spiral sides.

Remarks. *Hedbergella similis* is differentiated from *Hedbergella semielongata* by having a depressed inner spire and more chambers in the last whorl. The specimens identified as *Hedbergella similis* from the Tiringueo locality could be comparable to the transversal section illustrated by Sliter (1999).

***Globigerinelloides aptiensis* Longoria**
Figure 3.7

Globigerinelloides aptiense Longoria, 1974, p. 79, pl. 4, figs. 9–10, pl. 8, figs. 4–6, 17, 18. Sliter, 1999, p. 334, pl. 2, figs. 8, 9.
Globigerinelloides aptiensis Longoria. Premoli-Silva and Verga, 2004, p.239, pl. 9, fig. 6.

Description. Test evolute, small, peripheral outline subcircular lobate, with six globular chambers in the last whorl, sutures radial and depressed, relict apertures and flaps could be observed.

Remarks. *Globigerinelloides aptiensis* differs from *Globigerinelloides blowi* by having more numerous chambers in the last whorl and slow growth rate resulting in a lobate test. The spiral view of the specimen observed is comparable to the illustration of Premoli-Silva and Verga (2004).

***Globigerinelloides blowi* (Bolli)**
Figure 3.6

Planomalina blowi Bolli, 1959, p. 260, pl. 20, figs. 2–6
Globigerinelloides blowi (Bolli). Longoria, 1974 p. 82, pl. 4, figs. 4, 7, 11–13; Sliter, 1999, p. 334, pl. 2, fig. 2; Premoli-Silva and Verga, 2004, p. 239, pl. 9.10.

Description. Test small, planispiral biumbilicate involute. Globular chambers four to five in the last whorl increasing rapidly in size. Peripheral outline circular. Sutures radial deeply depressed.

Remarks. *Globigerinelloides blowi* differs from *G. paragottisi* by having globular chambers and more circular peripheral outline as well as a small but deeper umbilicus. The axial section of *Globigerinelloides blowi* is comparable to the photography presented by Sliter (1989).

***Globigerinelloides paragottisi* Verga and Premoli-Silva**
Figure 3.8

Globigerinelloides gottisi (Chevalier). Longoria, 1974, p. 85, pl. 7, figs. 12, 13.
Globigerinelloides paragottisi Verga and Premoli-Silva, 2003, p. 332, figs. 7.7ab, 7.3ab, 7.5ab. Premoli-Silva and Verga, 2004, p. 240, pl. 10, fig. 2.

Description. Test small planispiral with 5–5.5 (usually 5) chambers in last whorl increasing rapidly in size; chambers globular to subglobular, inflated in lateral view; equatorial periphery ovoid moderately lobate; sutures straight, slightly depressed and radial; umbilical area rather shallow and wide.

Remarks. This species was proposed by Verga and Premoli-Silva (2003) for some specimens previously identified in the literature as *G. gottisi*, the holotype of which is considered for them attributable to *Globigerinelloides blowi* (Bolli)

***Globigerinelloides* sp.**
Figure 3.9

Description. Test small, distinctly compressed, with 5 subglobular chambers in the last whorl increasing fast in size as added, umbilicus shallow. Peripheral outline ovoid subcircular. Sutures straight, radial and depressed.

***Gorbachikella* sp.**
Figure 3.10

Description. Test trochospiral, aperture semi-circular in shape with a thin rim, with four chambers in last whorl. The observed specimens are similar those illustrated by Premoli-Silva and Verga (2004).

Benthonic Foraminifera

***Gavellinella barremiana* Bettenstaedt**
Figure 3.12

Gavellinella barremiana Bettenstaedt, 1952, p. 275, pl. 2, fig. 27, pl. 2, figs. 26, 28, 29. Bolli *et al.*, 1994, p. 33, figs. 10. 35-39.

Description. Test trochospiral with 7.5–9 chambers in the last whorl with curved sutures, resulting in narrow chambers.

CORRELATION BETWEEN THE AMMONITE ZONES AND THE PLANKTONIC FORAMINIFERAL EVENTS.

The Tiringueo section contains abundant and well preserved ammonites which allow the recognition of most of the zones proposed by Hoedemaker *et al.* (2003). According to Ramírez–Garza (2003), the lower beds of the Tiringueo section can be assigned to the ammonite *Kotetishvilia nicklesi* Zone (lower Barremian) (SL-0-SL-1F). In this interval, the planktonic foraminifera are more abundant and larger in size than the specimens observed in the subsequent levels, and we recorded *Hedbergella similis* together with other foraminifera such as *Hedbergella mitra*, *H.* gr. *sigali*, *Globigerinelloides paragottisi*, *Globigerinelloides* sp. and *Gorbachikella* sp. Some benthonic foraminifera and radiolarians were observed (Figures 3.13 and 3.14).

Immediately above of this section, the *Kotetishvilia compressissima* Zone (level SL-1F- SL 2) was recognized. This interval is characterised by no identifiable pyritized foraminifera. The ammonite *Coronites darsi* Zone (level SL-2-SL-2C; lower Barremian) was defined upward in the studied section. In SL-2A' we found *Hedbergella aptiana*, *Favusella hoterivica*, and also the benthic foraminifera *Gavellinella barremiana* and *Lenticulina* sp. as well as abundant radiolarians. The following level corresponds to the *Ancyloceras vandenheckii* Zone (level SL-2C' SL-2D; upper Barremian), where *Globigerinelloides blowi* was first recorded (SL-2C'). Finally, the *Gerhardtia sartousiana* Zone (level SL-2D to SL-11; upper Barremian) was recognised. In the level SL-11, the foraminiferal assemblage contains scarce specimens of planispiral forms with six chambers identified as *Globigerinelloides aptiensis*; *Hedbergella excelsa* also appears.

These planktonic foraminiferal events could be correlated with the record of planktonic foraminifera found in Mexico (Longoria, 1977) and Río Argos (Coccioni and Premoli-Silva, 1994). The events observed in the Tiringueo section are difficult to correlate with the CI-5 Zone (*Nannoconus wasalli*/*Nannoconus colomi*), proposed by Longoria (1977) for the Barremian. This author reported the first appearance of *Globigerinelloides duboisi*, *G. blowi*, *Hedbergella excelsa*, *H. semielongata*, and *H. sigali*, but only in the upper part of this zone. However, some events can be correlated with the foraminiferal occurrences in Río Argos (Coccioni and Premoli-Silva, 1994). Thus, in the Tiringueo section the first occurrence of *Hedbergella similis* is in the *Kotetishvilia nicklesi* Zone (early Barremian), this event is consistent with the finding from the Río Argos site (Coccioni and Premoli-Silva, 1994). *Globigerinelloides blowi* first appears in the lower part of the ammonite *Ancyloceras vandenheckii* Zone (late Barremian), while at the Río Argos it was recorded later, at the top of the same ammonite zone. The first appearance of *Globigerinelloides aptiensis* was recorded in the *Gerhardtia sartousiana* Zone, which is earlier than in the Río Argos section, where this foraminifer species was registered in the *H. feraudianus* Zone.

Planktonic foraminifera and ammonites were studied using the same samples, allowing a direct correlation between both groups. Although planktonic foraminifera from the Tiringueo section were generally scarce, poorly preserved and unevenly distributed, it was possible to record several foraminiferal events which have been correlated with the ammonite zones. The first one is the FO (First Occurrence) of *Hedbergella similis*. This event indicates the *Hedbergella similis* Zone, where the first appearance of forms with clavate chambers occurs (Premoli-Silva and Sliter, 1999). Another important event is the FO of *Globigerinelloides blowi*, which has been used as a boundary marker to distinguish the later zone. On the basis of these foraminiferal data, two zones were identified, *Hedbergella similis* Zone (early Barremian) and *Globigerinelloides blowi* Zone (*partim*) (late Barremian), according to the zonal schemes of Sliter (1989, 1999), Coccioni and Premoli-Silva (1994), Robaszynski and Caron (1995), and Premoli-Silva and Verga (2004). Moreover, the FO of *Globigerinelloides aptiensis* and *Hedbergella excelsa* were recorded.

Depositional and environmental interpretation

The main lithology of the Tiringueo section consists of calcarenite in the lower part, followed above by calcareous silstone with pellets and pyrite. The overlying beds are composed of calcarenite and limestone. The limestone is predominantly wackestone with foraminifera and radiolarian. The lithology and faunal association suggest a pelagic deposit in an open marine environment.

CONCLUSIONS

The Tiringueo sequence of the San Lucas Formation represents an important record of Early Cretaceous deposits in SW Michoacan State, characterised by pelagic facies. The integrated study of planktonic foraminifera and ammonites dated this succession as early and late Barremian and made possible a correlation between the foraminiferal planktonic events and the ammonite zonal scheme.

Despite of the poor state of preservation of the planktonic foraminifera, different species of *Hedbergella*, *Globigerinelloides* and other foraminifera have been identified and described in thin section.

The planktonic foraminiferal assemblage is similar in content and stratigraphic distribution to the fauna of some European localities such as Río Argos (Coccioni and Premoli-Silva, 1994), where studies on the Lower Cretaceous planktonic foraminifera have provided an important contribution to knowledge of the evolution of the group.

ACKNOWLEDGMENTS

This paper is a contribution to the project DGAPA -PAPIT IN103799. We are deep grateful to the anonymous referees for the critical review and useful comments which greatly improved the manuscript. We acknowledge Ana Bertha Villaseñor and Pedro García Barrera for assisting in the field work . We thank Barbara Martiny for the English revision and Diego Aparicio for preparing the thin sections.

REFERENCES

Aguado, R., Company M., O'Dogherty, L., Sandoval, J., Tavera, J.M., 1992, Biostratigraphic analysis of the pelagic Barremian/Aptian in the Betic Cordillera (southern Spain); preliminary data: Cretaceous Research, 13, 445–452.

Banner, F. T., Dessai, D.A., 1988, Review and revision of the Jurassic-Early Cretaceous Globigerininae with the special reference to the Aptian assemblages of Speeton (North Yorkshire, England): Journal of Micropalentology, 7, 143-185.

Banner, F.T., Copestake, P., White, M.R., 1993, Barremian–Aptian Praehedbergellidae of the North Sea area; a reconnaissance: Bulletin of the Natural History Museum, Geology Series, 49, 1–30.

Bartenstein, H., 1965, Taxonomische Revision und Nomenklator zu Franz E. Hetch "Standard-Gliederung der Nordwestdeutschland Unterkreide nach Foraminiferen" (1938) Teil 4: Senckenbergiana Lethaea, 46, 327-366.

Bettenstaedt, F., 1952, Stratigraphisch wichtige Foraminiferen-Arten aus dem Barrême vorwiegend Nordwest-Deutschlands: Senckenbergiana, 33, 263-295.

Bolli, H.M., 1959, Planktonic Foraminifera from the Cretaceous of Trinidad: Bulletins of American Paleontology, 39, 257-277.

Bolli, H.M., Beckmann, J.-P., Saunders, J.B., 1994, Benthic Foraminiferal biostratigraphy of the south Caribbean region: Cambridge, UK, Cambridge University Press, 408 p.

Campa, M.F., Coney, P.J., 1983, Tectono-stratigraphic terrenes and mineral resource distributions in Mexico: Canadian Journal of Earth Sciences, 20, 1040–1051.

Cecca, F., Pallini, G., Erba, E., Premoli-Silva I., Coccioni, R., 1994, Hauterivian–Barremian chronostratigraphy based on ammonites, nannofossils, planktonic foraminifera and magnetic chrons from the Mediterranean domain: Cretaceous Research, 15, 457–467.

Coccioni, R., Premoli-Silva, I., 1994, Planktonic foraminifera from the Lower Cretaceous of Rio Argos sections (southern Spain) and biostratigraphic implications: Cretaceous Research, 15, 645–647.

Fuchs, W., 1971, Eine alpine Foraminiferenfauna des tieferen Mittel-Barreme aus den Drusbergschichten vom Ranzenberg bei Hohennems in Vorarlberg: Abhandlungen der Geologischen Bundesanstalt, 27, 49 p.

Gómez-Luna, M.E., Contreras-Montero, B., Guerrero-Suastegui, M., Ramírez-Espinosa, J., 1993, Ammonitas del Valanginiano superior, Barremiano de la Formación San Lucas en el área de Huetamo, Michoacán: Revista de la Sociedad Mexicana de Paleontología, 6(1), 57–65.

Grigelis, A., Gorbatchik, T., 1980, Morphology and taxonomy of Jurassic and Early Cretaceous representatives of the Superfamily Globigerinacea (Favusellidae): Journal of Foraminiferal Research, 10, 180–190.

Hoedemaeker, Ph.J., Reboulet, S., Aguirre-Urreta, M.B., Alsen, P., Aoutem, M., Atrops, F. Barragan, R., Company, M., González-Arreola, C., Klein, J., Lukeneder, A., Ploch, I., Raisossadat, N., Rawson, P.F., Ropolo, P., Vašíček, Z., Vermeulen, J., Wippich, M., 2003, Report of 1st International Workshop of the IUGS Lower Cretaceous Ammonite Working Group, the "Kilian" Group (Lyon, 11 July 2002): Cretaceous Research, 24, 1–6.

Longoria, J.F., 1974, Stratigraphic, morphologic and taxonomic studies of Aptian planktonic foraminifera: Revista Española de Micropaleontología, Número Extraordinario, 150 p.

Longoria, J.F., 1977, Bioestratigrafía del Cretácico Inferior basada en microfósiles planctónicos: Boletín de la Sociedad Geológica Mexicana, 38, 1–17.

Moullade, M., 1966, Etude stratigraphique et micropaléontologique du Crétacé inférieur de la «Fosse Vocontienne»: Lyon, Documents du Laboratoire de Géologie, Faculté des Sciences, 15, 369 p.

Neagu, T., 1975, Monographie de la faune des foraminifères éocrétacés de Couloir de Dimboviciora, de Codlea et des Monts Persani (Couches de Carhaga): Bucarest, Institut de Géologie et Géophysique, Mémoires, 25, 144 p.

Omaña, L., González-Arreola, C., Ramírez-Garza, B.M., 2003, Barremian planktic foraminiferal biostratigraphy of the San Lucas Formation, Michoacán (SW Mexico), *in* 99th Meeting, Geological Society of America, Cordilleran Section, Puerto Vallarta, Jal., April 1–3: Geological Society of America, Abstracts, 35(4), p. 31.

Pantoja-Alor, J., 1959, Estudio geológico de reconocimiento de la región de Huetamo, Estado de Michoacán: Boletín del Consejo de Recursos no Renovables, 50, 36 p.

Pantoja-Alor, J., 1990, Redefinición de las unidades estratigráficas de la secuencia mesozoica de la Región de Huetamo–Ciudad Altamirano, Estados de Michoacán y Guerrero, *in* 10th Convención Geológica Nacional: México, D.F., Sociedad Geológica Mexicana, Memoria, p. 66.

Pflaumann, U., Krasheninnikov, V.A., 1978, Early Cretaceous planktonic foraminifera from eastern North Atlantic, DSDP Leg 41, *in* Gardner, J., Herring, J. (eds.), Abidjan, Ivory Coast, to Malaga, Spain, February–April 1975: College Station, TX, Texas A & M University, Ocean Drilling Program, Initial Reports of the Deep Sea Drilling Project, 41, 539-564.

Premoli-Silva, I., Sliter, W.V., 1999, Cretaceous paleoeoceanography: Evidence from planktonic foraminiferal evolution, *in* Barrera, E., Johnson, C.C. (eds.), Evolution of the Cretaceous: Geological Society of America, Special Paper, 332, 301–328

Premoli-Silva, I., Sliter, W.V., 2002, Practical manual of Cretaceous Planktonic Foraminifera, *in* Premoli-Silva, I., Rettori, R. (eds.), International School on Planktonic Foraminifera, 1st Course, Cretaceous: Perugia, Italy, Dipartimento di Scienze della Terra.

Università degli Studi di Perugia, 462 p.

Premoli-Silva, I., Verga, D. 2004, Practical Manual of Cretaceous Planktonic Foraminifera, *in* Verga, D., Rettori, R. (eds), International School on Planktonic Foraminifera: Perugia, Italy, Tipografia Ponte Felcino, Universities of Perugia and Milan, 3th Course, 283 p.

Ramírez-Garza, B.M., 2003, Nuevos datos sobre la biostratigrafía basada en el estudio de la Familia Pulchelliidae del Barremiano (Cretácico Inferior) de la Región de Huetamo Michoacán: Puebla, Benemérita Universidad Autónoma de Puebla, Tesis Licenciatura, 97 p.

Robaszynski, F., Caron, M., 1995, Foraminifères planctoniques du Crétacé; commentaire de la zonation Europe-Méditerranée: Bulletin de la Société Géologique de France, 166(6), 681–692.

Salaj, J., 1980, Microbiostratigraphie du Crétacé et du Paléogène de la Tunisie septentrionale et orientale (Hypostratotypes tunisiens): Bratislava, Geologický Ústav Dionyza Stura, Slovenskej Akadémie vied v Bratislave, 238 p.

Salaj, J., 1984, Foraminifers and detailed microbiostratigraphy of the boundary beds of the Lower Cretaceous stages in the Tunisian Atlas: Geologický Zbornik, 35, 583–599

Sigal, J., 1977, Essai de zonation de Crétacé méditerranéen à l'aide des foraminifères planctoniques: Géologie Méditerranéene, 4, 99–108.

Sliter, W.V., 1989, Biostratigraphic Zonation for Cretaceous planktonic foraminifers: Journal of Foraminiferal Research, 19, 1–19.

Sliter, W.V., 1999, Cretaceous planktic foraminiferal biostratigraphy of the Calera Limestone, northern California, USA: Journal of Foraminiferal Research, 29, 318–339.

Subbotina, N.N., 1953, Fossil Foraminifera of the USSR: Globigerinidae, Hantkeninidae and Globorotaliidae (in Russian): Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geologo-razvedochnogo Instituta (VNIGRI), 76, 294 p.

Verga, D., Premoli-Silva, I., 2003, Early Cretaceous planktonic foraminifera from the Tethys; the small, few-chambered representatives of the genus *Globigerinelloides*: Cretaceous Research, 24, 305–334.

Manuscript received: February 11, 2004
Corrected manuscript received: October 22, 2004
Manuscript accepted: November 11, 2004