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First reported occurrence of wewokellid sponges (Calcarea, Heteractinida) from the Permian of central Iran

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Abstract The new calcisponges *Regispongia fluegeli* n. sp., and *Iranospongia circulara* n. gen. n. sp., are described from central Iran. These are the first heteractinid sponges reported from the Permian of the region. These wewokellid sponges are large, irregularly cylindrical forms with a distinct axial spongocoel. The calcareous spicular skeletons of both taxa have been overgrown and are recrystallized. However, the preserved skeleton of *Regispongia fluegeli* does include large polyactines in the main endosomal layer and small octactines and possibly other polyactine spicules in both the relatively massive dermal layer and the distinct, delicately spiculed, gastral layer. *Iranospongia* is characterized by a discontinuous ring of vertical exhalant canals interior to the dense dermal layer, and by an interior skeleton net that includes common coarse vertical fibers. Individual spicules in *Iranospongia* are commonly obscured, but locally some remnants of possible polyactines occur in outer parts of the skeleton.

Keywords Porifera · Calcarea · Heteractinida ·
Regispongia · *Iranospongia* · Permian · Iran

Introduction

The new wewokellid sponges were discovered by Senowbari-Daryan and Hamedani during field work on a

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newly recognized Permian section near Mount La Kaftari in central Iran, in northern Esfahan (Fig. 1). These fossils are associated with the thalamid asphinctozoan sponge *Amblysiphonella iranica* Senowbari-Daryan and Hamedani 2002, and abundant trace fossils, and other invertebrate fossils. The occurrence of sponges in the La Kaftari section is distinctive, for these sponges are not known from lithological similar Permian carbonate units elsewhere in northern and eastern Iran.

The productive Permian section is situated approximately 45 km northeast of Esfahan and south of the small town of Bagher-Abad, southwest of Kuh-e Kaftar, at approximately 32°52' N, 50°04' E (Fig. 1). The entire Permian section here is approximately 400 m thick (Senowbari-Daryan and Hamedani 2002: 795–796). The fossiliferous lower part of the section is a basal dark gray dolomite approximately 10 m thick, which is overlain by gray to dark gray limestone that locally contains reefoidal banks with corals and other less common invertebrates, along with fusulinids. A series of light gray limestone beds, approximately 30 m thick, overlies the darker basal dolomite beds and, in turn, is overlain by approximately 50 m of light gray limestones that contain the sponges and the abundant trace fossil *Zoophycos* and rare corals. The uppermost part of the section is approximately 300 m of dark gray dolomite with minor interbedded quartzite.

Depository: All specimens described here are deposited in collections of the Institute of Palaeontology, University Erlangen-Nürnberg, Material: Senowbari-Daryan, Permian La Kaftari, Esfahan.

Systematic paleontology

Class: **Heteractinida** De Laubenfels 1955
Order: **Octactinellida** Hinde 1887
Family: **Wewokellidae** King 1943
Genus: ***Regispongia*** Rigby 1978
Type species: *Wewokella contorta* King 1943

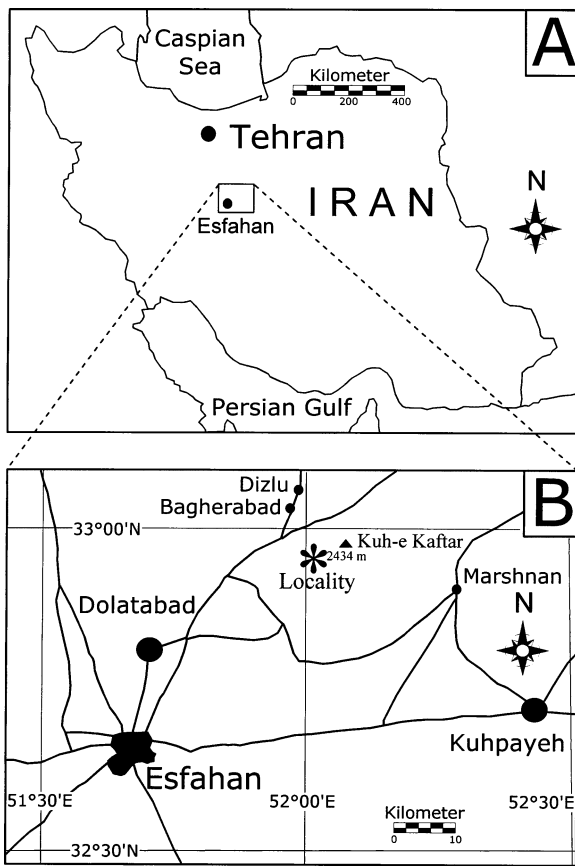


Fig. 1 Index maps showing the position of the locality from which the specimens of *Regispongia fluegeli* n. sp., and *Iranospongia circulata* n. gen., n. sp., were collected from the La Kaftari Permian section. **A** Index map of Iran showing the position of the more detailed locality map in the north-central part of the country. **B** Locality map showing position of the fossil locality (asterisk) northeast of the city of Esfahan and southwest of Kuh-e Kaftar, a mountain with a peak elevation of 2434 m (modified from Senowbari-Daryan and Hamedani 2002)

Diagnosis: “Cylindrical to conical sponges with a shallow to deep spongocoel and a thick wall composed of a main body layer of profusely rayed polyactines and an outer relatively thin dermal layer of similar, though distinctively smaller, polyactines with minor triactines and octactines also possibly present. Other types of spicules may occur as accessory types because of the great variation in numbers of rays within the polyactines. The entire skeleton net is weakly to strongly fused by additional calcification. Canals are irregularly radial and small because of the great irregularity of spicule placement and orientation within the net, and because of the additional calcification.” (Rigby 1978: 706).

Regispongia fluegeli n. sp.

Diagnosis: Large, irregularly bent cylindrical sponges with open axial spongocoel, principal skeleton of secondarily overgrown multirayed spicules and enlarged irregular fibers; both dermal and gastral layers differentiated and of

small spicules, including octactines and other polyactines; canals in skeleton small and irregular, although generally subhorizontal and radial, between and within fibrous elements; a few large exhalant canals may be present and convergent toward the spongocoel, or as longitudinal segments within the thick wall.

Description: Several large sponges of the species are in the collection. The holotype thin-section (Fig. 2A) is of an irregularly bent cylindrical form that is approximately 14 cm high and 4 cm × 6 cm across in the ovate basal region. It narrows upwards to a width of approximately 4 cm at the upper exposed end. An irregular axial spongocoel is 10 × 12 mm across, as cut in the lower part, and is 8 to 10 mm across in the upper part of the section. Walls range from approximately 20 mm thick in the lower part of the sponge to 10–20 mm thick in the upper narrowed part of the specimen, as seen in the thin-section.

The major part of the wall is composed of grossly enlarged fibers or tracts where the original spicules have been obscured by secondary calcium carbonate overgrowth and recrystallization. In the uppermost part of the skeleton, where spicules are less extensively overgrown, three- to six-rayed, Y- and cross-shaped to polyactine sections of spicules are locally preserved (Fig. 2B). These have distinct tapered rays with basal diameters of 0.3–0.6 mm and may be to 1 mm long. They are commonly associated with rounded fibers that have been recrystallized so that original spicule relationships have been destroyed. Main skeletal fibers are approximately 0.5 mm in diameter, but range to double that thickness. They have sharp boundaries with matrix, and are complexly intergrown with adjacent fibers. Skeletal structure is slightly more open, with fewer fibers and larger canals near the dermal and gastral surfaces of the wall and in uppermost youngest parts of the skeleton.

The dermal layer is mainly a fused structure with only a few preserved isolated polyactine spicules. The dermal layer is penetrated by numerous short canals approximately 0.10 mm in diameter, where the structure is most dense and the layer is 0.5–1.0 mm thick. That layer has a smooth outer surface and an irregular inner structure where it grades to the principal coarse skeletal fibers of the endosomal skeleton.

The gastral layer is more distinctly defined throughout the length of the sponge, but is most evident in the middle and upper part (Fig. 2C), and appears to have originated as several pulses of emplacement and spiculation during growth of the sponge. The layer ranges 0.3–1.0 mm thick, but is commonly approximately 0.5 mm thick. It is composed largely of irregularly oriented polyactines of various sizes. Smallest identifiable spicules are octactines that have central disks 0.02–0.03 mm in diameter, from which radiate abruptly tapering rays that are to 0.06 mm long. More common octactines have central disks 0.2 mm in diameter and rays with basal diameters of 0.08–0.10 mm that are to 0.4 mm long. These small spicules have recurved rays like larger elements in the layer. These spicules are intermixed and laterally fused where the dermal layer is also secondarily calcified, even where it is still recognizable

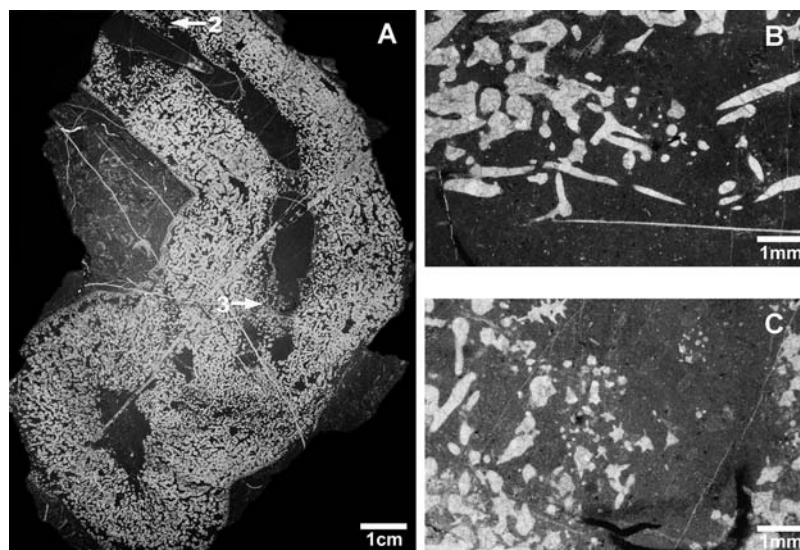


Fig. 2 Type specimens of *Regispongia fluegeli*, n. sp., from Permian rocks of the La Kaftari section, central Iran. **A–C** *Regispongia fluegeli*, n. sp., holotype, Senowbari-Daryan PI-10. **A** Thin-section with thick walls of coarse recrystallized fibers around broad axial spongocoel, distinct gastral layers show as light gray, thin, structures in dark matrix in upper and central part of spongocoel; gastral layer continues through wall to dermal surface between short, more open-textured segments of both walls near the oscular margin, and the main endosomal skeleton in the middle and lower parts of the

sponge; numbered arrows 2 and 3 indicate positions of photomicrographs shown in B and C respectively. **B** Photomicrograph of near-gastral part of partially overgrown endosomal skeleton where rays of both large and small spicules suggest a polyactinal structure; long straight element is upper part of orthoceroid nautiloid shell. **C** Photomicrograph of gastral layer and part of endosomal skeleton at midheight, where isolated and fused polyactinal spicules of gastral layer are well preserved, in the center, and coarser polyactinal endosomal spicules show in the lower part

and separated from the principal skeletal fibers. The small-spiculed gastral layer is traceable laterally through the endosomal skeleton in the upper part of the sponge where it marks a separation between coarsely overgrown dense older skeleton, below, and the less intensely overgrown segment of the skeleton, above, which is near the oscular margin. A newly developed gastral layer lines the upper end of the spongocoel.

Canals between fibers in the principal skeleton are 0.5–1.5 mm in diameter where the skeletal elements are least overgrown in the upper 15 mm of the skeleton. The canals are more than half of the volume of that part of the skeleton, but below that, where overgrown fabric dominates, large canals are 0.3–0.5 mm in diameter and associated with a series of interconnected fine tubular openings 0.1–0.2 mm between or in skeletal fibers that are mainly 0.3–0.7 mm across. That compact fibrous skeletal net of rounded elements continues to the base of the sponge, as preserved in the thin-section.

Etymology: *fluegeli*, named in honor of Professor Erik Flügel, University of Erlangen-Nürnberg, Erlangen, Germany, recently deceased. He was a major contributor to our understanding of invertebrate paleontology and paleoecology.

Discussion: *Regispongia fluegeli* n. sp., is similar to *Regispongia contorta* (King 1943), the type species of *Regispongia*, in gross form but the latter species lacks a distinct gastral layer like that so prominent in the new Iranian species. The two species have the same general irregular subcylindrical, commonly curved or contorted growth

form and endosomal skeletons that are coarse, fused, fibrous structures, which have resulted from secondary overgrowth of polyactine and perhaps simpler primary spicules.

Material examined: Holotype, thin-section Senowbari-Daryan PI-10, and paratypes thin-section Senowbari-Daryan PI-12 and Senowbari-Daryan PI-00, an unnumbered thin-section. An additional reference specimen of the species, thin-section Senowbari-Daryan PI-1, shows the gross form of the sponge, but the fossil has been intensely recrystallized so that all but its general shape and gross skeletal and canal structures have been destroyed.

Occurrence: Lower Upper Permian gray limestones in the middle part of the La Kaftari section of Senowbari-Daryan and Hamedani (2002: 795–796).

Iranospongia n. gen.

Diagnosis: Cylindrical to steeply obconical sponges, with a deep axial spongocoel, large vertical exhalant canals in ring between dermal layer and endosomal skeleton; small radial inhalant canals connect to exhalant canals and to gastral margin of endosomal skeleton and irregular spongocoel margin; skeleton includes some possible polyactines, but principally of enlarged overgrown and irregularly attached fibers that form dense outer endosomal skeleton; fibers of inner endosomal skeleton more linear, smaller and more widely spaced; dermal layer fused and spicules not preserved between fine inhalant canals; gastral layer not differentiated.

Type species: *Iranospongia circulata* n. sp.

Etymology: Iran, the country where these new fossils were discovered; “spongia” = sponge

Discussion: *Exotubispongia* Rigby and Senowbari-Daryan 1996, is similar to *Iranospongia* in that it has a ring of longitudinal exhalant canals near the dermal surface. However, both described species of *Exotubispongia* are small sponges and they lack a central spongocoel. Their large exhalant canals have vertically aligned large oscula on pustular nodes on the dermal surface, instead of a smooth surface such as is present in *Iranospongia*.

Heptatubispongia symmetrica Rigby and Senowbari-Daryan 1996, the type species, and related forms are all small twig-like sponges, only 4–8 mm in diameter. They all have a relatively small, walled, axial canal or spongocoel and six to ten parallel, walled, vertical exhalant canals near the periphery of the small sponges. Relatively coarse reticulate fibers fill the space between the canals and the spongocoel, but these are all much finer than the overgrown coarse skeletal fibers of *Iranospongia*.

Iranospongia circulata n. sp.

Diagnosis: Same as for genus with outer vertical exhalant canals 0.6–0.8 mm in diameter, with interconnected inhalant canals 0.1–0.2 mm in diameter throughout skeleton.

Description: The holotype (Fig. 3A) is a tangential to longitudinal thin-section of a relatively narrow cylindrical sponge that is 65 mm tall and 19–22 mm wide. It is incomplete at the base, but the complete osculum end is marked by a shallow depression that is a tangential view of the margin of the central spongocoel. That depression is 10 mm wide and 9 mm deep.

The canal system is distinguished by a series of upward convergent coarse exhalant canals. They originate near the dermal surface as openings 0.8–0.9 mm in diameter, then curve inward and upward to become larger, straight weakly convergent openings 1.4–1.8 mm in diameter. They occur in a discontinuous ring immediately gastral to the dermal layer, and range 0.4–2.0 mm apart, laterally.

A dense dermal layer of fused skeletal elements is 1–6 mm thick and is perforated by scattered small radial inhalant canals, 0.10–0.20 mm in diameter. That layer is well exposed in tangential section in the lower part of the holotype, where it is recrystallized and appears as a massive layer with abundant, small, radial inhalant canals. Lower inhalant canals curve upward and inward and merge with adjacent openings to form an inhalant network. Individual canals widen inward and are up to approximately 0.3 mm in diameter where they join the larger exhalant canals and are approximately 0.3 mm apart.

The thicker endosomal skeleton is composed of coarser tracts or fibers and larger, more interconnected canals. These rounded to lobate tracts are 0.5–1.0 mm in diameter or wide and form vertical or steeply aligned to discontinuous skeletal elements separated by irregular vertical exhalant canals that range 0.5–1.0 mm wide. The skeletal structure grades inward from the dense outer part to the

more open gastral part, where canals and skeletal elements occupy nearly equal volumes. A gastral layer is not differentiated.

One of the paratypes, Senowbari-Daryan PI-20C, is a relatively narrow cylindrical curved sponge, preserved in a longitudinal thin-section (Fig. 3D–E). The sponge is 41 mm tall, but is incomplete at the base. The sponge is 10–11 mm wide, as preserved, and has sections of the axial spongocoel that are to 4 mm wide, although these may be tangential sections of only the outer part of the cylindrical opening. Coarse vertical exhalant canals occur immediately inside the dense dermal layer and are 0.6–0.8 mm in diameter. They are evident as elongate diagonal sections in upper ones and in near transverse sections in lower ones, where they are 0.5–0.6 mm in diameter and 0.6–1.0 mm apart.

In the lower part of the slice, the section is tangential to the outer part of the endosomal skeleton that is relatively massively fused. Inhalant canals there are 0.10–0.20 mm in diameter and are 0.3–0.5 mm apart, uniformly, although not in any regular spacing or pattern.

In the upper part of the fossil, below the spongocoel depression, fibers are irregular and approximately 0.5 mm in diameter. They are elongate near the spongocoel margin, but not very regular in other parts of the slice. Inhalant canals are 0.10–0.15 mm in diameter, as in other parts of the skeleton. They are horizontal and radial in the outer 1 mm of the sections, but flex upward in the interior.

In the upper preserved part of the sponge wall, canals are larger, 0.2–0.3 mm in diameter, and the more isolated skeletal fibers are irregularly 0.3–0.4 mm in diameter. No spicules are identifiable in the skeleton and a gastral layer is clearly not developed.

Gross form of another paratype, Senowbari-Daryan PI-20A, is not clearly evident, for it appears to be a diagonal or possibly a tangential section that shows a possible ill-defined, matrix and crystalline calcite-filled, spongocoel (Fig. 3B, E). An isolated four-rayed skeletal fiber in that filling (Fig. 3F) suggests the skeleton included spicules with several rays, but it is inconclusive. One margin of the slice includes a well-differentiated dense dermal layer, over a series of diagonally transected coarse exhalant canals of the outer ring. These canals are 1.0–1.5 mm in diameter and are associated with small inhalant canals that are 0.10–0.15 mm in diameter and 0.2–0.5 mm apart. The upper part of the section includes coarse distinct fibers that are 0.5–1.0 mm in diameter and that are separated by interconnected canals that are 0.2–0.5 mm across, with much irregularity. A few of these fibers are perforated by isolated inhalant canals measuring 0.10 mm in diameter.

Etymology: *circulata*, L., form a circle, in reference to the discontinuous ring or circle of exhalant canals in the wall, interior to the dermal layer.

Material examined: Holotype, Senowbari-Daryan PI-19; and paratypes Senowbari-Daryan PI-20, specimens A–C. Three associated reference specimens are all on the same thin-section with the paratype.

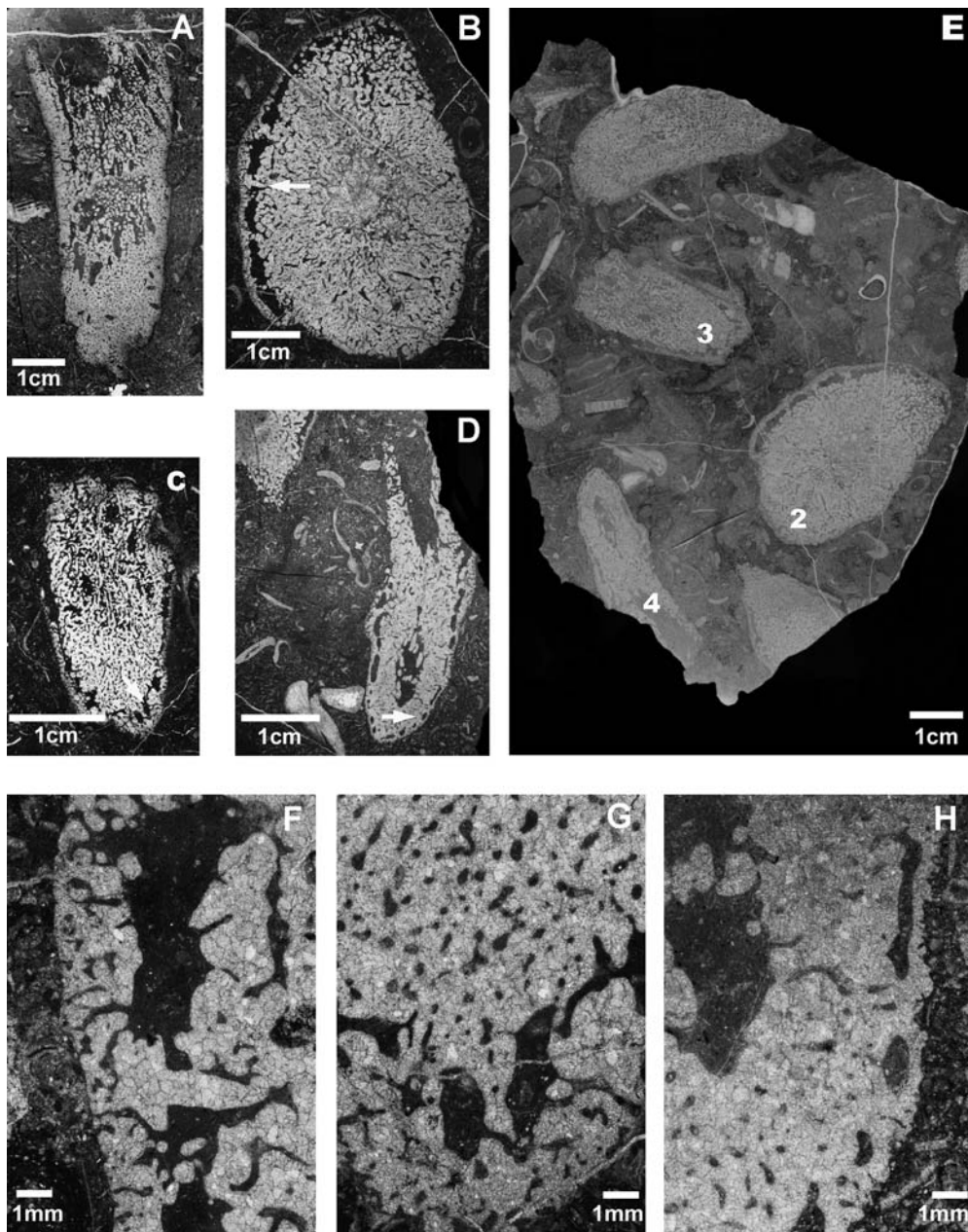


Fig. 3 Type specimens of *Iranospongia circulata* n. gen., n. sp., from Permian rocks of the La Kaftari section, central Iran. **A** Holotype, vertical tangential section showing densely overgrown and recrystallized structure of dermal layer in lower part with small inhalant canals, and coarse vertical to steeply convergent exhalant canals of outer ring interior to dermal layer and with coarse fibers of overgrown spicules in interior, beneath shallow depression of oscular area at summit, Senowbari-Daryan PI-19. **B** Paratype, diagonal to tangential section with prominent, dark matrix-filled, coarse exhalant canals of outer ring interior to thin dermal layer, on right; possible tangential section of outer part of spongocoel in center, marked by crystalline matrix and an isolated four-rayed skeletal fiber (arrow), shown in photomicrograph in F; and is suggestive of original polyactinal skeleton; main endosomal skeleton dense and recrystallized with small scattered common inhalant canals, Senowbari-Daryan PI-20A. **C** Paratype, tangential section of columnar sponge with matrix-filled segments of coarse outer exhalant canals, interior to thin dermal layer, and with tangential section of dense endosomal skeleton in the interior, Senowbari-Daryan PI-20B; arrow indicates position of photomicrograph shown in G. **D** Paratype, near-axial ver-

tical section of cylindrical curved sponge with deep open spongocoel surrounded by coarse endosomal skeleton, and with prominent thin dermal layer separated from main skeleton by segments of exhalant canals of outer ring; arrow indicates position of photomicrograph shown in H, Senowbari-Daryan PI-20C. **E** Entire thin-section containing paratypes of *Iranospongia circulata* n. gen., n. sp., and associated fossils; numbers indicate specimens shown in B (#2), C (#3) and D (#4) Senowbari-Daryan PI-20. **F** Photomicrograph of coarse exhalant canals with distinct dermal layer pierced by small inhalant canals, to left, and with coarser recrystallized part of the endosomal skeleton, to right, below, bridged by a possible coarse recrystallized spicule, Senowbari-Daryan PI-20A. **G** Photomicrograph of section through wall of paratype, with part of the matrix-filled spongocoel, to left, and with a thin dermal layer to the right of the small vertical exhalant canals, to right of dense endosomal part of skeleton that is pierced by small inhalant canals, Senowbari-Daryan PI-20C. **H** Tangential section of outer part of main endosomal layer, above, and dermal layer, below, separated by sections through two coarse exhalant canals, fine inhalant canals pierce both layers of the skeleton, Senowbari-Daryan PI-20B

Occurrence: Lower Upper Permian gray limestones in the middle part of the La Kaftari section of [Senowbari-Daryan and Hamedani \(2002: 795–796\)](#), in north-central Iran.

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