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THE GENUS *ORBITOLINA* D'ORBIGNY, 1850 (LARGER BENTHIC FORAMINIFERA) AND ITS CONSTITUENT SPECIES: NOTES ON IDENTITY AND STRATIGRAPHIC RANGES

Michael D. Bidgood[1], Felix Schlagintweit[2] & Michael D. Simmons[3, 4*]

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Abstract. Following a literature review of the species of *Orbitolina* and its allies, the identity criteria and stratigraphic ranges of the six potential constituent species of the commonly encountered mid-Cretaceous foraminiferal genus *Orbitolina* d'Orbigny, 1850 (*sensu stricto*) are reviewed based on published material. It is noted that correct taxonomic assignment of *Orbitolina* species requires observation and measurement of both the embryonic apparatus in centred axial thin-sections and of the chamber passage shape in tangential sections. As a consequence, many illustrations purportedly of *Orbitolina sensu stricto* in the published literature cannot confidently be identified to species level, and such specimens (including new material) should be described or re-described as *Orbitolina* spp. The genus *Orbitolina* has a range of late Albian – middle Cenomanian. Species of *Orbitolina,* when identifiable, have shorter ranges. *Orbitolina concava* (Lamarck 1816) is restricted to the early – middle Cenomanian, and its inception thus forms a potential proxy for the base of the Cenomanian in carbonate platform settings, but care needs to be taken in its identification and separation from other species of *Orbitolina* that have at least partial late Albian ranges.

Keywords: Orbitolinids, Orbitolina, taxonomy, biostratigraphy, Cretaceous, foraminifera.

INTRODUCTION

Orbitolinids (family Orbitolinidae) are agglutinating larger benthic foraminifera (LBF) that are commonly encountered in Cretaceous carbonate platform sediments of Neotethys, especially marly facies, where they can reach abundances that are rock-forming. Although known for over 200 years, it is only since the middle of the 20th Century that the importance of internal structure as seen in thin-section (as opposed to external appearance) has been understood to be of prime importance in their taxonomic classification. The principal test construction of the type genus *Orbitolina* d'Orbigny, 1850 has been provided by Henson (1948: fig. 4) with (from the outer test wall towards the centre) marginal, radial and reticulate zones.

For many years, the genus *Orbitolina* was used *sensu lato* to describe what is now considered to be a wide diversity of genera within the subfamily Orbitolininae (see Appendix). Herein, the genus is used *sensu stricto* as defined by Schroeder (1962, 1963, 1975) and Schroeder in Schroeder & Neumann (1985) by the structure of the megalospheric embryo, recognised as distinct from superficially similar taxa such as *Palorbitolina* Schroeder, 1963, the species of which have often been assigned to *Orbitolina sensu lato*. Moreover, it is used only to refer to those taxa that fit within *Orbitolina*, used at generic level by, for example, Loeblich & Tappan (1987) and Simmons et al. (2000). It thus excludes taxa within the genera *Mesorbitolina* Schroeder, 1962 and *Conicorbitolina* Schroeder, 1973. These two genera were defined and used as subgenera of *Orbitolina* (along with using *Orbitolina* as a subgenus of itself) in the 1960s to 1980s (Schroeder, 1962, 1973 and see Schroeder in Schroeder & Neumann, 1985). The practice of using subgenera (and subspecies) for fossil taxa has fallen out of favour in recent decades (e.g. Loeblich & Tappan, 1987) and a Linnean binomial name is preferred.

In thin-section, *Orbitolina* has a large apically-situated embryonic apparatus that, following Schroeder (1962) is subdivided into a proloculus, supra-embryonic zone and sub-embryonic zone where the supra-embryonic zone is distinctively about three times thicker than the sub-embryonic zone (Figure 1). The supra-embryonic zone and, to a lesser extent, the sub-embryonic zone are subdivided by vertical radial beams that may be of different orders on the basis of their length.

Orbitolina and its allies are understood to be useful biostratigraphic and palaeoenvironmental tools for studies of Early – mid-Cretaceous Neotethys sedimentary successions (Schroeder & Neumann, 1985; Moullade et al., 1985; Simmons et al., 2000). Constituent species can have relatively short stratigraphic ranges in the order of substages, making them especially useful as age proxies and for correlation, provided they are confidently identified (Schlagintweit & Simmons, 2022). *Orbitolina sensu stricto* is thought to range from the late Albian to within the Cenomanian, and its potential species have shorter ranges within this.

The inception of *Orbitolina concava* (Lamarck, 1816) has been used by non-micropalaeontological specialist stratigraphers (e.g., Tröger & Kennedy, 1996) as a proxy for the base of the Cenomanian in carbonate platform facies.

[1] GSS (Geoscience) Ltd, 2 Meadows Drive, Oldmeldrum, AB51 0GA, UK (mike@gssgeoscience.co.uk)
[2] Lerchenauerstr. 167, 80935 Munich, Germany (felix.schlagintweit@gmx.de)
[3] Halliburton, 97 Milton Park, Abingdon, OX14 4RW, UK (mike.simmons@halliburton.com)
[4] The Natural History Museum, Cromwell Road, London, SW7 5BD, UK
* Corresponding author

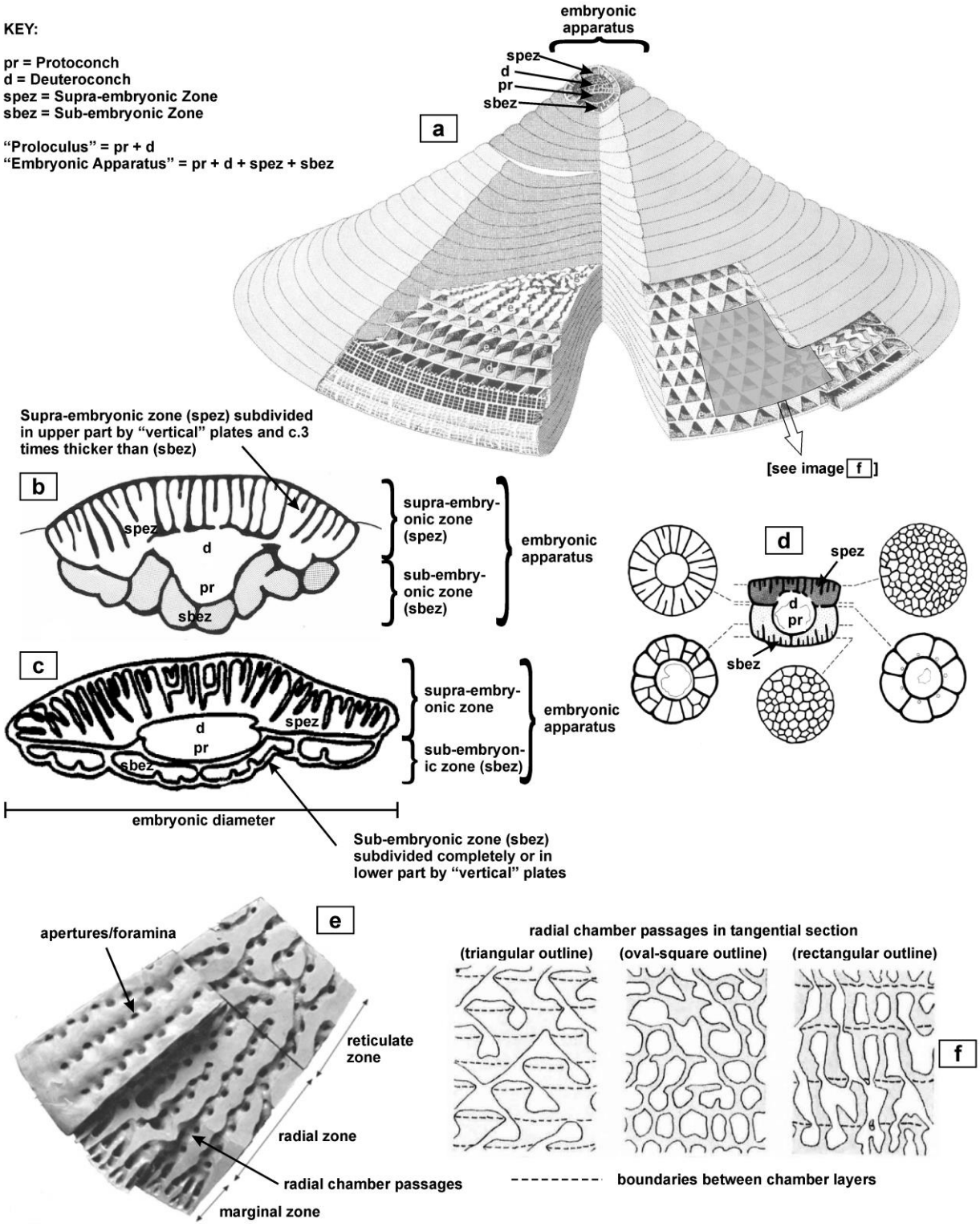


Fig. 1. Key morphological elements of Orbitolininae. **a.** Cutaway reconstruction of a generic "orbitoline" (Douglass, 1960a); **b.** Axial section through the embryonic apparatus of *O. duranddelgai* (Schroeder, 1985); **c.** Axial section through the embryonic apparatus of *O. concava* (Arnaud-Vanneau, 1980); **d.** Axial section through embryonic apparatus of an orbitoline (*Mesorbitolina*) with schematic appearance of horizontal slices through various levels (Schroeder et al., 2010); **e.** Top-down 3D plasticine model of a segment of basal section (sculpted by Reichel c.1955 published in Hottinger, 2006); **f.** Tangential sections through radial zone of three orbitolinid species (left to right: *O. hensoni*, *O. duranddelgai*, *O. concava*) showing different chamber passage shapes (adapted after Schroeder, 1975).

Nonetheless, it is now almost 40 years since the last widely-cited review of *Orbitolina* taxonomy and biostratigraphy was undertaken (Schroeder in Schroeder & Neumann, 1985), and much new data has appeared since then. There is therefore a need to review the identity and taxonomy of the possible species of *Orbitolina* and to assess stratigraphic ranges in the light of all available data. Accordingly, we have critically reviewed the

extensive literature on mid-Cretaceous *Orbitolina* to determine the validity, identity, and stratigraphic range of the six possible species of this genus.

PREVIOUS RESEARCH

Orbitolina and its allies have a long history of research (e.g., Martin, 1890), although it was not until the work of Henson (1948) that importance of internal structure, and especially of the megalospheric embryonic apparatus and of chamber passage shape began to take prominence in taxonomic studies. Henson, who worked for the Iraq Petroleum Company, documented the occurrence of orbitolinids in the Middle East and introduced as varieties of *O. concava* two of the taxa under consideration herein – *Orbitolina concava* var. *sefini* Henson, 1948 and *Orbitolina concava* var. *qatarica* Henson, 1948.

The importance of internal structure in taxonomic classification was amplified by workers at the beginning of the 1960's notably Douglass (1960a, 1960b), Schroeder (1962), and Hofker (1963). Hofker favoured placing all Orbitolininae into an evolutionary plexus of just one species – *Orbitolina lenticularis* (Blumenbach, 1805) – but the error in this thinking was rapidly demonstrated by Schroeder (1964) who subsequently became the most prominent researcher into orbitolinid taxonomy and biostratigraphy until his death in 2020 (Schlagintweit & Simmons, 2021).

Schroeder was a prime mover in the creation of subgenera/genera and subspecies/species of orbitolinids, including some of the taxa under consideration herein. In one of his first publications (Schroeder, 1962) he made it clear that the structure of the embryonic apparatus was of primary importance in taxonomic and evolutionary studies that allowed him to create subgenera (later elevated to genera). Other diverse groups of LBF (e.g., orbitoidids, lepidocyclinids, miogypsinids and others) also rely heavily on embryonic characters for their various classifications (Simmons & Aretz, 2000). Schroeder was clear that *Orbitolina* (*Orbitolina*) spp. with the type species *Orbitolina concava*, had a distinctive, large embryonic apparatus, subdivided into a proloculus, sub-embryonic zone and supra-embryonic zone, with the sub-embryonic zone much thinner than the supra-embryonic zone (Fig. 1b-c). In a subsequent paper (Schroeder, 1963) he proposed that many "*Orbitolina*" with a much simpler embryonic apparatus could be ascribed to a new subgenus, *Palorbitolina* Schroeder, 1963 with the type species *Palorbitolina lenticularis* (Blumenbach, 1805). Schroeder (1962) introduced one of the taxa under consideration herein – *Orbitolina concava pauletensis*, whilst Schroeder (1972) introduced another – *Orbitolina concava duranddelgai*.

With regard to the stratigraphic ranges of *Orbitolina* in its modern sense and its constituent species, a first attempt was provided by Schroeder (1975), although those ranges are now out of date. A key reference is the work of Schroeder in the seminal review of mid-Cretaceous larger benthic foraminifera by Schroeder & Neumann (1985). In this paper, Schroeder assesses the taxonomy, identity, and ranges of *Orbitolina concava*, *Orbitolina sefini* and *Orbitolina duranddelgai*, with an earlier paper by Neumann & Schroeder (1981) summarising some of the range data. Cherchi & Schroeder (1999) provide an important set of observations on their concept of *O. sefini*. The last major paper by Schroeder to examine *Orbitolina* is that of Schroeder et al. (2010), although the paper is focussed on older Orbitolininae such as *Palorbitolina*, *Praeorbitolina*, *Palorbitolinoides* and *Mesorbitolina*.

Following on from some initial work by Whittaker et al. (1998), Simmons et al. (2000) returned to the material of Henson (1948) with a study of the orbitolinids in the F.R.S. Henson and Associates Collection in the Natural History Museum, London. This work resulted in new descriptions of the identity of *Orbitolina sefini* (differing from Schroeder in Schroeder & Neumann (1985)) and *Orbitolina qatarica*. In turn, this resulted in the introduction of a new species, *Orbitolina hensoni*. Tentative stratigraphic range data was provided but was restricted by the limited information provided within the F.R.S. Henson and Associates Collection.

Recently, Schlagintweit & Simmons (2022, 2023) reviewed some issues with identification of *Orbitolina* and its allies, noting some potential misidentifications and implausible associations of taxa that lead to erroneous extensions to stratigraphic ranges.

POTENTIAL SPECIES OF *ORBITOLINA*

Since the creation of the genus *Orbitolina* by d'Orbigny (1850), many species have been originally assigned to this genus or commonly referred to it. The Appendix herein provides an inventory of approximately 150 of these taxa, drawing on the Ellis & Messina catalogue of foraminifera species (2002) and a literature review. Many were described purely from external morphology and, without further study of type material (if it can be located), are effectively indeterminate in terms of modern taxonomy. Many others can be placed in the allied genera to *Orbitolina sensu stricto* such as *Palorbitolina*, *Mesorbitolina* or *Conicorbitolina*.

Six species of *Orbitolina* have been considered by us as appearing to conform to the modern sense of the genus:

Orbitolina concava (Lamarck, 1816) (*sensu* Schroeder in Schroeder & Neumann, 1985)

Orbitolina sefini Henson, 1948 [emended Simmons et al., 2000]

Orbitolina qatarica Henson, 1948 [emended Simmons et al., 2000]

Orbitolina duranddelgai Schroeder, 1972 (*sensu* Schroeder in Schroeder & Neumann, 1985)

Orbitolina hensoni Simmons, Whittaker & Jones, 2000

Orbitolina pauletensis Schroeder, 1962

The criteria for the identity of each of these taxa are described in Figure 2. Species definition is based on

details of size of the embryonic apparatus and its constituent parts together with the shape of chamber passages that can be seen in tangential sections. The chamber passages originate in the marginal zone and form the radial part (or zone) of each chamber layer where each chamber passage is subdivided by radial partitions which are prolongations of the vertical main partitions (Henson, 1948; Douglass, 1960a, 1960b; Schroeder, 1975; Arnaud-Vanneau, 1980; Cruz-Abad, 2018). Associated with foramina, these endoskeletal elements are called septules (or septula) (Hottinger, 2006). In cross-section they can be triangular, rectangular, or oval, or show a gradation between shapes. These various shapes are due to different morphologies of the radial septules. A further complication is provided by the fact that the shape of the radial chamber passages varies between megalospheric and microspheric specimens (e.g., Cherchi & Schroeder, 1999).

It is clear that identification to species level requires the availability of suitably oriented thin-sections that capture

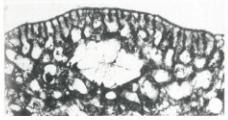
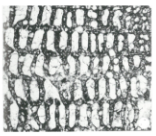
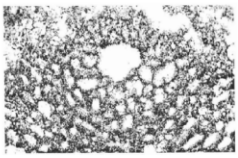
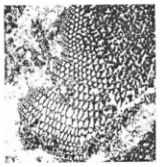
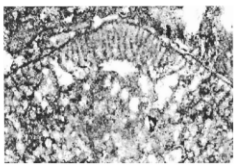
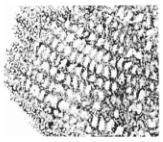
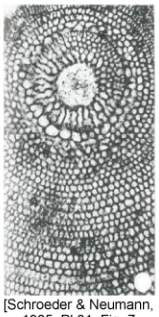
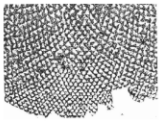
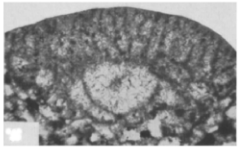
Name, Author(s) & Range	Embryonic Apparatus (axial view)				Radial Zone Chamber Passages	Chamber Passage Image
	Proloculus	Supra-embryonic Zone	Sub-embryonic Zone	Image		
Orbitolina concava (Lamarck, 1816) [sensu Schroeder & Neumann 1985] Early - middle Cenomanian	Diameter: 0.17 - 0.42mm (mean 0.27mm). Shape: irregularly elliptical.	External diameter: 0.67 - 1.21mm (mean 0.85mm) with numerous vertical partitions of 2 or 3 orders.	Thin (0.09 - 0.12mm), a layer of numerous, irregularly shaped chambers that run approx. parallel to the oval lower edge of the embryonic apparatus.	 [Schroeder & Neumann, 1985, Pl.29, Fig. 2]	Consistently have an irregular rectangular-oval outline, chamber septula of one chamber alternating with the next.	 [Schroeder & Neumann, 1985, Pl.29, Fig. 4]
Orbitolina sefini Henson, 1948 [emend. Simmons et al., 2000] ?Latest Albian - earliest Cenomanian?	Max. diameter c.0.25mm.	Diameter 0.45 - 0.60mm. Highly subdivided.	Thin (c.0.095mm)	 [Simmons et al., 2000, Pl.2, Fig. 4]	Initially high-triangular chamber passages becoming rectangular in later chambers, but possibly varies between generations (triangular in macrospheric, elliptical/subrect-angular in microspheric).	 [Simmons et al., 2000, Pl.2, Fig. 5]
Orbitolina qatarica Henson, 1948 [emend. Simmons et al., 2000] intra-late Albian - early Cenomanian, ?middle Cenomanian	Max. diameter 0.2mm, convex with flat base.	Diameter 0.72 - 0.75mm. Markedly conical, relatively thick and heavily subdivided.	Thin (c.0.085mm) and convex. Highly subdivided.	 [Simmons et al., 2000, Pl.2, Fig. 8]	Chamber passages almost exclusively rectangular.	 [Simmons et al., 2000, Pl.2, Fig. 9]
Orbitolina duranddelgai Schroeder, 1972 [sensu Schroeder & Neumann 1985] Latest Albian - earliest Cenomanian	Diameter 0.25 - 0.30mm (height 0.14 - 0.16mm). Irregularly ellipsoidal or cup-shaped.	0.5 - 0.7mm (0.8mm max). Strongly subdivided.	Thin (0.06mm), weakly subdivided.	 [Schroeder & Neumann, 1985, Pl.31, Fig. 3]	Numerous and densely spaced, oval - squarish.	 [Schroeder & Neumann, 1985, Pl.31, Fig. 7 holotype]
Orbitolina hensoni Simmons et al., 2000 Latest Albian - ?early Cenomanian	Max. diameter c.0.25mm. Shape not well known but concave upwards.	Diameter c.0.6mm. Highly subdivided.	Thin (c.0.03 - 0.06mm). Less subdivided than deuteroconch. Embryonic apparatus as a whole with a flat base.	 [Simmons et al., 2000, Pl.2, Fig. 1 paratype]	Very distinctive, exclusively equilateral triangle shaped chamber passages.	 [Simmons et al., 2000, Pl.2, Fig. 2 holotype]
Orbitolina pauletensis Schroeder, 1962 Earliest Cenomanian	Maximum diameter 0.28mm	Diameter c.0.875mm, highly subdivided.	Thin (0.04 - 0.05mm) and weakly subdivided.	 [Schroeder, 1962, Pl.20, Fig. 12]	Triangular, becoming rectangular in adult chambers.	No illustration available.

Fig. 2. Identification criteria for potential species of *Orbitolina*.

both the structure of the embryonic apparatus and chamber passage shape. This has led some workers to use terms such as "*Orbitolina* gr. *concava*" (e.g., Sartorio & Venturini, 1988; Velić, 1988, 2007; Schlagintweit & Yazdi-Moghadam, 2020, 2021, 2023; Yazdi-Moghadam & Schlagintweit, 2020, 2021, 2022), or the "*Orbitolina sefini – concava* plexus" (e.g., Simmons & Williams, 1992), "*Orbitolina* (*Orbitolina*) gr. *sefini – concava*" (Husinec et al., 2000) or "*Orbitolina sefini/duranddelgai"* (Castro et al., 2001; Bachmann et al., 2003). Alternatively, the term "*Orbitolina concava"* may have been used *sensu lato* rather than *sensu stricto*, either intentionally or unintentionally, thus encompassing more than one of the potential species of *Orbitolina sensu stricto*. This has implications for assessing stratigraphic range which is discussed further in the consideration of each species.

A NOTE ON MEASURMENTS

The dimensions of the Embryonic Apparatus (EA) as a whole, and of its various components (e.g., Proloculus (P), Sub- and Supra-embryonic zones etc.) have played a crucial role in species discrimination within *Orbitolina*, the orbitolinids and in many other LBF groups. In publications the use of magnification factors (e.g., x50, x100 etc.) to denote relative size is common but can lead to difficulties in re-measuring dimensions in images and converting (using the magnification factor) to actual sizes, as we have done occasionally in investigations for this manuscript. Not only must the original (print) page size be known (if using a PDF document) but it can often be only *assumed* that during the publication process itself, the image size remains enlarged by the same magnification factor as that observed and photographed in the microscope's eyepiece.

Such problems disappear with the use of scale bars (although they themselves can be prone to errors in initial calibration) but magnification factors are still commonly used. Where there may be doubts about size conversions these are mentioned in the text.

SYSTEMATICS

Phylum Foraminifera d'Orbigny, 1826
Subclass Textulariana Mikhalevich, 1980
Order Loftusiida Kaminski & Mikhalevich in Kaminski, 2004
Suborder Orbitolinina Kaminski, 2004
Superfamily Orbitolinoidea Martin, 1890
Family Orbitolinidae Martin, 1890
Subfamily Orbitolininae Martin, 1890
Genus *Orbitolina* d'Orbigny, 1850 (*sensu* Loeblich & Tappan, 1987 after Schroeder, 1962)

Orbitolina concava (Lamarck, 1816)

Non 1801 *Orbitolites concava* n. sp. – Lamarck, p. 376 T 1816 *Orbulites concava* n. sp. – Lamarck, p. 197. Early Cenomanian, France.
1837 *Orbitolites plana* n. sp. – d'Archiac, p. 178. Cenomanian, France.
Non 1890 *Orbitolina concava* - Martin, p. 211-219, pl. XXIV, fig. 1-13, pl. XXV, fig. 14-20 (= *Palorbitolina lenticularis fide* Schlagintweit & Simmons, 2023)
1960a *Orbitolina concava* – Douglass, p. 32-34; pl. 2, fig. 1-12; pl. 3, fig. 1-9. Early Cenomanian, France.
1960b *Orbitolina concava* - Douglass, pl. 2, fig. 6-7; pl. 4, fig. 12-13. Early Cenomanian, France.
1962 *Orbitolina* (*Orbitolina*) *concava concava* – Schroeder, p. 185-189, pl. 20, fig. 3-6, 8-10; pl. 21, fig. 6. Early Cenomanian, France.
1963 *Orbitolina lenticularis* (Blumenbach) – Hofker jr., text fig. 24; pl. 17, fig. 15-18; pl. 18, fig. 1-9. Early Cenomanian, France.
Non 1964 *Orbitolina* (*O.*) *concava concava* – Schroeder, p. 688-690; text-fig. 3a-d (= *Orbitolina duranddelgai fide* Schroeder in Schroeder & Neumann, 1985).
Non 1969 – *Orbitolina concava* – Sampò, pl. 37, fig. 8 (= *Palorbitolina lenticularis*), pl. 39, fig. 10, 22 (= *Mesorbitolina birmanica*).
1970 *Orbitolina concava* – Chernov, p. 30-31, pl. 2, figs. 1-9. Early Cenomanian, Ukrainian Carpathians.
Non 1972 *Orbitolina (Orbitolina) concava concava* – Ramirez del Pozo, p. 36, pl. 4, fig. 8-9 (= *Mesorbitolina* sp.)
Non 1976 *Orbitolina concava* – Ho et al., p. 20, pl. 3, fig. 5-11. (= *Palorbitolina ultima* or *Palorbitolinoides fide* Rao et al., 2017).
1979 *Orbitolina* (*Orbitolina*) *concava* – Decrouez & Kunzle, pl. 1, fig. 1, 4 ; pl. 2, fig. 1-3 – Early Cenomanian, France.
Non 1982 *Orbitolina* (*Orbitolina*) *concava* – Zhang, p. 75, pl. 12, fig. 8-9. Probably *Palorbitolinoides* sp.
1984 *Orbitolina* (*Orbitolina*) *concava* – Bilotte, p. 363-364, pl. 3, fig. 12-14. Middle Cenomanian, French Pyrenees.
1985 *Orbitolina* (*Orbitolina*) *concava* -Schroeder in Schroeder & Neumann, p. 62-66, pl. 29, fig. 1-8 Early Cenomanian, France.
1992 *Orbitolina concava* – Simmons & Williams, pl. 2, fig. 2. Early Cenomanian, France.
Non 1992 *Orbitolina concava* – Kalantari, pl. 78, text-fig. 158 (= *Mesorbitolina* sp.)

Diagnostic features: An *Orbitolina* with a relatively large embryonic apparatus (min 0.67mm, max 1.21mm, mean 0.85mm) and an irregularly elliptical proloculus (min 0.17mm, max 0.42mm, mean 0.27mm). Supra-embryonic zone divided by numerous vertical partitions of different lengths (orders). Sub-embryonic zone thin, a layer of numerous, irregular chambers. Radial zone chamber passages with an irregular rectangular-oval outline, with septulae alternating between chambers.

Remarks: *Orbitolina concava* (= *Orbulites concava* Lamarck, 1816) is the type species of *Orbitolina*

(Schroeder & Simmons, 1988, 1989). First described over 200 years ago, it has had a complex history of usage. In the 19th century and the first half of the 20th century, as much attention was paid to the external morphology as to the internal morphology of the orbitolinids, leading to the use of species names that would not be deemed appropriate today, as taxonomic classification is now based on internal features almost exclusively (Henson, 1948; Douglass, 1960a, 1960b; Schroeder, 1962, 1963, 1975) (see Appendix). Consequently, taxa such as *O. concava* have many potential synonyms (Schroeder, 1962).

An understanding of the stratigraphic range of *O. concava* is hampered by how the species name is being used – in a strict sense as used herein (*sensu* Schroeder, 1962); in a loose sense possibly including related *Orbitolina* (*sensu lato*) species, most of which were originally defined as varieties or subspecies of *O. concava*; or in the (incorrect) widest possible sense including a range of Orbitolininae. Some records, especially from the Aptian, Albian, and late Cenomanian of the Middle East, are clear misidentifications, unproven, or relate to outdated concepts of the species (see examples in Schlagintweit & Simmons, 2022 and also Bozorgnia & Banafti, 1964; Sampò, 1969; Kalantari, 1976, 1992; Rabu, 1993). Use of outdated species concepts also applies to records from Borneo (Schlagintweit & Simmons, 2023). Resolution of such taxonomic uncertainty requires detailed assessment of records that is beyond the scope of this study, although we have attempted to verify the most important range defining records.

Orbitolina birmanica Sahni 1937 emend. Sahni & Sastri 1957 was tentatively considered a synonym of *O. concava* by Schroeder (1962) but has subsequently been shown to be a species of *Mesorbitolina* (Zhang, 1994; Schlagintweit & Wilmsen, 2014; Schlagintweit, 2024). Ho et al. (1976), Yang et al. (1982), and Zhang (1982) reported *O. concava* as occurring in the Cenomanian of Tibet, but the material is considered to be of the *Palorbitolina ultima - Palorbitolinoides hedini* lineage by Rao et al. (2017) and thus pre-Cenomanian (Schroeder et al., 2010).

Measurements made by us on the embryonic apparatuses of scaled illustrations of topotypes of *O. concava* or from data from Douglass (1960a), Schroeder (1962), Hofker (1963), Decrouez & Kundle (1979), Schroeder & Neumann (1985) and Simmons & Williams (1992) yielded the range of values shown in the diagnosis. It was noticed that Schroeder's measurements in 1962 were close to those of Hofker's (1963). However, later measurements by Schroeder (in Schroeder & Neumann, 1985) appeared to be 20-25% larger and, in some respects, closer to those of Douglass (1960a). This (apparent) discrepancy may be connected with issues surrounding image scaling during publication and subsequent re-measurement as discussed above. It could also reflect a genuine wide range of values. Regardless of this and considering the mean values, *O. concava* is still generally characterised as the species of *Orbitolina* with the largest embryonic apparatus diameter.

Stratigraphic range: Early – middle Cenomanian (common records in the early Cenomanian, scarce records in the middle Cenomanian). First described from early Cenomanian sediments in Ballon, France (Lamarck, 1816), Schroeder in Schroeder & Neumann (1985) regarded the range of *O. concava* as being restricted to the entirety of the early Cenomanian (see range chart therein - a comment (p. 65) that it is "Cénomanien supérieur" is a *lapsus calami*). They reported no records outside of the early Cenomanian (with ammonite support) of France. This was followed by Simmons & Bidgood (2023). Its inception is considered as a useful proxy in carbonate platform settings for the base of the Cenomanian (Gale et al., 1996; Tröger & Kennedy, 1996; Velić, 2007; Simmons & Bidgood, 2023).

Nonetheless, there is evidence that *O. concava* can be found in middle Cenomanian strata. Bilotte (1984) illustrated reasonable *O. concava* from the middle Cenomanian of the Pyrenees, an observation also made by Caus et al. (2009) without illustration. Co-occurrence with *Praealveolina cretacea* (d'Archiac, 1837) or *Praealveolina debilis* Reichel, 1936 supports this assertion. El Sheikh & Hewaidy (1998) reported *O. concava* from the middle Cenomanian of Egypt (with *Praealveolina tenuis* Reichel, 1933), but the illustration is inconclusive. In the Adriatic Platform, Velić (2007), considers the species as occurring in the early and middle Cenomanian (see illustration in Velić, 1988). It is interesting to note that Schroeder (1975) placed the range of "*O. concava concava*" in the overlap between a twofold subdivision of the Cenomanian, thereby implying extension into the middle Cenomanian, a view he presumably changed in the ten years subsequent.

Although sometimes reported (but seldom illustrated) from late Albian strata (e.g., Decrouez & Moullade, 1974; Bilotte et al., 1978; Moullade et al., 1985; Görög, 1993; Ahmadi et al., 2008; Afghah et al., 2020), it may be that these records are actually of ancestral *Orbitolina* species or of *O. concava sensu lato* (herein *Orbitolina* spp.) (e.g., Rey et al., 1977 – see Berthou & Schroeder, 1978), or that the late Albian age is unproven, so are herein discounted.

In the literature on the Middle East, there are some misleading statements about the range of *O. concava* (Schlagintweit & Simmons, 2022). For example, Haftlang et al. (2020) misquote the literature suggesting that Schroeder et al. (2010) indicated that *O. concava* is an Albian species (and thereby justifying a possible Albian age for rocks in which they supposedly find this species – the illustrations are indeterminate). There is no such statement that *O. concava* is an Albian species in Schroeder et al. (2010). Other records of *O. concava* from the Albian of the Iranian Zagros (Kalantari, 1976; Keshavarzi et al., 2020, 2021) are indeterminate and must be doubted. An illustrated record from the potentially late

Albian Maududd Formation of southern Iraq (Manhi & Alsultani, 2021) is indeterminate.

Palaeogeographic distribution: Excepting an interesting record from eastern Europe (Chernov, 1970), the majority of viable records of this species are from western Europe. Although widely reported from the Arabian Plate (including the Zagros), most records cannot be confirmed as this species due to the illustrated specimens being unsuitable for definitive identification (e.g. Mohammed, 1996; Ameen & Gharib, 2014; Farsi et al., 2022). Amongst the possible records are those of Schlagintweit & Yazdi-Moghadam (2020, 2021, 2023) and Yazdi-Moghadam & Schlagintweit (2020, 2021, 2022), although as previously noted, they use the term "*Orbitolina* gr. *concava*" to designate a degree of uncertainty, given the need to access both suitable axial and tangential sections to observe all the relevant features to confirm identification. Thus, they are herein included within *Orbitolina* spp. (see below). The records of Weidich & Al Harithi (1990) from the Albian/Cenomanian transition of Jordan, seem to conform to *O. hensoni*.

Simmons et al. (2000) noted that the species appears to be absent from the F.R.S. Henson and Associates Collection in the Natural History Museum, London, which is based on Middle East material. Henson (1948: fig. 46) provided a detailed drawing of an embryo of '*O. concava* vars.' Displaying a broad peri-embryonic zone, this specimen can be referred to *Palorbitolinoides* Cherchi & Schroeder (compare Schlagintweit et al., 2022: fig. 5n).

***Orbitolina sefini* Henson, 1948**

T 1948 *Orbitolina concava* (Lamarck) var. *sefini* var. nov. – Henson, p. 64-65; pl. 5, fig. 1-2 (non 3-4 = *Conicorbitolina conica fide* Schroeder in Schroeder & Neumann, 1985) "Cenomanian", Iraq. Could be late Albian.

? 1962 *Orbitolina* (*Orbitolina) concava qatarica* – Schroeder, p. 191-193, pl. 20, fig. 11; pl. 21, fig. 2. Early Cenomanian, Spain.

1985 *Orbitolina* (*Orbitolina) sefini* - Schroeder in Schroeder & Neumann, pl. 30, fig. 1-3 "Cenomanian", Iraq. Could be late Albian.

Non 1985 *Orbitolina* (*Orbitolina*) *sefini* – Schroeder in Schroeder & Neumann, p. 66-68, pl. 30, fig. 4 -8. Probably *Orbitolina hensoni.*

Non 1992 *Orbitolina sefini* – Simmons & Williams, pl. 1, fig. 3-5. Probably *O. hensoni*.

?1999 *Orbitolina sefini* Henson – Cherchi & Schroeder, p. 20, pl. 2, figs. 1-8, pl. 3, figs. 1-3. Early Cenomanian, Spain.

2000 *Orbitolina sefini* – Simmons et al., p. 423, pl. 1, fig. 8 ; pl. 2, figs. 3-5 ; pl. 4, fig. 10. "Cenomanian", Iraq. Could be late Albian.

Non 2004 *Orbitolina sefini* – Schulze et al., text-fig. 10b. Indeterminate orbitolinid, but not *Orbitolina* sp.

Non 2013 *Orbitolina sefini* – Ghanem & Kuss, pl. 14, fig 5-6 (= *Conicorbitolina* sp.), 7 (= *Cuneolina* or *Dicyclina* sp.), 9 (= indeterminate orbitolinid)

Diagnostic features: An *Orbitolina* with a proloculus of max diameter c.0.25mm and an embryonic apparatus diameter of 0.45 – 0.60mm. The supra-embryonic zone is highly subdivided. Sub-embryonic zone thin. Radial zone chamber passages are initially triangular in section, becoming rectangular in later chambers. This variation is also observed in different generations (triangular in macrospheric, elliptical/subrectangular in microspheric).

Remarks: First defined as a variety (= subspecies) of *O. concava* by Henson (1948) based on material from Sefin Dagh in NE Iraq. As noted by a number of workers (e.g., Schroeder in Schroeder & Neumann, 1985; Simmons et al., 2000) the original description and illustration of the species included a variety of taxa recognised using modern concepts of Orbitolininae, further amplified by assessment of material in the F.R.S. Henson and Associates Collection in the Natural History Museum, London. Nonetheless, Schroeder in Schroeder & Neumann (1985), Schroeder et al. (1986) and Cherchi & Schroeder (1999) in a revaluation of the species considered that the type material included an *Orbitolina* distinct from *O. concava* by virtue of a smaller embryonic apparatus and exclusively triangular chamber passages (in megalospheric forms). The exclusively triangular nature of the chamber passages was refuted by Simmons et al. (2000) who considered that the chamber passages are initially triangular but become rectangular in later adult chamber layers. This is still distinct from *O. concava* and *O. qatarica* that have exclusively rectangular chamber passages. Simmons et al. (2000) introduced *Orbitolina hensoni* for material that has only triangular chamber passages based on "*Orbitolina* cf. *concava" sensu* Henson (1948).

Despite the work of Schroeder in Schroeder & Neumann (1985), Schroeder et al., (1986), Cherchi & Schroeder (1999) and Simmons et al. (2000) identification of *O. sefini* remains challenging, not least because the syntypes of Henson (1948) only include poor or somewhat oblique sections through the embryonic apparatus as illustrated by Simmons et al. (2000) (Henson, 1948 illustrated none). Schroeder in Schroeder & Neumann (1985) and Schroeder et al. (1986) illustrated axial sections of the embryonic apparatus based on material from western Europe thought to be *O. sefini*, but now might be better attributable to *O. hensoni* following Simmons et al. (2000).

Cherchi & Schroeder (1999) made an important observation in that in material considered by them to be *O. sefini* from the early Cenomanian of Spain, chamber passage shape varies between macrospheric and microspheric generations. In macrospheric forms they considered chamber passage shape to be exclusively triangular, but in microspheric forms to be elliptical to sub-rectangular (illustrations show some triangular passages as well). This complicates species

determination, as care needs to be taken to assess the generation of specimens being observed. For example, in the type material of *O. sefini* from Iraq, it is not possible to determine the generation of specimens showing tangential sections and chamber passage shape. This is also true for *O. hensoni*, leading to the possibility that *O. sefini* and *O. hensoni* (*sensu* Simmons et al., 2000) represent different generations of the same taxon. This can only be resolved by study of more topotype material. Herein, we consider that the material of Cherchi & Schroeder (1999) is probably *O. sefini* but needs to be proven by comparison with additional type material.

Stratigraphic range: Very latest Albian – earliest Cenomanian (uncertain). Difficulties in the reliable identification of *O. sefini* challenge an assessment of its stratigraphic range. Henson (1948) considered the species to be Cenomanian, but this is partly due to the broad concept of the taxa he employed that might include other Cenomanian Orbitolininae (e.g., species of *Conicorbitolina*). Furthermore, the Cenomanian age of the type locality at Sefin Dagh is unproven. It could certainly be late Albian. Schroeder in Schroeder & Neumann (1985) considered the species to be latest Albian – earliest Cenomanian and Schroeder et al (1986) recorded it from the late Albian of SW England supported by ammonite records. However, these records are now better assigned to *O. hensoni*.

Lopez-Horgue et al. (2009) consider that the range may extended to low in the late Albian of Spain (*variscum* Zone, *binum* subzone = approximately mid-*pricei* zone fig. 3 herein) because of ammonite co-occurrences, but confirmation of the identity of *O. sefini* is uncertain (= *Orbitolina* spp. herein). Specimens of "*Orbitolina* (*Orbitolina) concava qatarica"* illustrated by Schroeder (1962) from the early Cenomanian of Spain may be this species, given the embryonic apparatus dimensions (total diameter 0.68 mm and proloculus diameter 0.26 mm) and chamber passages that appear to grade from triangular to rectangular.

The species has been extensively reported from the Middle East, although many records are without illustration, or only supported by illustrations that are effectively inadequate to determine species. Simmons & Hart (1987) illustrated an uncertain specimen from the lower Natih Formation of Oman (latest Albian – earliest Cenomanian according to Bromhead et al., 2022). This is equivalent to the Mauddud Formation recognised in many parts of Arabia, and from which *O. sefini* is frequently reported, although seldom with supporting definitive illustration (see for example, Mohammed, 1996; Noori et al., 2016; Youssef et al., 2019; Navidtalab et al., 2020; Manhi & Alsultani, 2021; Shakir & Mousa, 2023 – all unconfirmed).

Al-Mamory & Al-Dulaimi (2020) Ameen & Gharib (2014) report the species from the Qamchuqa Formation of northern Iraq, but the illustrations are indeterminate.

The species has been reported from the early Cenomanian of Israel (Frank et al., 2010), whilst illustrations by Hamaoui (1965) from Israel of "*Orbitolina* cf. *O. concava sefini*" are probably of *Conicorbitolina*. Records from the middle – base late Cenomanian of NW Syria (Ghanem & Kuss, 2013) are also most likely of *Conicorbitolina* and can be discounted from an assessment of stratigraphic range. A record from the late Albian – early Cenomanian Naur Formation of Jordan (Schulze et al., 2004) is not of *Orbitolina* as illustrated.

Xu et al. (2023) illustrate the species (as "cf.") from the late Albian upper Khazdumi Formation of the Iranian Zagros, but the specimen is best considered as *Orbitolina* spp. as defined herein. Likewise, Luger (2018) confidently reports the species from the late Albian – early Cenomanian of Somalia, but the illustrations are probably better assigned to *Orbitolina* spp.

Palaeogeographic distribution: As with assessment of stratigraphic range, difficulties in the reliable identification of *O. sefini* challenge an assessment of its palaeogeographic distribution. Iraq remains the only area where its presence – poor definition notwithstanding – has been confirmed (southern Neotethys), with other possible occurrences in Oman and Spain.

Orbitolina qatarica Henson, 1948

T 1948 *Orbitolina concava* (Lamarck) var. *qatarica* – Henson, p. 66-67, pl. 5, fig. 7-10 (non fig. 11 = *Mesorbitolina aperta*), text-fig. 10. "Cenomanian", subsurface Qatar, but more likely late Albian (see text).

Non 1969 *Orbitolina concava* (Lamarck) *qatarica* Henson – Sampò, pl. 39, figs. 16-17, 19-21 (= *Palorbitolinoides hedini* Cherchi & Schroeder *fide* Schlagintweit et al., 2022).

Non 1976 *Orbitolina concava qatarica* – Ho et al., p. 20, pl. 3, fig. 4, 1-16. (=*Palorbitolina ultima* or *Palorbitolinoides fide* Rao et al., 2017).

?1993 *Orbitolina qatarica* - Hewaidy & Al-Hitmi, p. 479, pl. 5, fig. 4-7. Late Albian, subsurface Qatar.

?1996 *Orbitolina qatarica* – Mohammed, p. 66-68, pl. 7, fig. 8-9; pl. 8, fig. 1-3. Late Albian, subsurface southern Iraq.

2000 *Orbitolina qatarica* – Simmons et al., p. 423-424, pl. 2, figs. 7-9. Most likely late Albian, subsurface Qatar (see text).

2018 *Orbitolina qatarica* – Luger, p. 75-77, pl. 8, fig. 11-14, pl. 9, fig. 1-5. Early Cenomanian, Somalia.

Diagnostic features: An *Orbitolina* with a proloculus of max diameter c.0.20mm, and which is often convex upwards with a flat base. The embryonic apparatus diameter is 0.72 – 0.75mm. The supra-embryonic zone is markedly conical, relatively thick and highly subdivided. The sub-embryonic zone is thin, convex and highly subdivided. Radial zone chamber passages are almost exclusively rectangular in section.

Remarks: Initially introduced as a variety of *O. concava* by Henson (1948), it was elevated to subspecies then species status by a number of workers (e.g., Schroeder,

1962, 1975; Simmons et al., 2000; Luger, 2018). In his review of *O. concava* and *O. sefini*, Schroeder in Schroeder & Neumann (1985) considered *O. qatarica* as morphologically intermediate between them. Simmons et al. (2000) considered it as a distinct species, that whilst having mostly rectangular chamber passages and a large embryonic apparatus (both typical of *O. concava*), the embryonic apparatus was sufficiently distinct in subconical form and highly divided supra-embryonic and sub-embryonic zones. Luger (2018) independently came to similar conclusions, and emphasised the relationship to *O. sefini*, as opposed to *O. concava*, noting that some specimens could only be considered "*O. sefini/qatarica*". Nonetheless, he recorded viable specimens from the early Cenomanian of Somalia (including an invalid lectotype – not from original syntypes).

Within the syntypes of Henson (1948) there is a specimen (pl. 5, fig. 11 therein) that has been regarded as aberrant (Simmons et al., 2000; Luger, 2018). In fact, this specimen conforms to *Mesorbitolina aperta* (Erman), highlighting the mixture of taxa that can occur in several syntypic series of Henson (1948) (Simmons et al., 2000).

As with all species of *Orbitolina*, multiple, good quality axial and tangential sections are required to confirm identity, and as such, records of its stratigraphic range are hard to confirm. Misidentifications also occur, for example by Sampò (1969) from the Albian of the Iranian Zagros that include *Palorbitolinoides hedini* (*fide* Schlagintweit et al., 2022). Older records (e.g., Schroeder, 1962; Berthou & Schroeder, 1978) might be better incorporated in the modern concept of *O. sefini* or *O. hensoni.*

Stratigraphic range: Latest Albian – early Cenomanian (confident but scarce), uncertain in middle Cenomanian. The type locality in the subsurface of Qatar was considered Cenomanian by Henson (1948), supported by the co-occurrence with *Praealveolina tenuis*. Although this is oft-cited, Le Blanc (2015) showed that the type material in fact comes from the Mauddud Formation (late Albian according to Bromhead et al., 2022) and that the *P. tenuis* records represent caving. See also effective topotypes illustrated by Hewaidy & Al-Hitmi (1993), although their identity is uncertain. It is also reported from the Mauddud of Qatar by El Beialy & Al-Hitmi (1994), but the illustrations cannot be identified. Hofker (1963) illustrated the embryonic apparatus of each of three specimens of what he termed "*Orbitolina lenticularis*" from the type locality (but not the type horizon?) of *O. qatarica* (pl. 17, fig. 11-13). Their identity is uncertain but seems unlikely to be *Orbitolina sensu stricto*.

Owen & Nasr (1958) and van Bellen et al. (1959) reported (without illustration) the species from the Rumaila Formation of southern Iraq. If correct, this would imply an age as young as middle Cenomanian (Bromhead et al., 2022). Many other records from southern Iraq are from the late Albian Mauddud Formation (Noori et al, 2016; Ezzulddin & Ibrahim, 2022; Shakir & Mousa, 2023), although only those of Mohammed (1996) are potentially plausible, others indeterminate or being ascribable to *Orbitolina* spp. at best. This includes a record from the Mauddud in southern Iran (Farsi et al., 2022), although the authors regard this as proof of a middle Cenomanian age, counter to regional evidence.

It was also recorded from the late Albian Qamchuqa Formation of N. Iraq (Ameen & Gharib, 2014), but the illustrations are uncertain.

Records from the early Cenomanian of Spain (Ramirez del Pozo, 1972) and Tibet (Ho et al., 1976; Yang et al., 1982; BouDagher-Fadel et al., 2017; Xu et al., 2019, 2021) are either not illustrated or misidentified. The records of Ho et al. (1976) from Tibet are considered to be of the *Palorbitolina ultima - Palorbitolinoides hedini* lineage by Rao et al. (2017).

In summary, the potential stratigraphic range is late Albian – early Cenomanian, possibly middle Cenomanian, although more work is needed to confirm this.

Palaeogeographic distribution: In common with other *Orbitolina* species, confirmed records of *O. qatarica* remain few and so far, restricted to Qatar and Somalia (southern Neotethys). Other possible occurrences are reported from southern Iraq.

***Orbitolina duranddelgai* Schroeder, 1972**

1951 *Orbitolina conoidea* – Cuvillier & Sacal, pl. 26, fig. 1 Late Albian, France.

1963 *Orbitolina lenticularis* – Hofker jr., pl. 17, fig. 5; pl. 20, fig. 2, 4-6. Albian – Cenomanian transition, Spain.

1964 *Orbitolina* (*O.*) *concava concava* – Schroeder, p. 688-690, text-fig. 3a-d. Albian – Cenomanian transition, Spain.

1965 *Orbitolina conica* – Saint-Marc, pl. 4, fig. 2; pl. 14, fig. 7. Early Cenomanian, France.

T 1972 *Orbitolina* (*Orbitolina*) *duranddelgai* n. sp. – Schroeder, p. 114-116; text-fig. 2-3 Albian – Cenomanian transition, Spain.

1973 *Orbitolina* (*O.*) *duranddelgai* – Bilotte, pl. 1, fig. 1-4; pl. 4, fig. 9 Latest Albian, Pyrenees, France.

1973 *Orbitolina* (*O.*) *duranddelgai* – Schroeder, text-fig. 2-3 Albian – Cenomanian transition, Spain.

1976 *Orbitolina* (*O.*) *duranddelga*i – Peybernes, p. 394; pl. 31, fig. 3-4; pl. 32, fig. 18-19 Latest Albian, Spain

1976 *Orbitolina* (*O.*) *duranddelgai* – Cherchi & Schroeder, p. 1217; text-fig. 1 Latest Albian – early Cenomanian, Sardinia.

? 1977 *Orbitolina* (*O.*) *duranddelga*i – Rey et al., p. 378; pl. 2, fig. 7 Latest Albian, Portugal.

1984 *Orbitolina* (*Orbitolina*) *duranddelgai* – Bilotte, p. 364, pl. 1, fig. 10 (figs. 5-9 uncertain). Latest Albian, Pyrenees.

1985 *Orbitolina* (*O.*) *duranddelgai* – Schroeder in Schroeder & Neumann, p. 68-70, pl., 31, fig. 1-9 late Albian, Spain.

Non 1993 *Orbitolina* (*Orbitolina*) *duranddelgai* – Bravo & Garcia, pl. 3(1). Appears similar to *O. qatarica*, but best classified as *Orbitolina* spp. in the absence of definitive sections.

Diagnostic features: An *Orbitolina* with a proloculus of diameter 0.25 – 0.30mm and height 0.14 – 0.16mm, and which is irregularly ellipsoidal or cup-shaped. The embryonic apparatus diameter is 0.50 – 0.70mm (max 0.80mm). The supra-embryonic zone is highly subdivided. The sub-embryonic zone is thin, and only weakly subdivided. Radial zone chamber passages are numerous and densely-spaced, oval to squarish.

Remarks: This species was introduced by Schroeder (1972) for an *Orbitolina* with numerous, small, oval – squarish radial chamber passages, more densely spaced than in *Orbitolina concava* and an embryonic apparatus 0.5-0.7 mm (0.8 mm max) in diameter.

Stratigraphic range: Very latest Albian – earliest Cenomanian (confident and common). Based on the type material from Spain, the species was originally considered as Cenomanian, but corrected (for the type material) to latest Albian (*dispar* zone = approximately *rostratum/perinflatum* zones fig. 3 herein) by Schroeder in Schroeder & Neumann (1985). Nonetheless, it was (mistakenly) considered a useful early Cenomanian zonal fossil by Schroeder (1973, 1975). Following discussion of the age range by Bilotte et al. (1978) and Berthou & Schroeder (1978), *O. duranddelgai* was further described by Schroeder in Schroeder & Neumann (1985) with a suggested short range of latest Albian to earliest Cenomanian. The Cenomanian extension to the range was established from records with *Praealveolina* from France and Spain (Debuyser & Schroeder, 1972; Peybernes, 1976; Babinot et al., 1991; Caus et al., 1993, 2009; Calonge et al., 2003; Calonge-Garcia & Lopez-Carillo, 2003; Consorti et al., 2016). Nonetheless, Schroeder et al. (1993) noted its value as a marker for the latest Albian in eastern Spain (see also Bilotte et al., 1978; Moullade et al., 1985) and Bilotte (1984) illustrated material from the latest Albian of the French Pyrenees. Martin-Chivelet (1994) considered it an early Cenomanian marker in Spain, thereby emphasising the possibility of short local ranges.

The need to observe both sections of the embryonic apparatus and the chamber passages led Castro et al. (2001) and Bachmann et al. (2003) to use the term "*Orbitolina sefini/duranddelgai"*, with Luger (2018) emphasising the difficulty of identifying *Orbitolina sensu stricto* species in the absence of multiple suitably oriented sections. Bachmann et al. (2003) considered "*Orbitolina sefini/duranddelgai*" to potentially range from the *inflatum* zone (= approximately *cristatum-fallax* zones fig. 3 herein) of the late Albian – middle early Cenomanian (restricted to the late Albian in northern Sinai) but provided no illustrations.

Palaeogeographic distribution: The species may be endemic to the western Mediterranean (northern margin of Neotethys), with most viable records from Spain or the French Pyrenees. The only records from the Arabian Plate are those of Afghah & Fanati Rashidi (2007) from the (Albian) Kazhdumi Formation of the Iranian Zagros (not illustrated) and BouDagher-Fadel (2018) (identification and stratigraphic position uncertain, but not *O. duranddelgai).* Therefore, *O. duranddelgai* appears to be absent from the Arabian Plate, a view supported by Dr. Mohsen Yazdi-Moghadam (pers. comm., 2024).

Orbitolina hensoni Simmons, Whittaker & Jones 2000

1948 *Orbitolina* cf. *concava* – Henson, p. 61-64; pl. 4, fig. 5-10; text fig. 10. "Cenomanian" (late Albian), subsurface Iraq.

? 1978 *Orbitolina* (*Orbitolina*) cf. *concava qatarica* – Berthou & Schroeder, p. 76, pl. 4, fig. 8-12. Early Cenomanian, Portugal.

? 1985 *Orbitolina* (*Orbitolina*) *sefini* – Schroeder in Schroeder & Neumann, pl. 30, fig. 4-8. Late Albian, Spain.

1986 *Orbitolina* (*Orbitolina*) *sefini* – Schroeder et al., p. 383-385, text fig. 2a-g. Late Albian, SW England.

1990 *Orbitolina (Orbitolina) concava* – Weidich & Al-Harithi, p. 605-606, pl. 5, figs. 1-10. Albian – Cenomanian transition, Jordan (age in part based on this occurrence).

1992 *Orbitolina sefini* – Simmons & Williams, pl. 1, figs. 3-5. Late Albian, south-west England.

T 2000 *Orbitolina hensoni* n. sp. – Simmons et al., p. 423, pl. 2, fig. 1-2 ; pl. 4, fig. 9. Late Albian, subsurface Iraq.

Diagnostic features: An *Orbitolina* with a proloculus of max diameter c.0.25mm. The proloculus is not well known in published illustrations but appears concave upwards. The embryonic apparatus diameter is c. 0.60mm and generally has a flat base. The supra-embryonic zone is highly subdivided. The sub-embryonic zone is thin, and less strongly subdivided than the supra-embryonic zone. Radial zone chamber passages are distinctive and exclusively equilateral triangular in shape.

Remarks: Following their reappraisal of *Orbitolina sefini*, *Orbitolina hensoni* was introduced by Simmons et al. (2000) for *Orbitolina* with exclusively triangular chamber passages. An embryonic apparatus with a diameter of 0.6 mm and a flat-based, upwards concave proloculus is a supplementary defining feature, although the proloculus shape is poorly known.

Specimens of "*O.* (*O.*) *sefini*" from the late Albian of Spain illustrated by Schroeder in Schroeder & Neumann (1985) that may be better referred to *O. hensoni* (note triangular chamber passages) have a cup-shaped or spherical proloculus. The embryonic apparatus is a little larger (diameter 0.7-0.8 mm; proloculus diameter 0.2 mm) than the type material of *O. hensoni*. Specimens of "*O. sefini*" from the late Albian of southwest England

(Schroeder et al., 1986; Simmons & Williams, 1992) have clearly triangular chamber passages and an embryonic apparatus in the size range of *O. hensoni*, although its morphology is slightly different.
See discussion of *O. sefini* for issues surrounding chamber passage shape that differ between macrospheric and microspheric generations (Cherchi & Schroeder, 1999). Conceptually, this might be a difference that mistakenly led Simmons et al. (2000) to separate *O. hensoni* from *O. sefini* but cannot be proved without a review of better topotype material.
Stratigraphic range: Latest Albian (confident and common) – (uncertain) ?earliest Cenomanian. With type material from the Naftah-1 well in Iraq, the range was tentatively regarded as late Albian. The only other named record of the species is that of Farsi et al. (2022) who provided indeterminate illustrations from the (late Albian) Mauddud portion of the Sarvak Formation from the Iranian Zagros (Kuh-e-Genu).
The species may have been recorded from the early Cenomanian of Portugal as "*Orbitolina* (*Orbitolina*) cf. *concava qatarica*" (Berthou & Schroeder, 1978). Specimens of "*Orbitolina (Orbitolina) concava*" illustrated by Weidich & Al-Harithi (1990) from the Albian/Cenomanian transition of Jordan fit well with the identity of *O. hensoni* in terms of embryonic apparatus size and chamber passage shape.
Palaeogeographic distribution: Confirmed records (notwithstanding issues concerning identity) range from Jordan and Iraq to the UK with possible records also from Iran and the Iberian Peninsula. Consequently *O. hensoni* as interpreted herein appears to be the most widespread of the *Orbitolina* species.

***Orbitolina pauletensis* Schroeder 1962**

? 1847 *Orbitolites concava* – Michelin, p. 28, pl. 7, fig. 9. Early Cenomanian, France.
T 1962 *Orbitolina* (*Orbitolina*) *concava pauletensis* – Schroeder, p. 189-191, pl. 20, fig. 1-2, 12. Early Cenomanian, France.
1964 *Orbitolina* (*Orbitolina*) *concava pauletensis* – Schroeder, p. 687, text-fig. 2. Early Cenomanian, France.

Diagnostic Features: An *Orbitolina* with a proloculus of max diameter c.0.28mm. The embryonic apparatus diameter is c. 0.875mm. The supra-embryonic zone is highly subdivided. The sub-embryonic zone is thin, and weakly subdivided. Radial zone chamber passages are triangular at first, becoming rectangular in older chambers.
Remarks: Introduced as a new subspecies of *Orbitolina concava* by Schroeder (1962) based on type material from supposedly basal Cenomanian sandstones at St Paulet in the Gard region of southern France. At the time, Schroeder (1962) distinguished two other subspecies of *Orbitolina concava*: *Orbitolina concava concava* and *Orbitolina concava qatarica*. *Orbitolina concava pauletensis* was differentiated on the basis of a thin (0.04 – 0.05 mm) and poorly subdivided subembryonic zone. The embryonic apparatus appears to be around 0.875 mm in diameter (second largest to *O. concava*), and the proloculus has a maximum diameter of 0.24 – 0.28 mm. The chamber passage shape is triangular becoming rectangular in adult chambers. Schroeder (1962) considered it the oldest member of a *pauletensis* – *qatarica* – *concava* lineage.
However, after 1962, Schroeder almost never mentioned the species again (it is completely ignored in his 1975 and 1985 reviews for example and only very briefly mentioned and illustrated by Schroeder (1964)).
Stratigraphic range: Earliest Cenomanian (confident but scarce records). Neumann & Schroeder (1981) mention it with a late Albian – early Cenomanian range, but without explanation. In practice, the species needs to be redescribed on the basis of type and topotype material, and if valid, its range reassessed.
Palaeogeographic distribution: In so much as the species is known, it appears to be endemic to the western Mediterranean (Western Neotethys).

RECOMMENDATIONS FOR TAXONOMIC BEST PRACTICE

As noted by Schlagintweit & Simmons (2022) the correct identification of species of *Orbitolina* (and of orbitolinids in general) is not straightforward. Random thin-sections through rock samples containing *Orbitolina* need to fortuitously provide axial sections through the macrospheric embryonic apparatus, and also tangential sections that provide a view of chamber passage shape. Furthermore, it is useful to have multiple axial sections through the embryonic apparatus, so that a range of measurements of the feature and its constituent parts are available (e.g. Simmons & Williams, 1992). Given this, many specimens encountered during analysis or as published in the literature cannot be identified at species level. Nonetheless, a view of the embryonic apparatus that indicates a tripartite division into proloculus, sub-embryonic zone and supra-embryonic zone in which the sub-embryonic zone is markedly thinner than the supra-embryonic zone indicates that *Orbitolina* is present, and we recommend the use of the term *Orbitolina* spp. for such specimens that cannot be identified as definite discreet species. For example, the majority of the numerous relevant embryonic apparatus variations published by Hofker (1963) of "*Orbitolina lenticularis*" that are actually *Orbitolina* spp., and cannot be assigned to any of the six specific species listed here.

***Orbitolina* spp.**

1963 *Orbitolina lenticularis* – Hofker jr., pl. 17, 1-4, 6-10; pl. 19, fig. 1-14, pl. 20 fig. 1, 10, 15 Albian – Cenomanian transition, Spain.

1973 *Orbitolina* (*Orbitolina*) *concava qatarica* – Schroeder, text-fig. 2b. Late Albian, Spain.
1977 *Orbitolina* (*Orbitolina*) *concava* – Rey et al., p. 378, pl. 2, fig. 11-12. Late Albian, Portugal.
1981 *Orbitolina (Orbitolina) concava* – Schroeder, pl. 2, fig. 1-3. Lower Cenomanian, southern Germany.
1985 *Orbitolina* (*Orbitolina*) *concava* – Moullade et al., pl. 1, fig. 11. No age or location provided.
1985 *Orbitolina (Orbitolina) concava* – Weidich, pl. 4, fig. 1, 4. Reworked into Late Cretaceous strata, southern Germany.
1987 *Orbitolina* (*Orbitolina*) *sefini* – Simmons & Hart, pl. 10.2, fig. 3. Late Albian – early Cenomanian, Oman.
1988 *Orbitolina* gr. *concava* – Velić, pl. 2, fig. 14. Lower Cenomanian, Croatia.
1992 *Orbitolina* cf. *concava* – Simmons & Williams, pl. 1, fig. 6; pl. 2, fig. 1. Early Cenomanian, southwest England.
1993 *Orbitolina* (*Orbitolin*a) *duranddelgai* – Bravo & Garcia, pl. 3(1). Late Albian, Spain.
2000 *Orbitolina* (*Orbitolina*) gr. *sefini* – *concava* – Husinec et al., text-fig. 10(1). Early – Middle Cenomanian, Croatia.
2001 *Orbitolina* (*Orbitolina*) gr. *sefini-durandelgai* [sic] - Castro et al., text-fig. 5(R). Early Cenomanian, Spain.
2005 *Orbitolina concava* – Schlagintweit & Wagreich, p. 117-118, pl. 1, fig. 1, 10; pl. 2, fig. 1. Early Cenomanian, Austria (although age is implied by this record).
2009 *Orbitolina sefini* - Lopez-Horgue et al., text-fig. 10 K-L. Lower upper Albian (*varicosum* ammonite zone (*binum* subzone)).
2009 *Orbitolina (Orbitolina) concava* - Parvaneh Nejad Shirazi et al., pl. 1, fig. 8. Albian, Iranian Zagros.
2015 *Orbitolina concava* – Schlagintweit et al., text-fig., 1a. Early – middle Cenomanian, Spain (age in part defined by occurrence).
?2018 *Orbitolina sefini* – Luger, p. 74-75, pl. 7, fig. 10-14., pl. 8, fig. 1-3, 5. Late Albian, Somalia.
2018 *Orbitolina* ex interc. *sefini/qatarica* – Luger, pl. 8, fig. 4, 6-10. Late Albian, Somalia.
2020 *Orbitolina* gr. *concava* - Yazdi-Moghadam & Schlagintweit, text-fig 2A. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2020 *Orbitolina* gr. *concava* – Schlagintweit & Yazdi-Moghadam, text-fig. 3D. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2021 *Orbitolina* ex gr. *concava* - Yazdi-Moghadam & Schlagintweit, text-fig 7P. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2021 *Orbitolina* ex gr. *concava* – Schlagintweit & Yazdi-Moghadam, text-fig 2E. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2022 *Orbitolina qatarica* – Ezzulddin & Ibrahim, pl. 1, fig. A. Late Albian, Iraq.
2022 *Orbitolina qatarica* – Farsi et al., pl. 1, fig. 4. Late Albian, Iranian Zagros.
2022 *Conicorbitolina conica* – Farsi et al., pl. 1, fig. 5-6. Late Albian, Iranian Zagros.
2022 *Orbitolina* ex gr. *concava* - Yazdi-Moghadam & Schlagintweit, text-fig 2E. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2023 *Orbitolina* ex gr. *concava* – Schlagintweit & Yazdi-Moghadam, text-fig 3E. Early Cenomanian, Iranian Zagros (note age is partly based on this occurrence).
2023 *Orbitolina* cf. *sefin*i – Xu et al., text-fig. 3B. Late Albian, Iranian Zagros.

Remarks: From this compilation of occurrences, it appears that *Orbitolina* spp. has a stratigraphic range from intra-late Albian to perhaps as young as middle Cenomanian (effectively the range of the genus *sensu stricto*) with records from across Neotethys.
An additional complication is that, notwithstanding the efforts of Schroeder in Schroeder & Neumann (1985), Cherchi & Schroeder (1999) and Simmons et al. (2000), a number of *Orbitolina* species remain poorly described and difficult to use with confidence until new, ideally topotype, material is presented. *Orbitolina sefini* and *Orbitolina pauletensis* are particularly problematic in this respect with only limited axial sections through the embryonic apparatus available in type material. Note too, that different understanding of chamber passage shape for *O. sefini* between Schroeder in Schroeder & Neumann (1985), Cherchi & Schroeder (1999) and Simmons et al. (2000) adds uncertainty to past and ongoing use of this species and of *O. hensoni* until more material is available. Despite this, we consider these taxa display sufficient differences (in albeit non-ideal type material) to justify the separation we have afforded them here, at least for the present.
Palaeogeographic distribution: Mainly throughout southern Neotethys, from the western Mediterranean to the Arabian Plate, with relatively more sporadic occurrences in the North Neotethyan Margin.

ORBITOLINA AS A BIOSTRATIGRAPHIC TOOL

Orbitolina and its allies are widely cited as important tools for biostratigraphy in shallow-marine carbonate and marl facies from mid-Cretaceous Neotethys (Schroeder & Neumann, 1985, Moullade et al., 1985; Simmons et al., 2000). The inception of *O. concava* has been regarded as a proxy for the base of the Cenomanian, and to range no younger than a level within the Cenomanian (Schroeder & Neumann, 1985; Tröger & Kennedy, 1996; Velić, 2007; Schlagintweit et al., 2015; Simmons & Bidgood, 2023). Our review suggests that this is essentially correct – *O. concava sensu stricto* is not known from late Albian strata and appears to have definitely been recorded from both early and middle Cenomanian strata. On the other hand, other species of *Orbitolina* are definitely found or might be found within the late Albian (although not excluding a range into the Cenomanian). These include *O. duranddelgai* and possibly *O. sefini*, *O. qatarica*, and *O. hensoni*. *O. pauletensis* is too poorly known to be confident of its range.

There is thus an important caveat on the range of *O. concava*: confidently identified specimens can indicate an early – middle Cenomanian age range; but for those specimens that cannot be confidently identified as *O. concava* or another species of *Orbitolina* and are thus *Orbitolina* spp. as used herein, then an age range of late Albian – middle Cenomanian is indicated. This likely includes forms described in the literature as "*Orbitolina concava*" with a late Albian – intra-Cenomanian age range, but not illustrated (e.g. Saint-Marc, 1981). It is evident from the remarks above that there are some definite occurrences of *Orbitolina* as old as the *pricei* ammonite zone in the late Albian (recorded in Figure 3 as *Orbitolina* spp.), but it cannot yet be confirmed what species they are.

Age range summaries for the constituent species of *Orbitolina* including *Orbitolina* spp. are given in Figure 3.

In this work we have used three broad categories to depict stratigraphic range confidence:

Confident and Common - a wide, solid, green line on Figure 3

A relatively large number of (correctly) illustrated records (or if unillustrated, from a generally reliable source) with at least plausible age-control.

Confident but Scarce – a narrow, solid, green line on Figure 3

At least one, but relatively fewer records but which fit the same criteria as above.

Uncertain – a series of orange "?" on Figure 3

Occurrences that lie outside of the "confident" ranges that are neither confirmed in terms of identity nor age-control but cannot be completely dismissed (e.g., an illustrated record with poor age-control or an unillustrated record from a generally reliable source with good age control).

As can be readily understood, subjectivity plays a role here, and the boundaries between one category and another are inevitably gradational.

Records which exist of named species occurring in rocks outside of these ranges, but which are based on very uncertain (i.e. dubious) identity and/or age control are not shown on Figure 3.

Species of *Orbitolina sensu stricto* can be demonstrated to occur across an area extending from north-west Europe, the circum-Mediterranean, and to Somalia and the Arabian Plate. There may be some endemic patterns in this distribution as suggested by Luger (2018). For example, *O. concava* and *O. duranddelgai* are not convincingly found outside of the Northwest Europe - Mediterranean region. It is unclear if different lineages of *Orbitolina* independently arose from *Mesorbitolina* (?) ancestral stock in the Mediterranean and Arabian Plate, or if taxa arose in Arabia and rapidly migrated westwards (following prevailing palaeocurrents – Simmons & Bidgood, 2023, fig. 84 therein), with some morphological changes to create new species. Firm conclusions await the necessary taxonomic revisions derived from as yet unavailable data as highlighted in this paper.

O. concava and *O. qatarica* have been reported from Tibet (Ho et al., 1976; Yang et al., 1982; Zhang, 1982; BouDagher-Fadel et al., 2017), but these records cannot be validated or are clearly other taxa (Rao et al., 2017). Other species of *Orbitolina* (*Orbitolina*) reported by Zhang (1982, 1986) (*O. (O.) birmanica*, *O. (O.) aliensis*, *O. (O.) deltoides*, *O. (O.) bangoinica*, *O. (O.) toibaica*) are all species of *Mesorbitolina*, either valid (as in the case of *O. (O.) birmanica = M. birmanica* (see Schlagintweit & Wilmsen, 2014)) or synonyms of other *Mesorbitolina* species). Indeed, Zhang (1994) concluded that no *Orbitolina sensu stricto* or Cenomanian orbitolinids occurred in Tibet. A similar situation appears to be the case in Borneo (Schlagintweit & Simmons, 2023) and Japan (Iba et al., 2011).

CONCLUSIONS

Orbitolina is an important larger benthic foraminifera genus, often found in abundance in mid-Cretaceous shallow-marine facies within the former Neotethys realm. Following the work of Schroeder (1962) the genus has a clear and precise definition based on the characteristics of a tripartite subdivision of an apically-situated macrospheric embryonic apparatus. Many taxa once regarded as *Orbitolina* belong in allied genera.

There are six potential species of *Orbitolina* (*O. concava*, *O. sefini*, *O. qatarica*, *O. hensoni*, *O. duranddelgai*, and *O. pauletensis*). Their identity depends partly on details of the size and shape of the embryonic apparatus and its constituent parts, and on the shape of the chamber passages that may be triangular, oval, or rectangular, or grade between different shapes (and also vary between macrospheric and microspheric forms). Other than *O. concava* and *O. duranddelgai*, the other species of *Orbitolina* need better description requiring access to topotype material. Because confident identification requires observation of (ideally multiple) sections through the embryonic apparatus and of chamber passage shape and density, many specimens encountered cannot be identified to species level. It is proposed that these be referred to as *Orbitolina* spp..

O. concava is confirmed as a useful larger benthic foraminifera species for the recognition of Cenomanian (specifically early and middle Cenomanian) strata, but care needs to be taken to separate it from other similar species of *Orbitolina* that may range into the late Albian, whilst recognition of the more general *Orbitolina* spp. concept implies an age within the range late Albian - middle Cenomanian.

The limited confident data available suggests that the distinct species of *Orbitolina* may have at least partly endemic palaeogeographic distribution.

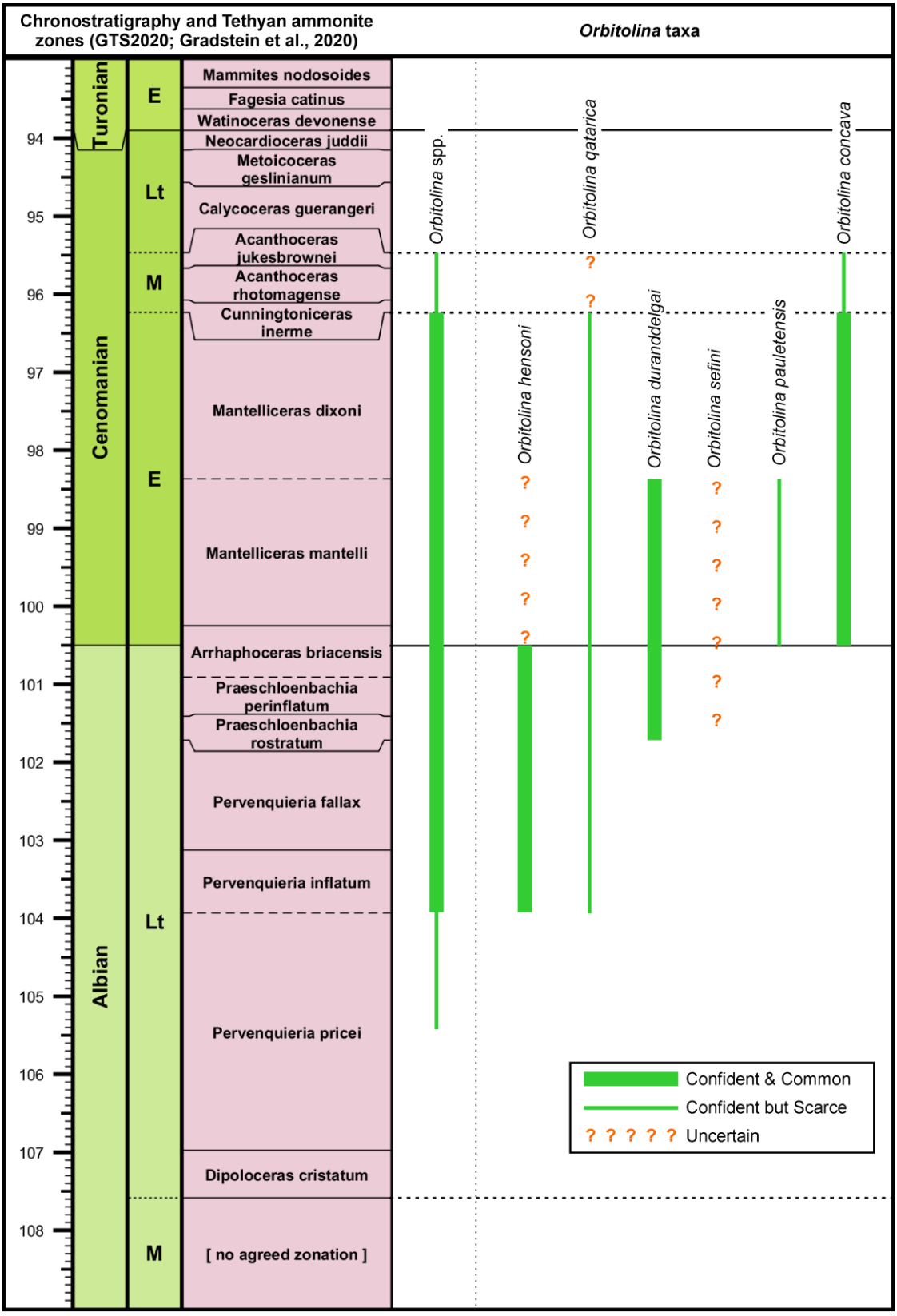


Fig. 3. Stratigraphic ranges of the constituent species of *Orbitolina*. Note there is a high degree of uncertainty.

Appendix – An Inventory of "*Orbitolina*"

The authors of this paper are aware of more than 150 taxa that have been originally assigned to the genus *Orbitolina*, following its introduction by d'Orbigny (1850), or have commonly been assigned to the genus. This includes species, subspecies, and varieties. Table 1 below lists these in alphabetical order, noting the broad age and location of the types (with comments as appropriate), and the modern synonymy of each taxon if it can be determined.

Tabel 1. List of taxa assigned to *Orbitolina* since its introduction by d'Orbigny (1850), or commonly assigned to that genus. Where possible, a modern taxon equivalent is shown, either based on literature or as reviewed herein.

Taxon	Full Original Name	Author	Type Age & Type Locality	Comment on Age	Accepted Name Herein	Key Synonymy Reference & Comment
a	*Orbitolina lenticularis* Lamarck var. *a*	Carter, 1861	Cretaceous, Ras Fartaq, Arabia (modern day Yemen)		Indeterminate	Drawing; no embryo
A	*Orbitolina* (*Mesorbitolina*) sp. *A*	Fourcade & Raoult, 1973	Late Aptian, Algeria		*Mesorbitolina birmanica*	Schlagintweit & Wilmsen, 2014; Schlagintweit, 2024
absidata	*Orbitolina* (*Columnorbitolina*) *absidata*	Zhang, 1986	Early Albian, Tibet	Late Aptian (Rao et al., 2015) (age based on identification as *Mesorbitolina parva*)	*Mesorbitolina parva* (= *Mesorbitolina tibetica fide* Schlagintweit & Le Coze, 2023)	Rao et al., 2015; Schlagintweit & Le Coze, 2023
aliensis	*Orbitolina* (*Orbitolina*) *aliensis*	Zhang, 1982	Albian, Tibet		*Mesorbitolina birmanica*	Schlagintweit & Wilmsen, 2014; Schlagintweit, 2024
alpha	*Orbitolina anomala* Prever var. α	Prever, 1909	Cenomanian, Italy		Indeterminate	Isolated specimen; no thin-section with embryo
alticonica	*Orbitolina* (*Columnorbitolina*) *alticonica*	Zhang, 1982	Albian, Tibet		*Mesorbitolina texana* (High-conical morphotype)	Herein
andreaei	*Orbitolina andreaei*	Martin, 1891	Cenomanian, Spain		*Mesorbitolina aperta*	Schroeder, 1962; Schroeder in Schroeder & Neumann, 1985
annularis	*Orbitolina concava* Lamarck var. *annularis*	Parker & Jones, 1860	Recent, Australia		*Annulopatellina annularis*	Parr & Collins, 1930 (type species of *Annulopatellina*)
anomala	*Orbitolina anomala*	Prever, 1909	Cenomanian, Italy		Indeterminate	Based on external features only (drawing)
aperta	*Orbitulites apertus*	Erman, 1854	Cretaceous, Spain	Early Cenomanian (Feuillée, 1967)	*Mesorbitolina aperta*	Schroeder (1962, 1975, 1979; Schroeder in Schroeder & Neumann, 1985
arcuala	*Orbitolina arcuala*	Mohammed, 2012	Late Albian, Iraq	The type section, in well Kirkuk-109, is early – middle Albian, based on regional correlation (e.g. Aqrawi et al., 2010).	*Mesorbitolina texana*	Consorti & Schlagintweit, 2021
arenosa	*Orbitolina arenosa*	Mamontova, 1961	Neocomian, Western Turkmenistan		Indeterminate	Thin-section images without embryo
asaguana	*Orbitolina texana* (Roemer) var. *asaguana*	Hodson, 1926	Aptian, Venezuela		Indeterminate	Based on external features only
aspera	*Orbitolina* (*Mesorbitolina*) *aspera*	Zhang, 1986	Early Albian, Tibet	Late Aptian - Late Albian (Rao et al., 2015) (age in part based on identification as *M. subconcava*)	*Mesorbitolina subconcava*	Rao et al., 2015
b	*Orbitolina lenticularis* Lamarck var. *b*	Carter, 1861	Cretaceous, Ras Fartaq, Arabia (modern day Yemen)		Indeterminate	Drawing; no embryo
baconica	*Orbitolina lenticularis baconica*	Méhes, 1964	Late Aptian, Hungary	Age may be Albian (Bodrogi, 1993)	Mixture of *Mesorbitolina texana*, *M. birmanica*. On the other hand, Görög (1990) suggested that some types may be *M. subconcava*.	Herein respectively *M. texana* = pl. 1, fig. 3; *M. birmanica* pl. 3, fig. 1 of Mehes (1964). Topotypes (?) (Bodrogi, 1993) may be *M. texana*. This species needs restudy.
badchysica	*Orbitolina badchysica*	Mamontova, 1961	Neocomian, Western Turkmenistan		Indeterminate	Thin-section images without embryo
bangoinica	*Orbitolina* (*Orbitolina*) *bangoinica*	Zhang, 1982	Cenomanian, Tibet	Cenomanian age unlikely (Rao et al., 2017)	*Palorbitolinoides hedini*	Schroeder et al., 2010 (see also Zhang, 1986, 1994)
beremendensis	*Orbitolina beremendensis*	Méhes, 1967	Aptian, Hungary		*Mesorbitolina texana*	Schlagintweit, 1990
beta	*Orbitolina anomala* Prever var. *β*	Prever, 1909	Cenomanian, Italy		Indeterminate	Isolated specimen; no thin-section with embryo
birmanica	*Orbitolina birmanica*	Sahni, 1937	Barremian, Myanmar	Revised range: Upper Aptian - upper Albian (Rao et al., 2020)	*Mesorbitolina birmanica*	Zhang, 1994; Schlagintweit & Wilmsen, 2014
birmanica (emend.)	*Orbitolina birmanica* Sahni emend.	Sahni & Sastri, 1957	Cenomanian, Myanmar	Revised range: Upper Aptian - upper Albian (Rao et al., 2020)	*Mesorbitolina birmanica*	Zhang, 1994; Schlagintweit & Wilmsen, 2014
boehmi	*Orbitolina boehmi*	Prever, 1909	Cenomanian, Italy		Indeterminate	Based on external features only
bulgarica	*Orbitolina bulgarica*	Boué, 1840	Lower Cretaceous, Bulgaria		*Palorbitolina lenticularis*	Schroeder, 1963
burzilensis	*Orbitolina kashmirica* Sahni & Sastri var. *burzilensis*	Sahni & Sastri, 1957	Aptian - Albian, Kashmir		Indeterminate	Cherchi et al., 1984. No visible embryo
c	*Orbitolina lenticularis* Lamarck var. *c*	Carter, 1861	Cretaceous, Ras Fartaq, Arabia (modern day Yemen		Indeterminate	Drawing; no embryo
chitralensis	*Orbitolina chitralensis*	Sahni & Sastri, 1957	Aptian - Cenomanian, Pakistan		*Mesorbitolina tibetica*	Herein
choffati	*Orbitolina choffati*	Prever, 1905	Cretaceous, Italy		Indeterminate	No thin-section with embryo
communis	*Orbitolina polymorpha* Prever var. *communis*	Prever, 1909	Cretaceous, Italy		Indeterminate	Isolated specimen; no thin-section with embryo
complanata	*Orbitolina* (*Palorbitolina*) *complanata*	Zhang, 1982	Albian, Tibet	Age revised to late Barremian (Zhang, 1994)	*Palorbitolina complanata*	Zhang 1994. Considered a synonym of *Palorbitolina lenticularis* by BouDagher-Fadel et al., 2017
concava	*Orbulites concava* (Not *Orbitolites concava* Lamarck 1801)	Lamarck, 1816	Early Cenomanian, France		*Orbitolina concava*	Schroeder, 1962
concava	*Orbitolites concava* (Not *Orbulites concava* Lamarck, 1816)	Lamarck, 1801	Cretaceous, France		*Lunulites* sp. (Bryozoan)	Parker & Jones, 1860; Schroeder, 1962
confusa	*Orbitolina confusa*	Pašić, 1962	Turonian, Serbia	Age must be questioned as Turonian *Orbitolina* are unknown.	*Mesorbitolina confusa*	Zhang 1994. Types possibly show an amalgam of several taxa. This species requires further research. It is not an *Orbitolina sensu stricto*
congesta	*Orbitolina concava* Lamarck var. *congesta*	Parker & Jones, 1860	Recent, Australia		Indeterminate, possibly a species of *Gypsina* (Brady, 1884).	No figure. No Recent Orbitolininae are known.
conica	*Orbitolites conica*	d'Archiac, 1837	Cretaceous, France	Now considered Cenomanian (Schroeder in Schroeder & Neumann, 1985)	*Conicorbitolina conica*	Schroeder in Schroeder & Neumann, 1985
conicoformis	*Orbitolina conicoformis*	Mamontova, 1961	Neocomian, Western Turkmenistan		Indeterminate	Thin-section images without embryo
conoidea	*Orbitolina conoidea*	Gras, 1852	Barremian - Aptian, France		*Palorbitolina lenticularis*	Schroeder, 1963
conulus	*Orbitolina conulus*	Douvillé, 1912	Barremian, Spain	Now considered late Albian (Schroeder, 1965)	*Neorbitolinopsis conulus*	Schroeder, 1965

cotyliformis	*Orbitolina* (*Mesorbitolina*) *cotyliformis*	Zhang, 1986	Early Albian, Tibet		Seems identical to *Orbitolina* (*Mesorbitolina*) *aperta* (primitive form) *sensu* Schroeder (1975, fig. 8)	Herein.
crassa	*Orbitolina crassa*	Douglass, 1960	Lower Cretaceous, New Mexico	Now considered Albian (Scott et al., 2007)	? *Mesorbitolina texana*	Poorly known.
cuvillieri	*Neoiraqia cuvillieri*	Moullade in Moullade et al., 1972	Latest Albian-earliest Cenomanian, France		*Conicorbitolina cuvillieri*	Schroeder, 1975
daviesi	*Orbitolina daviesi*	Hofker, 1966	Late Paleocene, Pakistan		*Karsella daviesi*	Schlagintweit, 2021
delicata	*Orbitolina discoidea* Gras var. *delicata*	Henson, 1948	Barremian, Qatar		*Palorbitolina lenticularis*	Schroeder, 1963; Simmons et al., 2000
deltoides	*Orbitolina* (*Orbitolina*) *deltoides*	Zhang, 1982	Albian, Tibet		*Mesorbitolina birmanica*	Schlagintweit & Wilmsen 2014; Schlagintweit, 2024
dinarica	*Orbitolina dinarica*	Pašić, 1962	Turonian, Serbia	Age must be questioned as Turonian *Orbitolina* are unknown.	*Mesorbitolina texana*	This species requires further research. It is not an *Orbitolina sensu stricto*
discoidea	*Orbitolina discoidea*	Gras, 1852	Aptian, France		*Palorbitolina lenticularis*	Schroeder, 1963
douvillei	*Orbitolina douvillei*	Prever, 1905	Cretaceous, Italy		Indeterminate	No thin-section with embryo
duranddelgai	*Orbitolina* (*Orbitolina*) *duranddelgai*	Schroeder, 1972	Latest Albian, Spain		*Orbitolina duranddelgai*	Schroeder, 1972; Schroeder in Schroeder & Neumann, 1985
equisepimenta	*Orbitolina* (*Columnorbitolina*) *equisepimenta*	Zhang, 1986	Early Aptian, Tibet	Age may need to be re-evaluated	*Mesorbitolina texana*	Herein
erratica	*Orbitolina* (*Mesorbitolina*) *erratica*	Cherchi, 1979	Albian?, Sardinia		*Mesorbitolina tibetica*	Herein
ezoensis	*Orbitolina discoidea-conoidea* var. *ezoensis*	Yabe & Hanzawa, 1926	Aptian?, Japan		Indeterminate	Based on external and dimensional features
franca	*Orbitolina polymorpha* Prever var. *franca*	Prever, 1909	Cenomanian, Italy		Indeterminate	No thin-section with embryo
gamma	*Orbitolina anomala* Prever var. γ	Prever, 1909	Cenomanian, Italy		Indeterminate	No thin-section with embryo
gigantea	*Orbitolina gigantea*	d'Orbigny, 1850	Late Cretaceous, France		*Cyclolites gigantea* (a coral)	Douvillé, 1933; Schroeder & Simmons, 1988, 1989
gigantea	*Orbitolina* (*Mesorbitolina*) *gigantea*	Zhang, 1986	Late Albian, Tibet	Late Albian - early Cenomanian (Rao et al., 2015). Age revision in part based on reidentification as *Mesorbitolina aperta*	*Mesorbitolina aperta*	Zhang, 1994; BouDagher-Fadel et al., 2017; Rao et al., 2015
gracilis	*Orbitolina gracilis*	Douglass, 1960	Lower Cretaceous, New Mexico	Now considered Albian (Scott et al., 2007)	*Mesorbitolina subconcava*	*M. subconcava* = specimen pl. 12, fig. 14 (paratype) of Douglass (1960) as determined herein
grossa	*Orbitolina grossa*	Douglass, 1960	Lower Cretaceous, New Mexico	Now considered Albian (Scott et al., 2007)	? *Mesorbitolina texana*	Herein
hensoni	*Orbitolina hensoni*	Simmons, Whittaker & Jones, 2000	Cenomanian - Late Albian, Iraq		*Orbitolina hensoni*	Simmons et al., 2000
hukawngensis	*Orbitolina hukawngensis*	Sahni & Sastri, 1957	Cenomanian?, Myanmar		Indeterminate	Lacking information on the embryo (Schroeder, 1962).
imparilis	*Orbitolina* (*Mesorbitolina*) *imparilis*	Zhang, 1986	Early Albian, Tibet	Late Aptian - late Albian (Rao et al., 2015). Age revision in part based on reidentification as *Mesorbitolina subconcava*	*Mesorbitolina subconcava*	Rao et al., 2015
intermedia	*Orbitolina intermedia*	Prever, 1905	Cretaceous, Italy		Indeterminate	Based on external features only
irregularis	*Orbitolina* (*Mesorbitolina*) *irregularis*	Zhang, 1986	Aptian, Tibet		*Mesorbitolina texana*	Herein
janenschi	*Orbitolina bulgarica* Toula var. *janenschi*	Dietrich, 1925	Early Cretaceous, East Africa		Indeterminate	No visible embryo; based on external and dimensional features
japonica	*Orbitolina japonica*	Yabe & Hanzawa, 1926	Aptian, Japan		Indeterminate	No visible embryo; based on external and dimensional features
kashmirica	*Orbitolina kashmirica*	Sahni & Sastri, 1957	Aptian - Albian Kashmir		*Palorbitolina lenticularis*	Cherchi et al., 1984
kiliani	*Orbitolina? kiliani*	Prever in Silvestri, 1932	Barremian, France		*Orbitolinopsis kiliani*	Moullade & Thieuloy, 1965
kurdica	*Orbitolina kurdica*	Henson, 1948	Lower Cretaceous, Iraq		*Mesorbitolina texana*	Simmons et al., 2000
kutaungensis	*Orbitolina birmanica* Sahni var. *kutaungensis*	Sahni & Sastri, 1957	Cenomanian, Myanmar		*Mesorbitolina texana*	Herein
laevis	*Orbitolina concava* Lamarck var. *laevis*	Parker & Jones, 1860	Not given		Considered a species of *Sphaerogypsina*	Horton, 1962
lamina	*Orbitolina lamina*	Ho et al., 1976	Cenomanian, Tibet		*Palorbitolinoides* or *Mesorbitolina*	Oblique section
langshanensis	*Orbitolina* (*Mesorbitolina*) *langshanensis*	Zhang, 1986	Early Albian, Tibet	Late Aptian - late Albian (Rao et al., 2015)	*Mesorbitolina subconcava*	Rao et al., 2015
lata	*Orbitolina texana* (Roemer) subsp. *lata*	Mehes, 1964	Late Albian, Hungary		*Mesorbitolina aperta*	Schroeder in Schroeder & Neumann, 1985
lenticularis	*Madreporites lenticularis*	Blumenbach, 1805	Aptian, France		*Palorbitolina lenticularis*	Schroeder, 1963
lepida	*Orbitolina* (*Columnorbitolina*) *lepida*	Zhang, 1982	Albian, Tibet		*Mesorbitolina texana*	Herein
leymeriei	*Orbitolina* (*Mesorbitolina*) *leymeriei*	Peybernès, 1980	Albian, Pyrenees		? *Mesorbitolina subconcava*	Herein
lhunzhubensis	*Orbitolina* (*Columnorbitolina*) *lhunzhubensis*	Zhang, 1982	Aptian, Tibet		*Mesorbitolina parva* = *M. tibetica* (Schlagintweit & Le Coze 2023)	Zhang, 1994; BouDagher-Fadel et al., 2017
libanica	*Orbitolina discoidea* Gras var. *libanica*	Henson, 1948	Aptian, Lebanon		*Mesorbitolina texana*	Schroeder in Schroeder & Neumann, 1985; Simmons et al., 2000
lotzei	*Orbitolina* (*Mesorbitolina*) *lotzei*	Schroeder, 1964	Aptian, Spain	Late early Aptian (Schroeder et al., 2010)	*Mesorbitolina lotzei*	Schroeder, 1964
mamillata	*Nummulina mamillata*	d'Archiac, 1850	Cretaceous, France		*Conicorbitolina conica*	Schroeder, 1962
maryoensis	*Orbitolina* (*Mesorbitolina*) *maryoensis*	Zhang, 1986	Early Aptian, Tibet	Age may need to be re-evaluated	*Mesorbitolina texana*	BouDagher-Fadel et al., 2017
megasphaerica	*Orbitolina* (*Palorbitolina*) *megasphaerica*	Zhang, 1982	Aptian, Tibet		*Palorbitolina lenticularis*	Zhang, 1994
melendezi	*Orbitolina* (*Mesorbitolina*) *texana melendezi*	Ramírez Del Pozo, 1971	Late Aptian, Spain		*Mesorbitolina birmanica*	Schlagintweit et al., 2016; Schlagintweit, 2024
michaelis	*Orbitolina michaelis*	Silvestri, 1907	Cretaceous, Italy		Indeterminate	Unillustrated
microsphaerica	*Orbitolina* (*Columnorbitolina*) *microsphaerica*	Zhang, 1982	Barremian, Tibet	Age may need to be re-evaluated	*Mesorbitolina tibetica*	Schlagintweit & Le Coze, 2023
minima	*Orbitolina polymorpha* Prever var. *minima*	Prever, 1909	Cretaceous, Italy		Indeterminate	Based on external features only

minor	*Orbitolina* (*Mesorbitolina*) *texana* (Roemer) subsp. *Minor*	Schroeder, 1965	Early Aptian, Spain		*Mesorbitolina parva* (= *Mesorbitolina tibetica fide* Schlagintweit & Le Coze, 2023)	Schroeder, 1965 (footnote)
minuscula	*Orbitolina* (*Columnorbitolina*) *minuscula*	Zhang, 1982	Aptian, Tibet		*Mesorbitolina parva* (= *Mesorbitolina tibetica fide* Schlagintweit & Le Coze, 2023)	Rao et al., 2015; BouDagher-Fadel et al., 2017
minuta	*Orbitolina minuta*	Douglass, 1960	Albian, Texas		*Mesorbitolina texana* and *M. subconcava*	Schroeder in Schroeder & Neumann, 1985
miyakoensis	*Orbitolina japonica* Yabe & Hanzawa var. *miyakoensis*	Yabe & Hanzawa, 1926	Aptian - Albian, Japan		Indeterminate	No visible embryo; based on external and dimensional features
monagasana	*Orbitolina texana* (Roemer) var. *monagasana*	Hodson, 1926	Aptian, Venezuela		Indeterminate	Based on external features only
morelensis	*Orbitolina morelensis*	Ayala-Castañares, 1960	Albian, Mexico		*Mesorbitolina subconcava*	Schroeder in Schroeder & Neumann, 1985
obesa	*Orbitolina obesa*	Sahni & Sastri, 1957	Aptian - Cenomanian, Tibet		Indeterminate	No visible embryo
oculata	*Orbitolina oculata*	Douglass, 1960	Lower Cretaceous, Texas	Now considered Albian (Scott et al., 2007)	*Mesorbitolina texana*	Herein
orientala	*Orbitolina* (*Columnorbitolina*) *orientala*	Zhang, 1982	Albian, Tibet		*Mesorbitolina texana*	BouDagher-Fadel et al., 2017
ovalis	*Orbitolina* (*Mesorbitolina*) *ovalis*	Görög & Arnaud-Vanneau, 1996	Late Aptian – Early Albian, Venezuela		*Mesorbitolina birmanica* (= *Mesorbitolina pervia*)	Schlagintweit & Wilmsen, 2014; Schlagintweit, 2024
paeneconica	*Orbitolina* (*Orbitolina*) *paeneconica*	Vial, 1973	Latest Albian, France		Indeterminate	Schroeder in Schroeder & Neumann (1985) considered this a poorly described taxon, consisting of at least two species with *Conicorbitolina corbarica* amongst the paratypes. Because of the poor illustration of the holotype, he considered *O. paeneconica* an indeterminate and doubtful species.
parma	*Orbitolina parma*	Fossa-Mancini, 1928	Cretaceous, Kashmir		Indeterminate	No visible embryo
paronai	*Orbitolina paronai*	Prever, 1909	Cenomanian, Italy		Indeterminate	Based on external features only
parva	*Orbitolina parva*	Douglass, 1960	Lower Cretaceous, New Mexico	Now considered Albian (Scott et al., 2007)	*Mesorbitolina tibetica*	Schlagintweit & Le Coze, 2023
patula	*Orbitolina patula*	Carter, 1857	Cretaceous, Arabia		Indeterminate	Not illustrated and poor description; was recognized by Carter (1861, p. 458) as belonging to "*Orbitolina lenticularis"*
pauletensis	*Orbitolina* (*Orbitolina*) *concava* (Lamarck) subsp. *pauletensis*	Schroeder, 1962	Cenomanian, France		*Orbitolina pauletensis*	Herein
pengboensis	*Orbitolina* (*Columnorbitolina*) *pengboensis*	Zhang, 1982	Aptian, Tibet		*Mesorbitolina tibetica* (= *Mesorbitolina parva*)	Schlagintweit & Le Coze, 2023
pervia	*Orbitolina pervia*	Douglass, 1960	Lower Cretaceous, Texas	Now considered Albian (Scott et al., 2007)	*Mesorbitolina birmanica*	Schlagintweit, 2024
pileus	*Orbitolina pileus*	Fossa-Mancini, 1928	Cretaceous, Kashmir		*Palorbitolina pileus*	Schlagintweit, 2023
plana	*Orbitolites plana*	d'Archiac, 1837	Cretaceous, France		*Orbitolina concava*	Schroeder, 1962; Schroeder in Schroeder & Neumann, 1985
planoconvexa	*Orbitolina planoconvexa*	Yabe & Hanzawa, 1926	Aptian - Albian, Japan		Indeterminate	No visible embryo
pleurocentralis	*Orbiculina pleurocentralis*	Carter, 1857	Lower Cretaceous, Arabia		Indeterminate	Drawing; no embryo
polymorpha	*Orbitolina polymorpha*	Prever, 1909	Cenomanian, Italy		Indeterminate	Based on external features only
praeconica	*Orbitolina praeconica*	Méhes, 1964	Late Albian, Hungary		Mixture of *Conicorbitolina conica* and an unknown orbitolinid with initial coil (pl. 4, fig. 8)	Herein
praecursor	*Orbitolina praecursor*	Montanari, 1964	Barremian-Aptian, Sicily		*Palorbitolina lenticularis praecursor*	Arnaud-Vanneau, 1980. The necessity for a subspecies on the basis of environmentally controlled external test shape can be questioned.
prisca	*Orbitolina* (*Eorbitolina*) *prisca*	Zhang, 1982	Late Barremian-Aptian, Tibet		*Eopalorbitolina charollaisi*	Zhang, 1994
qatarica	*Orbitolina concava* (Lamarck) var. *qatarica*	Henson, 1948	Cenomanian Qatar	More likely late Albian (see text herein)	*Orbitolina qatarica*	Simmons et al., 2000
radiata	*Orbitolina radiata*	d'Orbigny, 1850	Late Cretaceous, France		Indeterminate	Not illustrated
raoi	*Orbitolina raoi*	Sahni & Sastri, 1957	Cenomanian?, Myanmar		Indeterminate	No visible embryo
regularis	*Orbitolina* (*Mesorbitolina*) *regularis*	Zhang, 1986	Early Aptian, Tibet		Most likely *Mesorbitolina birmanica*	Herein
robusta	*Orbitolina* (*Eorbitolina*) *robusta*	Zhang, 1982	Aptian, Tibet		?*Dictyorbitolina ichnusae* (1), *Praeorbitolina wienandsi* (2), Undiagnostic for determination (3)	Loeblich & Tappan, 1988 (1); BouDagher-Fadel et al., 2017 (2); this work (3)
rutogensis	*Orbitolina* (*Columnorbitolina*) *rutogensis*	Zhang, 1982	Aptian, Tibet		*Mesorbitolina tibetica*	Schlagintweit & Le Coze, 2023
santonica	*Orbitolina santonica*	Eremeeva in Eremeeva & Belousova, 1961	Santonian - ?Coniacian, Russian Urals		Indeterminate	Trochospiral coiling thus not an orbitolinid. No internal description
scitula	*Orbitolina* (*Columnorbitolina*) *scitula*	Zhang, 1982	Aptian, Tibet	Age may need to be reconsidered based on identification as *Mesorbitolina subconcava*	*Mesorbitolina subconcava*	Herein
scutum	*Patellina scutum*	von Fritsch, 1878	Eocene, Borneo	Age incorrect, probably Aptian (Hashimoto & Matsumaru, 1974)	*Palorbitolina lenticularis*	The material of von Fritsch (1878) was used by Martin (1890) to recognise "*Orbitolina concava*". In turn, this material can be shown to be *Palorbitolina lenticularis* (Schlagintweit & Simmons, 2023)
sefini	*Orbitolina concava* (Lamarck) var. *sefini*	Henson, 1948	Cenomanian, Iraq	Could well be late Albian (see herein)	*Orbitolina sefini*	Simmons et al., 2000
semiannularis	*Orbitolina concava* Lamarck var. *semiannularis*	Parker & Jones, 1860	Recent, Indian Ocean		Indeterminate	No detailed description. Age precludes likelihood that this is a true *Orbitolina*.
serbica	*Orbitolina serbica*	Pašić, 1962	Turonian, Serbia	Age must be questioned as Turonian *Orbitolina* are unknown.	*Mesorbitolina birmanica*	Herein

shikokuensis	*Orbitolina shikokuensis*	Yabe & Hanzawa, 1926	Lower Cretaceous, Japan		*Mesorbitolina subconcava*	Schroeder in Schroeder & Neumann, 1985
simplex	*Orbitolina concava* Lamarck var. *simplex*	Parker & Jones, 1860	Eocene, France		Indeterminate	No detailed description. Age precludes likelihood that this is a true *Orbitolina*.
sphaerulata	*Orbitolina concava* Lamarck var. *sphaerulata*	Parker & Jones, 1860	Recent		*Baculogypsina sphaerulata*	It is the type species of *Baculogypsina* Sacco, 1893
sphaerulolineata	*Orbitolina concava* Lamarck var *sphaerulolineata*	Parker & Jones, 1860	Late Cretaceous, Belgium		Indeterminate	No detailed description. Age precludes likelihood that this is a true *Orbitolina*.
subaperta	*Orbitolina mamillata* d'Archiac var. *subaperta*	Astre, 1930	Aptian - Albian, Spain	Now considered lower Albian (Hofker, 1963)	Indeterminate	No internal description
subconcava	*Orbitolina sub-concava*	Leymerie, 1878	Lower Cretaceous, France	Now considered early - middle Albian (Schroeder in Schroeder & Neumann, 1985)	*Mesorbitolina subconcava*	Schroeder in Schroeder & Neumann, 1985
texana	*Orbitulites texanus*	Roemer, 1849	Cretaceous, Texas	Now considered early Albian (Scott et al., 2007)	*Mesorbitolina texana*	Schroeder, 1964; Schroeder in Schroeder & Neumann, 1985
thompsoni	*Orbitolina thompsoni*	Hodson, 1926	Aptian, Venezuela		Indeterminate	Based on external features only
tibetica	*Orbitolina tibetica*	Cotter, 1929	Lower Cretaceous, Tibet	Now considered Aptian (Zhang, 1994)	*Mesorbitolina tibetica*	Schlagintweit & Le Coze, 2023 (see also Zhang, 1994)
tibetica emend.	*Orbitolina tibetica* Cotter emend.	Sahni & Sastri, 1957	Lower Cretaceous, Tibet	Now considered Aptian (Zhang, 1994)	*Mesorbitolina tibetica*	Schlagintweit & Le Coze, 2023 (see also Zhang, 1994)
toibaica	*Orbitolina* (*Orbitolina*) *toibaica*	Zhang, 1986	Late Albian, Tibet		*Mesorbitolina aperta*	Herein
trochus	*Patellina trochus*	von Fritsch, 1878	Eocene?, Borneo	Age incorrect, probably Aptian (Hashimoto & Matsumaru, 1974)	*Palorbitolina lenticularis*	The material of von Fritsch (1878) was used by Martin (1890) to recognise "*Orbitolina concava*". In turn, this material can be shown to be *Palorbitolina lenticularis* (Schlagintweit & Simmons, 2023)
turonica	*Orbitolina turonica*	Pašić, 1962	Turonian, Serbia	Age must be re-evaluated based on identification as *Conicorbitolina conica*	*Conicorbitolina conica*	Schroeder in Schroeder & Neumann, 1985
umbellata	*Orbitolina* (*Palorbitolina*) *umbellata*	Zhang, 1982	Aptian, Tibet		*Palorbitolina lenticularis*	BouDagher-Fadel et al., 2017
venezuelana	*Orbitolina venezuelana*	Karsten, 1886	Early Cretaceous, Venezuela		Indeterminate	No illustration of embryo
vesicularis	*Orbitolina concava* Lamarck var. *vesicularis*	Parker & Jones, 1860	Recent, Australia		*Gypsina vesicularis*	Carter, 1877
wadiai	*Orbitolina wadiai*	Sahni & Sastri, 1957	Barremian - Aptian, Myanmar		Indeterminate	No illustration of embryo
walnutensis	*Orbitolina walnutensis*	Carsey, 1926	Cretaceous, Texas	Now considered Albian (Scott et al., 2007)	*Carseyella walnutensis*	Schlagintweit, 2021
whitneyi	*Orbitolina whitneyi*	Carsey, 1926	Cretaceous, Texas	Now considered Albian (Scott et al., 2007)	Indeterminate	Based on external features and size ('unusually large')
xainzaensis	*Orbitolina* (*Mesorbitolina*) *xainzaensis*	Zhang, 1986	Early Albian, Tibet	Late Aptian - late Albian (Rao et al., 2015) based in part on recognition as *Mesorbitolina subconcava*	*Mesorbitolina subconcava*	Rao et al., 2015; BouDagher-Fadel et al., 2017
cf. *aliensis*	*Orbitolina* (*Conicorbitolina*) sp. cf. *O.* (*C.*) *aliensis*	Arnaud-Vanneau & Premoli Silva, 1995	Latest Albian, Pacific		*Mesorbitolina birmanica*	Rodrigo & Schlagintweit, 2022
cf. *bulgarica*	*Orbitolina* cf. *bulgarica* (Deshayes)	Henson, 1948	Early Cretaceous, Lebanon		Indeterminate	No visible embryo. Simmons et al., 2000
cf. *chitralensis*	*Orbitolina* cf. *chitralensis*	Sahni & Sastri, 1957	Cenomanian, India		See remarks	The high-conical specimen shown in plate 1, figure 1 of Sahni and Sastri (1957) is here considered as belonging to *Mesorbitolina tibetica* (Cotter) showing the tripartite embryo of *Mesorbitolina*. The protoconch and embryo diameters have been indicated by Sahni and Sastri (1957, p. 16) as 0.1 mm and 0.20 mm respectively fitting this interpretation (Douglass, 1960; Schlagintweit, 2023). Pudsey et al. (1985, p. 162): either *M. parva* or *M. texana*.
cf. *concava*	*Orbitolina* cf. *concava* (Lamarck)	Henson, 1948	Cenomanian, Iraq	Could well be late Albian (Simmons et al., 2000)	*Orbitolina hensoni*	Simmons et al., 2000.
cf. *concava qatarica*	*Orbitolina* (*Orbitolina*) cf. *concava qatarica*	Berthou & Schroeder, 1978	Early Cenomanian, Portugal		Possibly *Orbitolina hensoni*	See discussion herein
cf. *discoidea*	*Orbitolina* cf. *discoidea* Gras	Douvillé, 1915	Late Barremian – Early Aptian, Tibet		Indeterminate	No embryo visible
cf. *discoidea*	*Orbitolina* cf. *discoidea* Gras	Henson, 1948	Aptian-Albian, Syria		*Palorbitolina lenticularis*	Schroeder, 1963; Simmons et al., 2000
cf. *discoidea*	*Orbitolina* (*Palorbitolina*) cf. *discoidea*	Zhang, 1982	Late Aptian - early Albian, Tibet		*Palorbitolina lenticularis*	Herein
cf. *lenticularis*	*Orbitolina* cf. *lenticularis* (Blumenbach)	Henson, 1948	Aptian, Lebanon		*Mesorbitolina* sp.	Simmons et al., 2000
cf. *lenticularis*	*Orbitolina* cf. *lenticularis* (Blumenbach, 1805)	Mamontova, 1961	Neocomian, Western Turkmenistan		Indeterminate	Thin-section images without embryo
cf. *trochus*	*Orbitolina* cf. *trochus* (Fritsch)	Henson, 1948	Cretaceous, Iran		Indeterminate	Thin-sections without embryo. Simmons et al., 2000

Many taxa were described purely from external morphology and without further study of type material (if it can be located) are effectively indeterminate in terms of modern taxonomy (Figure 4). This includes taxa introduced by Parker & Jones (1860) and Prever (e.g., 1909) who also used a very loose sense of the meaning of the genus *Orbitolina.* Many others where the internal structure was described can be placed in the allied genera to *Orbitolina sensu stricto* (*sensu* Schroeder, 1962) such as *Palorbitolina*, *Mesorbitolina* or *Conicorbitolina*. This includes the plethora of seemingly unnecessary taxa introduced from Tibetan stratigraphy by Zhang (1982, 1986). However, illustration of internal structure is not a guarantee of the ability to assign a taxon to a modern species concept. Figure 4 demonstrates our approach to determination:

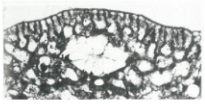
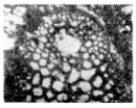
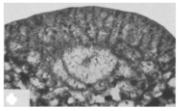
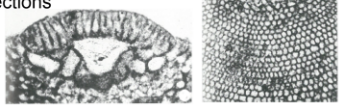
TYPE MATERIAL	ORBITOLINID NATURE / TYPES OF VIEW	TAXONOMIC CONCLUSION
Photo or drawing of external morphology  *Orbitolina obesa* Sahni & Sastri, 1957	Unproven but possible orbitolinid	No generic assignment possible [Orbitolinidae? indet.]
Thin-section image without embryo  *Orbitolina discoidea* var. *libanica* Henson, 1948	Confirmed as probable orbitolinid but unproven orbitolininid	No generic assignment possible [Orbitolininae? indet.]
Thin-section image with embryo  *Orbitolina concava* (Lamarck, 1801)	Random, not axial *Orbitolina aliensis* Zhang, 1982 	No generic nor specific assignment possible
	Axial but not centred *Orbitolina kurdica* Henson, 1948 	Different views among specialists (e.g., different taxa? synonymies?)
	Axial and centred *Orbitolina pauletensis* Schroeder, 1962 	Generic assignment probable-positive. Specific assignment questionable
	Axial and centred with visible chamber passages in tangential sections *Orbitolina duranddelgai* Schroeder, 1972 	Generic and specific assignment probable-positive

Fig. 4. Approach to determination of *Orbitolina* taxa listed in this appendix. All images taken from type specimens of various sorts as illustrated in the Catalogue of Foraminifera (Ellis & Messina, 1940-2015) except *Orbitolina concava* illustrated by Schroeder & Neumann (1985), Lamarck never providing an image.

This listing is almost certainly not exhaustive although we have reviewed a large amount of historical and international literature, assisted by tools such as the Ellis and Messina Catalogue (2002) and WORMS database (WoRMS Ed. Board, 2024). Our hope is that it will provide a useful tool for research into the Orbitolininae.

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