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Porosphaera globularis (Phillips, 1829) (Porifera, Calcarea) from the Maastrichtian of the Farokhi Formation of Central Iran

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A B S T R A C T

A small faunule of the calcareous sponge *Porosphaera globularis* (Phillips, 1829) (Calcarea, Minchinellidae) is described and illustrated from the Maastrichtian Farokhi Formation of Central Iran. The shape of the sponges varies from near-spherical to pyriform with diameters ranging between 5 and 13 mm. The surfaces show small, equidistant apertures corresponding to radiating oscular tubes within a choanosomal skeleton consisting of large tetractines fused to a rigid framework. Radially arranged superficial grooves may also be present in some specimens. External attachment scars have not been observed, but perforations in two specimens may represent sipunculan worm borings. A quiet and fairly deep-water environment can be inferred as the habitat of the sponges, corresponding to data in the literature. So far, *P. globularis* was known only from the Upper Cretaceous (Cenomanian–Maastrichtian) of the Boreal Realm. The record from Central Iran is the southernmost occurrence of *P. globularis* (palaeo-latitude ca. 20°N) known to date and is the first description of the species from Iran and the Middle East.

1. Introduction

Cretaceous strata in Central Iran are superbly exposed and relatively fossiliferous. However, their detailed stratigraphy (apart from gross lithostratigraphical mapping) and palaeontology are poorly known, with the exception of ammonite faunas, which have been recorded and described from numerous localities in Central Iran (e.g., Seyed-Emami, 1977, 1982; Kennedy et al., 1979; Seyed-Emami and Immel, 1995, 1996; Wilmsen et al., 2005). In contrast, data on benthic macro-invertebrates are scarce and only a few outdated monographs (e.g., on echinoids; Cotteau and Gauthier, 1895) exist. Here, we record the calcareous sponge *Porosphaera globularis* from the Khur area of Central Iran, which is the first documentation of the species from Iran and the Middle East.

2. Geological setting

The study area belongs to the Central-East Iranian Microcontinent (CEIM), which forms the core of the so-called Iran Plate. The CEIM consists, from east to west, of three structural units, the Lut, Tabas and Yazd blocks (see Berberian and King, 1981 and Davoudzadeh, 1997 for overview). While Jurassic strata are well exposed (and have been well studied) on the Tabas Block (see Fürsich et al., 2003; Wilmsen et al., 2003, 2009a, 2010), Cretaceous strata are widespread and very thick in the western part of the CEIM (Yazd Block). The Cretaceous successions of the Yazd Block document, in excellent outcrops, the development of a mid- to Late Cretaceous (Late Barremian–Maastrichtian) carbonate platform–basin system. In terms of geodynamic evolution, the area is of great importance for the Middle East as the CEIM formed a separate microplate during Cretaceous times which was separated from the nearby Eurasian margin by small oceanic basins (Fig. 1; e.g., Dercourt et al., 1986; Philip and Floquet, 2000). These oceanic basins started to open in Early Cretaceous ('Neocomian') times and may have been related to an inferred post-Triassic rotation of the CEIM around a vertical axis of about 135° with respect to Eurasia (e.g., Davoudzadeh et al., 1981; Soffel et al., 1996). The various small oceans (Nain-Baft Ocean in the west, Sabzevar Ocean in the north, and Sistan Ocean in the east; Fig. 1) were subsequently closed during the later part of the Early to Late Cretaceous and in the Palaeocene, in connection with the advance of the Arabian Plate and the closure of the Neotethys (e.g., Tirrul et al., 1983; Dercourt et al., 1986; Stampfli and Borel,

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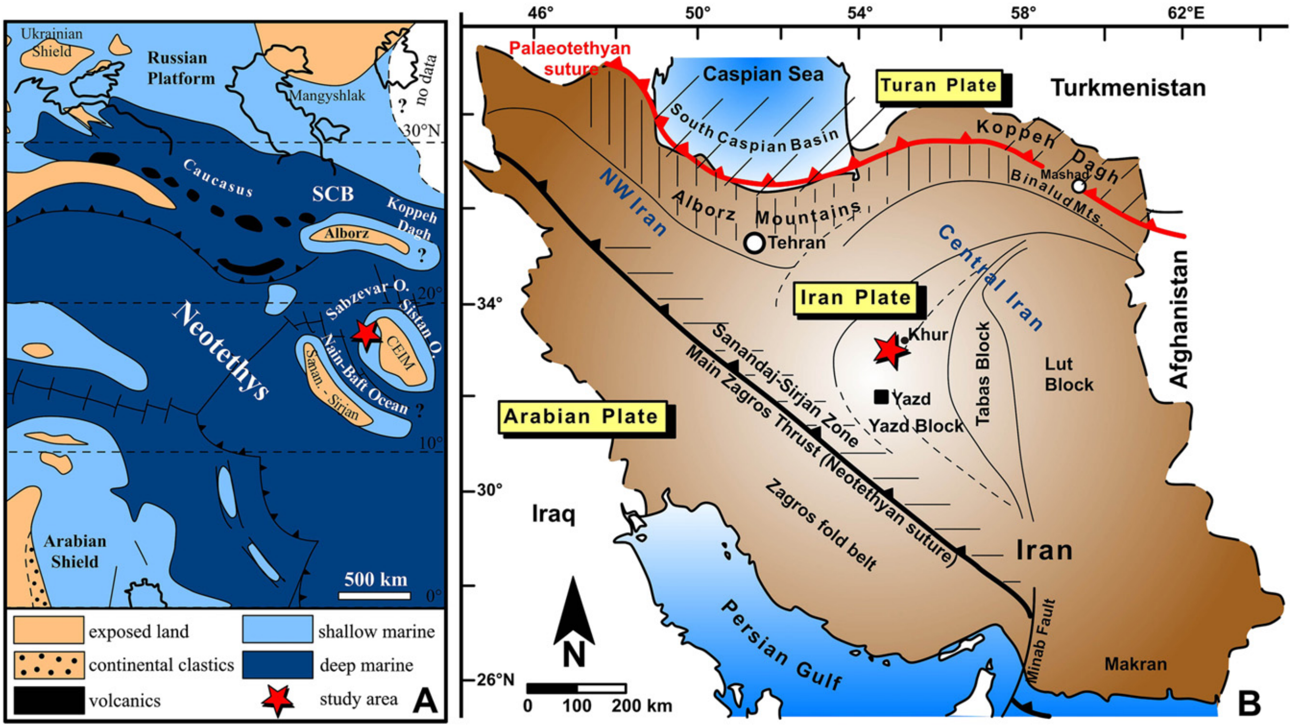

Fig. 1. Upper Cretaceous palaeogeographic map of the Middle East (A, modified after Philip and Floquet, 2000) and structural map of Iran (B) with indication of the Khur area, north of Yazd, in Central Iran (modified from Wilmsen et al., 2009b).

2002; Rosetti et al., 2010). Of special interest here are the Haftoman and Farokhi formations, which comprise the middle and upper part of the Upper Cretaceous succession in the Khur area (Fig. 2).

The section studied at Kuh-e-Honu, south of Khur (Figs. 1 and 3; N 33°43.355′, E 55°00.869′) starts with shallow-water carbonates of the Haftoman Formation, which rest unconformably on the Albian–Cenomanian Debarsu Formation. The age of the lower part of the up to 1000 m-thick Haftoman Formation is Early Coniacian, based on the occurrence of the inoceramid bivalve *Tethyoceramus* ex gr. *wandereri* (Andert). In the upper part of the Haftoman Formation, a deepening trend is indicated by intercalations of marly limestones and marls with more open marine faunas (echinoids, inoceramid bivalves and ammonites). The heteromorph ammonite *Bostrychoceras polyplocum* (Roemer) indicates an early Late Campanian age. Up-section, 100–200 m of unfossiliferous limestone follow until, at a sharp, karstic contact with reworked pebbles of the Haftoman Formation, the marls of the Farokhi Formation commence (Fig. 3). The Farokhi Formation is 21.5 m thick and consists of soft, grey marl. In a slightly more calcareous and bioclastic bed, ca. 8 m above the base of the formation, numerous specimens of the calcareous sponge *P. globularis* (Phillips) occur and a small number has been collected. The Farokhi Formation is unconformably overlain by the Palaeocene Chupanan Formation (Fig. 2; see Aistov et al., 1984 for details). The age of the Farokhi Formation at Kuh-e-Honu is thus late Late Campanian–Maastrichtian with an exclusively Maastrichtian age being more likely on the basis of stratigraphic and sedimentological data (early Late Campanian index fossils occur a considerable distance below the lower boundary of the Farokhi Formation which furthermore represents a subaerial unconformity).

3. Taxonomy

We here follow the classification of the Porifera as proposed by Hooper and van Soest (2002) and Finks et al. (2004). According to Vacelet et al. (2002), fossil Minchinellidae (to which *Porosphaera* belongs) are in urgent need of revision. Authors of higher rank taxonomic categories are not listed in the references.

Class: Calcarea Bowerbank, 1864
Order: Lithonida Doederlein, 1892
Family: Minchinellidae Dendy and Row, 1913
Genus *Porosphaera* Steinmann, 1878

Type species: *Millepora globularis* Phillips, 1829, p. 186, pl. 1, fig. 12, by original designation.

Porosphaera globularis (Phillips, 1829)
Figs. 4 and 5

1829 *Millepora globularis* Phillips, p. 186, pl. 1, fig. 12.
1878 *Porosphaera globularis* (Phillips); Steinmann, p. 102, pl. 13, figs 8–12.
1904 *Porosphaera globularis* (Phillips); Hinde, p. 18, pl. 1, figs 1–10, pl. 2, figs 1–3, 6–10. [with synonymy]
1961 *Porosphaera globularis* Phillips; Nestler, p. 39, pl. 10, pl. 11, figs 1–8. [with synonymy]
1970 *Porosphaera globularis* Phillips; Müller, text-fig. 1, pls 1, 2.
1985a *Porosphaera globularis* (Phillips); Termier and Termier, p. 153, fig. 4e.
1985b *Porosphaera globularis* (Phillips) Steinmann; Termier and Termier, p. 54, pl. 5, figs 1–3, pl. 6, figs 1–3.

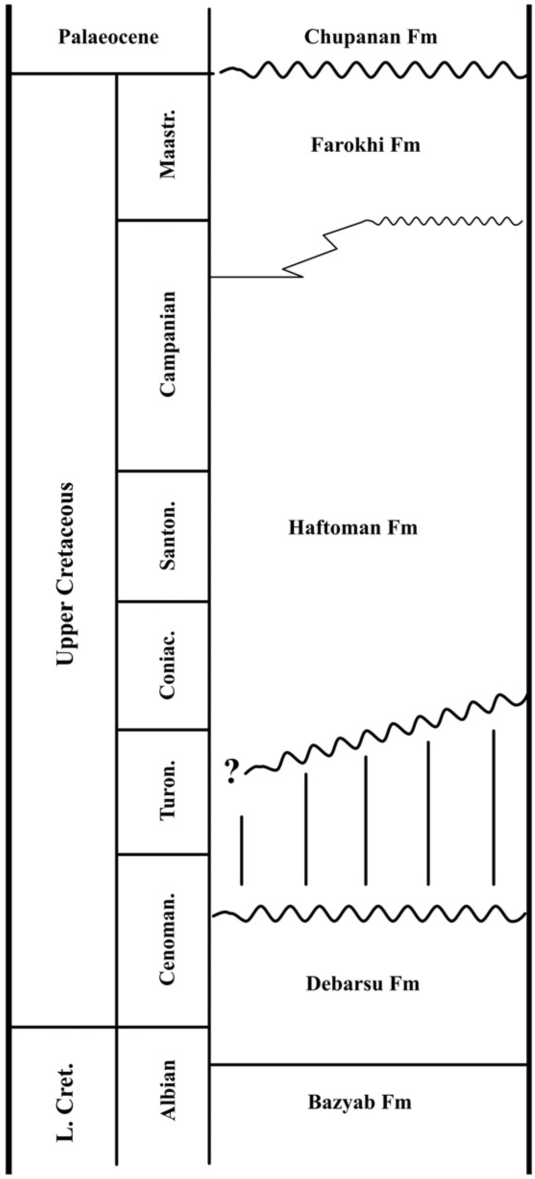

Fig. 2. Lithostratigraphy of the Upper Cretaceous in the Khur area, Yazd Block, Central Iran, after our own observations.

1989 *Porosphaera globularis* (Phillips); Małecki, p. 206, text-figs 1, 2, pls 1–4,
1992 *Porosphaera globularis* (Phillips); Reitner, p. 112, pl. 6, figs 1–3.
2002 *Porosphaera globularis* Phillips; Nestler, p. 38, fig. 36.
2002 *Porosphaera globularis* (Phillips); Wood, p. 35, pl. 4, fig. 3.
2002 *Porosphaera globularis* Phillips; Reich and Frenzel, p. 126, pl. 13, fig. 3.
2008 *Porosphaera globularis* with *Trypanites mobilis* isp. n.; Neumann et al., fig. 5.
2009 *Porosphaera globularis*; Rigaud et al., figs 2, 3, 7, 8.

Material. Fourteen specimens from the Farokhi Formation of Kuh-e-Honu (N 33°43.355′, E 55°00.869′ at 1.300 m altitude), ca. 20 km south of Khur, Central Iran (sample no. 091014-18, stored at the Museum für Mineralogie und Geologie der Senckenberg Naturhistorischen Sammlungen Dresden).

Measurements.

091014-18	max. Ø [mm]	min. Ø [mm]
–1	12.9	11.0
–2	11.9	8.0
–3	10.9	9.8
–4	9.7	7.8
–5	9.6	8.9
–6	9.2	7.9
–7	9.1	8.0
–8	8.9	8.1
–9	8.8	7.8
–10	8.6	8.0
–11	7.7	7.5
–12	6.9	6.3
–13	5.7	5.3
–14	5.6	5.5
Mean:	**9.0**	**7.9**

Description. The specimens are roughly spherical, but ovoid, flattened or pea-shaped forms also occur (Fig. 4). One specimen shows a flattened base and a tapering opposite end, resulting in a somewhat pyriform shape (Fig. 4H, I). Diameters range from 5.3 to 12.9 mm with a mean maximum diameter of 9.0 and a mean minimum diameter of 7.9 mm. The smaller forms are usually more spherical than the larger ones. The surface of all specimens shows small, equidistant apertures (ca. 0.1–0.2 mm in diameter). Radiating superficial grooves are sometimes also present (Fig. 4J, K) and two specimens show perforations (Fig. 4L, M). In thin section (Fig. 5), the radiating main oscular canals are clearly visible. The choanosomal skeleton consists of large tetractines fused to a rigid framework via cemented bridges. Skeletal interspaces are filled by a (late) diagenetic sparry calcite.

Discussion. The specimens from the Farokhi Formation do not differ significantly from *P. globularis* as described and illustrated in the literature. The mean diameter of 9.0 mm is comparable to that of a large population from the Lower Maastrichtian chalk of Rügen, Germany (2734 specimens with a mean diameter of 10 mm; Nestler, 1961). However, larger forms up to 50 mm in diameter as in Rügen have not been observed. External perforations are common in *P. globularis* and are interpreted as borings (Nestler, 1961; Müller, 1970; Neumann et al., 2008). The occasionally visible radiating superficial grooves almost certainly represent the traces of the oscular tubes in a zone between the dermal layer and the basal skeleton.

The internal structure of the skeleton shows the typical radiating oscular canals within a framework of mutually cemented tetractines (Fig. 5), also illustrated by Termier and Termier (1985b, pl. 5) and Reitner (1992, pl. 6, figs 1, 2). However, large diactines as relics of the non-cemented ectosomal spicular skeleton have not been observed (compare Reitner, 1992).

According to Nestler (1961, 1965), *P. globularis* from the Early Maastrichtian of Rügen thrived at sub-photic depths (ca. 100–300 m), and also Reitner (1992) regarded the sponge as a deep-water species adapted to low-energy conditions. The sponge may have been anchored to the substrate by a non-calcified dermal tissue, which could explain the lack of external attachment scars (Reitner, 1992). The occurrence of *P. globularis* in the Farokhi Formation is not in contradiction with this inferred mode of life as the facies also indicates a relatively low-energy environment below storm wave base.

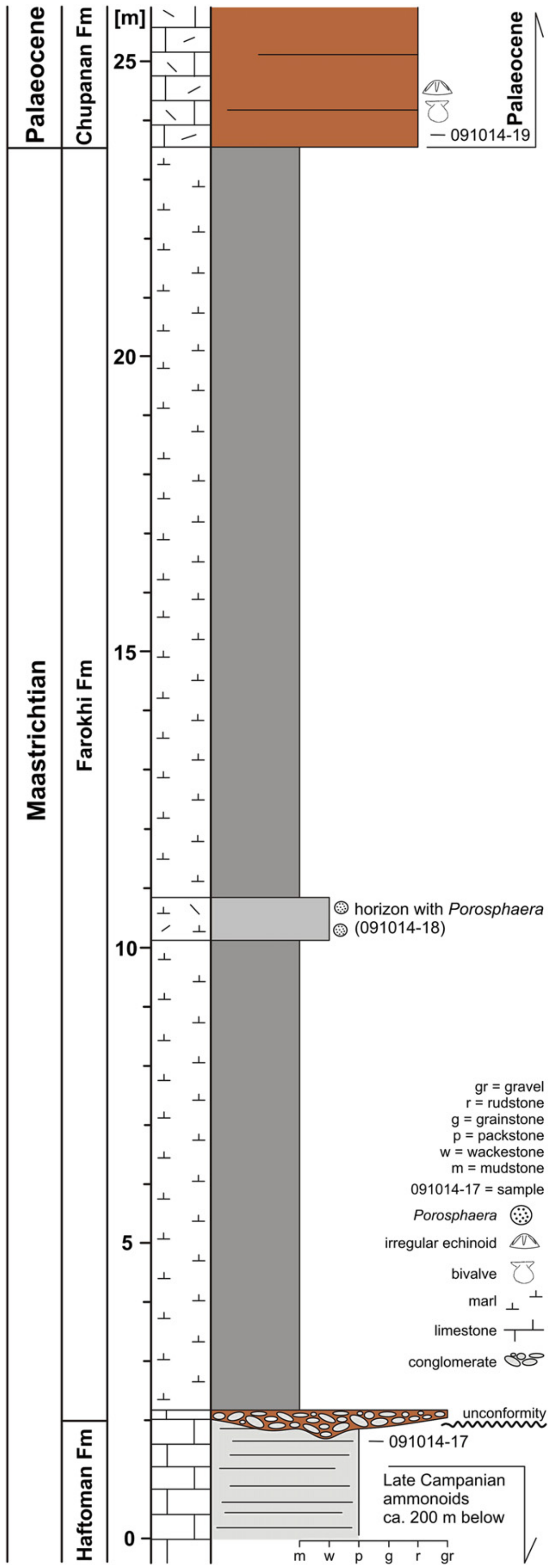

Fig. 3. Section of the Farokhi Formation at Kuh-e-Honu, Khur area, Central Iran (N 33°43.355′, E 55°00.869′).

The large perforations in two specimens (Fig. 4L, M) represent sipunculan worm borings named *Trypanites mobilis* by Neumann et al. (2008). The bored sponges are interpreted as mobile shelters for the worms. Neumann et al. (2008, table 1) found that ca. 11% of specimens in *P. globularis* populations were bored, which roughly (i.e., in the absence of a statistically significant population) matches the two bored specimens out of 14 (~14%) from the Farokhi Formation.

The form of *P. globularis*, albeit generally spherical, may be very variable: pea-, pear-, marble-, oval-, loaf- and cushion-shaped specimens occur (e.g., Nestler, 1961, p. 39; Wood, 2002). The different forms and the presence of superficial grooves have also been used to separate species within the genus *Porosphaera* [e.g., *Porosphaera patelliformis* Hinde, 1904, *Porosphaera nuciformis* (von Hagenow, 1839), *Porosphaera plana* Stolley, 1892]. According to this approach, the specimens illustrated in Fig. 4H–K are close to *P. nuciformis*, which is pyriform and in some cases shows superficial grooves radiating from a centre, the latter carrying a tubercle (not seen in the Iranian material and not present either in many *P. nuciformis* illustrated in the literature). However, there seem to be a gradual morphological transitions from globular to pyriform shapes in the sparse material from Iran as weak grooves are also present in some other specimens (e.g., Fig. 4C, D). Furthermore, the internal skeletal structure and surface perforations are identical to those of *P. globularis* (Nestler, 1961, p. 43), while authors such as Steinmann (1878) and Małecki (1989) doubted the validity of von Hagenow's species and regarded it as junior synonym. It is noteworthy that the stratigraphic ranges and distribution of the numerous species of *Porosphaera* recognized seem to be identical to those of the type species and that these taxa tend to be very rare (Nestler, 1961; Termier and Termier, 1985b; Małecki, 1989; Wood, 2002; Jagt and Snellings, 2009). Many of these 'species' may merely represent different growth or preservational forms. However, a taxonomic revision of the genus is beyond the scope of the present paper.

Occurrence. *P. globularis* occurs in the Farokhi Formation of Kuh-e-Honu, ca. 20 km south of Khur, Central Iran (N 33°43.355′, E 55°00.869′). Based on the presence of the Late Campanian heteromorph ammonoid *B. polyplocum* a considerable distance below in the underlying Haftoman Formation and the superposition by the Palaeocene Chupanan Formation, the Farokhi Formation at Kuh-e-Honu can be dated as late Late Campanian to Maastrichtian (an exclusively Maastrichtian age being more likely). *P. globularis* is mainly known from the Upper Cretaceous (Cenomanian–Maastrichtian) of Boreal Europe (Nestler, 1961; Termier and Termier, 1985a, b; Reitner, 1992; Wood, 2002). The type locality of *P. globularis* appears to be Danes Dyke in Yorkshire (Hinde, 1904, p. 3), from which a *Marsupites* Zone horizon (latest Santonian) can be inferred (pers. commun. C.J. Wood, 08/2011). Interestingly, the lowermost Maastrichtian strata in the Chalk of Norfolk were termed the *Porosphaera* Beds by Brydone (1908) because of the abundance in them of *Porosphaera*. However, Mortimore et al. (2001, 369) found this idea of a particular abundance difficult to understand but it is well possible that the find layer of *Porosphaera* from the Farokhi Formation is likewise of Early Maastrichtian age.

The record of *P. globularis* from Central Iran represents the southernmost known palaeo-latitudinal occurrence to date (ca. 15–20°N; Fig. 1) and it is the first mention of the species from the Middle East. However, it has been noted from the Asian part of the former Soviet Union (e.g., Pervushov, 1998). The present record from subtropical settings (rudists are common in the underlying Haftoman Formation) may be explained by the deep-water habitat of the sponge which lived at comparatively cool levels in the water column.

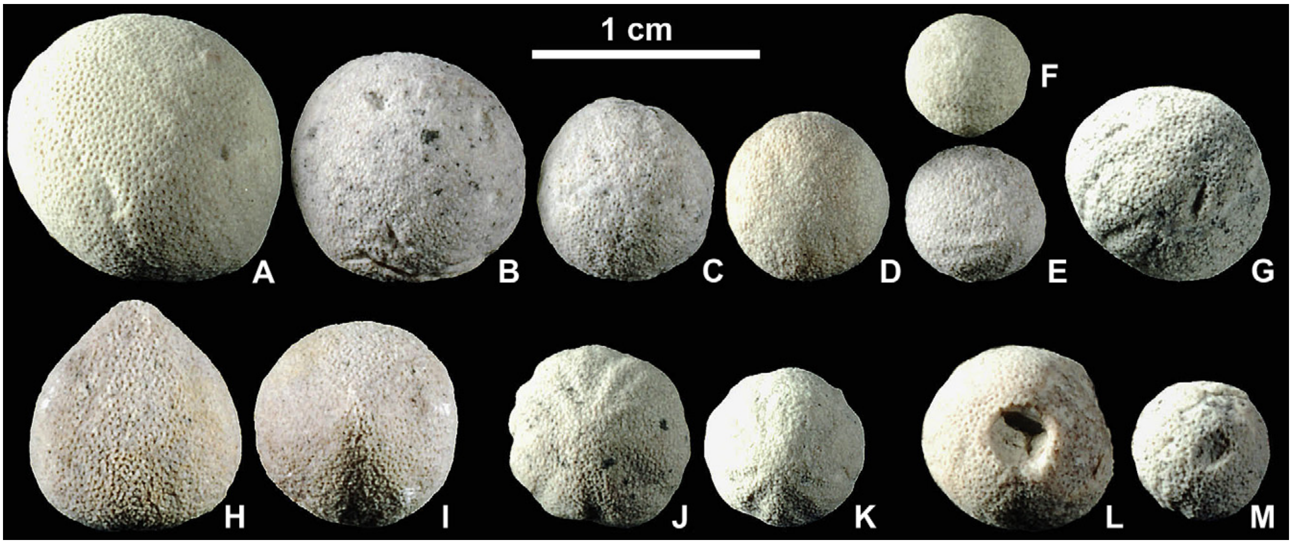

Fig. 4. *Porosphaera globularis* (Phillips, 1829) from the Farokhi Formation of Central Iran. All specimens ×3.0. A, 091014-18/1. B, 091014-18/2. C, 091014-18/7. D, 091014-18/8. E, 091014-18/13. F, 091014-18/14. G, 091014-18/4. H, I, 091014-18/4. J, 091014-18/9. K, 091014-18/10. L, 091014-18/5. M, 091014-18/12.

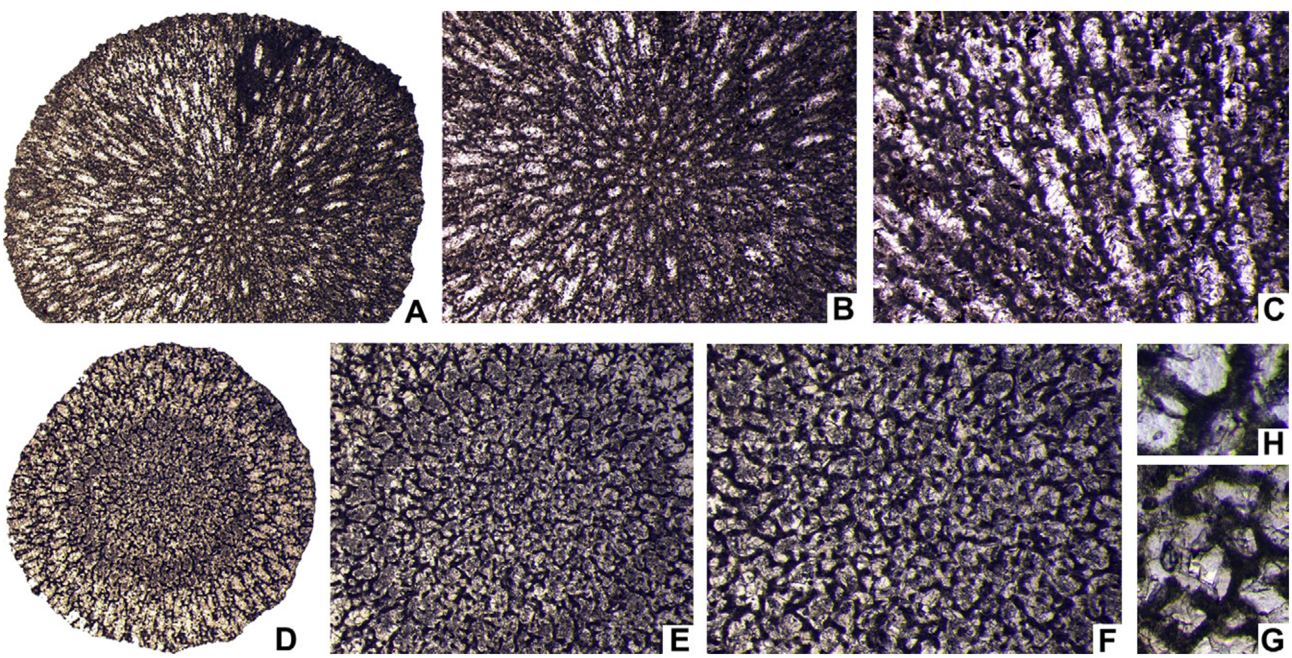

Fig. 5. Thin sections of *Porosphaera globularis* (Phillips, 1829) from the Farokhi Formation of Central Iran (plane-polarized light). A–C, 091014-18/6. D–F, 091014-18/11. A, near-median cross-section showing the radiating oscular canals (×6.0). B, close-up of the central part of the choanosomal skeleton (width of photomicrograph 7.5 mm). C, close-up of the marginal part of the choanosomal skeleton (width of photomicrograph 3.75 mm). D, tangential cross-section (×5.0). E, F close-up of the choanosomal skeleton (widths of photomicrographs 6 and 3.75 mm respectively). G, H, photomicrographs showing fused tetractines of the choanosomal skeleton (widths of photomicrographs 300 and 200 μm respectively).

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