# Orbitolinids from Cretaceous sediments of the Middle East - a revision of the F.R.S. Henson and Associates Collection

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## ABSTRACT

Orbitolinids (here taken to mean *Orbitolina sensu lato*) are agglutinating larger foraminifera and are one of the most important groups of microfossils for Early to mid-Cretaceous biostratigraphic studies of carbonate platform sediments in the Tethyan realm. Modern studies by Professor Rolf Schroeder (1962 onwards) have shown that the structure of the embryonic apparatus (initial chambers seen in thin-section) of this group is the most important feature for taxonomic subdivision. Differences in the structure of the embryonic apparatus allow for several evolutionary lineages to be recognised, with each lineage typically containing a number of stratigraphically restricted species.

Although there are some exceptions, the use of orbitolinids in biostratigraphic studies in the Middle East has been hampered by a reliance on archaic taxonomic nomenclature, which has prevented the stratigraphic value of these microfossils from being fully utilised. Therefore, in order to review the stratigraphic distribution of Middle Eastern orbitolinids, it has proved necessary to carry out a complete taxonomic review of the previously described orbitolinid occurrences in the region.

The starting point for such a review must be the seminal work of F.R.S. Henson. Although orbitolinids had been described from the Middle East before Henson's publications, Henson was the first micropalaeontologist to realise the significance of the internal structure of orbitolinids in taxonomy. In 1948 he published his monograph "Larger Imperforate Foraminifera from South-Western Asia" in which he completely reviewed the occurrence of orbitolinids in the Middle East, describing 10 species and varieties within the genus *Orbitolina*: *Orbitolina kurdica* Henson, *Orbitolina* cf. *discoidea* Gras, *Orbitolina discoidea* var. *delicata* Henson, *Orbitolina discoidea* var. *libanica* Henson, *Orbitolina* cf. *bulgarica* Deshayes, *Orbitolina* cf. *lenticularis* (Blumenbach), *Orbitolina* cf. *trochus* (Fritsch), *Orbitolina* cf. *concava* (Lamarck), *Orbitolina concava* var. *sefini* Henson and *Orbitolina concava* var. *qatarica* Henson. However, the nomenclature he used cannot readily be compared with the now widely accepted nomenclature of Schroeder.

The type and figured material of Henson is held in the collections of The Natural History Museum, London, and has been extensively reviewed to place these taxa within current taxonomic nomenclature. In addition, the museum holds supplementary unillustrated material in the F.R.S. Henson and Associates Collection, which has been of great assistance in redescribing Henson's species.

Of Henson's own taxa, only two species are retained - *Orbitolina sefini* and *O. qatarica*, but a new species, *O. hensoni*, is created for *O.* cf. *concava sensu* Henson. In the Henson material we now recognise 11 species in total - *Conicorbitolina cuvillieri* (Moullade), *Mesorbitolina lotzei* Schroeder, *M. pervia* (Douglass), *M. subconcava* (Leymerie), *M. texana* (Roemer), *Orbitolina hensoni* sp. nov., *O. qatarica* Henson, *O. sefini* Henson, *Palorbitolina lenticularis* (Blumenbach), *Palorbitolinoides hedini* Cherchi & Schroeder, and *Praeorbitolina wienandsi* Schroeder. Each of Henson's taxa can include more than one of these species, and these species often also occur under more than one name in the Henson and Associates Collection. As an example, *Palorbitolina lenticularis* occurs under the names: *Orbitolina* cf. *discoidea* and *Orbitolina discoidea* var. *delicata*.

By revising the Henson Collection we now have a better idea of the stratigraphic and palaeogeographic distribution of orbitolinids in the Middle East and so can improve their utility in correlation and palaeoenvironmental studies. Work is ongoing to assess the use of auxiliary features for identification such as chamberlet shape, chamber layer thickness and

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style of the marginal zone. In non-axial thin-sections where the embryonic apparatus is absent, these features may prove a useful aid to identification, if consistency can be found within a species.

## INTRODUCTION

Orbitolinids are agglutinating larger foraminifera and can often be common, even abundant, in Early to mid-Cretaceous platform carbonates from the Tethyan Realm, including the Middle East. The occurrence of stratigraphically short-ranging species make this group of immense practical value in biostratigraphic studies of the sediments in which they occur.

Although the Family Orbitolinidae contains a large number of genera of diverse complex internal structure, we concentrate here on the Orbitolininae or *Orbitolina sensu lato*, including the genus *Orbitolina*, and the allied genera *Palorbitolina*, *Palorbitolinoides*, *Praeorbitolina*, *Mesorbitolina* and *Conicorbitolina*. These genera are characterised by a conical test (Figure 1A), usually a few millimetres in height and diameter (although they can attain diameters of 5cm or more), with numerous rectilinear chambers, the chambers being divided into marginal and central zones, the marginal zone having subepidermal partitions, the central zone containing vertical partitions. The earliest formed chambers of the megalospheric generation can form a complex embryonic apparatus that can be subdivided into protoconch, deuteroconch, subembryonic zone and peri-embryonic chamberlets dependant on the genera involved (Figure 1B-G). Thus the nature of the embryonic apparatus is the basis for initial generic classification:

*Orbitolina* d'Orbigny (1850) has a large apically situated embryonic apparatus subdivided into protoconch, deuteroconch and subembryonic zone (Figure 1F). The deuteroconch is about three times thicker than the subembryonic zone. Both the deuteroconch and subembryonic zone are subdivided by vertical radial beams.

*Palorbitolina* Schroeder (1963) has a relatively simple embryonic apparatus consisting of a large apically sited, globular, fused protoconch and deuteroconch (Figure 1C). This can be surrounded by a peri-embryonic ring of obliquely arranged chamberlets.

*Palorbitolinoides* Cherchi & Schroeder (1980) is the evolutionary descendant of *Palorbitolina* in which the peri-embryonic ring of chambers has expanded and fused to form a subembryonic area with a few beams which divide into irregular chamberlets. The upper surface of the embryonic apparatus has many short exoskeletal beams forming an alveolar layer.

*Praeorbitolina* Schroeder (1965) has a small embryonic apparatus consisting of a protoconch, deuteroconch and subembryonic zone, eccentrically situated and not completely surrounded by the earliest post-embryonic chamber (Figure 1D).

*Mesorbitolina* Schroeder (1962) has an apically situated embryonic zone subdivided into protoconch; deuteroconch and subembryonic zone in which the deuteroconch and subembryonic zone are of more or less equal thickness (Figure 1E). Both are subdivided by vertical exoskeletal beams.

*Conicorbitolina* Schroeder (1973) has an apically situated embryonic zone subdivided into protoconch, deuteroconch and subembryonic zone (Figure 1G), similar to *Mesorbitolina*. However, the marginal zone of this genus is highly differentiated with radial beams of three orders and horizontal rafters of two orders between the septa.

Species definition in the Orbitolininae is based on details of size, shape and subdivision of a given type of embryonic apparatus together with the shape of chamber passages that can be seen in tangential sections. The chamber passages are formed in the radial part of the central zone of each chamber layer (Figure 1A), where each chamber passage is subdivided by radial partitions which are prolongations of the vertical main partitions of the marginal zone (Schroeder, 1975). In cross-section these can be triangular, rectangular or oval, or show a gradation between shapes.

The taxonomy of the Orbitolinidae is reasonably well established, thanks in particular to the studies of Professor Rolf Schroeder who has demonstrated (e.g., Schroeder, 1975) the value of the internal structure, especially the embryonic apparatus, in classifying this important taxonomic group. In the Mediterranean region, the occurrence and stratigraphic range of the various taxa is well established. However, in the Middle East, where orbitolinids can be very common, the taxonomy of Schroeder has not been universally applied and many *Orbitolina* occurrences are in need of significant taxonomic revision. This can only refine the stratigraphic utility of this group in the Middle East region.

Hofker (1963) also used the size and structure of the embryonic apparatus to classify the orbitolinids, but his attempts to group the Orbitolininae into one species, *Orbitolina lenticularis*, with a history of gradual evolution of complexity of the embryonic apparatus has met with little approval. Schroeder and others have convincingly demonstrated that there are several evolutionary groups within the Orbitolininae, each meriting at least subgeneric status. Following Loeblich & Tappan (1987), these subgenera are herein considered as distinct genera.

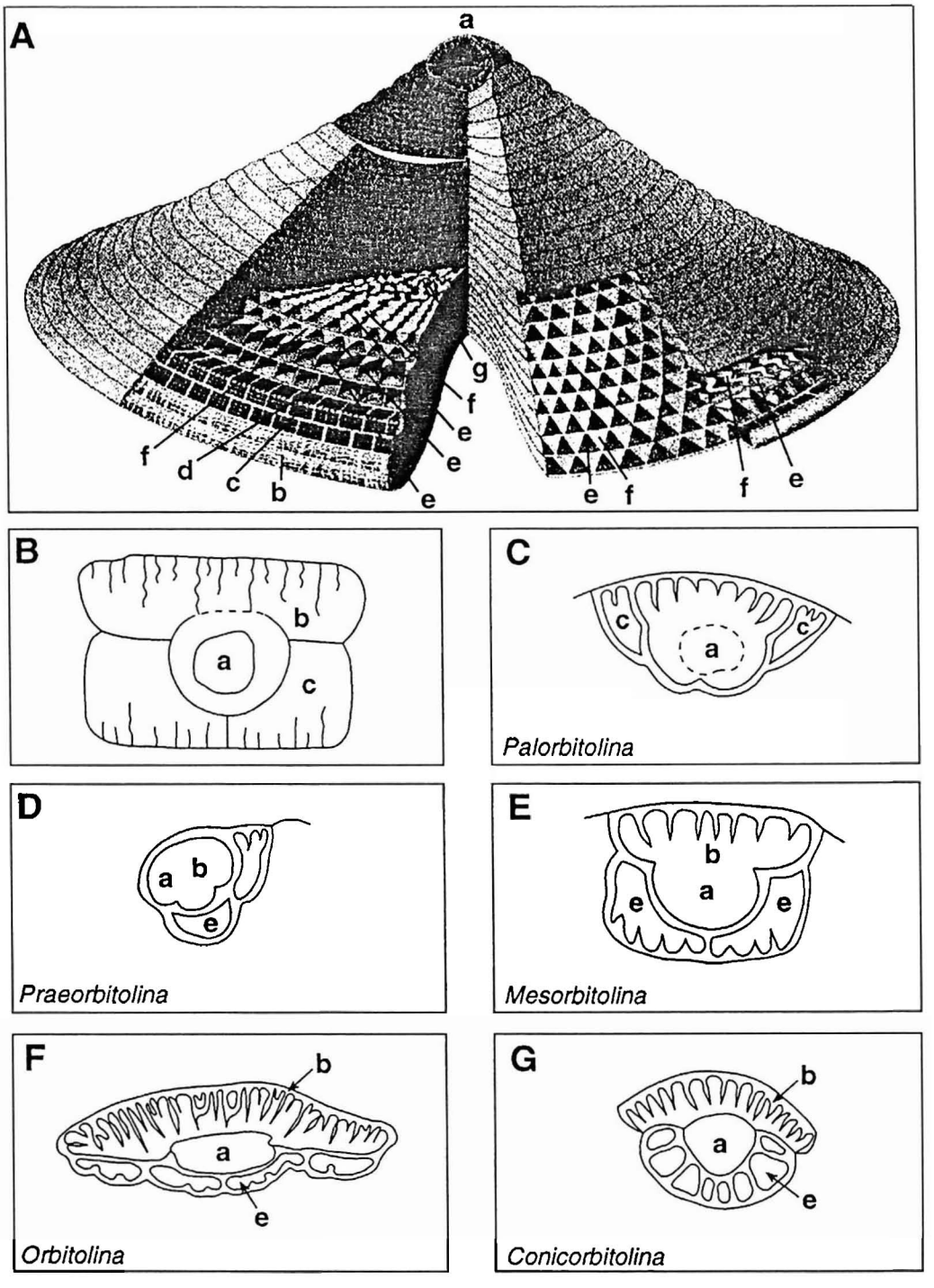


**Figure 1.** Key elements of the internal structure of Orbitolininae.
A. Reconstruction of *Orbitolina* (after Douglass, 1960) cut away in several planes to show key elements of internal structure. a - megalospheric embryonic apparatus; b - slightly eroded surface exposing cellules; c - marginal zone with surface cut away; d - deeper cut exposing chamberlets; e - chamber passages of the radial zone; f - main zigzag shaped partitions of the radial zone, in this case giving rise to triangular-shaped chamberlets; g - central complex.
B. Basic elements of the embryonic apparatus. a - Protoconch; b - Deuteroconch; c - Subembryonic zone. A remnant chitinous proloculus may be visible within the protoconch, whilst the deuteroconch and subembryonic zone may be subdivided by vertical exoskeletal beams.
C-G. Characteristic embryonic apparatus arrangement of the main genera of the Orbitolininae (after Arnaud-Vanneau, 1980). C. *Palorbitolina* with large fused protoconch and deuteroconch (a) surrounded by a ring of peri-embryonic chamberlets (c). D. *Praeorbitolina* with a small, eccentrically situated, embryonic apparatus consisting of a protoconch (a) and deuteroconch (b), partly surrounded by a subembryonic zone (e). E. *Mesorbitolina* with an apically situated embryonic apparatus subdivided into protoconch (a), deuteroconch (b) and subembryonic zone (e). The deuteroconch and subembryonic zone are of near-equal thickness and are divided by vertical exoskeletal beams. F. *Orbitolina* with protoconch (a) and highly subdivided deuteroconch (b) which is of greater thickness than the subembryonic zone (e). G. *Conicorbitolina* with protoconch (a) and convex deuteroconch (b) and concave subembryonic zone (e) of more or less equal thickness. Both are extensively subdivided.

The Natural History Museum, London [BMNH] holds significant numbers of orbitolinids from the Middle East in its F.R.S. Henson and Associates Collection. Henson (1948) published a very significant monograph on the orbitolinids (and many other larger foraminifera of Mesozoic and Cenozoic age) from the Middle East. Not only did this document the occurrence of orbitolinids over a wide region from modern-day Lebanon to Yemen, including Iraq, Iran and Qatar, but placed emphasis on the use of internal structure for taxonomic classification. In the 19th Century and early part of the 20th Century, orbitolinids had largely been characterised on the basis of their external shape. This is now known to vary with palaeoenvironment. However, Henson (1948), building on the work of Silvestri (1932), noted that internal features were the key to orbitolinid taxonomy. Using this as a criterion, Henson described 10 taxa from the Middle East: *Orbitolina kurdica* sp.nov., *Orbitolina* cf. *discoidea* Gras, *Orbitolina discoidea* Gras var. *delicata* var.nov., *Orbitolina discoidea* Gras var. *libanica* var.nov., *Orbitolina* cf. *bulgarica* Deshayes, *Orbitolina* cf. *lenticularis* (Blumenbach), *Orbitolina* cf. *trochus* (Fritsch), *Orbitolina* cf. *concava* (Lamarck), *Orbitolina concava* (Lamarck) var. *sefini* var.nov., and *Orbitolina concava* (Lamarck) var. *qatarica* var.nov.

Notwithstanding the work of Schroeder (*in* Schroeder & Neumann, 1985), the identity of most of these taxa, in terms of modern taxonomy, has not been established. The F.R.S. Henson and Associates Collection in The Natural History Museum, London, contains not only the type and figured specimens of Henson's species [BMNH thin-section numbers prefixed with the letter "P"], but also considerable supplementary material including metatypes (topotypes identified by the author) and other specimens used by Henson to establish the concept of his taxa [thin-section numbers usually prefixed with the letter "M"]. By reviewing all this material we have attempted to establish the identity of the Henson (1948) taxa and document their occurrence in the Middle East. In addition to the Henson and Associates material we also have access to extensive collections of orbitolinids from across the entire Middle East region thanks to our personal research and oil industry work. This additional material will be described in a forthcoming supplementary publication.

## THE HENSON (1948) TAXA

In the 19th Century and early part of the 20th Century, Orbitolininae were classified almost exclusively by external features. We now know (e.g., Schroeder, 1975) that their external shape and morphology varies with environmental conditions within a given species. Additionally, many descriptions of new species from that time are rudimentary in modern terms, resulting in difficulty in applying a consistent taxonomy to *Orbitolina* description. Silvestri (1932), followed by Davies (1939), recognised the value of internal structures, as seen in thin-section, in the classification of the Orbitolininae, but it was really Henson (1948) who first attempted to use these features in a systematic manner in classification (although, as will be shown, there were inconsistencies in his methodology).

Henson (1948), therefore, was the first worker to recognise that each chamber layer could be subdivided into three: a marginal zone; a radial zone; and a reticulate zone. The marginal zone, as described by him, consisted of a ring of marginal chamberlets, closed by the epidermis of the test and separated by vertical walls between roof and floor of the chamber. The outer end of each chamberlet is subdivided by short, intersecting vertical and horizontal plates forming a sub-epidermal layer. Within the radial zone, the primary chamber layers are subdivided by interseptal partitions, which follow the primary subdivisions of the marginal zone and give the chamber passage a rectangular or triangular cross-section. In the reticulate zone the chamber passages bifurcate and anastomose producing a reticulate complex. The radial and reticulate zones were jointly referred to as the central zone.

Henson (1948) regarded a number of features useful in classification. These included: (a) the thickness of chamber layers; (b) the shape in cross-section of chamber passages in the radial zone; (c) the degree of subdivision of the marginal zone (number of sub-epidermal plates); (d) the width of the radial zone; (e) the complexity of the reticulate zone; (f) the degree of "arenaceousness" and type of foreign material incorporated in the test; and (g) the size, shape and complexity of the embryonic apparatus. Unfortunately, Henson is rather vague concerning which characters were most important in his classification scheme, although it does appear that the embryonic apparatus, which today would be regarded as *the* most important characteristic, was not considered of the utmost importance by him. Whilst some of the features used in classification by Henson would be regarded today as being of minor or no importance, he did at least point the direction for other workers to follow. He certainly was correct in regarding external shape and size to be of minor importance.

As noted above, Henson (1948) described 10 taxa, ascribed to *Orbitolina*, from the Middle East. Amongst these taxa are new species, new varieties and several forms which he compared with ("cf.") existing, often long established, species. Nevertheless, it is clear from Henson's work that he regarded each of his Middle Eastern taxa as a separate, discrete taxonomic entity. Even those taxa which were compared with existing species, were to Henson distinct from the named species (for them he even had a "type locality"). No doubt Henson was

erring on the side of caution in referring his taxa, even in 1948, to species described 100-150 years previously. *Orbitolina discoidea*, *O. concava*, *O. lenticularis* and the like had already been much used in the literature, but no-one until the modern taxonomic revisions of Schroeder (and co-workers) could have known what these species were really like, particularly from the point of view of internal characters. Thus we have regarded each of Henson's taxa as a separate "species" and in the case of "cf." taxa, regard the material from the type locality also as "syntypes".

As will be shown, some of Henson's taxa are still valid today, although others have proved to be junior synonyms or are just not identifiable. We will evaluate the syntypes and metatype material first, then in a separate section, the supplementary material in the F.R.S. Henson and Associates Collection. The latter reveals that there was a good deal of inconsistency in the way in which Henson applied his nomenclature, several distinct species often being labelled under one of his taxa. This has allowed us to describe the occurrence of several further orbitolinid species from the Middle East and these are dealt with below in a separate section.

We will now consider each of Henson's taxa in turn and discuss its identity in terms of modern taxonomy. For each new taxon Henson listed a number of syntypes, rather than a holotype and paratypes. In only one species, *Orbitolina concava* (Lamarck) var. *sefini*, have subsequent workers (Schroeder, *in* Schroeder & Neumann, 1985) erected a lectotype. For all of the remaining nine "Henson species", therefore, including those he referred to as "cf.", we have now formally designated lectotypes. This is in order to stabilise their identity in the light of current systematics and make their subsequent revision thus more authoritative. For some taxa, the original syntypic series is inadequate for revisionary purposes. In such cases new thin-sections from matrix-free syntypic or topotypic material have been made, or reference made to metatypes (topotypes confirmed by the original author).

Below we note the type locality, age of the sediments at this locality and Henson's concept of each taxon. The age reported is that given by Henson (1948). It must be stressed that some of these ages were based on limited data and are open to revision. We have tried to summarise (under "Henson Concept") the features that Henson used to distinguish his taxa from each other and from other described species. Some of these features (e.g., presence or absence of agglutinating material within the test) would not be regarded as distinctive features in terms of modern taxonomy.

### *Orbitolina kurdica* Henson, 1948

**Type reference.** Henson (1948), pp. 48, 50, pl. 1, figs 9-15, text-figs 10, 11.

**Type Locality.** "Lower Cretaceous limestones", Kalam Gorge, Aoraman, Iraq.

**Henson Concept.** Henson (1948) regarded this species as distinctive because of its small embryonic apparatus (misleadingly sketched in his text-fig. 11) which he regarded as being *c.*0.2 mm in diameter and consisting of a protoconch and "peri-embryonic chamberlets" (see below for revised interpretation of these features), by the presence of triangular "chamberlets" (chamber passages) and the inclusion of "foreign matter" into the test wall.

**Syntypes.** BMNH nos. P 35934 - P 35936, P 35938.

**Lectotype.** BMNH no. P 35936, designated herein (Plate 1, Fig. 1).

**Identity.** *O. kurdica* has been regarded by several authors (e.g., Schroeder, 1963) as a junior synonym of *Palorbitolina lenticularis* (Blumenbach, 1805). However, an unillustrated specimen in syntype thin-section P 35936 identifies this taxon as *Mesorbitolina texana* (Roemer, 1849). This specimen (Plate 1, Fig. 1), here designated lectotype, displays a rectangular embryonic apparatus of a diameter of 0.23 mm with a subdivided subembryonic zone and deuteroconch, very similar to topotypes of *M. texana* (Schroeder, 1979; Schroeder, *in* Schroeder & Neumann, 1985). No other specimen in the syntypic series is so clearly identifiable, but a specimen in thin-section P 35938 and illustrated by Henson (1948, pl. 1, fig. 14) is clearly also a *Mesorbitolina* sp.

### *Orbitolina* cf. *discoidea* Gras, 1852

**Type reference.** Henson (1948), pp. 50-54, pl. 2, figs 1-9, text-figs 10, 11.

**Type Locality.** Wadi N'garra, Jabal Abd-el-Aziz, Syria. "Aptian-Albian".

**Henson Concept.** Distinguished by a lack of agglutinating material, presence of sharply triangular chamber passages, a "stoloniferous texture" in random sections and a distinct embryonic apparatus which is larger and more complex than in *O. kurdica*, consisting of a apically situated proloculus and "rosette" of peri-embryonic chamberlets, with a total diameter of 0.3-0.4 mm. Believed by Henson (1948) to be one the most geographically widespread and stratigraphically long-ranging orbitolinids in the Middle East.

**"Syntypes".** BMNH nos. P 35923-P 35929.

**Lectotype.** BMNH no. P35924, designated herein (Plate 1, Fig. 2).

**Identity.** Several specimens from the syntypic series (including our lectotype, the material illustrated by Henson (1948, pl. 2, figs 1-3) together with metatypes, are identifiable as *Palorbitolina lenticularis* (Blumenbach, 1805), as first noted by Schroeder (1963). The designated lectotype shows a large oval protoconch, 0.23 mm in diameter, but without deuteroconch or subembryonic zone. Peri-embryonic chamberlets are visible on the edge of

the protoconch, but are better developed in other syntypic and metatypic specimens.

### *Orbitolina discoidea* Gras var. *delicata* Henson, 1948

**Type reference**. Henson (1948, pp. 54, 55, pl. 1, fig. 4, pl. 2, figs 13, 14).
**Type locality**. Dukhan-2 Well, Qatar. "Barremian".
**Henson Concept**. Distinguished by small size (average *c*.3.0 mm) and small embryonic apparatus consisting of a protoconch and peri-embryonic chamberlets of a total diameter of about 0.2 mm. Thought to be ancestral to *O.* cf. *discoidea*.
**Syntypes**. BMNH nos. P 35919 - P 35922.
**Lectotype**. BMNH no. P 35919, designated herein (Plate 1, Fig. 6).
**Identity**. As noted by Schroeder (1963), this species is a junior synonym of *Palorbitolina lenticularis* (Blumenbach, 1805). A horizontal section through the embryonic apparatus of the lectotype, as illustrated by Henson (1948, pl. 2, fig. 13) (Plate 1, Fig. 6, herein) shows a protoconch 0.15 mm across, surrounded by a thin ring of peri-embryonic chamberlets. This compares well with specimens of *P. lenticularis* illustrated by Schroeder (1963). Since *O.* cf. *discoidea* is also regarded as a junior synonym of *P. lenticularis*, Henson (1948) may have been correct to regard O. *discoidea* var. *delicata* as ancestral to *O.* cf. *discoidea* since Gušić (1981) has shown that within populations of *P. lenticularis*, embryonic apparatus size increases through time.

### *Orbitolina discoidea* Gras var. *libanica* Henson, 1948

**Type reference**. Henson (1948, pp. 35, 36, pl. 2, figs 10, 12).
**Type Locality**. Mdereidj, Lebanon. "Aptian".
**Henson Concept**. Similar to *O.* cf. *discoidea* but with thinner walls and wider chamber passages in the central zone. The embryonic apparatus was (incorrectly) considered to be similar to *O.* cf. *discoidea* (i.e., consisting of a protoconch and rosette of peri-embryonic chamberlets) with a diameter of *c*.0.22 mm.
**Syntypes**. BMNH nos. P 35930, P35932.
**Lectotype**. BMNH no. P35932, designated herein (not figured).
**Identity**. None of the original type and figured material or metatypes in the F.R.S. Henson and Associates Collection can be identified in terms of modern taxonomy. However, Schroeder (*in* Schroeder & Neumann, 1985) illustrated a topotype of *O. discoidea* var. *libanica*, which is clearly *Mesorbitolina texana* (Roemer, 1849). This is confirmed by a new thin-section we have prepared from syntype P35932 (herein designated lectotype), which contains a mesorbitolinid with a poorly preserved embryonic apparatus, but within the size range of *M. texana*.

### *Orbitolina* cf. *bulgarica* Deshayes (*in* Toula, 1877)

N.B. - Henson (1948) was incorrect to assign authorship of *Orbitolina bulgarica* to Deshayes (*in* Toula, 1877). As shown by Elliott (1952), the correct authorship is Boué (1840).
**Type reference**. Henson (1948, pp. 55, 56, pl. 3, figs 1-4).
**Type Locality**. Savonnerie, Beirut, Lebanon. "Lower Cretaceous".
**Henson Concept**. Although regarded by Henson (1948) as a "very well defined form", his actual description gives few indications of the distinguishing features of this species. The embryonic apparatus was neither observed nor described. The most diagnostic character of this species appears to be the "cellular texture" in oblique sections that may relate to relatively thick chamber layers (*c*.5-20 per millimetre) and chamber passages which are triangular to rectangular in cross-section.
"**Syntypes**". BMNH nos. P 35890 - P 35892.
**Lectotype**. P35890, designated herein (not figured).
**Identity**. This species is poorly represented in the F.R.S. Henson and Associates Collection and none of the syntypes or metatypes is identifiable in terms of modern taxonomy due to the absence of sections preserving an embryonic apparatus. The relatively thick chamber layers (seen particularly in the lectotype) are reminiscent of *Mesorbitolina*, but precise identity remains uncertain. No specimens are available for further thin-sectioning.

### *Orbitolina* cf. *lenticularis* (Blumenbach, 1805)

**Type reference**. Henson (1948, pp. 57-60, pl. 3, figs 6-11).
**Type Locality**. Briqueteries Debs (brickworks), Beirut, Lebanon. "Aptian".
**Henson Concept**. Distinguished by a fine, irregular, cellular structure in the central zone, by a close honeycomb pattern in shallow tangential sections (rounded to triangular chamber passages) and by a thin, delicate, sub-epidermal cellular layer. Incorporation of foreign matter in the test is common. Embryonic apparatus described as a protoconch with rosette of peri-embryonic chamberlets, *c*.0.22 mm in diameter.
"**Syntypes**". BMNH nos. P 35940, P 35941, P 35943 - P 35947.
**Lectotype**. BMNH no. P 35940, designated herein (not figured).
**Identity**. None of the original syntypes or metatypes of this species is identifiable in terms of modern taxonomy. However, a new thin-section of a syntype from slide P 35940 (here formally

designated lectotype) suggests that this taxon is a *Mesorbitolina* with a small embryonic apparatus.

### *Orbitolina* cf. *trochus* (Fritsch, 1878)

**Type reference**. Henson (1948, pp. 60, 61, pl. 4, figs 1-4).
**Type Locality**. Hanna, Qashqai-Sarhad District, Iran. Age uncertain.
**Henson Concept**. Distinguished by the incorporation of fine agglutinating material in the test, outlining chamber layers and walls. Chamber passages described as rectangular to rounded. Embryonic apparatus not observed.
**"Syntypes"**. BMNH nos. P 35948, P 35949.
**Lectotype**. BMNH no. P 35948, designated herein (not figured).
**Identity**. None of the original syntypes or metatypes of this species is identifiable in terms of modern taxonomy. New thin-sections of matrix-free syntypes (ex. P 35949) failed to reveal a diagnostic embryonic apparatus. The species is characterised by relatively thin chamber layers with the main agglutinated material being silt-grade quartz grains, giving this species a distinctive appearance. One such metatype is illustrated in Plate 1, Fig. 7.

### *Orbitolina* cf. *concava* (Lamarck, 1816)

N.B. In the F.R.S. Henson and Associates Collection this species is referred to as "*Orbitolina concava* var. *iraqii*". Henson choose not to publish this taxa under this name and it must be considered a *nomen nudum*.
**Type reference**. Henson (1948, pp. 61-64, pl. 4, figs 5-10, text-fig. 10).
**Type Locality**. Nafatah-1 Well (3312'), near Ramadi, Iraq. "Cenomanian".
**Henson Concept**. Distinguished by the possession of a complex embryonic apparatus (0.35 - 0.77 mm in diameter) with a "supra-embryonic area" (deuteroconch) present. Distinguished from other members of the *Orbitolina concava* group *sensu* Henson (i.e., forms with complex embryonic apparatus) by the presence of triangular chamber passages.
**"Syntypes"**. BMNH nos. P 35895, P 35896, P 35899.
**Lectotype**. BMNH (Henson and Associates Collection) no. M/4810 (metatype), designated herein (holotype of *Orbitolina hensoni*. sp.nov., see below) (Plate 2, Fig. 2).
**Identity**. Previously unillustrated metatypes give the best indication of the identity of this species. Metatype M/8046 is an axial thin-section revealing a complex embryonic apparatus typical of *Orbitolina sensu stricto* with a highly subdivided deuteroconch and a thin less-subdivided sub-embryonic zone. Total diameter is *c*.0.6 mm. A flat-based, concave upwards protoconch is present, with a maximum diameter of *c*.0.25 mm. Metatype M/4810 (herein designated lectotype) exhibits a tangential section which clearly and best demonstrates the highly distinctive (equilateral) triangular chamberlet shape of this species (seen less well in syntype P 35896, originally figured in Henson, 1948, pl. 4, fig. 10). According to Schroeder (*in* Schroeder & Neumann, 1985) and Schroeder *et al.* (1986), the presence of exclusively triangular chamber passages in the megalospheric generation of *Orbitolina sensu stricto* is diagnostic of *Orbitolina sefini* Henson 1948. However (see also discussion of *O. sefini* below), examination of the lectotype of *O. sefini* (designated by Schroeder *in* Schroeder & Neumann, 1985) and the original syntypes and metatypes demonstrates that the chamber passages are, instead, sub-rectangular to rectangular in shape, and certainly not markedly triangular as in *Orbitolina* cf. *concava sensu* Henson. Indeed, Henson (1948) noted that..."*Orbitolina* cf. *concava* is distinguished from the varieties *sefini* and *qatarica* in shallow tangential sections by the regular 'engine-turned' pattern of sharply triangular chamber segments and oblique apertures; these features being maintained even in the later chamber layers".

In short, *Orbitolina sefini* has been inaccurately defined by Schroeder (*in* Schroeder & Neumann, 1985) and Schroeder *et al.* (1986); the shape of the chamberlets, as described by them, is not consistent with the type material of *O. sefini* and would better suit what we see in *Orbitolina* cf. *concava sensu* Henson. *Orbitolina concava sensu stricto* (Schroeder *in* Schroeder & Neumann, 1985) has rectangular chamber passages and a larger embryonic apparatus than *Orbitolina* cf. *concava sensu* Henson. Accordingly, *Orbitolina* cf. *concava sensu* Henson is recognised as a discrete new species - *Orbitolina hensoni* sp. nov. - the only *Orbitolina* to have entirely triangular chamber passages. The new species may form an evolutionary link between *Mesorbitolina* (e.g., *Mesorbitolina subconcava* Leymerie, 1878) which has triangular chamber passages, and *Orbitolina*, the most evolved forms of which (*Orbitolina concava* Lamarck, 1816) have entirely rectangular chamber passages. *Orbitolina hensoni* sp. nov., furthermore, is not the same species as many orbitolinids described as *O. sefini* from the Mediterranean region. They now require new taxonomic assignment since their embryonic apparatus is distinct from both *O. hensoni* sp. nov. and from *O. sefini*. This, however, is beyond the scope of the present paper.

### *Orbitolina concava* (Lamarck) var. *sefini* Henson, 1948

**Type reference**. Henson (1948, pp. 64, 65, pl. 5, figs 1-4, 6).
**Type Locality**. Chineran (deep gorge), Sefin Dagh, north-east of Erbil, Iraq. "Cenomanian".

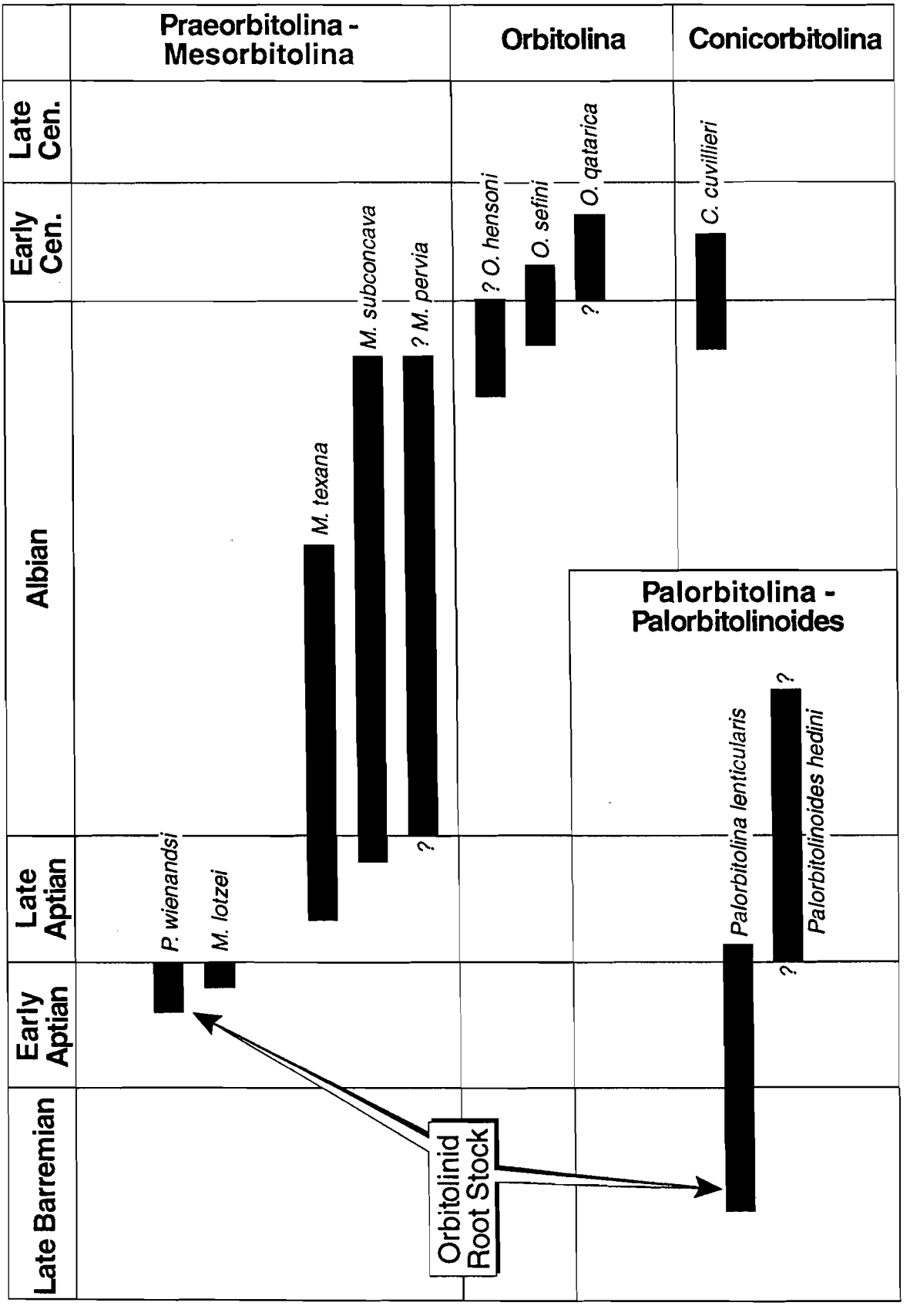


Figure 2. Stratigraphic range of Orbitolininae found in the F.R.S. Henson and Associates Collection. It must be stressed that the age range of these species is still poorly constrained, although the order of inception and extinction events is probably broadly correct. Thus a series of high-resolution orbitolinid based biozones can be defined, although their precise chronostratigraphic significance remains uncertain pending further research. In particular, the age ranges of *Palorbitolinoides hedini* and *Mesorbitolina pervia* remain highly uncertain, whilst the extension of *Orbitolina hensoni* into the Cenomanian and *Orbitolina qatarica* into the Albian is also unsure.

matches the original concept of Henson (1948) that these three species were distinct but interrelated. *O. qatarica* is associated at its type locality with *Praealveolina tenuis* Reichel, 1933 (Henson, 1948), which indicates that is of Middle Cenomanian age and thus indeed younger than *O. sefini* or *O. hensoni*. *O. concava sensu stricto* was first described by Lamarck (1816) from Early Cenomanian deposits at Ballon in France. This species, which only has rectangular chamberlets and a large, flattened, embryonic apparatus (Schroeder *in* Schroeder & Neumann, 1985) up to 1.1 mm in diameter, does not occur in the F.R.S. Henson and Associates Collection.

## THE VARIETY OF ORBITOLINID SPECIES IN THE F.R.S. HENSON AND ASSOCIATES COLLECTION

In addition to the type and figured material and metatypes in the F.R.S. Henson and Associates Collection, there are also a substantial number (over 200 thin-sections and innumerable matrix-free specimens) of orbitolinids from a variety of locations in the Middle East. These have now been reviewed by us in the light of modern taxonomy and serve to illustrate the occurrence of the Orbitolininae in the Middle East. They also demonstrate inconsistencies within the taxonomic concepts of Henson (1948), with "Henson taxa" including more than one species in modern terms and, on the other hand, a modern species occurring under several of Henson's names.

The 11 species now recognised in the F.R.S. Henson and Associates Collection are noted below, with brief notes on their occurrence, a description and synonymy (which notes nomenclatural changes and published occurrences in the Middle East). The opportunity is also taken to formally describe *Orbitolina hensoni* as new and emend the definitions of *O. sefini* Henson and *O. qatarica* Henson.

### ***Palorbitolina lenticularis*** (Blumenbach, 1805)

Plate 1, Figs 2-6; Plate 3, Figs 1-4

*Madreporites lenticularis* n.sp. - Blumenbach, 1805, pl. 80, figs 1-6.
*Orbulites lenticulata* - Lamarck, 1816, p. 197
*Orbitolites bulgarica* sp. nov. - Boué, 1840, p. 239
*Orbitolina lenticulata* (Lamarck). - d'Orbigny, 1850, p. 184
*Orbitolina conoidea* sp. nov. - Gras, 1852, pl. 1, figs 4-6
*Orbitolina discoidea* sp. nov. - Gras, 1852, pl. 1, figs 7-9
*Orbitolina* cf. *discoidea* Gras. - Henson, 1948, pl. 2, figs 1-3, 7-9
*Orbitolina discoidea* Gras var. *delicata* var. nov. - Henson, 1948, pl. 2, figs 13, 14
*Orbitolina (Palorbitolina) lenticularis* (Blumenbach). - Schroeder, 1963, pl. 23, figs 1-9, pl. 24, figs 1-10
*Palorbitolina lenticularis* (Blumenbach). - Schroeder, 1964, p. 465, not figured.
*Palorbitolina lenticularis* (Blumenbach). - Saint-Marc, 1970, pl. 1, figs 1-3
*Palorbitolina lenticularis* (Blumenbach). - Mehrnusch, 1973. fig. 14
*Palorbitolina lenticularis* (Blumenbach). - Simmons & Hart, 1987, pl. 10.2, figs 1, 7
*Palorbitolina lenticularis* (Blumenbach). - Kaddouri & Al-Shaibani, 1993, pl. 1, figs 4-5
*Palorbitolina lenticularis* (Blumenbach). - Simmons, 1994, pl. 9.3, fig. 1
*Palorbitolina lenticularis* (Blumenbach). - Witt & Gökdag, 1994, pl. 10.1, figs 1-4

As noted above, the Henson (1948) taxa *O.* cf. *discoidea* and *O. discoidea* var. *delicata* are both junior synonyms of *P. lenticularis*. *P. lenticularis* also occurs in the F.R.S. Henson and Associates Collection as *O.* cf. *discoidea* from "Lower Cretaceous" sediments of the Makhul-1 Well, Iraq (depth 3484 - 3559') (thin-section nos. M/2224, M/2251, M/2248). Several axial sections through the embryonic apparatus are present which reveal a globular protoconch, 0.135 - 0.175 mm in diameter. Associated fauna includes *Choffatella decipiens* Schlumberger, 1905.

Specimens also occur labelled as *O.* cf. *discoidea* from Tang-i-Marawi, Qashqai Sarhad, Iran (M/2040, M/2041) with a protoconch diameter of 0.14 - 0.20 mm and from Wadi N'garra, Jabal Abd-el-Aziz, Syria (M/2193). Here protoconch diameter varies between 0.11 and 0.175 mm. The sediments at this locality are recorded by Henson as being "Cenomanian", but they are clearly older, *P. lenticularis* being associated with *Vercorsella* sp. and the alga *Hensonella dinarica* (Radoičić, 1959).

Occurrences of *O. discoidea* var. *delicata* from "Barremian" sediments of Dukhan-1 Well (depth 3579-3584') (M/2792) and from "Lower Cretaceous" sediments of Hadhramaut (Yemen) (P 35918) are also *P. lenticularis*. In this material the proloculus is relatively large, *c.*0.25 mm.

*Palorbitolina lenticularis* is a widespread species in the Middle East. Within the F.R.S. Henson and Associates Collection it is represented by material from Syria, Iraq, Iran, Qatar and Yemen. Published records and our own unpublished observations would add Lebanon, Israel, United Arab Emirates, Afghanistan and Oman to this. Its stratigraphic range is well established as Late Barremian to early Late Aptian (e.g., Schroeder, 1975) (Figure 2).

### ***Palorbitolinoides hedini*** Cherchi & Schroeder, 1980

Plate 3, Fig. 5

*Palorbitolinoides hedini* gen. et sp. nov. - Cherchi & Schroeder, 1980, pl. 1, figs 1-5.
*Orbitolina (Mesorbitolina) aperta* (Erman). - Simmons & Hart, 1987, pl. 10.2, fig. 5.

*Palorbitolinoides hedini* is the evolutionary descendant of *Palorbitolina* and possesses a large complex embryonic apparatus in which the peri-embryonic chamberlets of *Palorbitolina* have expanded and fused to form a layer beneath the proloculus.

Specimens in the F.R.S. Henson and Associates Collection labelled as *O.* cf. *concava* from several localities in the Qashqai Sarhad region of Iran (near Jupa Zarawi (M/2044), Hana (M/2032) and Qaleh Qabri) are very similar to the types described by Cherchi & Schroeder (1980) from the Himalayas, and are without doubt this species.

This is the first published record of *P. hedini* under that name from the Middle East, although Simmons & Hart (1987) misidentified this species as *Orbitolina (Mesorbitolina) aperta* from the Albian Nahr Umr Formation of the Oman Mountains. Previously the species had been recorded only from the Himalayas. The authors have also observed this species in Late Aptian sediments of the United Arab Emirates (data unpublished). *P. hedini* is thought to have a Late Aptian - Early Albian age range (Marcoux *et al.*, 1987), although this is poorly constrained and may range younger (Figure 2), as would be suggested by the record from Oman of Simmons & Hart (1987).

### *Praeorbitolina wienandsi* Schroeder, 1964

Plate 3, Fig. 6

*Praeorbitolina wienandsi* sp. nov. Schroeder, 1964, p. 412, text-fig. B.
*Praeorbitolina wienandsi* Schroeder - Schroeder, 1979, pl. 1, fig. 2.

In the F.R.S. Henson & Associates Collection specimens described as *O. discoidea* var. *libanica* from "Aptian" sediments of Sofar, Lebanon (P 35931) belong to *P. wienandsi*. This species has a small eccentrically situated embryonic apparatus consisting of a spherical protoconch followed by a deuteroconch and a subembryonic zone with a few rudimentary subepidermal partitions. The specimen illustrated here has an embryonic apparatus of 0.12 mm diameter.

Although found in the F.R.S. Henson and Associates Collection only from Lebanon, unpublished observations by the authors would extend the occurrence of this species to include Yemen and the United Arab Emirates. *P. wienandsi* has a well established stratigraphic range of latest Early Aptian (Schroeder, 1975) (Figure 2).

### *Mesorbitolina lotzei* Schroeder, 1964

Plate 3, Figs 7, 8

*Orbitolina (Mesorbitolina) lotzei* sp.nov. - Schroeder, 1964, pp. 469, 470, text-fig. 3a-f.
*Orbitolina (Mesorbitolina) lotzei* Schroeder. - Schroeder, 1979, pl. 1, fig. 3
*Orbitolina (Mesorbitolina) lotzei* Schroeder. - Witt & Gökdag, 1994, pl. 10.1, fig. 5

*Mesorbitolina lotzei* is the most primitive of the *Mesorbitolina* lineage. It possesses a simple *Mesorbitolina*-type embryonic apparatus with subembryonic zone which is hardly subdivided by radial partitions, and with a diameter of 0.10-0.12 mm. In the F.R.S. Henson and Associates Collection it occurs under the name *O. discoidea* var. *libanica* from Colline de Kfernis, Lebanon (M/2297) and as *O. discoidea* var. *delicata* from the Hadhramaut (Yemen) (M/2256). Embryonic apparatus diameters range from 0.10 to 0.13 mm. In addition to Yemen and Lebanon, the species is also known from Oman and the United Arab Emirates (published and unpublished data). *M. lotzei* is known to be restricted to the latest Early Aptian (Schroeder, 1975, Witt & Gökdag, 1994) (Figure 2).

### *Mesorbitolina texana* (Roemer, 1849)

Plate 1, Fig. 1; Plate 3, Figs 10-12; Plate 4, Fig. 1

*Orbitulites Texanus* sp. nov. - Roemer, 1849, p. 392
*Orbitulites Texanus* Roemer. - Roemer, 1852, p. 86, pl.10, fig. 7a-d.
*Orbitolina kurdica* sp. nov. - Henson, 1948, p. 48.
*Orbitolina discoidea* Gras var. *libanica* var. nov. - Henson, 1948, p. 55.
*Orbitolina (Mesorbitolina) texana texana* (Roemer). - Schroeder, 1964, pp. 470, 471, text-fig. 4b
*Orbitolina (Mesorbitolina) texana* (Roemer). - Schroeder, 1979, pl.1, figs 6-7.
*Orbitolina (Mesorbitolina) texana* (Roemer). - Schroeder (*in* Schroeder & Neumann), 1985, pl. 36, figs 1-13.
*Orbitolina (Mesorbitolina) texana* (Roemer). - Simmons & Hart, 1987, pl. 10.2, fig. 4
*Orbitolina (Mesorbitolina) texana* (Roemer). - Witt & Gökdag, 1994, pl. 10.1, figs 7, 9.

As noted above, both the Henson (1948) taxa *O. kurdica* and *O. discoidea* var. *libanica* are junior synonyms of *M. texana* based on revision of their type material.

Within the F.R.S. Henson and Associates Collection there are several other occurrences of *M. texana* under the names *O. discoidea* var. *libanica* and *O.* cf. *discoidea*. Specimens can be relatively easily identified by the presence of an almost square embryonic apparatus, with clear deuteroconch and sub-embryonic zone, each being divided by radial partitions. Embryonic apparatus diameter is in the range 0.20 - 0.25 mm.

A specimen (M/2295) of *O. discoidea* var. *libanica* from Colline de Kfernis, Lebanon is a *M. texana* with an embryonic apparatus diameter of 0.22 mm. Specimens recorded as *O.* cf. *discoidea* from Jebel Akra, Syria (M/2285), south of Husainabad, Qashqai Sarhad, Iran (M/2050), Kuh-i-Banish, Qashqai Sarhad, Iran (M/2042, M/2043) and Merdjayoun, Lebanon (M/3043, M/3044) are also all *M. texana*.

A specimen (M/2080) described as *O.* cf. *discoidea* from Ardakan, S.W. Iran has an embryonic apparatus closer to the size range of *Mesorbitolina parva* (Douglass, 1960) (0.18 mm diameter), but it could be a small form of *M. texana*. *M. parva* is best distinguished from *M. texana* by the presence of fewer radial partitions visible in

horizontal sections of the subembryonic zone. In the absence of such sections, species identification is somewhat arbitrary. Specimens such as M/2080 are best referred to the "*M. parva - texana* gr.".

*M. texana* has a wide distribution in the Middle East, being known from Lebanon, Syria and Iran in the F.R.S. Henson and Associates Collection and from published and unpublished data it is also known to occur in Yemen, Oman and the United Arab Emirates. Although often recorded from "Aptian" sediments in the F.R.S. Henson and Associates Collection, this species has a well established Late Aptian - Early Albian age range (Schroeder, 1975) (Figure 2).

### *Mesorbitolina subconcava* (Leymerie, 1878)

Plate 2, Fig. 6; Plate 4, Figs 2, 3

*Orbitolina sub-concava* sp. nov - Leymerie, 1878, pl. E, fig. 7
*Orbitolina (Mesorbitolina) subconcava* Leymerie - Schroeder, 1979, pl. 1, fig. 8
*Orbitolina (Mesorbitolina) subconcava* Leymerie - Schroeder (*in* Schroeder & Neumann), 1985, pl. 37, figs 1-8
*Orbitolina (Mesorbitolina) subconcava* Leymerie - Simmons & Hart, 1987, pl. 10.2, fig. 2.

As noted above, *M. subconcava* occurs within the syntypes and metatypes of *Orbitolina concava* var. *sefini* from Sefin Dagh, N.E. Iraq. It also occurs within the F.R.S. Henson and Associates Collection, identified as *Orbitolina* cf. *concava* from Hana, Qashqai Sarhad, Iran (M/2031-M/2033). These specimens have a very consistent embryonic apparatus diameter of 0.45 mm, with an oval proloculus surrounded by a deuteroconch and subembryonic zone that are well subdivided, although the deuteroconch is subdivided to a greater degree. In contrast to the neotype illustrated by Schroeder (1979), the subembryonic zone is slightly thinner than the deuteroconch, although this is thought to be within the variation of the species. Associated taxa (e.g. *Palorbitolinoides hedini* Cherchi & Schroeder) suggest that these specimens are Late Aptian - Albian in age.

Specimens (M/2045) described as *O.* cf. *concava* from near Jupa Zarawi, Qashqai Sarhad, Iran are also thought to be *M. subconcava* (see Plate 4, Fig. 3). The embryonic apparatus diameter is 0.42 mm.

As well as occurring in Iran, published and unpublished data suggests that *M. subconcava* also occurs in Oman and Kuwait. *M. subconcava* is considered to have an overall age range of latest Aptian - Late Albian (Schroeder, *in* Schroeder & Neumann, 1985) (Figure 2).

### *Mesorbitolina pervia* (Douglass, 1960)

Plate 4, Fig. 4

*Orbitolina pervia* sp. nov. - Douglass, 1960, p. 41, pl. 11, figs 1-18.
*Orbitolina (Mesorbitolina)* sp. A - Fourcade & Raoult, 1973, p. 239, pl. 1, figs 8, 9, pl. 2, figs 1, 2
*Mesorbitolina* sp. A - Fourcade & Raoult - Marcoux *et al.*, 1987, pl. 2, fig. 9
*Orbitolina (Mesorbitolina) pervia* Douglass - Görög & Arnaud-Vanneau, 1996, pl. 1, figs 1-8

Within the F.R.S. Henson and Associates Collection there is a distinctive mesorbitolinid, similar to *M. subconcava*. Its embryonic apparatus diameter is typically 0.35 mm (although it can reach 0.42 mm) and of particular note is the triangular protoconch with its flat base. It occurs in slides labelled as *O.* cf. *concava* from Hana, Qashqai Sarhad, Iran (M/2033) and from Sefin Dagh, Iraq (P 35894, P 35895). These specimens are comparable with *M. pervia*, first described from Texas by Douglass (1960). This species has a wide distribution having recently been recorded from Venezuela (Görög & Arnaud-Vanneau, 1996), and the Himalayas (Marcoux *et al.*, 1987) and Algeria (Fourcade & Raoult, 1973). This is the first record of the species from the Middle East. It has a poorly constrained range within the Albian (Figure 2).

### *Conicorbitolina cuvillieri* (Moullade, *in* Moullade *et al.*, 1972)

Plate 4, Figs 5-7 (?8)

*Orbitolina concava* (Lamarck) var. *sefini* var. nov. - Henson, 1948, pl. 5, figs 3, 4 (ideotypes only).
*Neoiraqia cuvillieri* sp. nov. - Moullade (*in* Moullade *et al.* 1972), pp. 2321, 2322, pl. 1, figs 1-8.
*Orbitolina (Conicorbitolina) cuvillieri* (Moullade). - Schroeder, 1975, p. 227

According to Schroeder (1962) and Schroeder & Neumann (1985) specimens (but not the syntypes) illustrated by Henson (1948, pl. 5, figs 3, 4) of *O. concava* var. *sefini* from "Cenomanian" sediments from the "Hebron Road" and "Wadi Rumman, Palestine" are *Conicorbitolina conica* (d'Archiac, 1837). This includes P 35905 (Plate 4, Figs 5,6) and P 35906 (Plate 4, Fig. 7) re-illustrated here. However, we consider that they are better regarded as *C. cuvillieri*. These are markedly conical in test outline in axial section, with a spherical embryonic apparatus, *c.* 0.25 mm in diameter, with a spherical protoconch and cup-shaped deuteroconch and subembryonic area, each subdivided by radial partitions. The marginal zone of each chamber layer is noticeably alveolar. The size of the embryonic apparatus confirms that these specimens are *C. cuvillieri* rather than *C. conica*, since *C. conica* typically has a much larger embryonic apparatus with a diameter of 0.7-0.8 mm (Schroeder, *in* Schroeder & Neumann, 1985).

A poorly preserved specimen (M/2074) described as *Orbitolina concava* var. *sefini* from "Cenomanian" sediments of Surmich Shirabad, Iranian Baluchistan, is most likely also *C. cuvillieri*.

*C. cuvillieri* has a stratigraphic range (Figure 2) of latest Albian - earliest Cenomanian (Schroeder *in* Schroeder & Neumann, 1985) but has not previously been recorded from the Middle East under this name, although records of *C. conica* should be re-examined to check for misidentification of this species.

### *Orbitolina hensoni* sp. nov.

Plate 2, Figs 1, 2; Plate 4, Fig. 9

*Orbitolina* cf. *concava* (Lamarck). - Henson, 1948, pl. 4, figs 7, 10.

**Type Locality**. Well Nafatah-1 (depth 3312'), near Ramadi, Iraq. Type sediments regarded as Cenomanian by Henson (1948), but may be older (Late Albian).

**Holotype**. Specimen in thin-section M/4810, held in The Natural History Museum, London (also designated lectotype of *O.* cf. *concava sensu* Henson, see above); illustrated in Plate 2, Fig. 2. Paratype from M/8046 (Plate 2, Fig. 1), also from type locality.

**Derivation of name**. In honour of Dr Francis Roger Spencer Henson (Chief Palaeontologist of the then Iraq Petroleum Company) who first recognised this fossil in sediments from the Middle East and for his contribution in general to our understanding of the larger foraminifera in that area.

**Diagnosis**. An orbitolinid with a complex embryonic apparatus typical of *Orbitolina sensu stricto* with a highly subdivided deuteroconch and a thin less-subdivided subembryonic zone. Diameter of embryonic apparatus *c.*0.6 mm. A flat-based, concave upwards protoconch is present, with a maximum diameter of *c.*0.25 mm. In tangential section highly distinctive (equilateral) triangular chamber passages are present.

**Remarks**. Distinguished from other species of *Orbitolina sensu stricto* (*Orbitolina sefini*, *Orbitolina qatarica* (see emended diagnosis below) and *Orbitolina concava*) by the presence of exclusively triangular chamber passages in the megalospheric generation. Size and shape of the embryonic apparatus, especially the flat based protoconch, are also useful identification criteria, although determination is uncertain without tangential sections showing chamber passage shape.

The species may form an evolutionary link between *Mesorbitolina* (e.g., *Mesorbitolina subconcava* (Leymerie, 1878)) which has triangular chamber passages, and *Orbitolina*, the most evolved forms of which (e.g., *Orbitolina concava*, *Orbitolina qatarica*) have sub-rectangular/rectangular chamber passages.

In the F.R.S. Henson and Associates Collection this species is referred to as "*Orbitolina concava* var. *iraqii*". Henson choose not to publish this taxa under this name and it must be considered a *nomen nudum*.

**Stratigraphic range and geographic distribution**. The age of the sediments in which this species was originally recorded from in Iraq is said to be Cenomanian by Henson (1948), although it is suspected that this could be open to some revision. In the F.R.S. Henson and Associates Collection this species also occurs in material from Burgan, Kuwait (M/2100) (Plate 4, Fig. 9). Previous records attributed to *Orbitolina sefini* and *Orbitolina concava* from the Middle East now need to be re-examined for misidentification. Other than the types, the majority of occurrences of *O.* cf. *concava sensu* Henson in the F.R.S. Henson and Associates Collection, however, are not *O. hensoni* sp. nov. For the present, the range of *O. hensoni* is tentatively considered to be late Albian (Figure 2).

### *Orbitolina sefini* Henson, 1948 (emend.)

Plate 2, Figs 3-5; Plate 4, Fig. 10

*Orbitolina concava* (Lamarck) var. *sefini* var. nov. - Henson, 1948, pl. 5, figs 1-2 only (syntypes).

**Emended Diagnosis**. Orbitolinid possessing a large and complex *Orbitolina*-type embryonic apparatus, which is between 0.45 mm and 0.60 mm in diameter, with a markedly conical deuteroconch, highly subdivided, and flat-based protoconch of maximum diameter *c.*0.25 mm. In tangential sections chamber passages are initially high-triangular/subrectangular, but become rectangular in later chamber layers.

**Remarks**. The nature of *O. sefini* and the need to emend the diagnosis from that given by Schroeder & Neumann (1985) is discussed in detail above. In the F.R.S. Henson and Associates Collection, the species is abundant in material from the type locality of Sefin Dagh, Iran. Its occurrence there is recorded as being of Cenomanian age by Henson, (1948), but this could be open to revision (Late Albian). Many other specimens referred to *O. concava* var. *sefini* in the F.R.S. Henson and Associates Collection are of uncertain identity or other species, but a specimen (M/1512) from "Lower Cenomanian" sediments near Mahis, "Transjordan" is clearly *O. sefini*. Previous records of *O. sefini* and *O. concava* from the Middle East now need to be checked for misidentifications.

### *Orbitolina qatarica* Henson, 1948 (emend.)

Plate 2, Figs 7-9

*Orbitolina concava* (Lamarck) var. *qatarica* var. nov. - Henson, 1948, pl. 5, figs 7-11.

**Emended Diagnosis**. Orbitolinid possessing an *Orbitolina*-type embryonic apparatus, with a diameter of 0.72 - 0.75 mm. The embryonic apparatus is markedly conical in shape with a

relatively thick, heavily subdivided, deuteroconch. The sub-embryonic zone is thin and convex. The protoconch in axial sections is flat-based and convex, with a maximum diameter of 0.2 mm. In tangential section the shape of the chamber passages can be seen to be almost exclusively rectangular.

**Remarks.** The revision of this species has been discussed in detail above. It is only known with confidence from subsurface material from Qatar (Dukhan-1 Well), the type locality, where its occurrence is Middle Cenomanian by virtue of the associated fauna (*Praealveolina tenuis* Reichel, 1933). Previous records of *O. sefini* and *O. concava* from the Middle East now need to be re-examined for misidentification of this species.

## OTHER ORBITOLINIDS

Within the F.R.S. Henson and Associates Collection there are a number of orbitolinids identified as belonging to the genus *Orbitolina*, but which are most likely not Orbitolininae, but instead Dictyoconinae (i.e., orbitolinids with a simple embryonic apparatus and with or without pillars in the central zone). These may be more correctly assigned to the genera *Neoiraqia*, "*Valdanchella*", *Paleodictyoconus* and *Orbitolinopsis*, or other, perhaps new, genera. A selection of these forms is illustrated herein (Plate 5, Figs 1-6) with some preliminary identifications. They include forms labelled as *O. concava* var. *sefini* from Iranian Baluchistan (M/2070, M/2072, M/2074) and as *O.* cf. *concava* from Qaleh Qabri, Qashqai Sarhad, Iran (M/2055). Most are poorly preserved, but they will be described in detail in a subsequent review of the Dictyoconinae in the F.R.S. Henson and Associates Collection. The form illustrated in Plate 5, Fig. 6, is almost certainly *Neoiraqia convexa* Danilova 1963, an orbitolinid originally described from the "Upper Cenomanian" of the former Yugoslavia (Danilova, 1963), but now regarded as indicative of a latest Albian to earliest Cenomanian age (Schroeder *in* Schroeder & Neumann, 1985).

## STRATIGRAPHIC AND PALAEOENVIRONMENTAL RANGE

Orbitolinids have long been regarded as very useful biostratigraphic markers in Cretaceous Tethyan carbonate platform sediments (Henson, 1948; Schroeder, 1975, Schroeder & Neumann, 1985; Simmons & Hart, 1987). However, their utility is limited by the taxonomic precision to which they have been identified. In the Middle East, orbitolinids have often been referred to "dustbin" species names such as "*Orbitolina conoidea-discoidea*", "*Orbitolina lenticularis*" or "*Orbitolina concava*" without accurate reference to what these names actually mean. This is largely due to uncertainty in how to use internal structures to identify specimens accurately and a legacy of taxonomic confusion.

We are now able to recognise 11 species of Orbitolininae in the F.R.S. Henson and Associates Collection using modern taxonomic nomenclature. In addition to their occurrence in the F.R.S. Henson and Associates Collection, published and unpublished observations suggest that these species occur throughout the Middle East in suitable facies. The stratigraphic range of these species is shown in Figure 2. It must be stressed that the age ranges of these species are still poorly constrained, even if the order of inception and extinction events is probably broadly correct. Thus a series of high-resolution orbitolinid based biozones can be defined, although their precise chronostratigraphic significance remains uncertain pending further research. Figure 2 shows our estimate of their chronostratigraphic ranges based on regional evidence for the age of the formations in which the species occur, supplemented by range charts from outside the Middle East region (e.g., Schroeder, 1975; Schroeder & Neumann, 1985). Future work will concentrate on precisely determining the age range of these species and other Middle East orbitolinids by reference to age-significant macrofossils (e.g., ammonites) which co-occur at some localities and perhaps new strontium isotope derived dates.

As well as having biostratigraphic value, orbitolinids are also useful palaeoenvironmental indices, especially with reference to palaeobathymetry. Their ability to reflect changes in palaeobathymetry make them useful for sequence stratigraphic studies, such as the definition of systems tracts (Figure 3). Although orbitolinids can be found anywhere within sediments of a carbonate platform (Arnaud-Vanneau, 1980), they are most common in the more open, and thus outer parts of the platform (Masse, 1976; Vilas *et al.*, 1995). Using associated algae, Banner & Simmons (1994) noted that *Palorbitolina lenticularis* was most common in sediments thought to be deposited in water depths between 10m and 50m below sea level. The size and morphology of orbitolinid tests suggests that they had a free, epifaunal mode of life (Masse, 1976), lying on the substrate by their apertural faces (with the flat base of their conical test downwards) (Arnaud-Vanneau, 1975). However small, conical forms (mainly the Dictyoconinae) may have been epiphytic (Arnaud-Vanneau, 1975).

Vilas *et al.* (1995) have described how *Palorbitolina* wackestones and packstones developed during transgressive episodes on the Aptian carbonate platforms of southeast Spain. Furthermore, they noted how large flat forms with abundant silt-grade agglutination of quartz characterise relatively deeper water settings ("outer shelf"), whilst conical forms of the same species with a microgranular structure are more characteristic of shallower water settings ("platform interior"). Our own observations on the Early - middle Cretaceous carbonate platforms of the Middle East

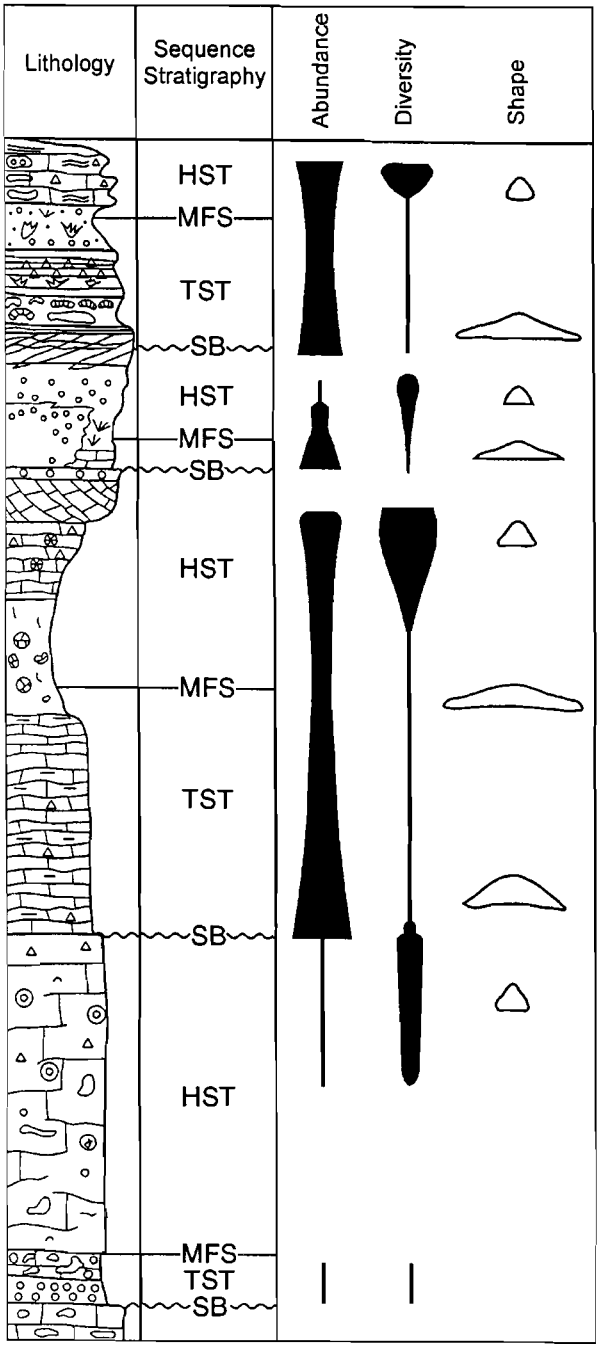


**Figure 3.** Relationship of orbitolinid abundance, diversity and shape to sequence stratigraphy and hence palaeobathymetric change. Based on observations from several Cretaceous carbonate platforms across Tethys. Abundance is typically highest in early transgressive systems tracts and late highstand systems tracts, whilst diversity is greatest during highstands. During transgressive systems tracts, orbitolinids typically have a flat shape (flattest around the maximum flooding surface) and are increasingly conical throughout highstands.

confirm these patterns. Muddy, orbitolinid-rich beds, with large, flat, orbitolinids seem to be characteristic of transgressive deposits. Indeed, shallowing-up cycles at sequence and parasequence scale can be recognised on the basis of orbitolinid content. For example, in the Early Cretaceous Kharaib Formation of Oman and Abu Dhabi, stacked parasequences can be recognised where initial flooding sediments rich in large flat *Palorbitolina*, pass up into packstones with more conical *Palorbitolina* and *Paleodictyoconus*, then into beds with more common miliolids and dasycladacean algae in the shallowest water, uppermost part of the parasequence.

We have been able to study Cretaceous carbonate platforms from a number of localities throughout the Tethyan realm and have been able to recognise a pattern of orbitolinid occurrence at the systems tract scale (Figure 3). Abundance is typically highest in early transgressive systems tracts (TST) and late highstand systems tracts (HST), whilst diversity is greatest during highstands. During transgressive systems tracts, orbitolinids typically have a flat shape (flattest around the maximum flooding surface) and are increasingly conical throughout highstands. The estimations of changing bathymetry and hence, system tract are based on associated fossils and stratigraphic architecture. Similar observations have already been briefly reported by Simmons *et al.* (1992) and Arnaud-Vanneau (1994). The relationship of orbitolinid shape to palaeobathymetry mimics observations on Recent larger foraminifera. For example, Reiss & Hottinger (1984) observed a flattening of *Operculina* tests with increasing water depth.

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## REFERENCES

Archiac, A'd 1837. Mémoire sur la formation Crétacé du sud-ouest de la France. *Mémoires de la Société Géologique de France*, **2** (7), 157-192.

Arnaud-Vanneau, A. 1975. Reflexion sur le mode de vie de certains Orbitolinides (Foraminiféres) barremo-aptiens de l'Urgonien du Vercors. *Compte Rendu des Seances de la Société de Physique et d'Histoire Naturelle de Genève*, **10**, 126-130.

Arnaud-Vanneau, A. 1980. Micropaléontologie, paléoécologie et sédimentologie d'une plate-forme carbonatée de la marge passive de la Téthys: l'Urgonien du Vercors septentrional et de la Chartreuse (Alpes occidentales). *Géologie Alpine, Mémoire*, **11**, 1-874.

Arnaud-Vanneau, A. 1994. Benthic foraminifer distribution and sequence stratigraphy. Examples from Lower Cretaceous carbonate platforms in France and Azerbaijan. *Géologie Méditerranéenne*, **21**, 13-15.

Banner, F.T. & Simmons, M.D. 1994. Calcareous algae and foraminifera as water-depth indicators: an example from

the Early Cretaceous carbonates of Northwest Arabia. *In:* Simmons, M.D. (Ed.), *Micropalaeontology and Hydrocarbon Exploration in the Middle East.* pp. 243-252. Chapman & Hall, London.

Blumenbach, J.F. 1805. *Abbildungen naturhistorischer Gegenstände.* Volume 8 (80). 2pp. (+ pl. 80). Dieterich, Göttingen

Boué, A. 1840. *La Turquie d'Europe.* 4 volumes. Paris.

Cherchi & Schroeder, R. 1980. *Palorbitolinoides hedini* n.gen. n.sp., grand foraminifère du Crétacé du Tibet méridional. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Paris,* (sér. D), **291**, 385-388.

Danilova, A. 1963. *Neoiraqia convexa,* a new foraminifer from the Cenomanian-Turonian of Kosovo Polje. *Vesnik Zavoda za Geološka i Geofizika Istra ivanja, Nr. Srbije, Beograd,* (ser. a), **20** (for 1962), 223-226.

Davies, L.M. 1939. An early *Dictyoconus,* and the genus *Orbitolina*: their contemporaneity, structural distinction and respective natural allies. *Transactions of the Royal Society of Edinburgh,* **59**, 773-790.

Douglass, R.C. 1960. The foraminiferal genus *Orbitolina* in North America. *Professional Papers of the United States Geological Survey,* **333**, 1-52.

Elliott, G.F. 1952. Biographical note on the Cretaceous foraminifer *Orbitolina bulgarica* (Boué). *Journal of the Society for the Bibliography of Natural History,* **2**, 383-385.

Fourcade, E. & Raoult, J-F. 1973. Crétacé du Kef Hahouner et position stratigraphique de *"Ovalveolina" reicheli* de Castro (série septentrionale de môle néritique du Constantinois, Algérie). *Revue de Micropaléontologie,* **15**, 227-246.

Fritsch, K. von 1878. Einige Eocäne Foraminiferen von Borneo. *Palaeontographica,* suppl. **3** (1a), 139-146.

Görög, A. & Arnaud-Vanneau, A. 1996. Lower Cretaceous orbitolinas from Venezuela. *Micropaleontology,* **42**, 65-78.

Gras, A. 1852. *Catalogue des corps organisés fossiles qui se recontrent dans le département de l'Isère.* 54pp. Grenoble.

Gušić, I. 1981. Variation, range, evolution and biostratigraphy of *Palorbitolina lenticularis* in the Lower Cretaceous of the Dinaric Mountains in Yugoslavia. *Palaeontologische Zeitschrift,* **55**, 191-208.

Henson, F.R.S. 1948. *Larger Imperforate Foraminifera of South-Western Asia (Families Lituolidae, Orbitolinidae and Meandropsinidae).* xi+127pp. British Museum (Natural History), London.

Hofker, J. Jr. 1963. Studies on the genus *Orbitolina* (Foraminiferida). *Leidse Geologische Mededelingen,* **29**, 181-254.

Kaddouri, N. & Al-Shaibani, A. 1993. *Palorbitolina lenticularis* (Blumenbach) 1805, an Upper Barremian - Lower Aptian biozone in Iraq. *Iraqi Geological Journal,* **26**, 98-106

Lamarck, J.B. 1816. *Histoire Naturelle des Animaux sans Vertèbres.* Volume 2. 568pp. Verdière, Paris.

Leymerie, A. 1878. *Description géologique et paléontologique des Pyrénées de la Haute-Garonne.* 2 volumes. 1010pp. Toulouse (privately published).

Loeblich, A.R. Jr. and Tappan, H. 1987. Foraminiferal Genera and their Classification. 2 vol., 1182p., Van Nostrand Reinhold Co, New York.

Marcoux, J., Girardeau, J., Fourcade, E., Bassoullet, J.-P., Philip, J., Jaffrezo, M., Xuchang, X. & Chengfa, C. 1987. Geology and biostratigraphy of the Jurassic and Lower Cretaceous series to the north of the Lhasa Block (Tibet, China). *Geodinamica Acta,* **1**, 313-325.

Masse, J.-P. 1976. *Les calcaires urgoniens de Provence (Valanginien-Aptien inferieur). Stratigraphie, Paléontologie, les paléoenvironments et leur evolution.* Thesis, Université Marseille, 445pp.

Mehrnusch, M. 1973. Eine Orbitoliniden-Fauna aus der Unterkreide von Esfahan (Zentral Iran). *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte,* **1973**, 374-382.

Moullade, M., Billotte, M., Busnardo, R., Canerot, J., Fourcade, E. & Peybernès, B. 1972. Valeur stratigraphique et description de *Neoiraqia cuvillieri* n.sp., orbitolinidé nouveau du Vraconien-Cénomanien inférieur des Pyrénées françaises et de la péninsule ibérique. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Paris,* (sér. D), **275**, 2319-2322.

Orbigny, A.D. 'd 1850. *Prodrome de Paléontologie stratigraphique universelle des animaux Mollusques et rayonnés faisant suite au cours élémentaire de Paléontologie et de Géologie stratigraphique.* Volume 2. 427pp. V. Masson, Paris.

Radoičić, R. 1959. *Salpingoporella dinarica* nov. sp. dans les sediments Crétacés inférieurs des Dinarides. *Geološki Glasnik,* **3**, 33-42.

Reichel, M. 1933. Sur une alvéoline cénomanienne du Bassin du Beausset. *Eclogae Geologicae Helvetiae,* **26**, 269-280.

Reiss, Z. & Hottinger, L. 1984. *The Gulf of Aqaba - Ecological Micropaleontology.* 354 pp. Springer-Verlag, New York.

Roemer, F. 1849. *Texas, mit besonderer Rücksicht auf Deutsche Auswanderung und die physischen Verhältnisse des Landes.* 464 pp. A. Marcus, Bonn.

Roemer, F. 1852. *Die Kreidebildungen von Texas und ihre organischen Einschlüsse.* vii+100pp. A. Marcus, Bonn.

Saint-Marc, 1970. Contribution à la connaissance du Crétacé basal au Liban. *Revue de Micropaléontologie,* **12**, 224-233.

Schlumberger, C. 1905. Note sur le genre *Choffatella* n.g. *Bulletin de la Société Géologique de France,* (ser. 4), **5**, 115-134.

Schroeder, R. 1962. Orbitolinen des Cenomans Süd-westeuropas. *Paläontologische Zeitschrift,* **36**, 171-202.

Schroeder, R. 1963. *Palorbitolina,* ein neues Subgenus de Gattung *Orbitolina* (Foram.). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen,* **117**, 346-359.

Schroeder, R. 1964. Orbitoliniden-Biostratigraphie des Urgons nordöstlich von Teruel (Spanien). *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte,* **1964**, 462-474.

Schroeder, R. 1965. Communication préalable sur l'origine des Orbitolines. *Compte Rendu Sommaire des Séances de la Société Géologiques de France,* **1964** (10), 411-413.

Schroeder, R. 1973. El Corte de Aulet (Prov. de Huesca). Evolución de las orbitolinas en el limite del Cretaceo inferior superior. *XIII Coloquio Europeo de Micropaleontología España 1973.* pp. 141-149. CNG and Enadimsa, Madrid.

Schroeder, R. 1975. General evolutionary trends in orbitolinas. *Revista española de Micropaleontología, Numero especial,* **1975**, 117-128.

Schroeder, R. 1979. Les orbitolines de l'Aptien: définitions, origine et évolution. The Aptian orbitolinas - definitions, origin and evolution. *Géobios, Mémoire Spécial* **3**, 289-299.

Schroeder, R. 1985. (See Schroeder & Neumann, 1985).

Schroeder, R. & Neumann, M. (Coordiators). 1985. Les grands foraminifères du Crétacé moyen de la région Méditerranéenne. *Géobios, Mémoire Spécial,* **7**, 1-161.

Schroeder, R., Simmons, M.D., Hart, M.B., Williams, C.L. 1986. A note on the occurrence of *Orbitolina (Orbitolina) sefini* Henson, 1948 (Foraminiferida) in the Upper Greensand of S.W. England. *Cretaceous Research,* **7**, 381-387.

Silvestri, A. 1932. Foraminiferi del Cretaceo della Somalia. *Palaeontographia Italica,* (n. ser.), **32**, 143-204.

Simmons, M.D. 1994. Micropalaeontological biozonation of the Kahmah Group (Early Cretaceous), central Oman Mountains. *In:* Simmons, M.D. (Ed.), *Micropalaeontology and Hydrocarbon Exploration in the Middle East,* pp. 177-220. Chapman & Hall, London.

Simmons, M.D. & Hart, M.B. 1987. The biostratigraphy and microfacies of the Early to mid-Cretaceous carbonates of Wadi Mi'aidin, central Oman Mountains. *In:* Hart, M.B. (Ed.), *Micropalaeontology of Carbonate Environments.* pp. 43-80. Ellis Horwood, Chichester.

Simmons, M.D., Preobrazhensky, M.B. & Bugrova, I.J. 1992. Biostratigraphic characterisation of systems tracts - examples from the Middle East and Turkmenia. *CNRS-*

*IFP Conference on Sequence Stratigraphy of European Basins, Dijon, France, May 1992*, 290-291.

Toula, F. 1877. Geologischen Untersuchungen im westlichen Theile des Balkan und in den angrenzenden Gebieten. 4. Ein geologisches Profil von Osmanieh am Arer, über den Sveti-Nikola-Balkan, nach Ak-Palamka an der Nišava. *Sitzungsberichte der Akademie der Wissenschaften, Wien*, **75**, 465-549.

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

Witt, W. & Gökdag, H. 1994. Orbitolinid biostratigraphy of the Shuaiba Formation (Aptian), Oman: implications for reservoir development. *In:* Simmons, M.D. (Ed.), *Micropalaeontology and Hydrocarbon Exploration in the Middle East*. pp. 221-242. Chapman & Hall, London.

PLATE 1
[All scale bars - 0.2mm]

1. ***Mesorbitolina texana* (Roemer, 1849)**. Axial section through embryonic apparatus. Embryonic apparatus is very distinctive - square, with protoconch and subdivided deuteroconch and subembryonic area of approximately equal thickness. Diameter of embryonic apparatus 0.23 mm. Syntype (herein designated the lectotype) of *Orbitolina kurdica* Henson, 1948. From Kalam Gorge, Aoraman, Iraq. BMNH thin-section no. P 35936.

2. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. Embryonic apparatus consists of globular fused protoconch and deuteroconch (diameter 0.23 mm) with traces of peri-embryonic chambers. "Syntype" (here designated the lectotype) of Henson's *Orbitolina* cf. *discoidea* Gras. From Wadi N'garra, Jabal Abd-el-Aziz, Syria. BMNH thin-section no. P 35924.

3. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. Metatype of *Orbitolina* cf. *discoidea*. From Wadi N'garra, Jabal Abd-el-Aziz, Syria. Henson and Associates Collection thin-section no. M/2171.

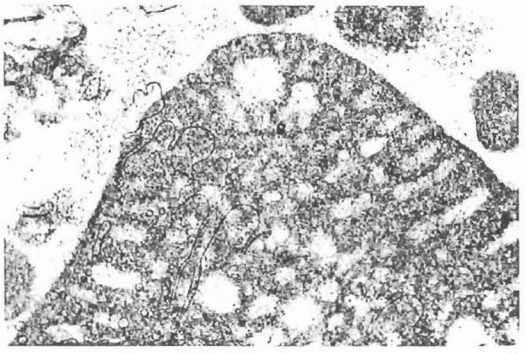
4. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. The peri-embryonic chamberlets are clearly visible. Metatype of *Orbitolina* cf. *discoidea*. From Wadi N'garra, Jabal Abd-el-Aziz, Syria. Henson and Associates Collection thin-section no. M/2171.

5. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Horizontal section through embryonic apparatus. Section cuts through fused protoconch and peri-embryonic chamberlets. Note the triangular shape of the chamber passages. "Syntype" of Henson's *Orbitolina* cf. *discoidea* Gras. From Wadi N'garra, Jabal Abd-el-Aziz, Syria. BMNH thin-section no. P 35923.

6. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Horizontal section through embryonic apparatus. Peri-embryonic chamberlets weakly developed. Syntype (here designated lectotype) of *Orbitolina discoidea* var. *delicata* Henson. From Dukhan-2 Well, Qatar. BMNH thin-section no. P 35919.

7. **Gen. et sp. indet.** Axial section. Metatype of Henson's *Orbitolina* cf. *trochus* (Fritsch). Identity uncertain, but fine chamber layers and presence of silt-grade agglutinating material was regarded by Henson as diagnostic. The value of such criteria in modern orbitolinid taxonomy, however, is not thought to be important. From Hanna, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2021.

8. ***Orbitolina sefini* Henson, 1948**. Tangential section of lectotype nominated by Schroeder (in Schroeder & Neumann, 1985). The chamber passages are initially high-triangular/subrectangular, but become rectangular in later chamber layers, a feature diagnostic of this species. From one mile north of Khoran, Sefin Dagh, Iraq. BMNH thin-section no. P 35902.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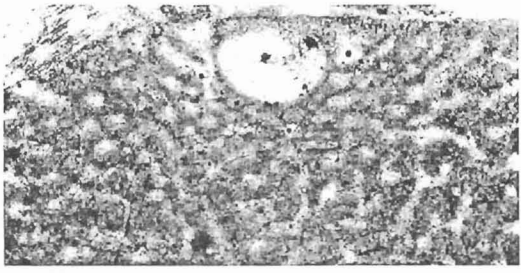
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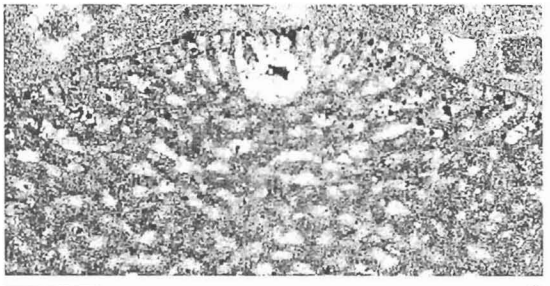
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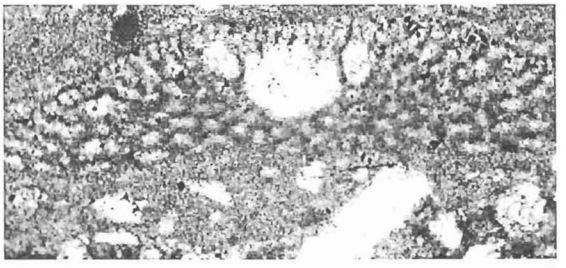
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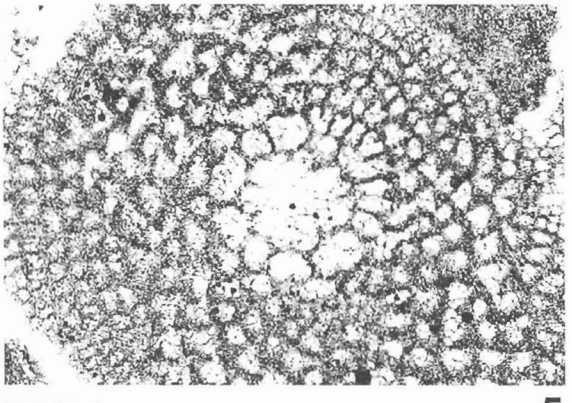
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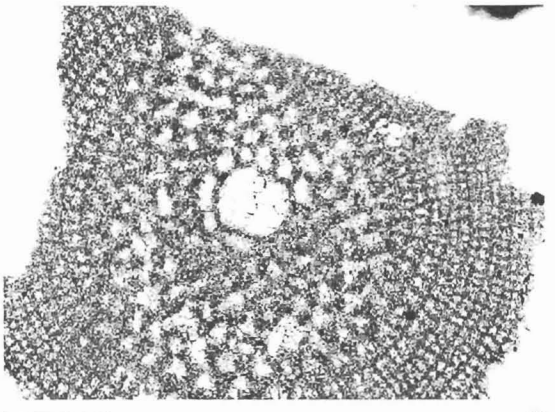
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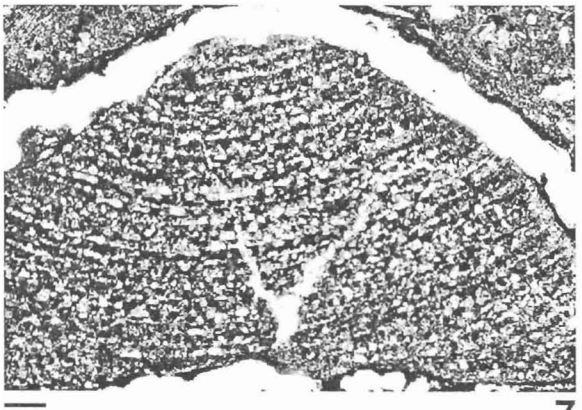
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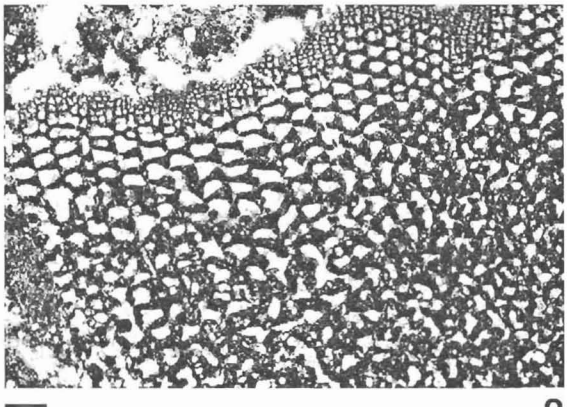
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## PLATE 2

[All scale bars = 0.2 mm]

1. ***Orbitolina hensoni* sp.nov.** Paratype. Axial section through embryonic apparatus. It possesses an *Orbitolina*-type embryonic apparatus of 0.6 mm diameter, with a thin subembryonic zone, weakly partitioned and a thicker, more alveolar deuteroconch. The dome-shaped protoconch is also a noticeable feature. Formerly a metatype of Henson's *Orbitolina* cf. *concava* (Lamarck). From Nafatah-1 Well, Iraq. Henson and Associates Collection thin-section no. M/8046.

2. ***Orbitolina hensoni* sp.nov.** Holotype. Tangential section through chamber passages. This section reveals the presence of exclusively triangular chamber passages in the radial zone, the diagnostic feature of this species. Compare with *Orbitolina sefini* Henson (Plate 2, Fig. 5) and *O. qatarica* Henson (Plate 2, Figs 7, 8). Formerly a metatype (here designated the lectotype) of Henson's *Orbitolina* cf. *concava* Gras. From Nafatah-1 Well, Iraq. Henson and Associates Collection thin-section no. M/4810.

3. ***Orbitolina sefini* Henson, 1948**. Axial section through embryonic apparatus. It possesses an *Orbitolina*-type embryonic apparatus, 0.62 mm in diameter, with a dome- shaped protoconch and markedly alveolar and domed deuteroconch. Syntype (herein designated a paralectotype). From Sefin Dagh, Iraq. BMNH thin-section no. P 35903.

4. ***Orbitolina sefini* Henson, 1948**. Axial section through embryonic apparatus. Section probably not truly axial, resulting in globular appearance of protoconch. Syntype (herein designated a paralectotype). From Sefin Dagh, Iraq. BMNH thin-section no. P 35903.

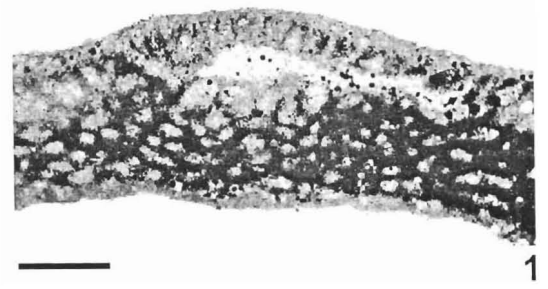
5. ***Orbitolina sefini* Henson, 1948**. Tangential section through chamber passages. Note transition from high triangular chamber passages in early chamber layers to rectangular in later chamber layers. Syntype (herein designated a paralectotype). From Sefin Dagh, Iraq. BMNH thin-section no. P 35903.

6. ***Mesorbitolina subconcava* (Leymerie, 1878)**. Axial section through embryonic apparatus. Syntype of *Orbitolina concava* var. *sefini* Henson, 1948. Some syntypes are clearly distinct from the majority of specimens present. As illustrated by this specimen, they have a smaller, *Mesorbitolina*-type embryonic apparatus of about 0.3-0.35 mm diameter. From Sefin Dagh, Iraq. BMNH thin-section no. P 35902.

7. ***Orbitolina qatarica* Henson, 1948**. Tangential section, showing the exclusively rectangular chamber passages. Syntype (herein designated the lectotype). From Dukhan-1 Well, Qatar. BMNH thin-section no. P 35916.

8. ***Orbitolina qatarica* Henson, 1948**. Axial section through embryonic apparatus. It possesses a large *Orbitolina*-type embryonic apparatus, 0.7 mm in diameter. Note the domed protoconch and thick, well-subdivided, domed deuteroconch. Metatype (herein designated the paralectotype). From Dukhan-1 Well (2430-2438'), Qatar. Henson and Associates Collection thin-section no. M/2091.

9. ***Orbitolina qatarica* Henson, 1948**. Tangential section through chamber passages. Enlargement of Plate 2, Fig. 7. Lectotype. Dukhan-1 Well, Qatar. BMNH thin-section no. P 35916.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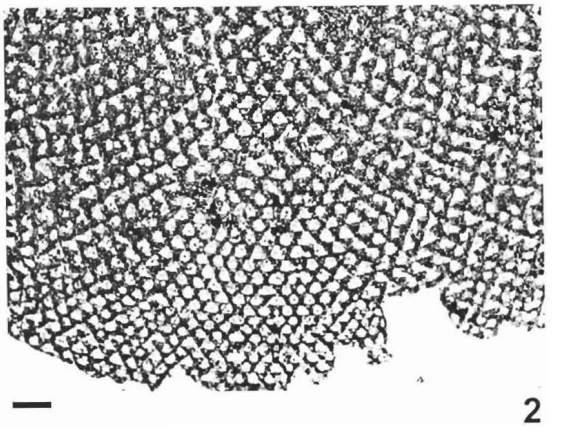
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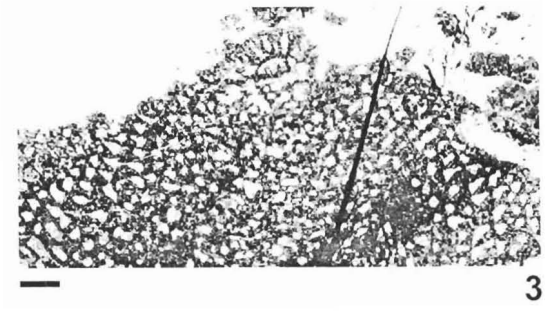
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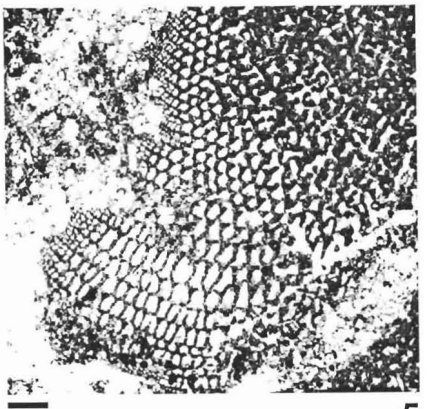
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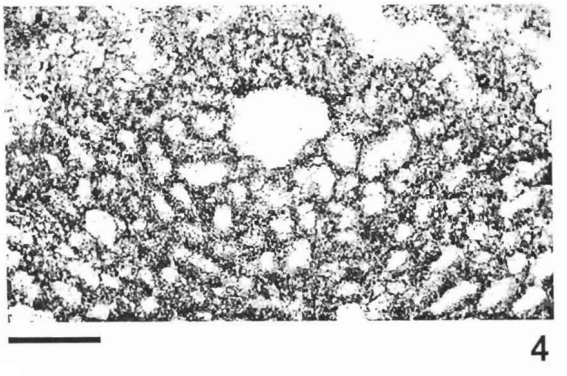
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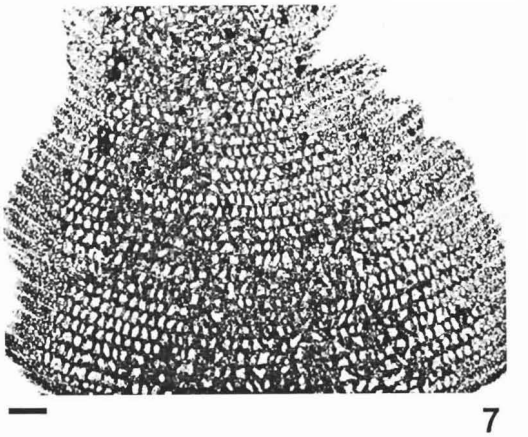
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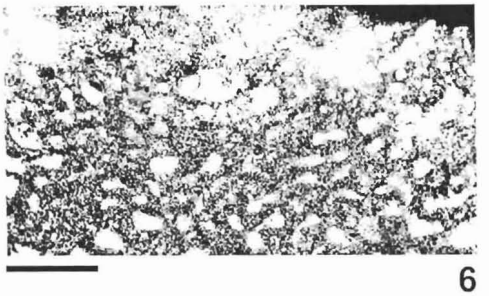
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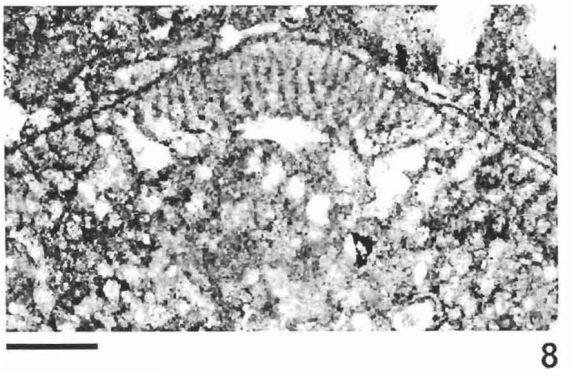
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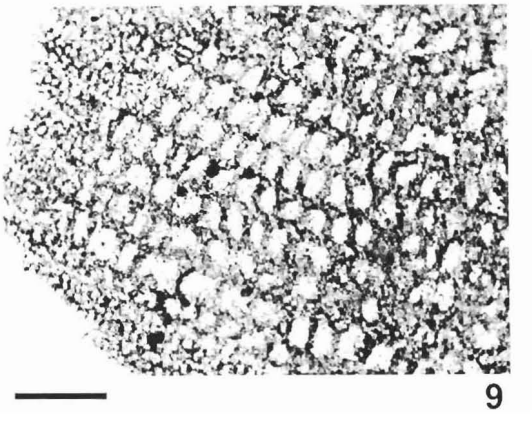
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PLATE 3

[All scale bars = 0.2 mm]

1. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *discoidea* Gras. From Tang-i-Marawi, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2041.

2. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *discoidea* Gras. From Makhul-1 Well (3555-3559'), Iraq. Henson and Associates Collection thin-section no. M/2251.

3. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *discoidea* Gras. From Makhul-1 Well (3484-3494'). Iraq. Henson and Associates Collection thin-section no. M/2224.

4. ***Palorbitolina lenticularis* (Blumenbach, 1805)**. Tangential section through chamber passages, which are triangular in shape. Originally identified as *Orbitolina* cf. *discoidea* Gras var. *delicata* Henson. From Dukhan-1 Well (3579-3584'), Qatar. Henson and Associates Collection thin-section no. M/2792.

5. ***Palorbitolinoides hedini* Cherchi & Schroeder, 1980**. Axial section through embryonic apparatus. The large embryonic apparatus consisting of alveolar protoconch and fused peri-embryonic chamberlets (of total diameter 0.62 mm) is diagnostic. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From Jupa Zarawi, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2044.

6. ***Praeorbitolina wienandsi* Schroeder, 1964**. Axial section through embryonic apparatus. The eccentric location of small (0.12 mm) embryonic apparatus, with weakly subdivided subembryonic zone is diagnostic. Originally identified as *Orbitolina discoidea* Gras var. *libanica* Henson. From Sofar, Lebanon. BMNH thin-section no. P 35931.

7. ***Mesorbitolina lotzei* Schroeder, 1964**. Axial section through embryonic apparatus. The small (0.11 mm diameter) *Mesorbitolina*-type embryonic apparatus with weakly subdivided deuteroconch and subembryonic zone is diagnostic. Originally identified as *Orbitolina discoidea* Gras var. *libanica* Henson. From Colline de Kfernis, Lebanon. Henson and Associates Collection thin-section no. M/2297.

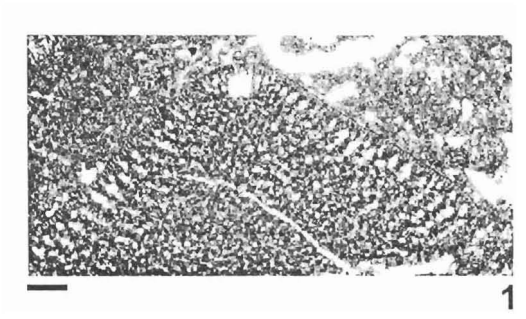
8. ***Mesorbitolina lotzei* Schroeder, 1964**. Axial section through embryonic apparatus. Shows a small (0.13 mm diameter) *Mesorbitolina*-type embryonic apparatus with weakly subdivided deuteroconch and embryonic zone. Originally identified as *Orbitolina discoidea* Gras var. *delicata* Henson. From the Hadhramaut, Yemen. Henson and Associates Collection thin-section no. M/2256.

9. ***Mesorbitolina parva-texana* gr**. Axial section through embryonic apparatus. This mesorbitolinid has an embryonic apparatus of 0.18 mm diameter. Such dimensions are compatible with both *M. parva* (Douglass, 1960) and *M. texana* (Roemer, 1849). Differentiation is only possible from horizontal sections through the subembryonic zone - *M. texana* will have regularly spaced partitions (see Plate 3, Fig. 12). Originally identified as *Orbitolina* cf. *discoidea* Gras. From Ardakan, S.W. Iran. Henson and Associates Collection thin-section no. M/2080.

10. ***Mesorbitolina texana* (Roemer, 1849)**. Axial section through embryonic apparatus. Embryonic apparatus (of 0.21 mm diameter) is very distinctive - square with protoconch and subdivided deuteroconch and subembryonic area of approximately equal thickness. Originally identified as *Orbitolina* cf. *discoidea* Gras. From south of Husainabad, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2050.

11. ***Mesorbitolina texana* (Roemer, 1849)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *discoidea* Gras. From Merdjayoun, Lebanon. Henson and Associates Collection thin-section no. M/3044.

12. ***Mesorbitolina texana* (Roemer, 1849)**. Horizontal section through embryonic apparatus. The regular partitions within the subembryonic zone are visible. Originally identified as *Orbitolina discoidea* Gras var. *libanica* Henson. From Colline de Kfernis, Lebanon. Henson and Associates Collection thin-section no. M/2295.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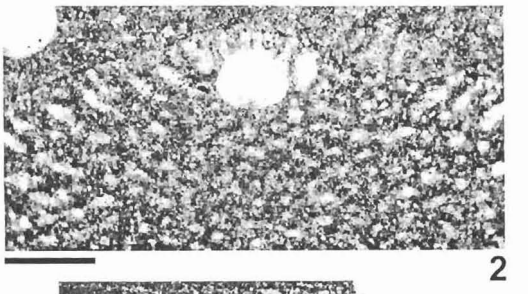
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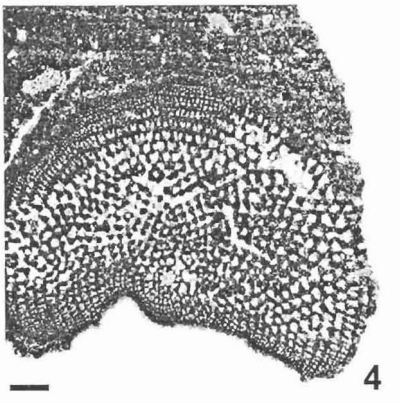
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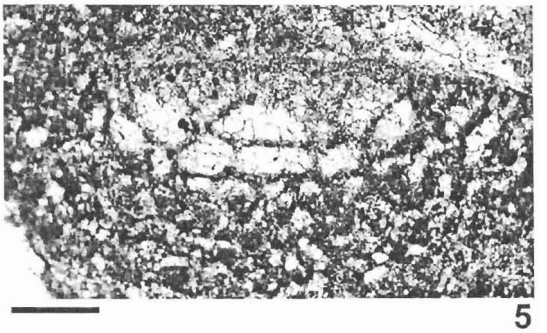
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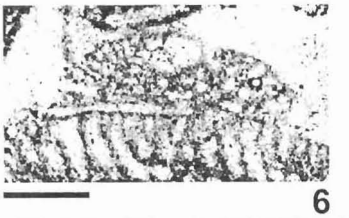
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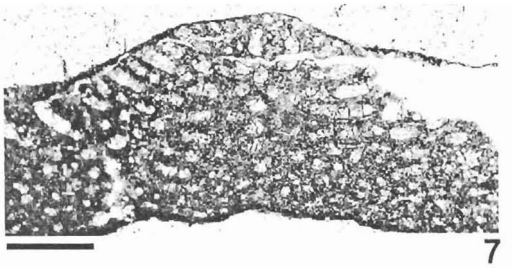
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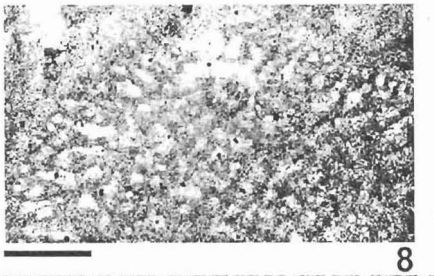
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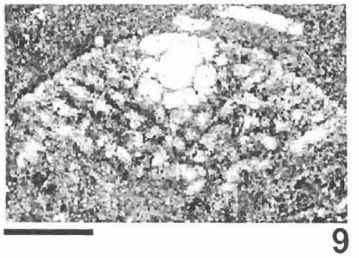
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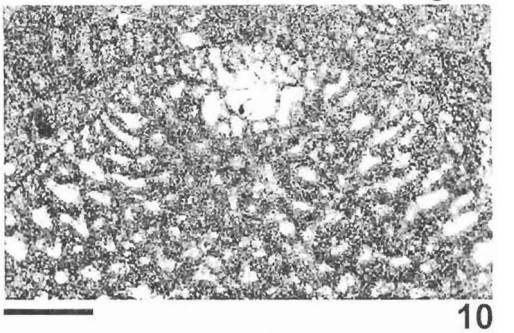
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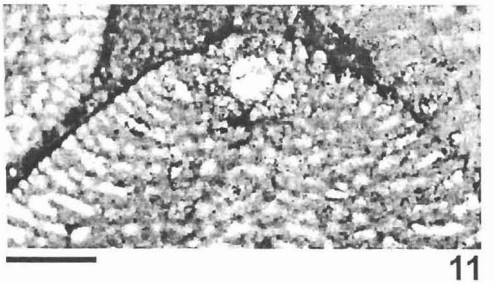
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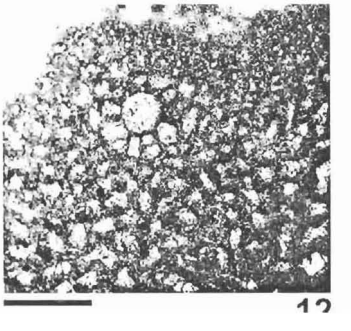
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## PLATE 4

[All scale bars = 0.2 mm]

1. *Mesorbitolina texana* **(Roemer, 1849)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *discoidea* Gras. From Kuh-i-Banish, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2042.

2. *Mesorbitolina subconcava* **(Leymerie, 1878)**. Axial section through embryonic apparatus. Possesses a *Mesorbitolina*-type embryonic apparatus (0.45 mm in diameter) with lenticular shaped protoconch. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From Hana, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2032 .

3. *Mesorbitolina subconcava* **(Leymerie, 1878)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From near Jupa Zarawi, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2045.

4. *Mesorbitolina pervia* **(Douglass, 1960)**. Axial section through embryonic apparatus. The embryonic apparatus (0.35 mm in diameter) is similar to *M. subconcava* (Leymerie) but the domed protoconch is diagnostic. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From Hana, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2033.

5. *Conicorbitolina cuvillieri* **(Moullade, 1972)**. Axial section through embryonic apparatus. The highly conical test, together with the small (0.25 mm diameter) embryonic apparatus, with cup-shaped deuteroconch and sub-embryonic area are diagnostic. The marginal zone is also strongly differentiated. Ideotype (specimen other than topotype identified by the original author) of *Orbitolina concava* (Lamarck) var. *sefini* Henson, 1948. From Wadi Rumman, Israel. BMNH thin-section no. P 35905.

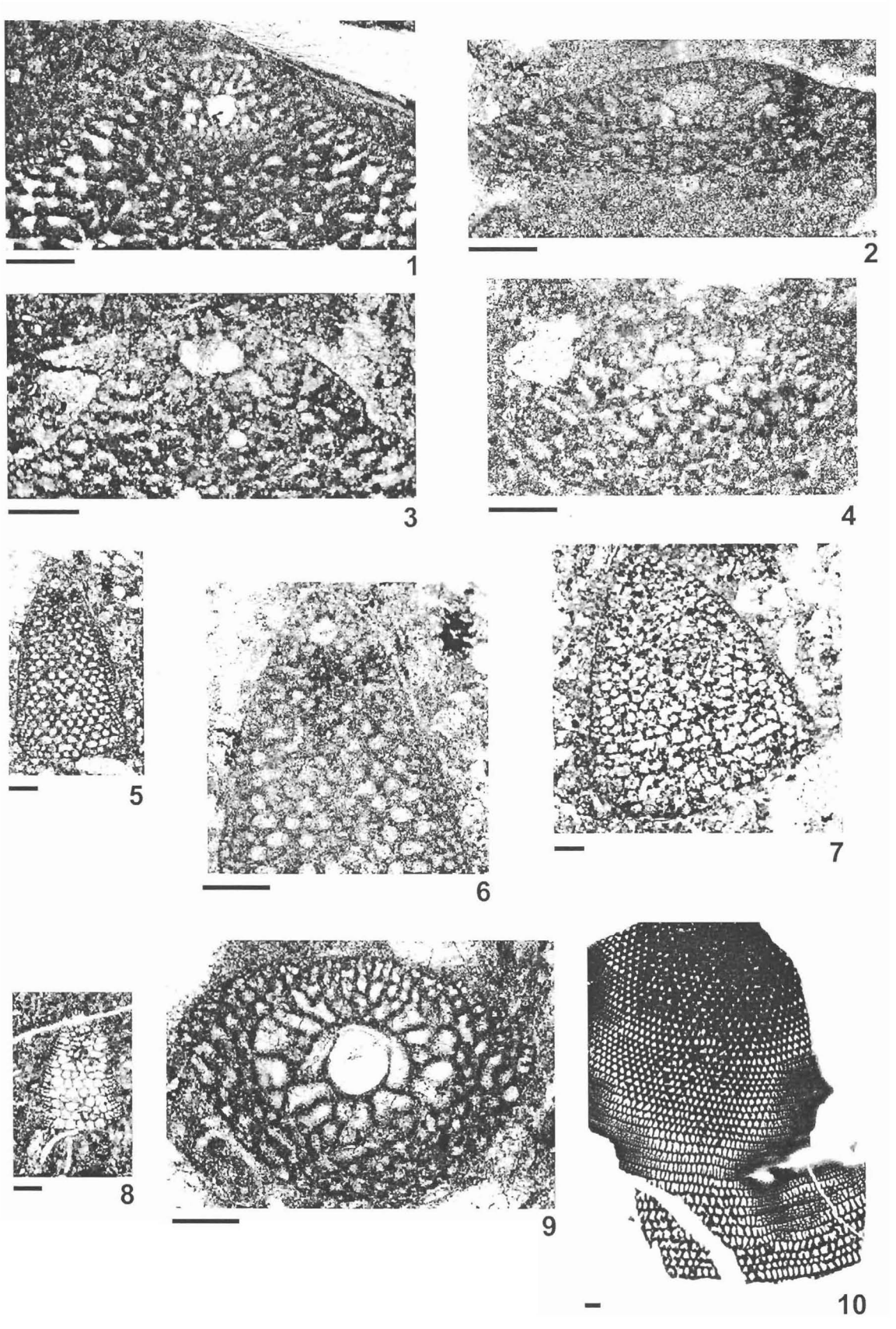
6. *Conicorbitolina cuvillieri* **(Moullade, 1972)**. Axial section through embryonic apparatus. Enlargement of Plate 4, Fig. 5. From Wadi Rumman, Israel. BMNH thin-section no. P 35905.

7. *Conicorbitolina cuvillieri* **(Moullade, 1972)**. Axial section through embryonic apparatus. Ideotype of *Orbitolina concava* (Lamarck) var. *sefini* Henson, 1948. From the Hebron Road, Israel. BMNH thin-section no. P 35906.

8. *?Conicorbitolina cuvillieri* **(Moullade, 1972)**. Axial section through embryonic apparatus. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From Surmich Shirabad, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2074.

9. *Orbitolina hensoni* **sp.nov.** Horizontal section through embryonic apparatus. The complex partitions of the deuteroconch are clearly visible. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From Burgan, Kuwait. Henson and Associates Collection thin-section no. M/2100.

10. *Orbitolina sefini* **Henson, 1948**. Tangential section through chamber passages. The transition from high-triangular to rectangular chamber passages is clearly visible. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From near Mahis, Jordan. Henson and Associates Collection thin-section no. M/1512.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## PLATE 5

[All scale bars = 0.2 mm]

1. ***?Orbitolinopsis* sp.** Axial section through embryonic apparatus of an indeterminate orbitolinid, possibly a species of *Orbitolinopsis*. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From Surmich Shirabad, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2072.

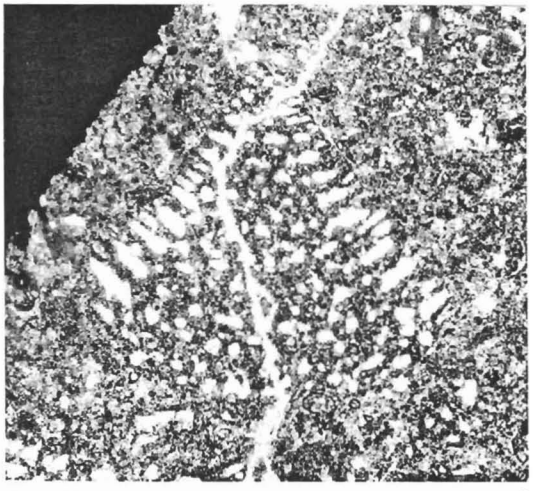
2. ***?Orbitolinopsis* sp.** Almost an axial section of an indeterminate orbitolinid, possibly a species of *Orbitolinopsis*. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From Surmich Shirabad, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2072.

3. ***"Valdanchella"* sp.** Axial section through embryonic apparatus of indeterminate orbitolinid, possibly a species of *"Valdanchella"*. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From Surmich Shirabad, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2072.

4. ***"Valdanchella"* sp.** Almost an axial section of an indeterminate orbitolinid, possibly a species of *"Valdanchella"*. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From west of Surmich, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2070.

5. ***"Valdanchella"* sp.** Basal section of an indeterminate orbitolinid, possibly a species of *"Valdanchella"*. Originally identified as *Orbitolina concava* (Lamarck) var. *sefini* Henson. From Surmich Shirabad, Iranian Baluchistan. Henson and Associates Collection thin-section no. M/2074.

6. ***Neoiraqia convexa* Danilova, 1963.** Axial section through embryonic apparatus of an orbitolinid, tentatively referred to *N. convexa*. Originally identified as *Orbitolina* cf. *concava* (Lamarck). From Qaleh Qabri, Qashqai Sarhad, Iran. Henson and Associates Collection thin-section no. M/2055.



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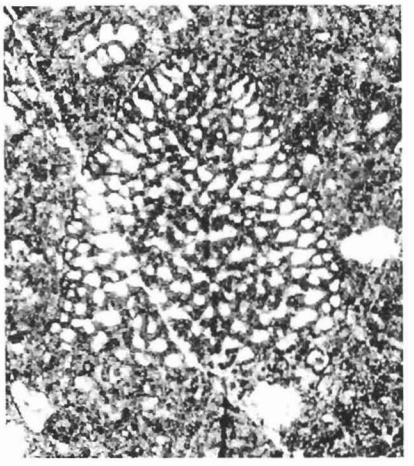

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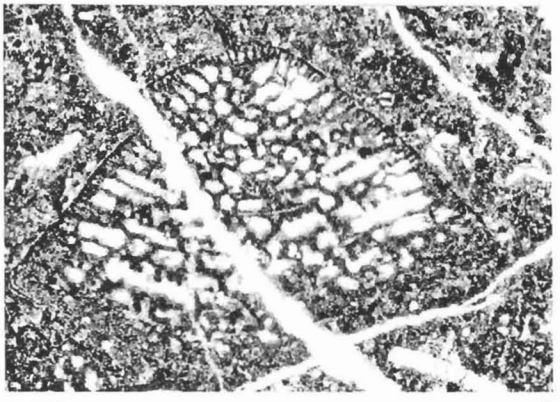

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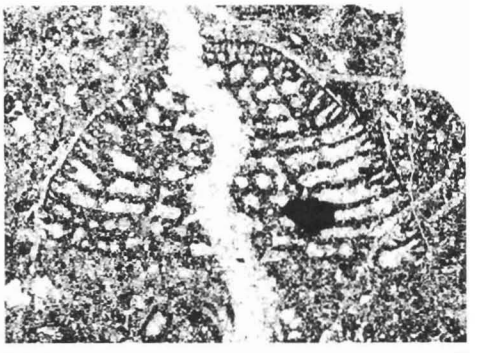

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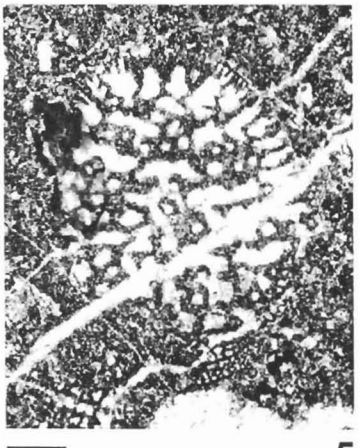

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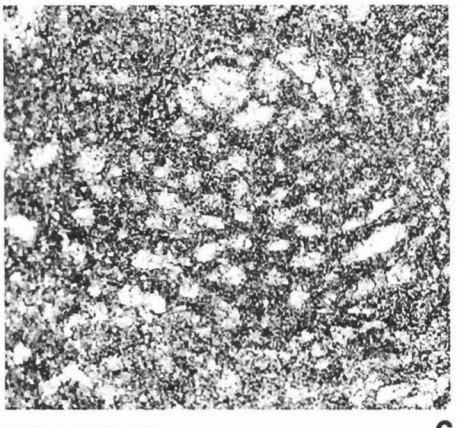

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# The former British Petroleum Microfossil Collection at The Natural History Museum, London. An important resource for the study of agglutinated foraminifera

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## INTRODUCTION

In the early 1990's The Natural History Museum received an important microfossil collection from British Petroleum. It represents BP's extensive exploration record since the 1950's and consists of over 250,000 slides and residues of foraminifera, ostracods, palynomorphs and nannoplankton.

The collection can be divided into three parts: a reference collection (consisting of around 60,000 slides, primarily of Mesozoic and Cenozoic benthonic and planktonic foraminifera and ostracods which were used as BP's type and reference collection); a palynology and nannoplankton collection (around 100,000 Mesozoic to Cenozoic slides and residues mainly of well material) and the collection of well run material which is the largest component of the collection consisting of over 100,000 slides.

The vast majority of the well run collection consists of foraminiferal assemblage slides and residues from thousands of wells world-wide. It is sorted geographically and includes well material from the following areas: North West Europe (Netherlands, onshore and offshore United Kingdom, offshore Norway); Central and South America; West Indies (Trinidad, Jamaica); Pacific and North America (Alaska, Arctic, Canada); Africa (Guinea Bissau, Libya, Namibia, Nigeria, Somalia, Tanzania, Tunisia); South East Asia (China, Fiji, Papua New Guinea); the Middle East and Australasia. The collection is further subdivided by basin location, well location, well name and finally by well depth.

The collection represents a major repository of micropalaeontological material and includes wells from important regions of petroleum exploration. It is therefore an extremely useful resource for the study of agglutinated foraminifera as exemplified by the numerous accounts of "flysch-type" agglutinated assemblages which have been published from these same regions; including: the Labrador and North Seas (Gradstein & Berggren, 1981; Gradstein & Kaminski, 1989); the North Sea (Charnock & Jones, 1990); North Sea and the Norwegian Sea (Gradstein & Kaminski, 1997); Spitsbergen (Nagy & Basov, 1998) and Trinidad (Kaminski *et al.*, 1988).

The collection is available for study by all interested parties, subject to some restriction and has been utilised previously as a source for a diverse range of academic and commercial research as well as student projects. Please e-mail BP-Collection@nhm.ac.uk for details and additional information.

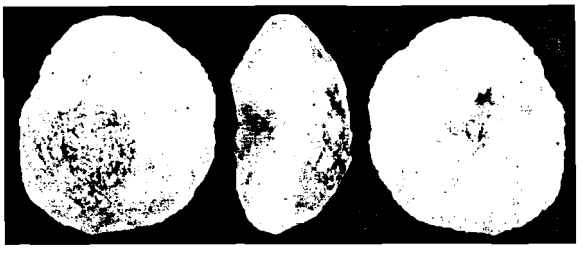

**Figure 1.** *Ammoanita ruthvenmurrayi* (Cushman & Renz). BP Well 211/12-7, North Sea. The Natural History Museum former BP Collection. NHM PalaeoVision Image.

## REFERENCES

Charnock, M.A. & Jones, R.W., 1990. Agglutinated foraminifera from the Palaeogene of the North Sea. *In:* C. Hemleben *et al.* (eds), *Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera.* Kluwer Academic Publishers, NATO ASI Series, Ser. C, **327**, Netherlands, 139-244.

Gradstein, F.M. & Berggren, W.A., 1981. Flysch-type agglutinated foraminifera and the Maestrichtian to Recent Palaeogene history of the Labrador and North Seas. *Marine Micropaleontology*, **6**, 211-268.

Gradstein, F.M., & Kaminski, M.A., 1989. Taxonomy and biostratigraphy of new and emended species of Cenozoic deep-water agglutinated foraminifera from the Labrador and North Seas. *Micropaleontology*, **35**, 72-92.

Gradstein, F.M., & Kaminski, M.A., 1997. New species of Paleogene deep-water agglutinated foraminifera from the North Sea and Norwegian Sea. *Annales Societatis Geologorum Poloniae*, **67**, 217-229.

Kaminski M.A., Gradstein, F.M., Berggren, W.A., Geroch, S. & Beckmann, J.P., 1988. Flysch-type agglutinated foraminiferal assemblages from Trinidad: taxonomy, stratigraphy and paleobathymetry. *In: Proceedings of the Second Workshop on Agglutinated Foraminifera, Vienna 1986. Abhandlungen der Geologischen Bundesanstalt*, **41**, 155-227.

Nagy, J. & Basov, V.A., 1998. Revised foraminiferal taxa and biostratigraphy of Bathonian to Ryazanian deposits in Spitsbergen. *Micropaleontology*, **44**, 217-255.

*In:* Hart, M.B., Kaminski, M.A., & Smart, C. (eds) 2000. Proceedings of the Fifth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **7**, 438.