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HEMICYCLAMMINA WHITEI (HENSON, 1948): THE SENIOR SYNONYM OF *HEMICYCLAMMINA SIGALI* MAYNC 1953, A DISTINCTIVE LARGER BENTHONIC FORAMINIFER FROM THE MID-CRETACEOUS OF NEOTETHYS

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Abstract In 1953 Wolf Maync introduced the lituolid (now regarded as loftusiid) foraminiferal genus *Hemicyclammina*, with its type species *Hemicyclammina sigali* from the Cenomanian of Algeria. Since then, this distinctive microfossil has been frequently reported from mainly Neotethyan mid-Cretaceous (mostly Albian and Cenomanian) sedimentary rocks in locations as far apart as Brazil and Oman. However, Maync was seemingly unaware of the 1948 publication of Francis R.S. Henson in which a new species of foraminifera, *Cyclammina whitei*, was described from the mid-Cretaceous of the Middle East. During the course of the last 70 years, *C. whitei* has been placed in the genus *Hemicyclammina*, tenuously regarded as distinct from *H. sigali*.

We demonstrate that *H. whitei* and *H. sigali* are synonyms, with *H. whitei* the senior synonym, and hence the type species of *Hemicyclammina*. This argument is supported by the re-illustration of the type material of *H. whitei* and *H. sigali*. It is also argued that a number of poorly known taxa (e.g., *Hemicyclammina evoluta* Hamaoui, *Ismailia neumannae* El-Dakkak, *Sinainella aegyptiaca* El-Dakkak) are most likely the junior synonyms of *H. whitei* and that thus, for the Albian – Cenomanian at least, there is only one species of *Hemicyclammina*. Limited Barremian/Aptian records of *Hemicyclammina* are probably best assigned to a potentially ancestral form herein termed "*Hemicyclammina*? sp." pending access to further material and a full assessment of the evolution of *Hemicyclammina*.

A critical review of the many published records demonstrates that *H. whitei* ranges throughout the Albian and Cenomanian, although locally it may have a more restricted range because of facies control on its inception, extinction, and abundance. It is confidently known to occur from southern and central America, North Africa, the Mediterranean, the Arabian Plate and Somalia.

Keywords: Foraminifera, *Hemicyclammina*, Neotethys, Cretaceous, micropalaeontology, biostratigraphy

INTRODUCTION

Hemicyclammina Maync is a distinctive genus of planispiral agglutinating foraminifera that can be readily identified in equatorial thin-sections by virtue of a simple (single layer) alveolar (*sensu* Hottinger, 2006) wall structure ("réseau hypodermique" [= hypodermic network] *sensu* Septfontaine (1981)), and the presence of short, pointed septa that project from the outer edge of the chamber wall (Figures 1-4). The genus was introduced by Maync (1953) using material from the Cenomanian of Algeria, with the type species being *Hemicyclammina sigali* Maync. Since then, this species has been widely recognised across Neotethys where it occurs in marly mid-outer shelf sediments of Albian and Cenomanian age. Locally, its inception or abundance may have value for correlation (e.g. Sampò, 1969). However, five years previous to the description of *H. sigali*, Henson (1948) described *Cyclammina whitei* Henson from the Cenomanian (now regarded as latest Albian) of Qatar. Banner (1966, 1970) recognised that this species should be assigned to *Hemicyclammina*, but despite great morphological similarity and similar age ranges, maintained *H. sigali* and *H. whitei* as separate species. Saint-Marc (1974) and Whittaker et al. (1998) commented that that the two species were probably synonyms, but formal recognition of this has been delayed until now.

Herein we use re-illustrations of the types of *H. whitei* and *H. sigali* and other comparative material to confirm the synonymy with the consequence that *H. whitei* (= *H. sigali)* is the type species of *Hemicyclammina*. We also place the poorly known species *Hemicyclammina evoluta* Hamaoui, *Ismailia neumannae* El-Dakkak and *Sinainella aegyptiaca* El-Dakkak in probable synonymy with *H. whitei*.

The stratigraphic and palaeogeographic distribution of *H. whitei* is reassessed in light of the numerous records of it and its synonyms that have appeared in the last 75 years.

Taxonomic Discussion

Class FORAMINIFERA d'Orbigny 1826
Order LOFTUSIIDA Kaminski and Mikhalevich in Kaminski 2004
Suborder LOFTUSIINA Kaminski and Mikhalevich in Kaminski 2004
Superfamily LOFTUSOIDEA Brady 1884
Family CYCLAMMINIDAE Marie 1941
Subfamily HEMICYCLAMMININAE Banner 1966
Genus *Hemicyclammina* Maync 1953

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Probable synonyms: *Popovia* Suleymanov, 1965, *Sinainella* El-Dakkak, 1975, *Ismailia* El-Dakkak, 1974,
Type species *Cyclammina whitei* Henson 1948 (= *Hemicyclammina sigali* Maync 1953)
Hemicyclammina whitei (Henson, 1948**)**
1948 *Cyclammina whitei* n. sp. – Henson, p. 13-14, pl. 13, figs. 3, 12-14.
1953 *Hemicyclammina sigali* n. sp. – Maync, p. 148-149, figs 1-5.
1965 *Hemicyclammina sigali* Maync – Hamaoui, pl.1, fig. 7; pl. 6, fig. 10; pl. 15, fig. 9.
1965 *Hemicyclammina* nov. sp.? – Hamaoui, pl. 5, figs. 1-3.
?1965 *Haplophragmoides difformis* – Hamaoui, p. 17, pl. 6, fig. 9, non pl. 3, figs. 5-8.
1965 *Hemicyclammina sigali* Maync – Hamaoui & Raab, pl. 1, fig. 9 ; pl. 3, fig. 6.
1966 *Hemicyclammina whitei* (Henson) – Banner, pl. 2, figs. 4a, b, 5.
1966 *Hemicyclammina sigali* Maync – Banner, pl. 12, figs. 3a, b; pl. 13, figs. 1-6.
1967 *Hemicyclammina sigali* Maync – Arkin & Hamaoui, pl. 1, figs 17-18 (?), pl. 2, fig. 1.
1969 *Hemicyclammina sigali* Maync – Sampò, pl. 39, figs. 1-5; pl. 40, fig. 2; pl. 41, fig. 1.
1970 *Hemicyclammina whitei* (Henson) – Banner, pl. 10, figs. 1-2.
1970 *Hemicyclammina sigali* Maync – Banner, pl. 10, figs. 3-8.
1970 *Hemicyclammina sigali* Maync – Saint-Marc, pl. 3, fig. 4-6, 10.
1973 *Hemicyclammina sigali* Maync – Berthou, pl. 11, figs. 1-3.
?1974 *Hemicyclammina sigali* Maync – Bignot & Poisson, pl. 3, figs. 1-4.
?1974 *Ismailia neumannae* n. sp. – El-Dakkak, p. 173-175, pl. 1, figs. 1-5.
1974 *Hemicyclammina sigali* Maync – Saint-Marc, p. 212-214, pl. 1, figs. 1-6.
1974 *Hemicyclammina sigali* Maync – Radoičić, pl. 8, fig. 1?, pl. 9, fig. 1.
?1975 *Sinainella aegyptiaca* n.sp. – El-Dakkak, p. 107-110, pl. 1, figs. 1-7.
1976 *Hemicyclammina sigali* Maync – Kalantari, pl. 19, fig. 4; pl. 22, fig. 16.
?1979 *Ammobaculites difformis* – Hamaoui, p. 338-340, fig. 1f, non fig. 1a-e.
1981 *Hemicyclammina sigali* Maync – Saint-Marc, pl. 1, fig. 1.
?1985 *Hemicyclammina* sp. – Bilotte, p. 355, pl. 4, fig. 10.
1987 *Hemicyclammina sigali* Maync – Shakib, pl. 23, figs. 14-16.
1987 *Hemicyclammina sigali* Maync – Simmons & Hart, pl. 10.4, fig. 7.
1988 *Hemicyclammina sigali* Maync – Sartorio & Venturini, p. 106.
1988 *Hemicyclammina sigali* Maync – Berthou & Bengtson, pl. 5e-g; pl. 6e-f, i.
1990 *Hemicyclammina sigali* Maync – Weidich & Al-Harithi, p. 602-603; pl. 2, figs. 8-11; pl. 4, figs. 2-3, 7-9, 12-13.
1990 *Hemicyclammina* n. sp.? Hamaoui – Weidich & Al-Harithi, p. 603; pl. 4, figs. 21-22.
1990 *Pseudocyclammina* aff. *massiliensis* Maync – Weidich & Al-Harithi, p. 604, pl. 4, fig. 1.
1990 *Haplophragmoides*? *difformis* Hamaoui – Weidich & Al-Harithi, p. 599, pl. 4, fig. 6.
?1990 *Haplophragmoides* sp. 2 – Weidich & Al-Harithi, p. 599, pl. 4, fig. 14.
1992 *Hemicyclammina sigali* Maync – Kalantari, pl. 78.
?1993 *Ismailia neumannae* El-Dakkak – Al-Rifaiy et al., pl. 1, fig. 3.
?1993 *Hemicyclammina evoluta* Hamaoui – Al-Rifaiy et al., pl. 1, fig. 4.
?1993 *Hemicyclammina sigali* Maync - Al-Rifaiy et al., pl. 1, fig. 5.
?1993 *Everticyclammina whitei* (Henson) – Hewaidy & Al-Hitimi, p. 476-477; pl. 3, figs. 9-10.
1996 *Hemicyclammina sigali* Maync – Andreu et al., pl. 1, fig. 3.
1998 *Hemicyclammina sigali* Maync – Whittaker et al., p. 40, pl. 59, figs. 3-9; pl. 60, fig. 1.
1998 *Hemicyclammina whitei* (Henson) – Whittaker et al., p. 40-41, pl. 12, figs. 1-2; pl. 60, figs. 2-7; pl. 61, figs. 1-3.
2005 *Hemicyclammina sigali* Maync – Hart et al., fig. 6f-g.
2008 *Hemicyclammina* sp. – Ahmadi et al., pl. 2, fig. 6.
2009 *Hemicyclammina sigali* Maync – Shirazi et al., pl. 1, fig. 9.
2010 *Hemicyclammina whitei* (Henson) – Forbes et al., fig. 6.7d-e.
?2010 *Hemicyclammina sigali* Maync – Schroeder et al., fig. 11(6).
Non 2011 *Hemicyclammina sigali* Maync – Roozbahani, pl. 2, fig. 4.
2011 *Hemicyclammina sigali* Maync – Shirazi et al., pl. 2, figs. 11-12.
2012 *Hemicyclammina sigali* Maync – Omaña et al., pl. 1, fig. 1; pl. 4, fig. 1.
?2012 *Hemicyclammina sigali* Maync – Ghanem et al., fig. 6b/12, 14.
?2013 *Hemicyclammina sigali* Maync – Ghanem & Kuss, fig. 10/27.
?2015 *Hemicyclammina sigali* Maync – Moosavizadeh et al., fig. 12m.
?2016 *Hemicyclammina sigali* Maync – Hosseini et al., fig. 14j-l.
?2016 *Hemicyclammina* sp. – Ghaseminia et al, fig. 4k.
Non 2017 *Hemicyclammina sigali* Maync – Ahmadi et al., pl. 1, fig. 10.
2018 *Hemicyclammina sigali* Maync – BouDagher-Fadel, fig. 5.4; pl. 5.6, figs. 12-13.

2018 *Hemicyclammina whitei* (Henson) – BouDagher-Fadel, pl. 5.6, figs. 14-15.
2018 *Hemicyclammina sigali* Maync – Luger, p. 60, pl. 3, fig. 11.
2019 *Hemicyclammina sigali* Maync – Omaña et al., fig. 9e.
?2019 *Hemicyclammina sigali* Maync – Shirzade et al., pl. 1, figs. 6, 7.
2020 *Hemicyclammina sigali* Maync – Haftlang et al., fig. 15c; pl. 1, fig. 6.
2020 *Hemicyclammina sigali* Maync – Afghah et al., fig. 5a.
2020 *Hemicyclammina sigali* Maync – Keshavarzi et al., pl. 1, fig. a; pl. 2, fig. h.
?2020 *Hemicyclammina sigali* Maync – Moosavizadeh et al., fig. 8h.
?2021 *Nezzazata* sp. – Dehghanian & Afghah, fig. 8/5.
2021 *Hemicyclammina sigali* Maync – Shapourikia et al., pl. 9e, j.
2021 *Hemicyclammina sigali* Maync – Arampour et al., fig. 3g.
2021 *Hemicyclammina sigali* Maync – Keshavarzi et al., fig. 6a.
2022 *Hemicyclammina sigali* Maync – Keshavarzi et al., fig. 7a, ?9a.

Description

Planispiral, involute test, somewhat compressed, but with a rounded to subacute periphery. A single areal aperture occupying all, or nearly all, of the total height of the apertural face in equatorial section, reducing the solid straight septa which are clearly different in structure from the spiral, simple (single-layered) alveolar *(sensu* Hottinger, 2006) wall. In the later stage test, lower part of the septa coalesce to form a basal layer that is present over the chamber floors against the previous whorl. Chamber interiors are simple (modified after Loeblich and Tappan, 1988; BouDagher-Fadel, 2018). Macrospheric forms can be distinguished by the presence of a large proloculus (50-100μm).

The type description and illustrations of *C. whitei* by Henson (1948) are limited by modern standards. The sketches of the holotype (Henson, 1948, pl. 13, figs. 12-14) reveal little other than an involute, coarsely agglutinated form, with a sub-acute periphery and what appears to be a single slit-like aperture, although Henson notes that the "aperture is not clearly seen". A single equatorial section of a paratype (Henson, 1948, pl. 13, pl. 13, fig. 3) is suggestive of the "sub-epidermal cellular structure" (i.e. alveolar *sensu* Hottinger, 2006) of the test wall. The simple straight septa are visible, "bending back sharply" near the margin. Approximately 10 septa are present in the last whorl, and up to three whorls may be present. Diameters are given as 1.7 mm, 2.3 mm (holotype), and 2.7 mm (largest specimen), with thicknesses at broadest point 1.2 mm (holotype) and 0.9 mm (in the largest diameter specimens). Whilst not commented upon, the simple nature of the septa is clear, and they are only developed on the outer margin of the chamber. These features led Banner (1966, 1970) to place *C. whitei* in the genus *Hemicyclammina*.

The types of *H. whitei* are re-illustrated herein (Figures 1 & 2), including scanning electron microscope views of matrix-free material. These confirm the involute nature of the test, the sub-angular periphery, and in a paratype, the likely presence of a slit-like aperture. The apertural face is flat to slightly convex outwards. External size measurements as reported by Henson (1948) are confirmed. Thin-sections of paratypes clearly confirm the alveolar (*sensu* Hottinger, 2006) nature of the wall, although much detail is obscured by detrital quartz used in the agglutination of the test. The simple straight septa are clearly visible, limited to the outer chamber wall.

Remarks and comparisons

The type description and illustrations (partly refigured here – Figure 2) of *H. sigali* by Maync (1953), provide a good basis for comparison with *H. whitei*. Key observations made by Maync (1953) include the involute, coarsely agglutinated test with a "slightly rounded to subacute" periphery; "the wall of the test is clearly labyrinthic, with ramifying passages and alveoles"; the "discontinuous, straight or slightly curved, pointed septa projecting from the periphery inward one half or four fifths into chamber cavity" – these "semi-septa" are "irregularly spaced… there are nine to eleven in the last whorl". He noted that the septa are non- labyrinthic. The aperture was said to be obscure, but possibly cribrate. This does not seem to be borne out by illustration and has subsequently (e.g. Banner, 1966, 1970; Saint-Marc, 1974; Loeblich & Tappan, 1988) been regarded as a single, areal aperture. (Technically whether the term should rather be "basal, extending up the apertural face" or truly "areal" depends on the perception of the coalescing of the septa forming a basal layer upon which the aperture may sit.) Dimensions were not mentioned by Maync (1953) in his description, but from the illustrations (and re-illustrations herein), the holotype has a diameter of 1.3 mm and thickness of 0.4 mm. A larger illustrated specimen has a diameter of 2.0 mm. The illustrations also highlight the variable thickness of the septa. Saint Marc (1974) provided additional dimension details on the basis of material available to him: equatorial diameter 0.7 – 1.4 mm; thickness 0.2 – 0.35 mm; whorls 2-3; chambers in last whorl 9-11; proloculus diameter 100 μm.

H. whitei and *H. sigali* have long been regarded as very similar. Banner (1966, 1970) thought that the septa might be thinner in *H. sigali*, but this can be challenged by comparison of the range present in the type material. In any case, Banner (1966) thought this to be a sub-specific difference. Saint-Marc (1974) also noted the potentially thinner septa in *H. sigali*, which he also thought was slightly smaller in test diameter and with a less pronounced axial bulge in axial section. Nonetheless, Saint-Marc (1974) thought the differences between the two species were minimal and synonymy likely. Whittaker et al. (1998) noted that "the main (?only) difference be-

tween *H. whitei* and *H. sigali*… appears to be the abundant quartz grains agglutinated by the former; perhaps this is of subspecific value at most" (see illustrations in Figure 3), a view which we would uphold. Nature of agglutinating material in foraminifera is not a specific character.

The use of the name *H. whitei* is relatively limited in the literature, with many more references to *H. sigali*. Those records that do exist of *H. whitei* are almost exclusively from the Middle East, where the name is a little more ingrained in the industrial literature (e.g., Forbes et al., 2010; Youssef et al., 2019). An exception is a mention from Honduras by Rogers et al. (2007). Hewaidy & Al-Hitimi (1993) and El Beialy & Al-Hitimi (1994) mistakenly placed the species in the genus *Everticyclammina* Redmond (*Everticyclammina* has septa projecting from both the outer and inner chamber wall – Banner & Highton, 1990). Despite *H. sigali* being a name deeply ingrained in the literature, *H. whitei* and *H. sigali* are effectively synonyms and *H. whitei* must carry priority.

Hamaoui (1965) introduced "*Hemicyclammina* nov. sp.?" (see Figure 4 herein), differing from *H. sigali* by virtue of a coarser wall structure, a flatter test that is laterally compressed, thicker septa, and chambers uncoiling. Subsequently named "*Hemicyclammina evoluta*" by Hamaoui (1979) in a thesis with limited publication, this species has subsequently been mentioned by Bilotte (1985), Weidich & Al-Harithi (1990), Al-Rifaiy et al., (1993), and Lipson-Benitah (2009) (who considers its inception to mark the base of the Cenomanian in Israel). The morphology of "*H. evoluta*" seems to be within the range of variation of *H. whitei* (= *H. sigali*), as discussed above, noting that one of the type figures of *H. sigali* shows an uncoiling trend (Maync, 1953, fig. 5).

One of the paratypes of *Haplophragmoides difformis* Hamaoui (Hamaoui, 1965, pl. 6, fig. 9) (reassigned to *Ammobaculites by* Hamaoui, 1979) is possibly referable to *H. whitei*. However, other type material appears to be a distinct taxon.

El-Dakkak (1974, 1975) introduced two new lituolid taxa from the Cenomanian of Sinai: *Ismailia neumannae* and *Sinainella aegyptiaca.* These taxa are synonymous and have been considered as being possibly referable to *Charentia cuvillieri* Neumann (Loeblich & Tappan, 1985, 1988). Others (e.g., Hassanei & Sigal, 1983, Orabi, 1992) have thought they are probably synonyms of *H. sigali.* The original descriptions and illustrations are limited but do seem to show dimensions and morphological features in keeping with *Hemicyclammina* (e.g., alveolar wall, solid septa and with an apparent slit-like areal aperture – see Figure 4f-g herein). Nonetheless, the external morphology is rather umbilically compressed, tending towards evolute, so in the absence of definitive material, synonymy with *H. whitei* is tentative. If it is confirmed that *Ismailia* and its synonym *Sinainella* are indeed junior synonyms of *Hemicyclammina* they then become invalid genera. The Paleocene genus *Popovia* Suleymanov (type species *Alveolophragmium planum* Bykova) described from Central Asia (Suleymanov, 1965) is morphologically very similar to *Hemicyclammina* and would also appear synonymous. A form identified as *Hemicyclammina plana*? (Bykova) by Seiglie and Baker (1983) from the Paleocene of West Africa (Seiglie and Baker 1893; pl. 2, fig. 11) appears clearly to be *Hemicyclammina* but the species assignment is questioned because Bykova (1939) only illustrated an external view of her new species (see Loeblich and Tappan, 1988, pl. 97, fig. 8 for a reproduction of Bykova's illustration). Nonetheless, illustrations of *A. planum* by Suleymanov (1965) when defining his new genus *Popovia* with *A. planum* as the type species, shows an internal structure compatible with *Hemicyclammina*. The Coniacian – Campanian species *Hemicyclammina chalmasi* (Schlumberger) – see below – shows that *Hemicyclammina* (including very *Hemicyclammina*-like forms such as *Popovia*) has an apparently long but interrupted stratigraphic range or is polyphyletic.

The genus *Alveocyclammina* Hillebrandt from the lower Albian of Peru (Hillebrandt, 1971) is also similar possessing an alveolar wall, but its septa are also alveolar and appear to be very short. These features seem to be more characteristic of the genus *Buccicrenata* Loeblich and Tappan which differs from *Hemicyclammina* by the presence of alveolar rather than solid, pointed septa.

The Late Cretaceous (mostly Coniacian – Campanian) species *H. chalmasi* differs from *H. whitei* by virtue of a thicker, coarsely agglutinating wall, and a larger test with chambers increasing in height to produce a peneropliform test. The exoskeleton is particularly well developed in *H. chalmasi* with long beams and less pronounced rafters. Excellent illustrations of this species are provided by Schlagintweit & Wagreich (2004) and Albrich et al. (2015).

Hemicyclammina praesigali Banner (Banner, 1966 – based on material in Hofker, 1965) is a junior synonym of *Charentia cuvillieri* (Loeblich & Tappan, 1988).

There are many records of *H. whitei* (in the sense used herein) in the literature and a substantial number with illustration (see synonymy list). However, there are few illustrations that show very well-preserved specimens. In particular, the alveolar wall can be obscure (e.g., Arampour et al., 2021; Keshavarzi et al., 2022) and identity relies more on size, morphology, and clear presence of the distinctive short and solid septa in thin-section. Specimens in which the alveolar wall is not visible could be confused with *Haplophragmoides* sp. (Hamaoui, 1965). Particularly good illustrations are provided by Banner (1966, 1970), Arkin & Hamaoui (1967), Sampò (1969), Saint-Marc (1974), and Omaña et al. (2019).

STRATIGRAPHIC AND PALAEOGEOGRAPHIC DISTRIBUTION

H. whitei was first described (Henson, 1948) from the Dukhan-3 well in Qatar at a depth of 3542'-3543'. Although said to be "probably early Cenomanian", this depth equates to the Mauddud/Nahr Umr Formation boundary and is of latest Albian age (Bromhead et al., 2022).

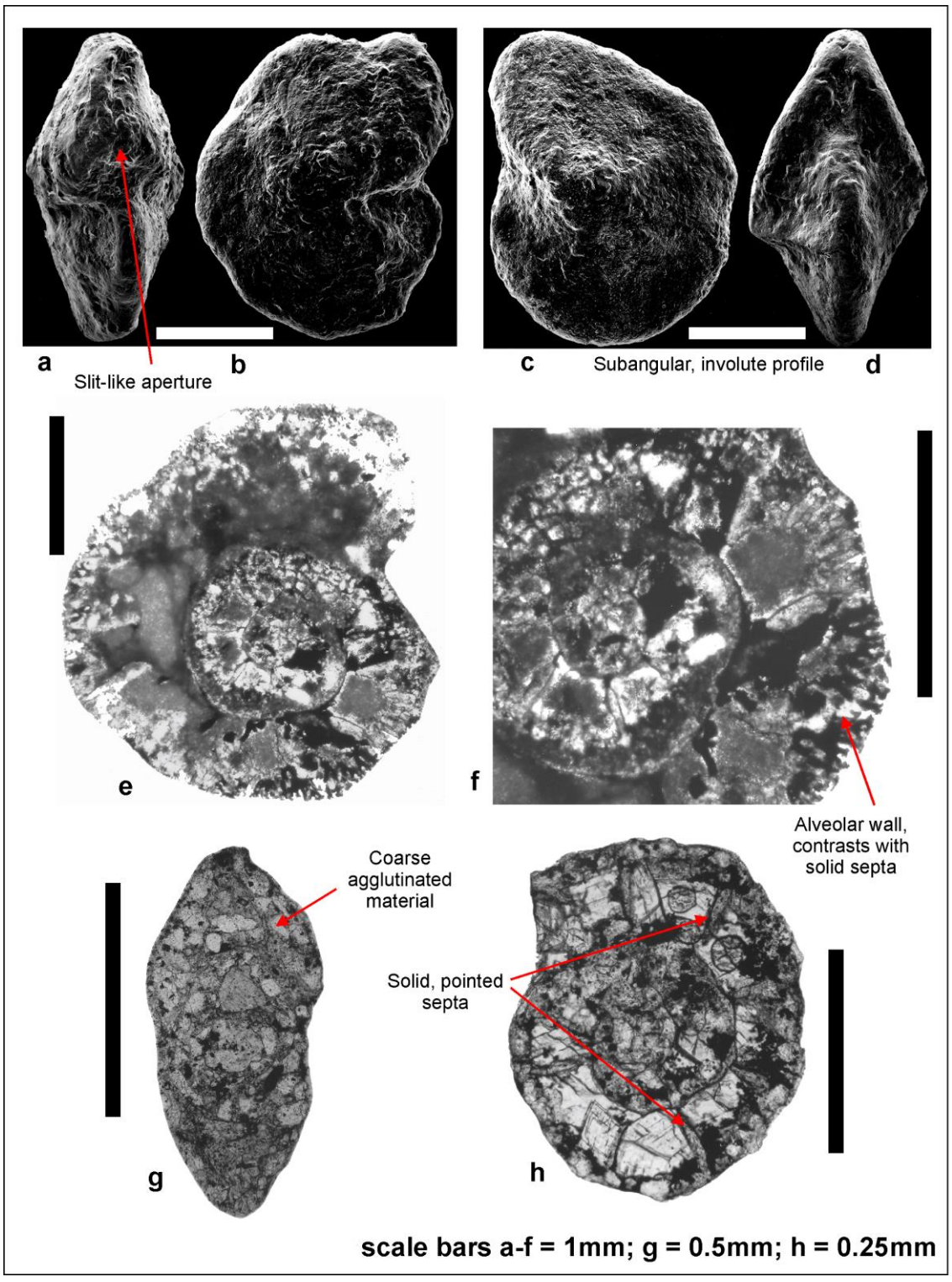

Fig. 1 a, b – Holotype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3723; NHMUK PM P35798. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Image reproduced courtesy of the Trustees of the Natural History Museum. **c, d** - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3724; NHMUK PM P35799. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Image reproduced courtesy of the Trustees of the Natural History Museum. **e, f** - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3722; NHMUK PM P35797. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Probable microspheric form. Note alveolar (*sensu* Hottinger, 2006) wall and solid short septa. Image reproduced courtesy of the Trustees of the Natural History Museum. **g** – *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/8357. Rumaila-1 well, Iraq, 8010-8415' Nahr Umr Formation, Albian. Probable macrospheric form. Image reproduced courtesy of the Trustees of the Natural History Museum. **h** - *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/8378. Rumaila-1 well, Iraq, 8010-8415' Nahr Umr Formation, Albian. Short, pointed septa clearly visible. Image reproduced courtesy of the Trustees of the Natural History Museum.

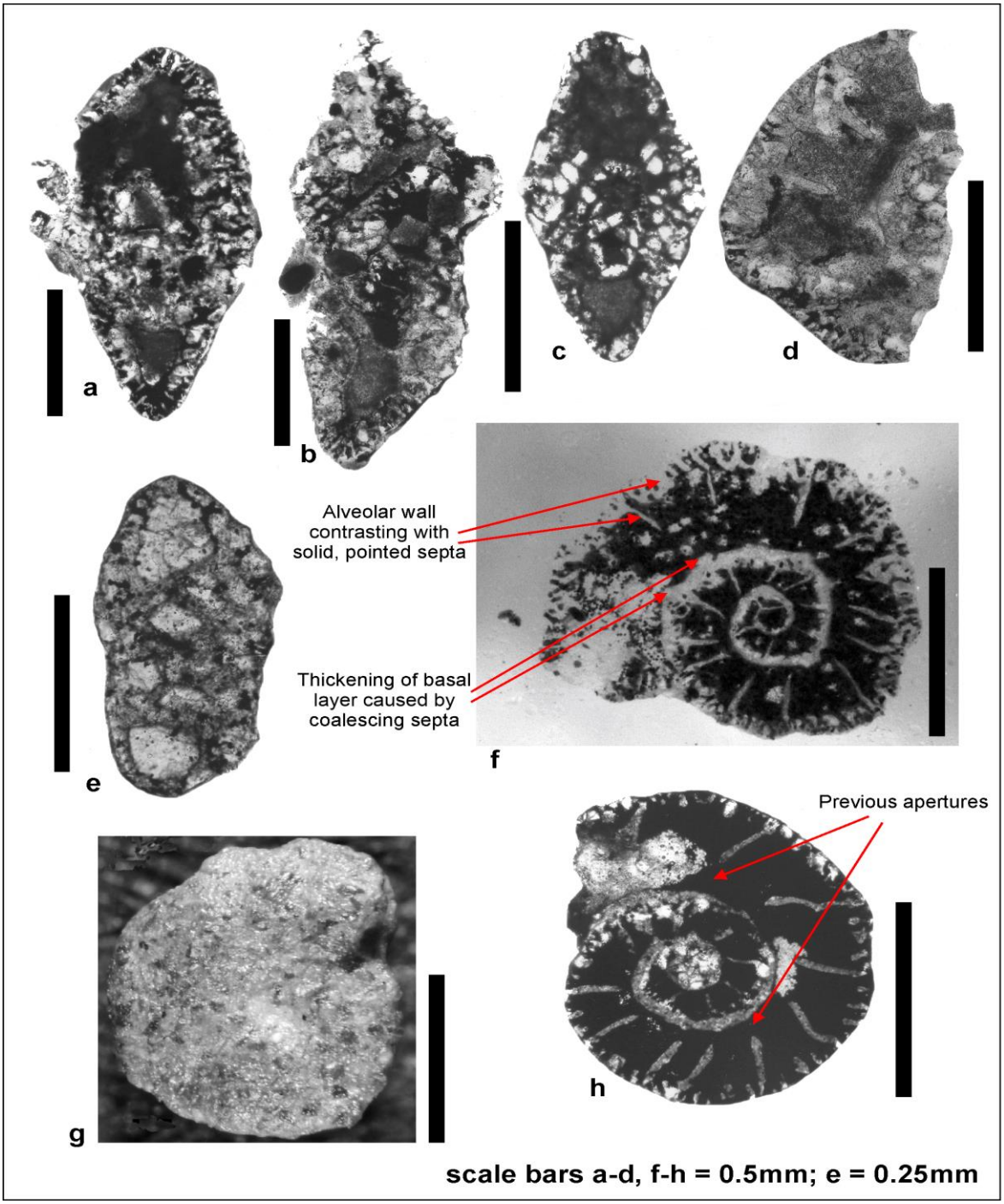

Fig. 2 a - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3725; NHMUK PM P35800. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Alveolar (*sensu* Hottinger, 2006) wall clearly visible. Image reproduced courtesy of the Trustees of the Natural History Museum. **b** - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3744. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Image reproduced courtesy of the Trustees of the Natural History Museum. **c** - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3743. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Image reproduced courtesy of the Trustees of the Natural History Museum. **d** - Paratype of *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/3745. Dukhan-3 well, Qatar, 3542-3543' reinterpreted as latest Albian (see text). Note alveolar (*sensu* Hottinger, 2006) wall and solid short septa. Image reproduced courtesy of the Trustees of the Natural History Museum. **e** - *Hemicyclammina whitei* (Henson). Natural History Museum, London Specimen IPC M/8378. Rumaila-1 well, Iraq, 8010-8415' Nahr Umr Formation, Albian. Image reproduced courtesy of the Trustees of the Natural History Museum. **f** – *Hemicyclammina whitei* (Henson). Paratype of *Hemicyclammina sigali* Maync. United States Natural History Museum Specimen PAL 324620. Middle Cenomanian, near Morsott, Algeria. **g** - *Hemicyclammina whitei* (Henson). Holotype of *Hemicyclammina sigali* Maync. United States Natural History Museum Specimen PAL 370417. Middle Cenomanian, near Morsott, Algeria. **h** - *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina sigali* Maync". Natural History Museum, London Specimen IPC M/8372. Rumaila-1 well, Iraq, 9008' Nahr Umr Formation, Albian. Image reproduced courtesy of the Trustees of the Natural History Museum

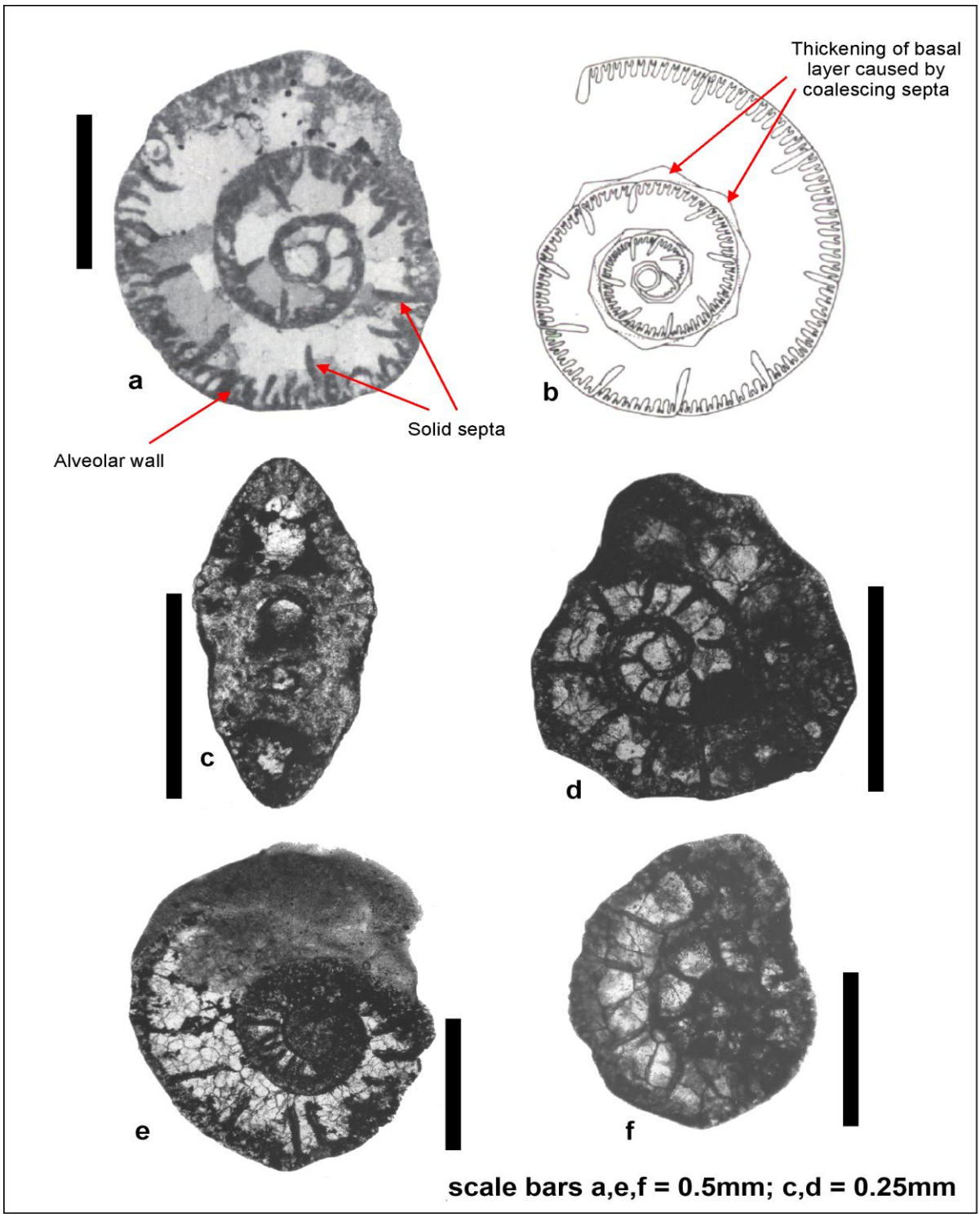

Fig. 3 a - *Hemicyclammina whitei* (Henson). Specimen documented as "*Hemicyclammina sigali* Maync". Early Cenomanian, Umm Shaif, Offshore Abu Dhabi. After Banner (1970). **b** – Schematic sketch after Banner (1970) showing the key internal morphological features of *Hemicyclammina*. Features such as the thickening of the basal layer may not be easily visible in every specimen. **c** - *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina sigali* Maync". Natural History Museum, London Specimen IPC M/8389. Murban-1 well, 7670', Albian, United Arab Emirates. Image reproduced courtesy of the Trustees of the Natural History Museum. **d** - *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina sigali* Maync". Natural History Museum, London Specimen IPC M/8389. Murban-1 well, 7670', Albian, United Arab Emirates. Image reproduced courtesy of the Trustees of the Natural History Museum. **e** - *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina sigali* Maync". Natural History Museum, London Specimen IPC M/8389. Murban-1 well, 7670', Albian, United Arab Emirates. Image reproduced courtesy of the Trustees of the Natural History Museum. **f** - *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina sigali* Maync". Natural History Museum, London Specimen IPC M/8389. Murban-1 well, 7670', Albian, United Arab Emirates. Image reproduced courtesy of the Trustees of the Natural History Museum.

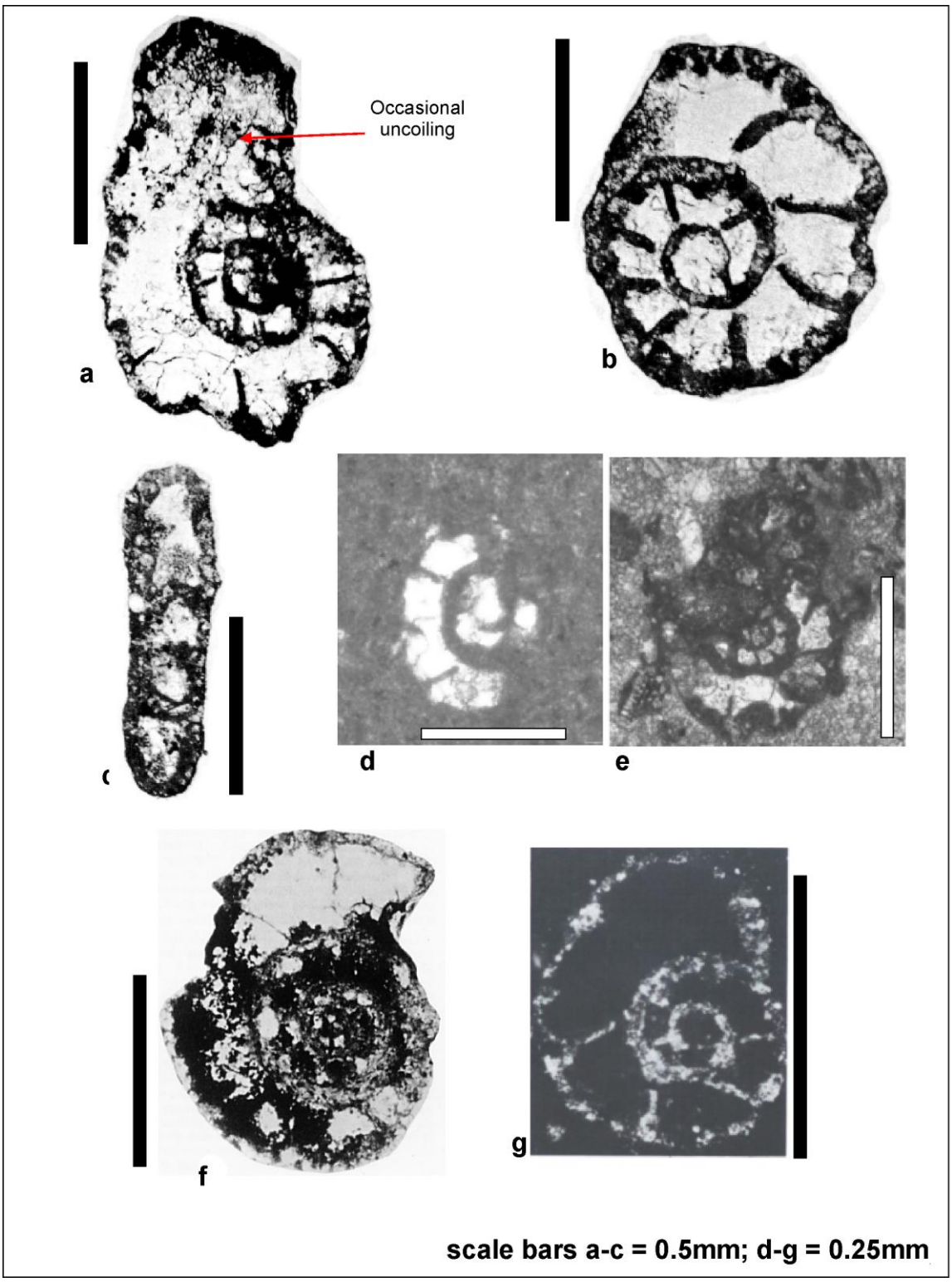

Fig. 4 a – *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina*, nov. sp.?" by Hamaoui (1965) (subsequently *H. evoluta sensu* Hamaoui 1979) IT.649 – 19718 – 63.5/196. Type Hazera Formation, Israel. Note uncoiling. **b** – *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina*, nov. sp.?" by Hamaoui (1965) (subsequently *H. evoluta sensu* Hamaoui 1979) IT.686 – 19696 – 63.5/156. Type Hazera Formation, Israel. **c** – *Hemicyclammina whitei* (Henson). Specimen labelled as "*Hemicyclammina*, nov. sp.?" by Hamaoui (1965) (subsequently *H. evoluta sensu* Hamaoui 1979) IT.687 – 19699 – 63.5/161. Type Hazera Formation, Israel. **d** – *Hemicyclammina*? sp. Specimen labelled as "*Hemicyclammina sigali*" by Hosseini et al. (2016) Sample ARP 976. Lar outcrop, Iranian Zagros. **e** – *Hemicyclammina*? sp. Specimen labelled as "*Hemicyclammina sigali*" by Hosseini et al. (2016) Sample ARP 261. Anneh outcrop, Iranian Zagros. **f** – ?*Hemicyclammina whitei* (Henson). Specimen labelled as *Ismailia neumannae* n. gen., n. sp. by El-Dakkak (1974) from Djebel Nezzazat, Sinai, Egypt. **g** - ?*Hemicyclammina whitei* (Henson). Specimen labelled as *Sinainella aegyptiaca* n. gen., n. sp. by El-Dakkak (1975) from Djebel Nezzazat, Sinai, Egypt.

Henson (1948) also recorded the species from the Nahr Umr Formation at Rumaila-1 in Iraq, suggestive of an Albian age (Aqrawi et al., 2010). The type material of *H. sigali* is from the middle Cenomanian of Algeria (Maync, 1953).

A number of authors have commented on the likely Albian – Cenomanian age range of *H. sigali* (= *H. whitei*). These include Saint-Marc (1977) and Sartorio & Venturini (1988). Some authors have limited the youngest part of the range to within the Cenomanian (e.g., BouDagher-Fadel, 2018), but there is clear evidence that the species can range into the late Cenomanian. Hart et al. (2005) recorded it from strata in Portugal, confidently assigned to the *guerangeri* and *geslinianum* ammonite zones, following earlier records by Berthou (1973), Lauverjat (1976) and Crosaz-Galletti (1979). Saint-Marc (1981) reported the species from latest Cenomanian strata in Lebanon with the ammonites *Eucalycoceras palaestinense* (Blackenhorn) and *Protacanthoceras angolaense* (Spath) and planktonic foraminifera *Helvetoglobotruncana praehelvetica* (Trujillo) and *Whiteinella* spp. *H. whitei* can be included in those larger benthic foraminifera that became extinct just below the Cenomanian – Turonian boundary (Parente et al., 2008).

H. whitei has frequently been reported from the Iranian Zagros (mostly as *H. sigali*). Wynd (1965) erected a *Hemicyclammina – Orbitolina* assemblage zone within the Kazhdumi Formation, that by association with *Knemiceras* ammonites is Albian in age (although he noted that the species can range into the Cenomanian), whilst Sampò (1969) noted a zone typified by this species at the Albian – Cenomanian transition. Ahmadi et al. (2008), Afghah et al. (2014, 2020), Afghah & Dookh (2014), and Arampour et al. (2021) restrict the species to the Kazhdumi Formation and hence the Albian, but numerous authors have reported the taxon from the overlying Sarvak Formation, alongside late Cenomanian taxa such as *Cisalveolina fraasi* (Gümbel) (e.g. Omidvar et al., 2014; Shirazi, 2009; Shirazi et al., 2011; Rahimpour-Bonab et al., 2012; Toulabi & Roozbahni, 2015).

The oldest possible records of the species are those of Hosseni et al. (2016) who illustrate material under the name *H. sigali* from the Barremian Gadvan Formation of the Iranian Zagros. However, the specimens are very small (0.2 – 0.3 mm in diameter), and the presence of an alveolar wall is not demonstrated. A similar, slight larger (0.3 mm diameter) specimen has been illustrated by Ozkan & Altiner (2019) from south-east Turkey as "*Hemicyclammina*? sp.". Such old records are unusual with several authors (e.g., Saint-Marc, 1981, Schroeder et al., 2010) regarding the genus and species as no older than Albian. It is certainly common in the marly Albian sediments of the Arabian Plate (Kazhdumi and Nahr Umr formations), and the "*Hemicyclammina sigali* beds" of Lebanon – see previous cited references, plus Saint-Marc (1970, 1974), Simmons & Hart (1987), Kalantari (1992), Forbes et al. (2010).

Whilst Henson (1948) offered no opinion on the origins of his *Cyclammina* (=*Hemicyclammina*) *whitei*, Maync (1953) believed that *Hemicyclammina* was a link between the Ammodiscidae and the Lituolidae, occupying a position between *Discammina* and *Alveolophragmium-Cyclammina*, and assigned it to the Lituolidae.

Banner (1970) and Banner & Highton (1990) thought that *Hemicyclammina* descended from *Everticyclammina* Redmond (= *Mayncella sensu* Banner) by reduction of the septa, with *Ammobaculites* as the original rootstock. They considered transitional forms to occur in the late Aptian from the progenitor species *Everticyclammina greigi* Redmond, although Banner and Highton (1990; fig. 1) tentatively extended the range of *Hemicyclammina* down to the latest Barremian. However, the presence of primitive "*Hemicyclammina*? sp." in the Barremian sediments of the Iranian Zagros (Hosseini et al., 2016 – see Fig.4d-f herein) as well as in early Aptian sediments from south-east Turkey (Ozkan & Altiner, 2019), suggests that an alternative evolution may be possible with *Hemicyclammina* arising independently from a *Haplophragmoides*-type or *Lituola*-type root stock and progressive development of an alveolar wall. Progressive size increase in *Hemicyclammina whitei* may occur as possible forms from the early Albian are small (~0.5 mm diameter) and an alveolar wall is indistinct (Schroeder et al., 2010; Moosavizadeh et al., 2015, 2020; Shirzade et al., 2019).

H. whitei has a broad palaeogeographic distribution across Neotethys and the western Atlantic margin (Figure 5) and seemed to thrive in marly sediments deposited on middle – outer shelves. Confirmed records of *H. whitei* are mostly from the southern margin of Neotethys. Most records from the northern margin require further substantiation. Confirmed records in addition to those previously mentioned, include from Brazil (Berthou & Bengtson, 1988), Mexico (Omaña et al., 2019), Morocco (Andreu et al., 1996); Serbia/Kosovo – (Radoičić, 1974; see also Radoičić & Schlagintweit, 2007 unillustrated); Turkey (Bignot & Poisson, 1974), Jordan (Weidich & Al-Harithi, 1990 under a variety of names – see synonymy), Saudi Arabia (Dr. Wyn Hughes, pers. comm.) Abu Dhabi (Banner, 1970), and Somalia (Luger, 2018). Unillustrated records are known from numerous intermediate locations (Pyrenees – Peybernes, 1984; Tunisia – Robaszynski et al. 2010; Italy – Simone et al., 2012; Croatia – Husinec et al., 2000; Kuwait – Youssef et al., 2019) and may extend the range to Tibet (BouDager-Fadel et al., 2017).

CONCLUSIONS

It is shown that the well-known Tethyan species, *H. sigali*, is the junior synonym of *H. whitei* which was described five years earlier. This synonymy has long been suspected (Banner, 1966, 1970; Saint-Marc, 1974; Whittaker et al., 1998) but is formalised for the first time herein, supported by re-illustration of type material. *H. whitei* as defined herein thrived on mid-Cretaceous marly

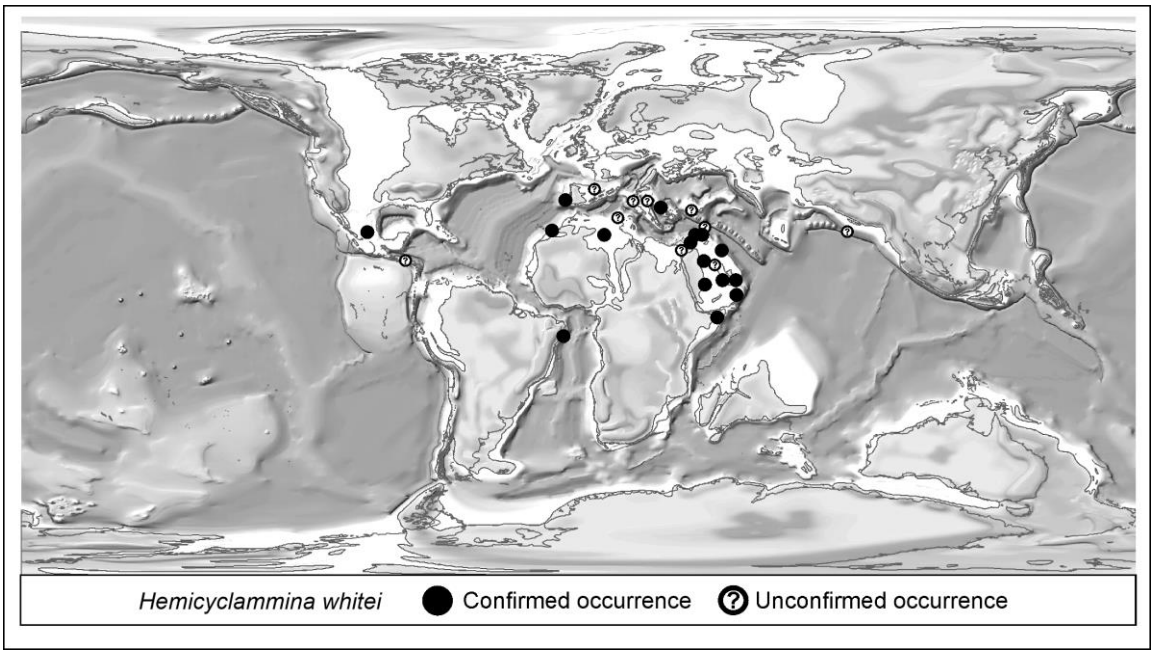

Fig. 5 Recorded geographical distribution of *Hemicyclammina whitei* on map reconstructed to Cenomanian palaeogeography (plate model provided courtesy of Halliburton). Black dots are occurrences confirmed by illustration. Open circles with "?" are reported occurrences not verified by illustration.

shelves from across Neotethys with confirmed records as far apart as Brazil, Mexico and the Arabian Plate. The species ranges throughout the Albian and Cenomanian, and possibly ancestral forms best described as *Hemicyclammina*? sp. occur within the Aptian and Barremian.

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