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Orbitolina-bearing beds in Albian Mal Paso Formation, Chumbítaro, Michoacán, SW Mexico

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Abstract

The Mal Paso Formation crops out in the Chumbítaro region in the state of Michoacán. It comprises a lower and an upper member. The upper member is a calcareous deposit with *Orbitolina*-bearing beds containing an abundant foraminiferal association, mostly composed of *Mesorbitolina texana* (Roemer, 1849), *Nezzazata isabellae* Arnaud-Vanneau and Sliter 1995, *Arenobulimina* cf. *A. chapmani* Cushman, 1936, *Glomospira* sp. and *Istriloculina* sp.; moreover corals and echinoids are also present. Based on the stratigraphic range of the species *Mesorbitolina texana,* part of the formation is assigned an early Albian age. The orbitolinid larger foraminifera are excellent age markers for correlation of lower and mid-Cretaceous platforms. The wackestone–packstone textured limestone and the larger benthic assemblage suggest a shallow-water platform deposit. *M. texana* is regarded as a cosmopolitan Tethysian species.

Keywords: *Mesorbitolina texana*, early Albian, Mal Paso Formation, Chumbítaro, SW Mexico.

Resumen

La Formación Mal Paso aflora en la región de Chumbítaro, en el Estado de Michoacán, y comprende un miembro inferior y un miembro superior. El miembro superior es un depósito calcáreo con estratos con Orbitolina que contienen una abundante asociación de foraminíferos compuesta principalmente de Mesorbitolina texana (Roemer, 1849), además Nezzazata isabellae Arnaud-Vanneau y Sliter, 1995, Arenobulimina cf. A. chapmani Cushman, 1936, Glomospira sp. e Istriloculina sp.; además corales y equinodermos están también presentes. Con base en el alcance estratigráfico de la especie Mesorbitolina texana, una parte de la formación es asignada una edad Albiano temprano. Los macroforaminíferos orbitolínidos son excelentes marcadores de edad usados para correlaciones en las plataformas del Cretácico Inferior y medio. La textura y la asociación de foraminíferos sugiere un depósito de plataforma de agua somera. M. texana es considerada como una especie cosmopolita Tethysiana.

Palabras clave: Mesorbitolina texana, Albiano temprano, Formación Mal Paso, Chumbítaro, SO México.

1. Introduction

The Orbitolinidae is a large, significant benthic foraminiferal family that developed during the Early and mid-Cretaceous. It shows a relatively rapid evolutionary trend, as observed in the embryonic structures, which provides valuable biostratigraphic information (Arnaud-Vanneau, 1998; Schroeder and Neumann, 1985; Schroeder *et al*., 2010). The family Orbitolinidae was established by Martin (1889). This author also described the internal structure of *Orbitolina*, which had been previously mentioned by d'Orbigny (1850). Egger (1899) was the first to depict the embryonic apparatus. Henson (1948) studied the structure of the megalospheric embryo in detail. Douglass (1960) revised the family Orbitolinidae and proposed some new species of the genus *Orbitolina*. Schroeder (1962) emphasized the significance of the internal structure of the embryonic apparatus. He divided the genus *Orbitolina* into subgenera *Orbitolina* and *Mesorbitolina* based on characteristics of the embryonic apparatus. Schroeder *et al*. (2010) claim, "the structures of the embryonic apparatus of the large orbitolinid foraminifers are valuable distinctive markers that allow a definition of different species and the establishment of phylogenetic lineages." Species of this family flourished in shallow-marine carbonate environments of the Tethys region.

The purpose of this paper is to date the larger benthic foraminiferal assemblage recovered from *Orbitolina*-bearing beds of the upper member of the Mal Paso Formation, which is mostly composed of *Mesorbitolina texana* (Roemer, 1849). In addition, the paleoenvironment is inferred based on a study of the microfacies. The age calibration of part of the upper member of the Mal Paso Formation contributes to improving chronostratigraphic knowledge of the Cretaceous sedimentary sequence, which is poorly known in Michoacán state.

2. Geological setting

Most of the southwestern margin of Mexico is situated in the Guerrero Terrane (Campa and Coney, 1983), which is a typical island arc characterized mostly by submarine and locally subaerial volcanic and sedimentary successions that range in age from Jurassic (Tithonian) to middle-late Cretaceous (Cenomanian), with scarce exposure of older rocks (Centeno García *et al*., 2008).

The Mal Paso Formation described by Pantoja Alor (1959) is located in the Guerrero Terrane; it is a thick succession (750 – 1000 m), including clastic and calcareous rocks. This unit conformably overlies the platform limestone of the El Cajón Formation and is covered by the deltaic sequence of the Cutzamala Formation through an angular unconformity. Based on the lithology, the Mal Paso Formation is divided informally into two different lithostratigraphic and depositional units: the lower unit consists of a sequence of medium to thick-bedded, yellowish quartz feldspathic and lithic sandstone, and the upper calcareous member yields diverse and abundant invertebrates. The Mal Paso Formation was deposited in a tectonically active island-arc setting; the lithology, sedimentology, and paleontology suggest that the upper member of the Mal Paso Formation represents a transgressive marine sequence (Filkorn, 2002). The age of the upper member of the Mal Paso Formation has been defined as late Albian–early Cenomanian based on its stratigraphic position; although it contains a great diversity of fossils, few are useful for an accurate dating. The gastropods suggest an Albian age (Buitrón Sánchez and Pantoja Alor, 1994, 1996, 1998), as do the echinoids (García-Barrera and Pantoja-Alor, 1991). Ayala-Castañares (1960) describes *Orbitolina morelensis* as a new species, and collected approximately 300 m to the north of the village of Mal Paso, defining the age of this succession as lower Albian. The *Mexicaprina* rudist occurrence determines a late Albian–early Cenomanian age for this interval (Filkorn, 2002). Recently Filkorn and Scott (2011) dated this member as late Albian based on the assemblage composed of rudists, foraminifers and algae.

3. Material and Methods

The samples were collected from the upper member of the Mal Paso Formation (*Orbitolina*-bearing beds) in the Chumbítaro region. Its geographical coordinates are 18° 31' 0" N, 100° 45' 0" W. It is located in the municipality of San Lucas in the state of Michoacán (Figure 1). For micropaleontological and microfacies analysis, the samples were prepared in thin sections 50 µm thick. The faunal preservation is good, which allowed accurate identification of the foraminifers that were used for age assignment. In addition, a microfacies study was carried out to reconstruct the paleoenvironment.

4. Foraminiferal assemblage

A foraminiferal assemblage, principally composed of *Mesorbitolina texana* (Roemer, 1849) also containing *Nezzazata isabellae* Arnaud-Vanneau and Sliter, 1995, *Arenobulimina* cf. *A. chapmani* Cushman, 1936, *Glomospira* sp. and *Istriloculina* sp., was observed in samples from the Orbitolina-bearing beds (Figure 2 a-i).

5. Taxonomic notes

There is a discrepancy between the assignment of the species *Orbitolina texana* proposed by Roemer (1849) as later described by Douglass (1960), and Schroeder's (1975) attribution of the species to *Mesorbitolina subconcava* (Leymerie, 1878). On the other hand, Moullade and Saint-

Marc (1975) and Moullade *et al*. (1978) refuted the validity of the species *Mesorbitolina subconcava* re-defined by Schroeder (1975).

The identification of *Mesorbitolina texana* is based on size and morphology of the test, as well as the structure of the embryonic apparatus. Taking into account the arrangement and size of the protoconch, deuteroconch and subembryonic zones, we follow the criterion of Douglass (1960) and Moullade and Saint-Marc (1975) to define this species. In addition, we include morphological and size (test and embryon) differences from *Mesorbitolina subconcava*.

Description. This species is characterized by having a conical test, with pointed apex. The base is convex; it has a maximum diameter of 4 mm and a height of 2 mm. The embryonic apparatus is composed of a protoconch, deuteroconch and subembryonic zones. The protoconch is

Figure 1. Geographic Google map showing the location of the area studied.

hemispheric, maximum diameter 0.20 mm; the deuteroconch and subembryonic zones are, more or less equally thick and are subdivided by few anastomosing septules.

Remarks. The specimens illustrated in this paper differ from *Mesorbitolina subconcava* by having both the test and embryonic apparatus smaller, and less evolved morphology, while the exemplars of *M. subconcava* presented by Schroeder and Neumann (1985, pl. 37) have a more oval and flattened test and the dimensions of all the structures larger. For example, the test has a maximum diameter of 8.6 mm and height up to 1.3 – 2.2 mm. The protoconch is flatter, measuring up to 0.25 mm and the deuteroconch has a more developed alveolar layer, with maximum diameter 0.4 to 0.5 mm.

6. Age

Mesorbitolina texana is characteristic of the lower Albian of the Glen Rose Formation (Schroeder and Neumann, 1985 p. 78; Scott and González León, 1991, p. 55); however, in the Mediterranean area, this species ranges from the uppermost Aptian to basal upper Albian, but in the Gulf Coast *Mesorbitolina texana* occurs with early Albian ammonites (Scott and González León, 1991, p. 55). Madhavaraju *et al*. (2013) suggested an early Albian age based on the occurrence of *Colomiella recta* and *Calpionellopsella maldonadoi*, and larger foraminifera *Mesorbitolina texana* in the Canova member of the Mural Formation in northern Sonora. Schroeder (1975) indicated that *Mesorbitolina texana* has a well-established late Aptian–early Albian age range. In the Pyrenees region, it is reported for the end of the middle Albian (Peybernès, 1976, identified as *M. minuta*). According to the Groupe de Travail Européen des Grands Foraminifères (1981, p. 385), *M. texana* ranges from late Aptian to middle Albian. Husinec *et al*. (2000) and Husinec and Sokac (2006) recognized a *Mesorbitolina texana* Zone in the early Albian from Croatia. Dozet and Sribar (1997) proposed an *Orbitolina* (*M.*) ex gr. *texana* Cenozone in southeastern Slovenia. Their stratigraphic range is defined as lower Albian. Schroeder *et al*. (2010) proposed a Barremian–Aptian zonation from the eastern Arabian and northeastern African plates including offshore Abu Dhabi, Ethiopia, southwest Iran, Oman, Somalia and Yemen. They indicated a late Aptian age for the *Mesorbitolina texana* Zone. Frequent occurrence of the orbitolinid *M. texana*, which is assigned to the late Aptian (Marian and Bucur, 2012), is documented from the calcareous deposits in the eastern Carpathians (Romania). Shirazi and Abedi (2013) in Iran identified a *M. texana* assemblage Zone in strata dating as uppermost Aptian–lower Albian. In Oman, bed I of the early Albian from the Nahr Umr formation is marked by *Mesorbitolina texana* (Jones, 2006, p. 70). The stratigraphic distribution of *Mesorbitolina texana* ranges from the Mediterranean areas to the New World; it could be due to the dispersion that took place from E to W, facilitated by Tethyan transoceanic currents, and may be related to the meroplanktonic stage of the megalospheric embryos. This dispersion caused the species to arrive to America later than what was claimed by Cherchi (2004). In this paper, we assign an early Albian age, consistent with the view of Scott and González León (1991, p. 55), who indicate the same age. In addition, the isotopic numerical age of *M. texana* specimens in the Trinity Group was used, which spans from 113.70 to 108.19 Ma (Scott, 2014).

Orbitolina-bearing beds are located between two well-defined horizons, delimited at the bottom by the El Cajón Formation, dated as lower Aptian (Omaña and Pantoja Alor, 1998), and at the top by part of the Mal Paso Formation, defined as upper Albian (Filkorn and Scott, 2011). For comparison, the middle Albian succession in the El Abra Platform is characterized by a foraminiferal assemblage composed of *Dictyoconus walnutensis* – *Paracoskinolina sunniladensis* without occurrence of *Mesorbitolina texana*. This finding is important because it contributes to the integration of the stratigraphy of the region, since the El Cajón Formation, as the oldest unit, is dated as early Aptian, while part of the overlying Mal Paso Formation is considered upper Albian; so, the *Orbitolina*-bearing beds of early Albian age in the middle part would complete the sequence.

7. Paleoecology

The recent larger foraminifera are distributed in tropical and subtropical regions, and are most abundant in nutrient-deficient environments in warm shallow-water seas (BouDagher-Fadel, 2008). Murray (2006) stated, “the controls on global distribution are thought to be water temperature, nutrient content, light intensity and hydrodynamic energy.” It is usually considered that the orbitolinids could have had symbiotic algae in the periphery (marginal zone) of the test (Hottinger, 1997). The light essential for their symbionts determines the depth distribution of these larger foraminifers as a water-depth proxy, indicating a shallow-water oligotrophic setting. Despite this, Birkeland (1998) and Vilas *et al*. (1995) considered that these foraminifers lived in mesotrophic conditions with high nutrient input, suggesting that they were tolerant of a variety of different environmental settings. The ecology of fossil larger foraminifera without equivalent recent forms may be inferred from their size, morphostructure, and test architecture. Orbitolinids such as *Palorbitolina* and *Mesorbitolina* are characterized by having a conical test, which suggests a free epifaunal mode of life (Masse, 1976), living on soft substrates with the flat base of their conical test on the apertural face (Arnaud-Vanneau, 1975; BouDagher-Fadel, 2008). It is consistent with the wackestone-textured limestone where they have been deposited, which enables the inference that the deposit

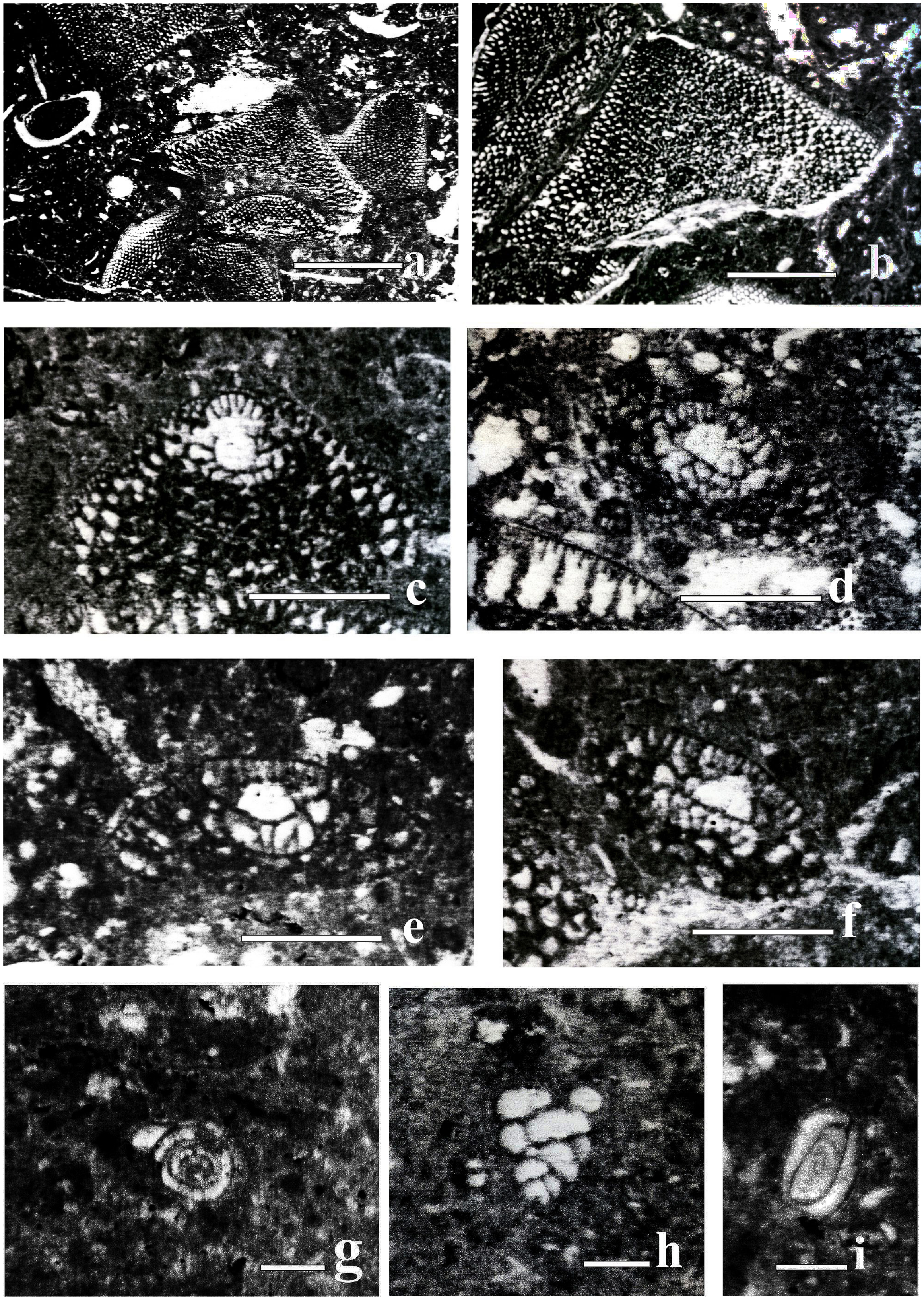

Figure 2. Early Albian foraminifera and microfacies from the Mal Paso Formation (scale bar 500 μm). a) Orbitolinid wackestone-packstone. Sample JP-92067a. b) Tangential section of a conical form of *Mesorbitolina texana* (Roemer, 1849). Sample JP-92067a. c) Subaxial section of *Mesorbitolina texana* (Roemer, 1849). Sample JP-92067b. d, f) Slightly oblique axial section of a young form of *Mesorbitolina texana* (Roemer, 1849). Sample JP-92067c. e) Axial section of a young *Mesorbitolina texana* (Roemer, 1849); embryo zone subdivided into globular protoconch, deuteroconch and subembryonic zones. Sample JP-92069b. g) Transverse-oblique section of *Glomospira* sp. Sample JP-92067c. h) Axial section of *Arenobulimina* cf. *A. chapmani* Cushman, 1936). Sample JP-92067b. i) Axial section *Istriloculina* sp. Sample JP-92067b.

occurred in shallow water with low energy input into the euphotic zone.

8. Microfacies and Paleoenvironment

The paleoenvironmental analysis is based on the microfacies and foraminiferal association study. The succession is characterized by the occurrence of larger foraminifers such as *Mesorbitolina* and other small benthic foraminifera as well as corals and echinoids. The microfacies (Sample JP-92067a-d) is a foraminiferal wackestone–packstone showing a foraminiferal association that consists mostly of *Mesorbitolina texana* embedded in a micrite matrix. The orbitolinid associations suggest a shallow marine environment within the euphotic zone of low-energy lagoonal-type environments deposited under tropical conditions. This microfacies may correspond to SMF 8 (Flügel, 2004).

9. Paleobiogeography

According to Pélissié *et al*. (1982), the complex megalospheric embryonic apparatus of the cosmopolitan forms, whose protoconch is covered by large peri-embryonic chambers (*Palorbitolina*) or by the deuteroconch and the subembryonic zone (*Mesorbitolina*), possibly facilitated their flotation during the meroplanktic initial stage, subsequently favoring their dispersion by marine currents. As reported by BouDagher-Fadel (2008), large conical, agglutinated, internally complicated orbitolinids inhabited the shallow warm reefal environments of the Tethys during the Barremian–Aptian. The late Aptian shows an increase in extinctions, but some of these were replaced by new genera at the Aptian–Albian boundary. In the Albian, and for the first time in the Cretaceous, a small percentage of larger foraminifera become restricted to the Caribbean Province; however, *Mesorbitolina texana*, although originally described from Texas in the lower Albian (Glen Rose Formation) by Roemer (1849, p. 393), is widely distributed along the margins of the Tethys in the Mediterranean area. Raspini (2012) states, "in the Apenninic carbonate platform sequence the so-called 'Livello ad *Orbitolina*' (*Orbitolina* Level) marks the first occurrence of *Mesorbitolina texana*." This species is also recorded in Spain (Cherchi and Schroeder, 1982; Castro *et al*., 2001) and Romania (Bucur *et al*., 2008). Masse *et al*. (2002) reported the species from the western Black Sea, Turkey. *M. texana* has a wide distribution in the Middle East in Lebanon, Syria and Iraq (Simmons *et al*., 2000), and in Iran by Afghah and Haghighi (2014) as well as in Israel (Lipson-Benitah, 2009). In the Tunisian carbonate platform, this species is recorded by Heldt *et al*. (2009). In Egypt, it was observed by Kuss and Schlagintweit (1988). It was recorded in the Pacific Northwest by Iba *et al*. (2011). In the New World, *Mesorbitolina texana* is known from the USA (Texas, New Mexico and Arizona) (Stoyanow, 1949; Douglass, 1960); in Mexico including Sonora (Scott and González León, 1991; González León *et al*., 2008), the Chihuahua basin (Ortuño Arzate *et al*., 1989; Monreal and Longoria, 1999) and the Chiapas platform (Michaud, 1987). In Guatemala, it was recorded by Vaughan (1932); and in Venezuela by Vaughan (1932); Rod and Maync (1954).

10. Conclusions

A foraminiferal assemblage from *Orbitolina*-bearing beds of the calcareous upper member of the Mal Paso Formation is reported.

The age of these rocks is lower Albian, based on the occurrence of *Mesorbitolina texana* (Roemer, 1849), defined by the characters and size of the test, and the dimension and morphology of the megalospheric embryon. This information is important in completing Lower and middle Cretaceous stratigraphic knowledge in this region.

A quiet shallow-water platform environment is inferred on the basis of the limestone (wackestone–packstone) and the benthic foraminiferal assemblage.

The benthic foraminiferal association is typical of the Tethys Realm, which was widely distributed in the platforms of the late Aptian–Albian. Its occurrence is documented from numerous localities in the Old and New World.

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Referencias

Afghah, M., Haghighi, A.S., 2014, Aptian biostratigraphy in South Zagros Basin, southwest Iran: Geosciences Frontiers, 5(2), 277–288.

Arnaud-Vanneau, A., 1975, Réflexion sur le mode vie de certains Orbitolines du synclinal d'Autrans (Vercors septentrional): Géologie Alpine, 44, 25–48.

Arnaud-Vanneau, A., 1998, Larger Benthic Foraminifera, *in* Hardenbol, J., Jacquin, T., Farley, M.B., de Graciansky, P.C., Vail, P. (eds.), Cretaceous biochronostratigraphy, SEPM Special Publication, Tulsa, 60 pp.

Arnaud-Vanneau, A., Sliter, W.V., 1995, Early Cretaceous shallow-water benthic foraminifers and fecal pellets from Leg 143 compared with coeval faunas from the Pacific Basin, Central America, and Tethys, *in* Winterer, E.L., Sager, W.W., Finch, J.V., Sinton, J.N. (eds.), Proceedings of the Ocean Drilling Program. Scientific Results, 143, 537–564.

Ayala-Castañares, A., 1960, *Orbitolina morelensis* sp. nov. de la Formación Morelos del Cretácico Inferior (Albiano) en la Región de Huetamo, Michoacán México: Paleontología Mexicana, 6, 1–16.

Birkeland, C., 1988, Second-order ecological effects of nutrient input into coral communities: Galaxea, 91–100.

BouDhager-Fadel, M., 2008, Evolution and geological significance of larger benthic foraminifera, *in* Wignall, P.B. (ed.), Developments in Palaeontology and Stratigraphy 21, Elsevier Amsterdam, 515 pp.

Bucur, I.I., Granier, B., Săsăran, E., 2008, Upper Aptian calcareous algae from Pădurea Craiului (Northern Apuseni Mountains, Romania): Geologica Croatica, 61, 297–309.

Buitrón-Sánchez, B.E., Pantoja-Alor, J., 1994, Esponjas perforantes de moluscos del Cretácico Temprano en la región centro-occidental de México: Revista Mexicana de Ciencias Geológicas, 11(2), 222–231.

Buitrón-Sánchez, B.E., Pantoja-Alor, J., 1996, Albian gastropods of the rudist–bearing Mal Paso Formation of the Chumbítaro region, SW Mexico (abstract), *in* Quatrième Congrès International sur les Rudistes (Fourth International Conference on Rudists), Université de Provence, Centre de Sédimentologie-Paléontologie: Marseille, France, 3.

Buitrón Sánchez, B.E., Pantoja-Alor, J., 1998, Albian gastropods of the rudist-bearing Mal Paso Formation, Chumbítaro region, Guerrero, Mexico: Revista Mexicana de Ciencias Geológicas, 15(1), 14–20.

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

Castro, J.M., Company, M., de Gea, G.A., Aguado, R., 2001, Biostratigraphy of the Aptian-Middle Cenomanian platform to basin domain in the Prebetic Zone of Alicante, SE Spain: calibration between shallow water benthonic and pelagic scales: Cretaceous Research, 22, 145–156.

Centeno García, E., Guerrero Suastegui, M., Talavera Mendoza, O., 2008, The Guerrero Composite Terrane of western Mexico: Collision and subsequent rifting in a supra-subduction zone, *in* Draut, A., Clift, P.D., Scholl, D.W. (eds.), Formation and Applications of the Sedimentary Record in Arc Collision Zones: Geological Society of America Special Paper, 436, 279–308.

Cherchi, A., 2004, Evolution and paleogeographic distribution of Orbitolinids (Larger Foraminifera) in the Urgonian carbonates platforms of SW Europe. Comparison with Caribbean Tethyan species: Geological Society of America, Abstracts with Programs 36(4), 83.

Cherchi, A., Schroeder, R., 1982, Sobre la edad de la transgresión mesocretácica en Asturias: Cuadernos Geología Ibérica, 8, 219–233.

Douglass, R.C., 1960, The foraminiferal genus *Orbitolina* in North America: Geological Survey Professional Paper, 333, 1–51.

Dozet, S., Sribar, L., 1997, Lower Cretaceous shallow-marine sedimentation and biota on Dinaric carbonate platform between Logatec, Krka and Kolpa (southeastern Slovenia): Geologija, 40, 156–185.

Egger, J.G., 1899; Foraminiferen und Ostrakoden aus den Kreidemergeln der Oberbayerischen Alpen: Abhandlungen der Königlich Bayerische Akademie der Wissenschaften, München, Classe II, Band XXI, Abth. I, 3–230.

Filkorn, H.F., 2002, A new species of *Mexicaprina* (Caprinidae, Coalcomaninae) and review of the age and paleobiogeography of the genus: Journal of Paleontology, 76(4), 672–691.

Filkorn, H., Scott, R.W., 2011, Microfossils, paleoenvironments and biostratigraphy of the Mal Paso Formation (Cretaceous, upper Albian): Revista Mexicana de Ciencias Geológicas, 28(1), 175–191.

Flügel, E., 2004, Microfacies of Carbonate Rocks, Analysis, Interpretation and Application: Germany, Springer, 976 pp.

García-Barrera, P., Pantoja-Alor, J., 1991, Equinoides del Albiano tardío de la Formación Mal Paso, de la región Chumbítaro, estados Guerrero y Michoacán, México: Revista de la Sociedad Mexicana de Paleontología, 4, 23–41.

González-León, C., Scott, R.W., Löser, H., Lawton, T.F., Robert, E., Valencia, V.A., 2008, Upper Aptian-lower Albian Mural Formation: stratigraphy, biostratigraphy and depositional cycles on Sonoran shelf, northern Mexico: Cretaceous Research, 29, 249–266.

Groupe de Travail Européen des Grands Foraminifères, 1981, Tableau de répartition stratigraphique des grands foraminifères caractéristiques du Crétacé moyen de la région méditerranéenne: Cretaceous Research, 2, 383–393.

Heldt, M., Lehman, J,. Bachmann M,. Negra, H., Kuss, J., 2009, Increased terrigenous influx but no drowning: palaeoenvironmental evolution of the Tunisian carbonate platform margin during the late Aptian: Sedimentology, 1–25.

Henson, F.R.S., 1948, Larger Imperforate Foraminifera of southwestern Asia - London 1949, Recent publications on larger foraminifera of the Middle East: Annals and Magazine of Natural History, 2(15), 173–177.

Hottinger, L., 1997, Shallow benthic foraminiferal assemblages as signals for depth of their deposition and their limitations: Bulletin de la Société Géologique de France, 168, 491–505.

Husinec, A., Sokać, B., 2006, Early Cretaceous benthic associations (foraminifera and calcareous algae) of shallow tropical-water platform environment (Mljet Island, southern Croatia): Cretaceous Research, 27, 418–441.

Husinec, A., Velić, I., Fuček, L., Vlahović, I., Matičec, D., Oštrić, N., Korbar, T., 2000, Mid Cretaceous orbitolinid (Foraminiferida) record from the islands of Cres and Losinj (Croatia) and its regional stratigraphic correlation: Cretaceous Research, 21, 155–171.

Iba, I, Sano, S., Miura, T., 2011, Orbitolinid foraminifers in the Northwest Pacific: Their taxonomy and stratigraphy: Micropaleontology, 57, (2), 163–171.

Jones, R.W, 2006, Applied Paleontology: Cambridge University Press, 224 pp.

Madhavaraju, J., Sial, A.N., González León, C.M., Nagarajan, R., 2013, Carbon and oxygen isotopic variations in early Albian limestone facies of the Mural Formation, Pitaycachi section, northeastern Sonora, Mexico: Revista Mexicana de Ciencias Geológicas, 30 (3), 526–539.

Kuss, J., Schlagintweit, F., 1988, Facies and Stratigraphy of Early to middle Cretaceous (late Aptian-early Cenomanian) strata from the Northern Rim of the African Craton (Gebel Maghara, Sinai, Egypt): Facies, 19, 77–96.

Lipson-Benitah, S., 2009, Mid Cretaceous (Aptian-Turonian) Planktic and Benthic Foraminifera from Israel: Zonation and markers: The Ministry of National Infrastructures Geological Survey of Israel Report GSI/16/2009, 1–17.

Marian, V.A., Bucur, I.I., 2012, Microfacies of the Urgonian limestones from the Perşani Mountains (eastern Carpatian, Romania): Acta Paleontologica Romaniae, 8(1–2), 3–32.

Martin, K., 1889, Untersuchungen über den Bau von *Orbitolina* (Patellina Auct.) von Borneo: Sammlungen des Geologischen Reichs-Museums in Leiden,. ser. 14, 209–231.

Masse, J.P., 1976, Les calcaires urgoniens de Provence (Valanginien-Aptien inférieur). Stratigraphie, Paléontologie, les paléoenvironments et leur évolution: Thèsis, Université Marseille, 445 pp.

Masse, J-P, Fenerci Masse, M., Özer, S., 2002, Late Aptian rudist faunas from the Zonguldak region, western Black Sea, Turkey (taxonomy, biostratigraphy, palaeoenvironment and palaeobiogeography: Cretaceous Research, 23, 523–536.

Michaud, F., 1987, Stratigraphie et paléogeographie du Mesozoique du Chiapas (Sud Est du Mexique): Académie de Paris Université Pierre et Marie Curie: Mémoires de Sciences de la Terre, 87, 298 pp.

Monreal, R., Longoria, J.F., 1999, A revision of the Upper Jurassic and Lower Cretaceous stratigraphic nomenclature for the Chihuahua through north-central Mexico: implications for lithocorrelations, *in* Bartolini, C., Wilson, J.L., Lawton, T.F. (eds.), Mesozoic Sedimentary and Tectonic History of North-Central Mexico, Special Paper, 340, 69–89.

Moullade, M., Saint Marc, P., 1975, Les "Mesorbitolines": révision taxinomique, importance stratigraphique et paléobiogéographique: Bulletin de la Société Géologique de France 17(5), 28–842.

Moullade, M., Peybernès, B., Saint Marc, P., 1978, Validité d'*Orbitolina subconcava* Leymemerie, 1878: Geobios, 11, 745–753.

Murray, J.W., 2006, Ecology and Applications of Benthic Foraminifera. Cambridge University Press, Cambridge, 164–170.

Omaña, L., Pantoja Alor, J., 1998, Early Aptian Benthic Foraminifera from the El Cajón Formation Huetamo, Michoacán SW México: Revista Mexicana de Ciencias Geológicas, 15(1), 64–72.

Orbigny, A. d'., 1850, Prodrome de paléontologie stratigraphique universelle des animaux mollusques et rayonnés faisant suite au cours élémentaire de Paléontologie et de Géologie Stratigraphiques, vol. 2. Paris.

Ortuño Arzate, F., Arnaud Vanneau, A., Delfaud, J., 1989, Enregistrement des principaux épisodes transgressifs albiens sur la plate-forme carbonatée de Chihuahua (Mexique): Geobios, Spécial Mémoire, 11,169–177.

Pantoja Alor, J., 1959, Estudio geológico de reconocimiento de la región de Huetamo, Estado de Michoacán: Boletín del Consejo de Recursos Naturales No-Renovables (México) 50, 36 pp.

Pélissié, T., Peybernès B., Rey, J., 1982, Tectonique des plaques et paléobiogéographie des grands Foraminifères benthiques et des Algues calcaires du Dogger à l'Albien sur le pourtour de la Mésogée: Bulletin de la Société Géologique de France, ser. 7, 24, (5–6), 1069–1076.

Peybernès, B., 1976, Le Jurassique et le Crétacé inférieur des Pyrénées Franco-Espagnoles, entre la Garonne et la Méditerranée: Thèse de Doctorat ès Sciences Naturelles Université Paul Sabatier III, Toulouse, 1–459.

Raspini, A., 2012, Shallow water carbonate platforms (late Aptian–early Albian, Southern Apennines) in the context of supraregional to global changes: re-appraisal of palaeoecological events as reflectors of carbonate factory response: Solid Earth, 3, 225–249.

Rod, E., Maync, W., 1954, Revision of Lower Cretaceous stratigraphy of Venezuela: The American Association of Petroleum Geologists, 38(2), 193–283.

Roemer, F., 1849, Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes. Bonn, 464 pp.

Schroeder, R., 1962, Orbitolinen des Cenomans Südwesteuropas: Paläontologische Zeitschrift, 38(3,4), 171–202.

Schroeder, R., 1975, General evolutionary trends in Orbitolinas: Revista Española de Micropaleontología, Número especial, 117–128.

Schroeder, R., Neumann, M., 1985, Les grands foraminifères du Crétacé moyen de la Région Méditerranénne: Geobios, Mémoire Spécial, 7, 161, 68 pl.

Schroeder, R., van Buchem, F.S.P., Cherchi, A, Baghbani D, Vincent B,. Immenhauser, A., Granier, B., 2010, Revised orbitolinid biostratigraphic zonation for the Barremian–Aptian of the eastern Arabian Plate and implications for regional stratigraphic correlations: GeoArabia Special Publication, 4(1), 49–96.

Scott R.W., 2014, Cretaceous chronostratigraphic database: construction and applications: Carnets de Géologie, 14(1), 1–13.

Scott, R.W., González-León, C., 1991, Paleontology and stratigraphy of Cretaceous rocks, Lampazos area, Sonora, Mexico: Geological Society of America, Special Paper, 254, 51–67.

Shirazi, M.P.N., Abedi, F., 2013, Lower Cretaceous orbitolinid (Foraminiferida) record from the southwest of Iran (Zagros, Shiraz): Open Journal of Geology, 3(1), 1–6.

Stoyanow, A., 1949, Lower Cretaceous stratigraphy in southern Arizona: The Geological Society of America, Memoir, 38, 1–157.

Simmons, M.D., Whittaker, J.E., Jones, R.W., 2000, Orbitolinids from Cretaceous sediments of the Middle East- a revision of the FRS Henson and associates collections, *in* Hart, M.B., Kaminski, M.A., Smart, C.W. (eds.), Proceedings of the Fifth International Workshop on Agglutinated Foraminifera: Grzybowski Foundation Special Publication, 7, 411–437.

Vaughan, T.W., 1932, The foraminiferal genus *Orbitolina* in Guatemala and Venezuela: Proccedings of the National Academy of Sciences, 18, 609–610.

Vilas, L., Masse J.P., Arias, C., 1995, *Orbitolina* episodes in carbonate platform: the early Aptian model from SE Spain: Palaeogeography, Palaeoclimatology, Palaeoecology, 119, 35–45.

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