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DEVONIAN AND CARBONIFEROUS SPONGES FROM SPAIN

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ABSTRACT—New collections of fossil sponges have been recovered from Devonian to Upper Carboniferous sections of Spain. These include two new hexactinellids from Devonian rocks of northwestern Spain: the small globular protospongiid *Iberospongia globulara* new genus and species, and the much larger, bowl-shaped, pelicaspongiid *Asturiaspongia aqualiforma* new genus and species. The three specimens of *Asturiaspongia* n. gen. were collected from the calcareous member of the Aguión Formation, of late Emsian age, at Arnao Beach, Asturias. This member has been interpreted as a developing patch reef. The single specimen of *Iberospongia* n. gen. was collected from late Zlichovian (Emsian) beds of the Cortés Member of the Abadía Formation, near Polentinos, Palencia. These beds represent the beginning of the transition to deeper water that took place during the Emsian and which lasted throughout the Devonian.

Lower Carboniferous sponges have been collected from southern Spain. The hexactinellid *Estrellaspongia irregulara* new genus and species, is a thick-walled, basin-shaped pelicaspongiid with irregular, branched, inhalant canals and coarser irregular canals in a skeleton of irregularly oriented and spaced small hexactines. It is from late Viséan rocks of Sierra de la Estrella, near Espiel in Córdoba. The reticulosid *Stereodictyum orthoplectum* Finks, 1960 was collected from Viséan beds at Las Pilitas 2, Badajoz. It has a body wall of alternating layers of regularly spaced vertical and horizontal bundles of spicules in the quadrate-appearing skeleton. This is the first report of the genus from Europe and it is the oldest known occurrence of the genus.

Upper Carboniferous sponges, Bashkirian to Moscovian-Kasimovian, have been collected from northern Spain. Demosponges include: *Heliospongia excavata* King, 1933; *Coelocladia spinosa* Girty, 1908; small generically unidentifiable anthaspidellids; *Haplistion* Girty, 1908 sp. 1 and sp. 2; and a small fragmentary monaxonid demosponge of uncertain taxonomic assignment. Hexactinellida include the reticulosids, *Stioderma perforata* new species, and *Stioderma* Finks, 1960 sp. A, and the new amphidiscosids, *Ascospongiella capdevilae* new genus and species and *Hadrophragmos soleniscus* new genus and species. Root tufts A, B, and C are of uncertain taxonomic assignment.

INTRODUCTION

NEW COLLECTIONS of fossil sponges from the Devonian and Carboniferous of Spain expand the record of demosponges and hexactinellids from the Iberian Peninsula. Hexactinellid sponges are reported for the first time from Devonian rocks of Spain. The two new genera are from the Lower Devonian Emsian of northern Spain and include a small globular protospongiid, *Iberospongia globulara* n. gen. and sp. and a much larger, thicker walled, bowl-shaped, pelicaspongiid, *Asturiaspongia aqualiforma* n. gen. and sp. The pelicaspongiid is from the late Emsian Aguión Formation on the western side of Arnao Beach, west of Salinas, approximately 25 km north-northeast of Oviedo, Asturias (Fig. 1.1). The fossils were collected at 43°35′N, 5°59′W on the Geologic Map of Spain (1:50,000) Sheet No. 13—Avilés (Julivert et al., 1973). Three main lithologies are recognized in the formation from the base up—limestones, marly shales, and red and green marls (Álvarez-Nava and Arbizu, 1986), with a total thickness of 58 m. Because matrix surrounding the specimens is gray bioclastic limestone, we believe that they came from the calcareous member. However, we cannot be absolutely sure because the fossils were collected in 1934 and the label with them does not give a precise point of origin. The Aguión Formation also contains the crinoid *Triblyocrinus flatheanus* Breimer, 1962 and a rich association of fenestellid bryozoans and brachiopods. The basal member of the Aguión Formation is a reefal succession, where the stabilization, colonization, diversification, and domination phases can be recognized (Álvarez-Nava and Arbizu, 1986; Fernandez et al., 1995).

The protospongiid was found 800 m west of Polentinos, 100 km north of Palencia, in the province of Palencia (Fig. 1.2). The outcrop is located at 42°56′30″N and 4°32′20″W on the Geologic Map of Spain (1:50,000) Sheet No.106—Camporredondo de Alba (Lobato et al., 1985). The small fossil came from the Abadía Formation, which is 165 m thick here and includes several members (Rodríguez Fernández, 1994). It overlies the Lebanza Formation and underlies the Gustalapiedra Formation. The sponge was collected from its late Zlichovian (late Emsian) lower Cortés Member, which is 55 m thick and composed primarily of shale, but with some minor interbedded layers of mudstone, sandstone, and calcarenite (Fig. 2). In addition to the small protospongiid, the Abadía Formation has produced, among other fossils, tabulate corals, trilobites, brachiopods, goniatites, ammonites, and gastropods. The good preservation of the specimen of *Iberospongia globulara* n. gen. and sp. indicates that it was not transported, or that transport was very limited. Co-occurrence with the ichnofossil *Zoophycos* Massalonga, 1855 suggests that fossils were autochthonous in quiet waters. Seilacher (1967) pointed out that *Zoophycos* is indicative of shallow to medium water depths. These data corroborate sedimentological analyses, which concluded that the Abadía Formation accumulated in subtidal environments, with low deposition rates and low hydrodynamic energy conditions (Rodríguez Fernández, 1994).

Two hexactinellid sponges from the Lower Carboniferous (Viséan) of southern Spain are described here. A new thick-walled form, *Estrellaspongia irregulara* n. gen. and sp., was discovered in the Sierra de la Estrella (Fig. 1.4), 3 km southeast of Espiel, Cordoba, at 38°09′N, 5°00′ W on the Geologic Map of Spain Sheet No. 901—Villaviciosa de Córdoba (Apalategui et al., 1985).

The stratigraphic section at the Sierra de la Estrella locality includes about 100 m of marls, bioclastic and massive limestones, calcareous breccias, and conglomerates (Rodríguez-Martínez et al., 2000). *Estrellaspongia irregulara* n. gen. and sp. was collected from the base of a dome-shaped bioherm composed of massive gray limestone, created by microbial activity and associated with sponges. The bioherm is similar to mud mounds found in other Carboniferous basins (Cózar and Rodríguez, 1999; Rodríguez-Martínez et al., 2000), where they attain thicknesses of tens of meters. Dasycladacean and rhodophytic algae have been recognized within this bioherm, which points to its formation in the photic zone, at least in its latest stages. However, the marly surrounding sediments include a *Cyathaxonia* Michelin, 1847 fauna

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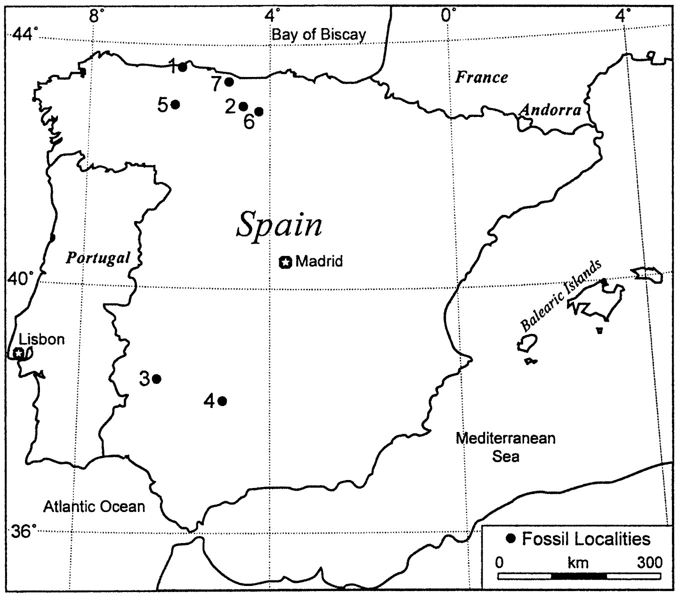


FIGURE *1*—Generalized index map to localities where fossil sponges discussed in the text were collected. Localities are numbered according to their geologic age, from older to younger. Devonian: 1, Arnao Beach, Asturias; 2, Polentinos, Palencia; Lower Carboniferous; 3, Las Pilitas 2, Badajoz; 4, Sierra de la Estrella, Córdoba; Upper Carboniferous; 5, Villafeliz, León; 6, Vergaño, Palencia; 7, Demués, Asturias.

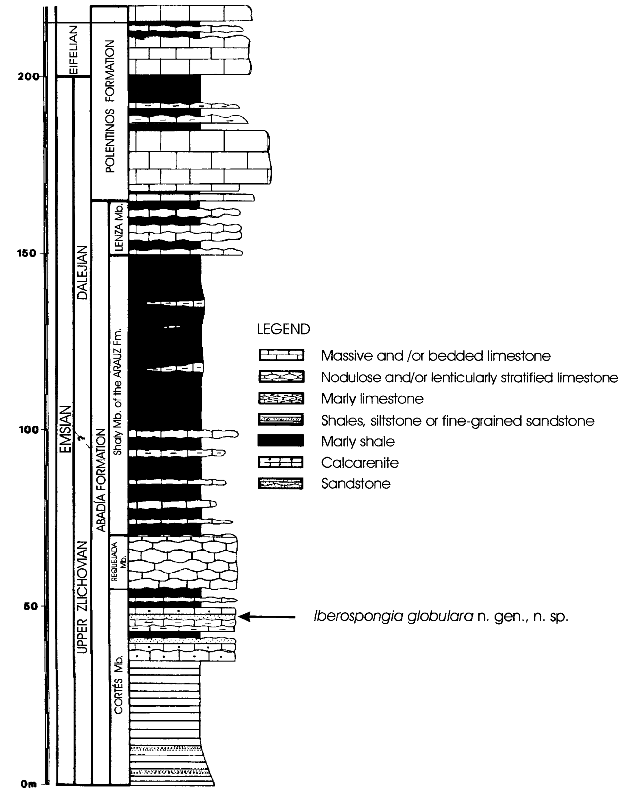


FIGURE *2*—Generalized stratigraphic column of the Abadía and Polentinos Formations in the area northeast of Polentinos (modified from Rodríguez Fernández, 1994).

of solitary corals, characteristic of deep environments, as on the outer platform and slope (Cózar and Rodríguez, 1999). These data suggest that *Estrellaspongia irregulara* n. gen. and sp. lived in association with large microbial bioherms, in low-energy deep-marine environments far from the coast.

The Las Pilitas 2 locality, which yielded *Stereodictyum orthoplectum* Finks, 1960, is 4 km northwest of Los Santos de Maimona, at 38°29′30″N, 6°28′W on the Geologic Map of Spain (1:50,000) Sheet No. 858—Zafra (Odriozola et al., 1983) in the province of Badajoz (Fig. 1.3). This locality is within the Los Santos de Maimona Carboniferous Basin, an important area of Lower Carboniferous rocks in the Ossa-Morena Zone. The basin is 11 km long, northwest to southeast. Its succession was subdivided by Rodríguez et al. (1992) into eight units, with a total thickness of more than 1000 m. Rodríguez (1992) interpreted the section as a Viséan transgressive sequence. *S. orthoplectum* was collected from rocks included in Unit 6 (30 m), which consists of an alternation of bioclastic limestones, encrinitic marls with numerous fossil remains, and black siltstones. Fossils from the unit include corals (mostly from the *Cyathaxonia* fauna), brachiopods, crinoids, bryozoans, foraminifera, and algae. Unit 6 has been dated as Asbian/Brigantian, late Viséan (Rodríguez, 1992). The section at Las Pilitas 2 is 45 m thick, and the upper portion is regarded as Unit 6. There, five resistant limestone layers are separated by shale units that are covered by vegetation in many places. A marly breccia (LP-2/8), beneath a limestone bed 1.5 m thick near the top of the section, contains abundant fossil invertebrates and algae (Rodríguez et al., 1992) and produced the specimen of *Stereodictyum* Finks, 1960 described here, along with large fragments of other fossil groups. The breccia is interpreted as a turbiditic debris layer, typical of the outer edge of the slope. Many fossils in the bed are almost complete and only slightly disarticulated (corals and crinoids), which suggests short to medium transport distances. These fossils probably originated on the outermost platform. The preserved fragment of *Stereodictyum* is only a fraction of the whole sponge, so either its platelike shape made it more fragile than other fossil remains or it may have come from farther away.

Fossil sponges described here from the Upper Carboniferous of Spain came from five localities in the Cantabrian Ranges in the northwestern part of the Iberian Peninsula. The locality of Villafeliz (Fig. 1.5) is located about 1000 m northeast of the town, at 42°57′N, 5°58′30″W on the Geologic Map of Spain (1:50,000) Sheet No. 102—Los Barrios de Luna (Suárez Rodríguez et al., 1990). Villafeliz lies on the southern flank of the Cantabrian Ranges in the province of León. The fossil sponge fauna occurs above the massive limestones of the Bashkirian Valdeteja Formation and below shaly beds that characterize the overlying Bashkirian-Moscovian San Emiliano Formation. We consider the sponge-bearing beds as part of the San Emiliano Formation, for they record onset of more detrital conditions. They consist of an alternation of limestone and marls, which, toward the top of the section, developed into bioherms with abundant sponge fossils. The age of these beds is regarded as late Bashkirian (Suárez Rodríguez et al., 1990). According to Rodríguez Fernández et al. (1990 *in* Suárez Rodríguez et al., 1990), the Valdeteja Formation is dome-shaped in this area, with a flat isochronous base and a convex diachronous top, which laterally changes to the siliciclastic sediments of the San Emiliano Formation. The fossiliferous beds that contain the sponges, brachiopods, and crinoids probably represent transitions between the carbonate- and siliciclastic-dominated environments.

Fossil sponges have also been collected from three localities: VR1, VR3, and VR4, in the Vergaño Formation, at approximately 0.5, 1, and 4 km, respectively, northeast of Vergaño in Palencia, northwestern Spain (Fig. 1.6), on the southeastern flank of the Cantabrian Ranges. The localities are on the Geological Map of

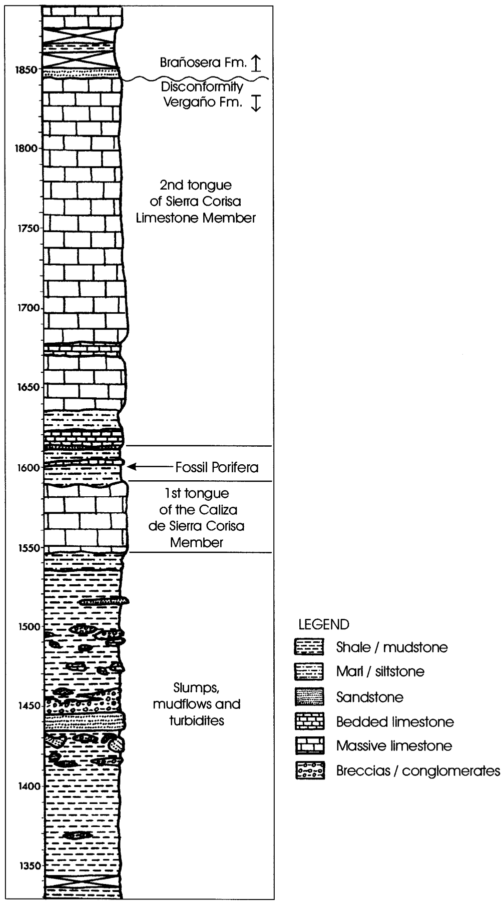


FIGURE 3—Stratigraphic column of the Vergaño Formation in the area northeast of Vergaño (modified from Van de Graaff, 1971).

Spain (Scale 1:50,000) Sheet No. 107—Barruelo de Santullán (Wagner et al., 1984) at 42°54′N, 4°24′W. Here the Vergaño Formation overlies massive sandstone of the upper Vañes Formation. The top of the Vergaño Formation is defined by a fault contact with sediments deposited after the Leonian Tectonic Phase, that were termed the Brañosera Formation by Van de Graaff (1971), or the Ojosa Formation by Wagner et al. (1984). The Vergaño Formation was defined by Van de Graaff (1971) as having a lower part of cross-stratified sandstones—shales with thin interbedded layers of mudstone and sandstone, limestones, and a turbidite bed—and an upper part, the Sierra Corisa Limestone Member, of 300 m of limestones that contain some interbedded layers of marl and shale (Fig. 3). The fossil Porifera described here were collected from marls at the base of the second tongue of the Sierra Corisa Limestone Member. Fossils in the Vergaño Formation include remains of both marine and continental organisms: foraminifera, sponges, corals, brachiopods, gastropods, bivalves, and plants (Wagner et al., 1984). Age of the upper part of the Vergaño Formation was established by Van Ginkel (1965) as Myachkovsky, late Moscovian (Late Carboniferous).

The locality at Demués (Fig. 1.7) is on the northern flank of the Cantabrian Ranges at 43°18′40″N, 4°58′40″W on Geologic Map of Spain (1:50,000) Sheet No. 55—Beleño (Julivert et al., 1984). The fossil sponges described here were collected from a section exposed along the unpaved road that extends southeast of the town of Demués, Asturias, in northwestern Spain. Sánchez de Posada et al. (1998) studied this section and noted fossil Porifera. Martínez García and Villa (1998) defined several formations in the area, among them the Demués Formation, of which the section noted here is the type section. They concluded that the Demués Formation lies unconformably on the Gamonedo Formation and that basal beds of the Demués Formation contain fusulines dated as early Kasimovian up into the middle Kasimovian. The top of the Demués Formation also occurs at an unconformity, related to the Asturian Tectonic Phase. That unconformity is overlain by sandstones of the Puentellés Formation, dated as late Kasimovian based on its fossil flora. Sánchez de Posada et al. (1998) concluded that lower beds of the section contain fossil foraminifera of latest Moscovian age and that overlying beds extend up into the Kasimovian.

This section of the Demués Formation is 220 m thick, but it is from the lower 30 m that the fossil sponges were collected. These lower beds are primarily marls and shales, with some intercalated decimeter-thick limestone beds. Sánchez de Posada et al. (1998) and García-Bellido Capdevila (1999) described an abundant fossil marine fauna and flora from the section that includes sponges, especially sphinctozoans such as *Amblysiphonella* Steinmann, 1882, *Discosiphonella* Inai, 1936, and *Sollasia* Steinmann, 1882, along with corals, bryozoans, brachiopods, gastropods, crinoids, echinoid spines, and dasycladacean and encrusting algae mostly recovered from the marly layers.

SYSTEMATIC PALEONTOLOGY

Unless specified otherwise, all the specimens described here are deposited in collections of the Department of Paleontology, Faculty of Geology, Universidad Complutense de Madrid (UCM).

Class DEMOSPONGEA Sollas, 1885
Subclass CLAVAXINELLIDA Lévi, 1956
Order EPIPOLASIDA Sollas, 1888
Family HELIOSPONGIIDAE Finks, 1960

Type genus.—*Heliospongia* Girty, 1908.
Occurrence.—Upper Carboniferous (Desmoinesian)-Upper Permian (Changxingian).

Genus HELIOSPONGIA Girty, 1908

Type species.—*Heliospongia ramosa* Girty, 1908.
Occurrence.—Upper Carboniferous (Missourian)-Upper Permian (Changxingian).

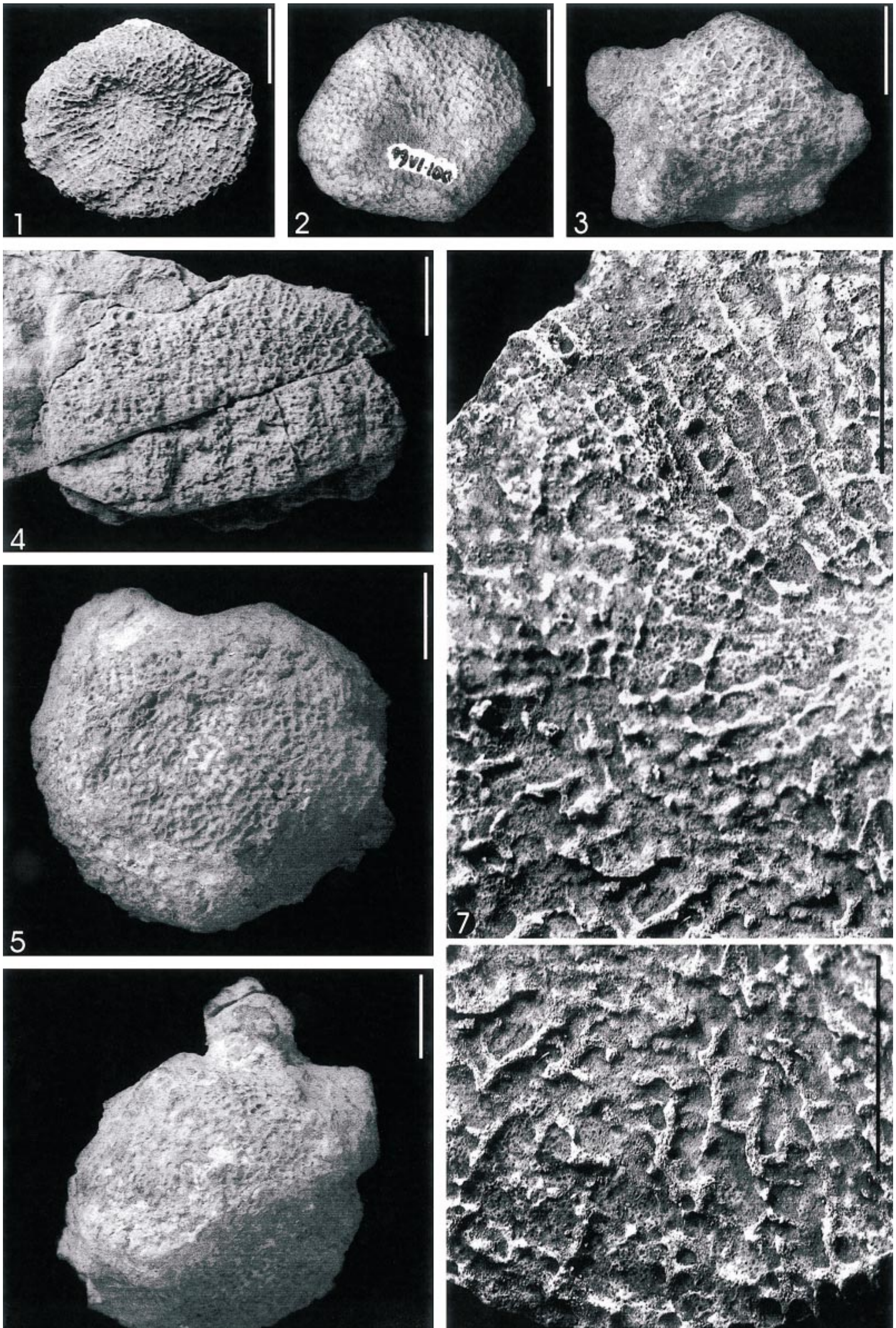
HELIOSPONGIA EXCAVATA King, 1933
Figure 4.1–4.8

Heliospongia excavata KING, 1933, p. 85, pl. 8, fig. 8; FINKS, 1960, p. 45–47, pl. 1, figs. 1–6; pl. 2, figs. 1, 2, 5–8; pl. 3, fig. 1.
Heliospongia ramosa GIRTY, 1908: KING, 1933, p. 84, pl. 8, fig. 6.

Description.—Form flattened, initially discoidal, to larger globular. Flattened sponge, 99VI–100, discoidal, 28 × 31 mm across, with maximum thickness of 11 mm (Fig. 4.1, 4.2). Lower surface with several relatively straight, more or less continuous, skeletal tracts radiating from slightly offset center (Fig. 4.1); tracts 0.4–1.0 mm apart, with moderately uniform spacing maintained by insertion of new tracts (Fig. 4.7); these cross-connected by discontinuous concentric skeletal tracts 1.0–1.4 mm, with most 1.2 mm apart. Radial tracts 0.2–0.3 mm in diameter, expanding slightly at merger with concentric tracts 0.3–0.4 mm in diameter and 1.2 mm long.

Ghosts of closely packed oxeas preserved in silicified skeletal structure. Tracts weathering with micronodular surface obscuring most spicule traces (Fig. 4.8).

Similar, though not radially constructed, discoidal sponge, 99VI–101, with silicified skeletal tracts, 25 × 28 mm in diameter, approximately 11 mm thick (Fig. 4.3); skeletal tracts up to 0.3–0.4 mm in diameter, enclosing circular to rectangular openings



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commonly approximately 1.0 mm across, although some oval openings to 1.5 mm across. Most tracts 0.2–0.3 mm thick, swelling toward tract junctions where nodes to 0.5 mm thick. Traces of closely packed smooth oxeas in weathered tract surfaces, 0.02–0.03 mm in maximum diameter, fragments up to 0.2–0.25 mm long irregularly preserved.

Flattened flabellate sponge, 99VI–50, 41 × 38 mm across, 8–9 mm thick (Fig. 4.4), of reticulate skeletal tracts 0.2–0.4 mm in diameter, with most 0.25–0.30 mm thick, apparently vertically compressed, probably during compaction of the fine enclosing sediments, because tracts virtually in contact with each other in a vertical section. Abundant silicified fragments of oxeas scattered over weathered tract surfaces. These spicules 0.25–0.35 mm in maximum diameter, fragments up to approximately 0.2 mm long exposed.

Larger spheroidal sponge, 99VI–94, nearly complete, with maximum oval cross section of 32 × 42 mm, height of 36 mm (Fig. 4.5, 4.6). Rounded summit with small oval osculum 7 × 9 mm across. Weathered lower side exposing interior and dermal parts of skeleton (Fig. 4.5).

Dermal layer thin, of tips of radiating skeletal tracts normal to surface and interconnecting tracts tangential to the surface. Radial tracts separated 0.7–1.0 mm, center to center, expressed as nodes approximately 0.3 mm in diameter. Tangential tracts 0.1–0.2 mm in diameter at midlength, thicker at contact with nodes of radial series, outlining triangular to rectangular or rounded openings up to 1.2 mm across, although most 0.6–0.8 mm across. Spicule details not preserved on micronodose weathered surfaces of silicified tracts.

Internal skeletal structure with coarser tracts and concentric ''layering'' of skeleton parallel to dermal surface. Radial tracts 0.5 mm in diameter at tract junctions, separated 1.3–2.0 mm, with most approximately 1.5 mm apart. Concentric or tangential tracts 0.8–1.0 mm long, 0.3–0.4 mm in diameter at midlength, expanding to approximately 0.5 mm in diameter at mergers with radial series. Triangular to circular or rectangular skeletal openings in moderately regular pattern, commonly 1.0–1.5 mm across, but rarely up to 1.6 mm across as oval openings.

Material examined.—99VI-94, 100, 101, and 50, all from the San Emiliano Formation, late Bashkirian, Upper Carboniferous at Villafeliz, León.

Discussion.—*Heliospongia* has been reported from Carboniferous and Lower Permian rocks in the United States (Girty, 1908; King, 1933, 1943; Finks, 1960) and from the Permian of Tunisia (Termier et al., 1977; Rigby and Senowbari-Daryan, 1996). The sponges described here document its first occurrence in Europe. Deng (1982) described *Heliospongia*? *houchangensis* from the Permian of China. However, the type specimen is incompletely preserved and its affinity with *Heliospongia* is uncertain. Similarly, the specimen he designated *Heliospongia* sp. is more uncertain.

The small discoidal sponges described here differ from the relatively large cylindrical to branching tubular species of the genus described previously. These Spanish sponges may be juveniles of the finer-textured *Heliospongia excavata* King, 1933, for the associated larger spheroidal specimen appears to be that species.

Genus Coelocladia Girty, 1908

Type species.—*Coelocladia spinosa* Girty, 1908.
Occurrence.—Carboniferous.
Discussion.—*Coelocladiella* Finks, 1960 is a similar cylindrical sponge, but it lacks the prominent tubular inhalant canals, or exaules, on the dermal surface that are so characteristic of *Coelocladia*, and *Coelocladiella* is a thinner-walled form, too, with a broad spongocoel. The related *Heliospongia* is a much larger sponge with coarser skeletal tracts throughout.

Coelocladia spinosa Girty, 1908
Figure 5.1–5.9

Coelocladia spinosa Girty, 1908, p. 288, pl. 16, figs. 1–7; King, 1933, p. 83, pl. 8, fig. 7; Finks, 1960, p. 51–52, pl. 5, figs. 1–8; pl. 6, figs. 1–13; pl. 7, figs. 4–6; pl. 8, fig. 9; Debrenne and Vacelet, 1984, pl. 1, fig. c; Rigby and Mapes, 2000, p. 31–32, pl. 1, figs. 10, 11.

Description.—Several included cylindrical specimens (Fig. 5.1, 5.2) without hollow funnel-shape, range from fragments only 3–4 mm in diameter and 14 mm tall, to larger fragments 4 mm in diameter and 47 mm tall (Fig. 5.1); all with thick walls around central tubular spongocoels, 2–3 mm in diameter in small sponges to 6 mm in diameter in largest fragments. Tubular openings usually one-third diameter of stems (Fig. 5.8, 5.9), with perforate distinct walls of thickened spicules.

Dense dermal layer on all fragments, 0.2–0.3 mm thick, although to 0.5 mm thick where layers overlapped during pulses of growth (Fig. 5.7, 5.9). Dermal layer perforated by coarse inhalant ostia (Fig. 5.3, 5.5) separated 0.4–0.8 mm, wall to wall, or 0.9–1.7 mm apart, center to center, in medium-sized specimens. Ostia 0.4–0.8 mm in diameter as single circular openings, or compound vertically to horizontally elongate, 8-shaped, interruptions in dermal layer. Ostia may be circular perforations or conical to tubular exaules as outward flexures of dermal layer (Fig. 5.4). Exaules distinctly cylindrical and over 1 mm long (Fig. 5.7), or lower conical mounds (Fig. 5.5), with walls to 0.2–0.3 mm thick, where conical, but less than 0.2 mm thick where tubular and tapered toward distal inhalant opening.

Inhalant or prosochete canals cylindrical, 0.4–0.5 mm in diameter, traceable only short distances into porous skeleton before identities lost. In contrast, tubular exhalant canals or apochetes, relatively long and traceable through three-fourths of wall thickness from gastral surface (Fig. 5.8). Apochetes average 0.4–0.6 mm in diameter, but to 0.8 mm in diameter, with distinct walls to 0.06 mm thick. They initiate as convergent branches in outer wall from mergers of skeletal pores or spaces between spicules or skeletal tracts approximately 0.02 mm in diameter.

Skeleton upwardly divergent discontinuous tracts of merged spicules, whose certain identities lost in calcareous replacement. Tracts from 0.03 mm across, where single spicules apparently represented, to 0.10 mm across where several elements cross within wall interior. Many areas with small, double-pointed, needlelike dark fillings of possible axial canals of isolated single spicules (Fig. 5.6), or as a loose ''thatch'' where tracts widen and several spicules apparently present. Such occurrences common in thickened elements of dermal and gastral layers. Individual dark

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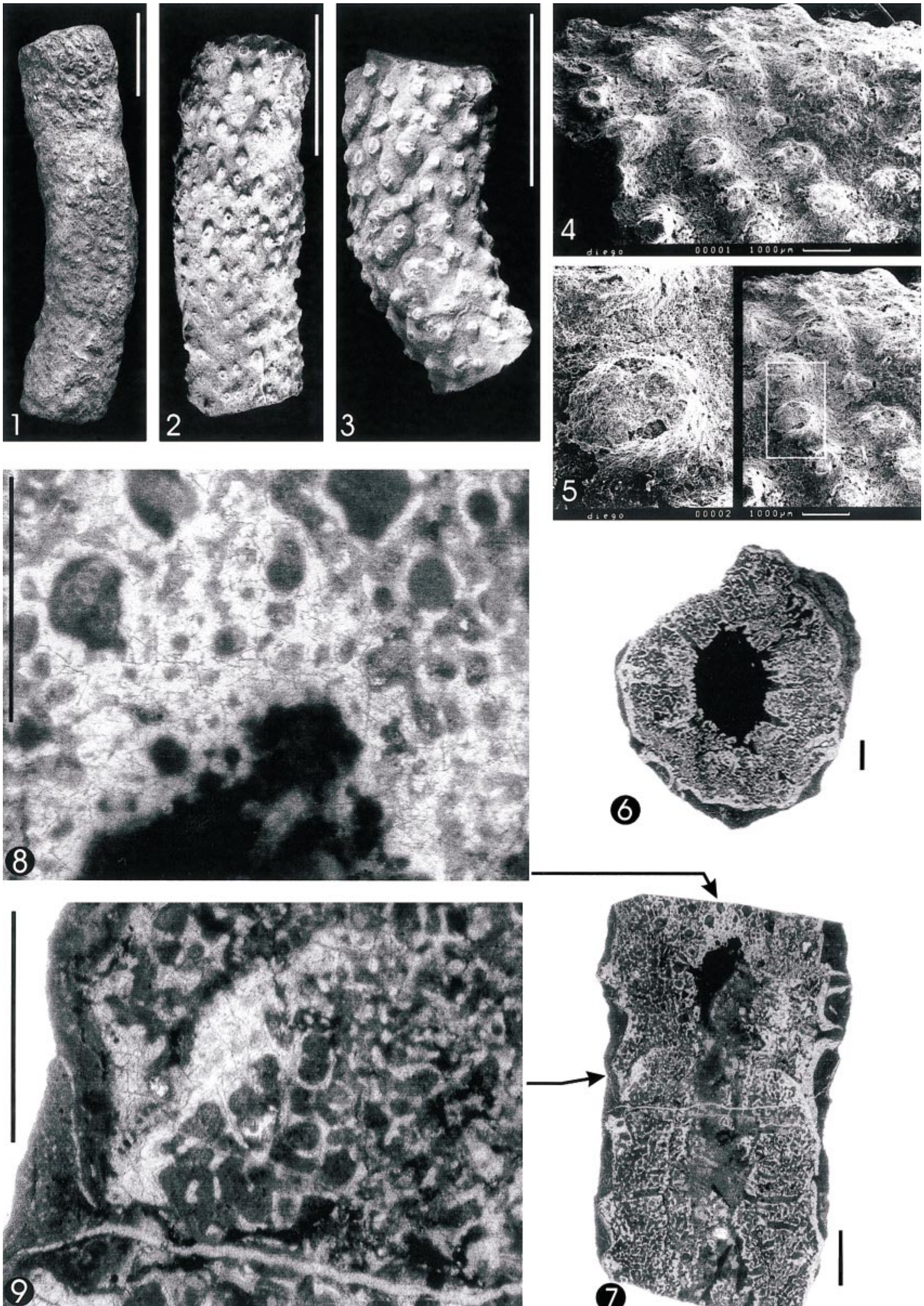
Figure 4—*Heliospongia excavata* King, 1933, Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *1,* 99VI–100, Flattened discoidal specimen, complete view of lower side, where the radial disposition of the skeletal tracts can be recognized; *2,* 99VI–100, dorsal view; *3,* 99VI–101, complete view of the specimen, showing silicified skeletal tracts, in an apparently unoriented reticular pattern; *4,* 99VI–50, flattened flabellate specimen; *5,* 99VI–94, spherical specimen, view of lower side, showing in its upper left corner the rounded summit where the osculum is located; *6,* 99VI–94, lateral view, note the interior nature of the skeleton in the partially eroded left side of the sponge; *7,* 99VI–100, view of lower side, detail of radially arranged skeletal tracts; *8,* 99VI–100, view of lower side, detail of radial and concentric skeletal tracts forming a reticulate pattern. Scale: *1–6,* bar 10 mm; *7, 8,* bar 5 mm.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''needles'' traceable to 0.20 mm long, taper in both directions to sharp tips, from maximum thicknesses of 0.003–0.004 mm at midlength. Where thin section tangential to gastral layer, ''needles'' appear as open loose ''strew'' around skeletal pores where several spicules probably represented in fused structure. Where thin section essentially normal to dermal layer, ''needles'' at high angles to surface, suggesting spicules at similar high angles.

Material examined.—Thirteen cylindrical fragments including 99VR1-131 and 99VR1-132 from VR1; 99VR3-100 from VR3; and 99VR4-122 from VR4, close to Vergaño, Palencia, from level 1,600 of the section of the Vergaño Formation, Moscovian (Fig. 5.1). Other studied specimens include 98DM25-24, 98DM25-25, 98DM25-26, 98DM30-19, 98DM35-7, and 98DM35-9, from which were cut transverse and longitudinal sections, from the late Moscovian-Kasimovian, Upper Carboniferous, Demués Formation, at Demués, Asturias (Fig. 5.2–5.9).

Discussion.—The Spanish specimens are all small cylindrical morphotypes, and none shows either the size or the funnel shape described for some North American specimens. This habit may correspond, as suggested by Finks (1960, p. 52), to an adaptation to certain environmental conditions, because it is present only in middle Missourian specimens of central Texas, but not in other specimens of that same state.

These are the first examples of *Coelocladia spinosa* recorded from Europe. Hayasaka (1923) described what he termed *Coelocladia spinosa* var. *minor* from Japan, but Finks (1960, p. 52) concluded that the Japanese fossil is not a *Coelocladia*, but possibly an example of *Wewokella* Girty, 1908. Similarly, Finks (1960, p. 52) concluded that the sponge described as *Coelocladia tanchiensis* by Reed (1927, p. 98, pl. 7, fig. 2, 2a) is also probably not an example of *Coelocladia*. Thus, previously reported occurrences of the genus and species have been documented from only the Desmoinesian-Virgilian of Texas (equivalent to late Moscovian-Gzelian in Europe and Asia).

Order, Family, and Genus UNCERTAIN
Figure 6.2, 6.4

Description.—Silicified fragment of dermal crust of terminal(?) ''chamber'' approximately 4 mm in diameter, with wall perforated by scattered common canals 0.2–0.3 mm in diameter, and less common smaller canals, 0.1 mm in diameter. Crustose wall 0.3–0.4 mm thick, composed largely of tangential monaxial spicules in thin layer (Fig. 6.4) pierced by radial, vertical spicules that extend through wall so surface microspinose, with spicules spaced 0.15–0.2 mm apart, laterally. These spicules extend 0.2–0.3 mm inward and 0.15–0.2 mm outward from surfaces of that layer.

Spicules cylindrical, 0.03 mm in diameter, with tips not well preserved so may be gently curved strongylelike. Spicule surfaces may be microspinose, but some such ''sculpture'' may be result of secondary silicification of this and associated sponges.

Material examined.—A single partially etched fragment is exposed on the surface of sample 99VI–69, where it is associated with a discoidal to bowl-shaped *Haplistion* sp. 2, and several fragments of a small anthaspidellid. It came from late Bashkirian (Upper Carboniferous) beds of the San Emiliano Formation at Villafeliz, León.

Discussion.—So little is preserved of the sponge that even its gross growth form is not known for certain. The sponge does belong to the monaxonid demosponges; however, because so little of it is preserved detailed classification is impossible.

Subclass CERACTINOMORPHA Lévi, 1956
Order LITHISTIDA Schmidt, 1870
Suborder ORCHOCLADINA Rauff, 1893
Family ANTHASPIDELLIDAE Miller, 1889

Type genus.—*Anthaspidella* Ulrich and Everett, 1890.
Occurrence.—Middle Cambrian-Upper Permian.

Genus UNCERTAIN
Figure 6.1, 6.3

Description.—Several fragments of silicified skeletal net on 99VI-69, including small fragment, 7 × 5 mm across, of radially and upwardly divergent trabs with prominent cross-connecting dendroclone ''rungs'' in characteristic anthaspidellid structure (Fig. 6.1, 6.3). Shape uncertain but possibly twiglike or weakly branching, based on irregular divergence of rodlike trabs.

Trabs straight, 0.10–0.14 mm in diameter, with some irregularity produced by remnants or fused tips of broken dendroclones. Trab segments to approximately 2.5 mm long in divergent structure, and approximately 0.025 mm apart where parallel (Fig. 6.3). Within ladderlike series, dendroclones uniformly 0.010–0.015 mm apart in regular structure. Trabs inserted radially in structure to maintain uniform skeletal spacing.

Individual dendroclones Y-shaped with shafts 0.03–0.04 mm in diameter, where thinnest, expand to approximately 0.06 mm, or more, in diameter where clads diverge. Clads 0.015–0.020 mm in diameter, but lengths uncertain because tips lost in crystalline replacement where merged to help form trabs. As many as five or six series of dendroclones may fuse to form subcylindrical trabs with their combined clad tips. Coring monaxial spicules indicated by remnants of one to three spicule fragments in some trab tips.

Longitudinal canals locally present parallel to trabs, approximately 0.20 mm in diameter, formed where one or two series of dendroclones not developed, leaving opening (Fig. 6.3). Rare radial canals developed perpendicular to trabs and dendroclone series, approximately 0.02 mm wide and 0.03 mm high, with rounded elliptical outlines.

Another small node- or moundlike fragment of about same size and general skeletal structure on etched surface of the same sample (Fig. 6.2), with cylindrical radial canals 0.5 mm in diameter, but others elliptical and 0.3 mm wide and 0.5 mm high. Additional smaller associated fragments only 2–3 mm across, with radial structure and trabs only approximately 0.01 mm in diameter. These fragments may be more juvenile parts of same species.

←

FIGURE 5—*Coelocladia spinosa* Girty, 1908. *1,* Vergaño, Palencia; Vergaño Formation, late Moscovian, Upper Carboniferous; *2–9,* Demués, Asturias (northwestern Spain); Demués Formation late Moscovian-Kasimovian, Upper Carboniferous. *1,* 99VR3–100, longest specimen; *2,* 98DM25–24, whitened specimen, one of the widest in the collection; *3,* 98DM30–19, whitened specimen showing a slightly conical morphology; *4,* 98DM35–7, SEM photograph of the ostia-covered dermal wall; *5,* 98DM35–7, SEM photograph of details of some conical ostia; *6,* 98DM35–9, transverse thin section showing the radial arrangement of the exhalant canals and their extension into the body wall; *7,* 98DM35–9, longitudinal thin section of specimen with two growth episodes, defined by a thickened dermal wall which grew inwardly to meet the spongocoel. Two prominent tubular exaules can be recognized in the upper right side. The arrows indicate the detailed areas shown in *8* and *9*; *8,* 98DM35–9, detail of the longitudinal thin section, showing the ''needles'' (axial canals of the spicules) integrated in the massive skeleton and some canals of the aquiferous system; *9,* 98DM35–9, detail of the longitudinal thin section showing the wall that defines the end of a growth pulse and the beginning of a new pulse. Scale: *1, 2,* bar 10 mm; *4, 5, 8, 9,* bar 1 mm; *3, 6, 7,* bar 0.5 mm.

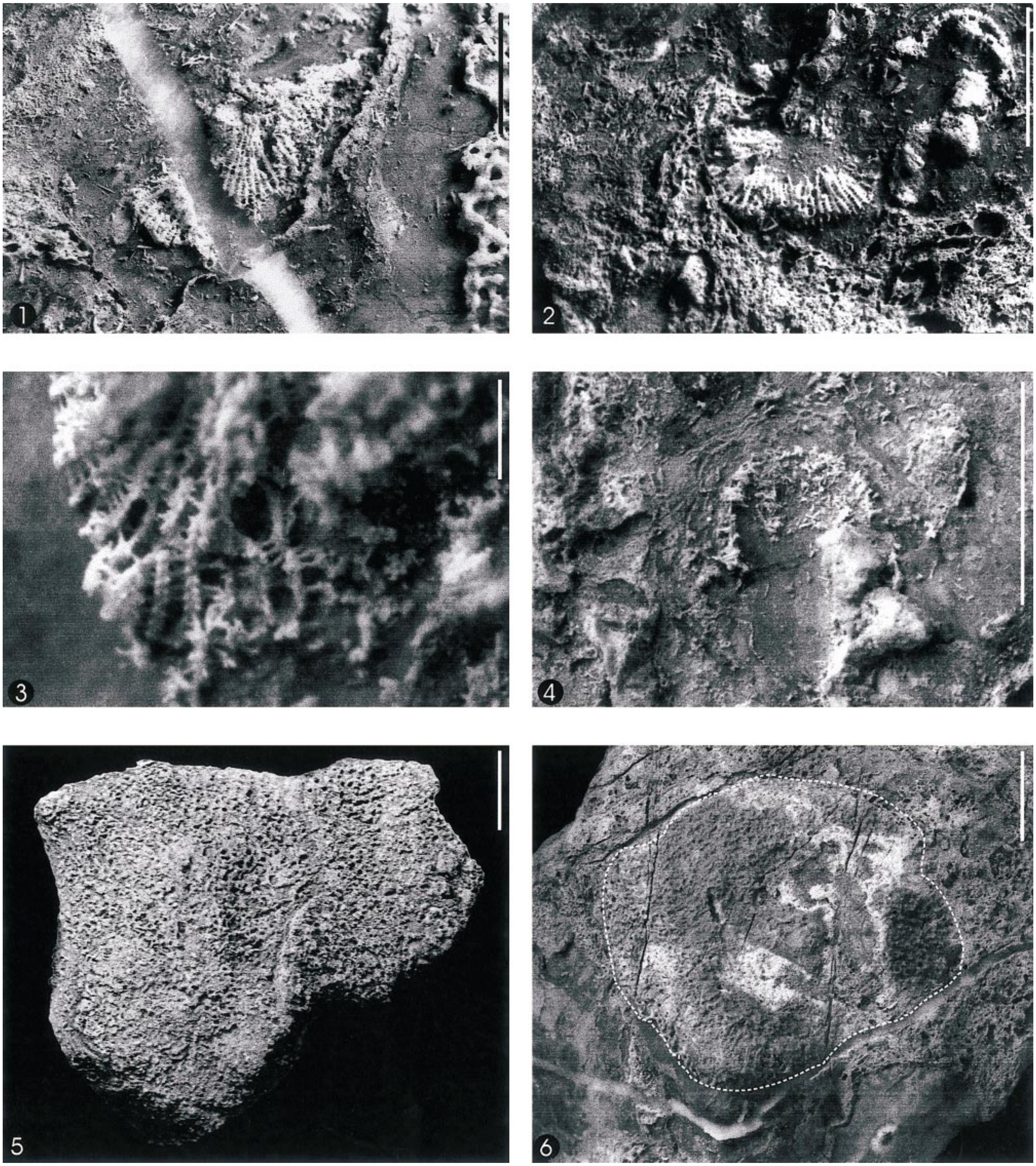


FIGURE 6—*1, 3,* Family Anthaspidellidae, genus uncertain, Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *2, 4,* Order, Family, and genus uncertain, Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *5, Haplistion* sp. 1, Vergaño, Palencia; Vergaño Formation, late Moscovian, Upper Carboniferous. *6, Haplistion* sp. 2. Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *1,* 99VI–69, view of the most complete specimen, with trabs of interconnected dendroclones, characteristic of the Family Anthaspidellidae; *2,* 99VI–69, complete view of two specimens, the one in the center belongs to the Family Anthaspidellidae, and an uncertain sponge in the upper right corner (arrow); *3,* 99VI–69, detail of the ladderlike structure formed by fused dendroclones, a longitudinal canal can be recognized in the center of the image; *4,* 99VI–69, detail of the sponge of uncertain affinities, with a thin layer of monaxial spicules forming the curved dermal wall; *5,* 99VR4–75, complete view of the preserved fragment, showing the irregular arrangement of the tracts in the dermal wall; *6,* 99VI–69, complete view of the partially eroded specimen, where the spongocoel can be seen in its center; a dashed line has been drawn around the specimen to enable recognition of its limits. Scale: *1, 2, 4–6,* bar 10 mm; *3,* bar 1 mm.

Material examined.—Two larger fragments and three smaller fragments occur on the etched surface of sample 99VI-69, with *Haplistion* sp. 2 and other lithistid sponge fragments, from the San Emiliano Formation, late Bashkirian, Upper Carboniferous, at Villafeliz, León.

Discussion.—Growth form of the genus and species represented by the several fragments is uncertain. They are too small to be identified beyond family level.

Suborder RHIZOMORINA Zittel, 1878
Family HAPLISTIIDAE De Laubenfels, 1955

Type genus.—*Haplistion* Young and Young, 1877.

Occurrence.—Lower Ordovician, Middle Ordovician-Middle Permian.

Genus HAPLISTION Young and Young, 1877

Type species.—*Haplistion armstrongi* Young and Young, 1877.

Occurrence.—Middle Ordovician-Lower Permian.

HAPLISTION sp. 1
Figure 6.5

Description.—Silicified, flattened, irregular fragment, 60×44 mm across and 13–14 mm thick (Fig. 6.5), composed of moderately uniform tracts arranged in crudely rectangular network, which may be radially disposed. Tracts 0.3–0.4 mm in diameter, although some only 0.2 mm in diameter occur irregularly. Tracts with circular to elliptical cross sections, thin between adjacent small ostia and expand into tract junctions. Tracts micronodose to microspinose, with nodes 0.01–0.05 mm in diameter, but commonly 0.03–0.04 mm across, side-by-side on surface but may be 0.01–0.02 mm apart. Tracts lack linearity in surface sculpture so nature of spicules in skeleton unknown.

Skeleton perforated by larger circular canals, approximately 1.2 mm in diameter, to elliptical ones, 1.1 to 2.0 mm across and 1.2 mm high. Numerous smaller circular canals between spicule tracts 0.3–0.4 mm in diameter.

Material examined.—The single specimen, 99VR4–75, is from Vergaño VR-4, at level 1600 of the section of the Vergaño Formation, late Moscovian, Upper Carboniferous, close to Vergaño, Palencia.

Discussion.—The fragment is placed with considerable question in *Haplistion*, based on general tract structure and similarity to *Haplistion* sp. 2, which does have recognizable spicules. Openings in the skeletal net in *Haplistion* sp. 1 are much larger, in general, than those in *Haplistion* sp. 2.

HAPLISTION sp. 2
Figure 6.6

Description.—Single specimen undulatory discoidal to irregularly saucer-shaped and slightly elliptical, 41×38 mm across, approximately 1 mm thick, with irregularly radial skeletal structure of discontinuous spicule tracts. Tracts cross-connected at moderately regular intervals by similar tracts, to produce crudely rectangular, open, skeletal structure.

Openings between tracts circular to irregularly hexagonal or rectangular. Smaller ones 0.3–0.4 mm across, larger ones circular to rectangular and to 0.5–0.6 mm in diameter or across as most common openings. Largest openings to 0.8 mm across with circular to rectangular cross sections.

Tracts with circular to elliptical transverse sections, 0.2–0.5 mm in diameter, thinnest and commonly 0.3 mm in diameter at midlength, between junctions, and expand to greatest widths near junctions. Tracts solid silica so spicule structure obscured, also lack surface sculpture that would hint at spicule shapes and packing. Near one end of sponge, tracts oriented upwardly and outwardly in thin plates. Some with micronodose exteriors where small hemispherical nodes 0.03–0.04 mm in diameter could be beekite structures from secondary silicification.

Small fragments with well-preserved tracts of small rhizoclones occur in adhering matrix on upper part of sponge. These fine spicules approximately 0.02 mm in diameter, with irregularly nodose to microspinose surfaces, parallel to one another and to tract surface. Ten to 20 spicules occur per cross section, with space between them. Whether they represent the structure of the larger underlying sponge is uncertain, because they are only tract fragments and occur in association with fragments of other genera or orders.

Material examined.—Single fragment on specimen 99VI-69 is from late Bashkirian (Upper Carboniferous) beds of the San Emiliano Formation at Villafeliz, León. Other associated fragments are of uncertain taxonomic relationships.

Discussion.—The general appearance of our specimen corresponds to that of *Haplistion*, particularly in the associated rhizoclones. However, we are unable to confirm the connection of these spicules with the rest of the sponge structure. Because this and associated fragments are so small, and abundant foreign oxeas and other spicules occur in the same general area of matrix, we prefer to leave taxonomic assignment of the species open. Although diameters of their skeletal tracts are similar, *Haplistion* sp. 2 generally has canal openings much smaller than those in *Haplistion* sp. 1 from the late Moscovian of Vergaño, Palencia.

Class and Order UNCERTAIN
ROOT TUFT A
Figure 7.1, 7.2

Description.—Small weathered fragment of root tuft an elliptical compact spicule cluster, 36 mm long, 22 mm wide, and 4 mm thick (Fig. 7.1), with bilaterally spreading brushlike structure of monaxial spicules, probably all oxeas (Fig. 7.2). Spicules packed side-by-side, remarkably uniform, parallel, cylindrical, with maximum diameters of 0.08–0.10 mm; where most solid rods of silica, although a few preserved as thin siliceous crusts only, axial canals not defined. Fragments to 6 mm long, with ray tips broken on most weathered side of cluster. Largely matrix-covered side with scattered short fragments that taper slightly, from diameters of 0.15 mm to half that size, although even here pointed ray tips not preserved.

Material examined.—The single fragment, 99VR4-50, was collected from level 1,600 of the Vergaño section (Fig. 3), from the Vergaño Formation, late Moscovian, Upper Carboniferous, at VR4, northeast of Vergaño, Palencia.

Discussion.—The fine-textured root tuft is considerably more compact and with more uniformly fine spicules than those of either Root Tuft B or C. Type specimens of *Stioderma coscinum* Finks, 1960, from the Permo-Carboniferous of the United States, have associated root tufts that are similar to the tuft considered here, but those typical tufts are clearly associated with the dorsal cups. Here the tuft is isolated from the cup fragments, but it could have been part of *Stioderma perforata* n. sp.

ROOT TUFT C
Figure 7.5, 7.6

Description.—Tuft coarse, brushlike, 10.5 cm long with spicules distinctly coarser than in other tufts of collection, closely packed cluster of parallel, doubly tapering, monaxial spicules to 1.0 mm in diameter, with coarse spicules occurring singly or in clusters among parallel, finer, monaxial thatch (Fig. 7.6). Coarse spicule fragments to 30 mm long may represent less than half full length of largest spicules. Common smaller oxeas 0.2–0.3 mm in diameter and at least 4 mm long, where complete, but tapered fragments of longer, similar diameter, spicules also occur. Tuft with pronounced wavy plastic deformation of spicules in thick

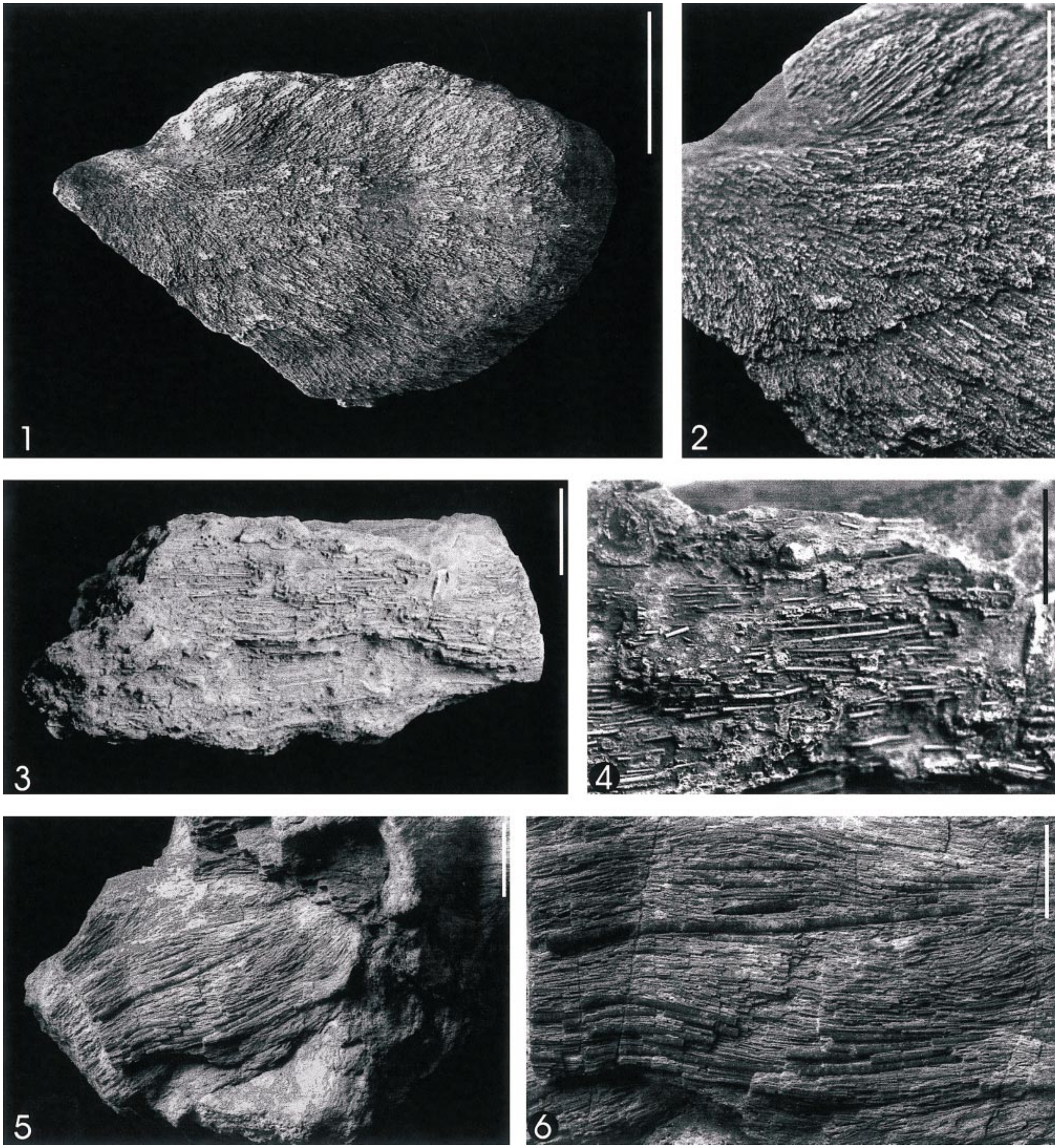


FIGURE 7—*1, 2,* Root tuft A; *3, 4,* Root tuft B; *5, 6,* Root tuft C; all from Vergaño, Palencia; Vergaño Formation, late Moscovian, Upper Carboniferous. *1,* 99VR4–50, root tuft of densely packed diverging monaxons; *2,* 99VR4–50, detail of the spicules; *3,* 99VR4–51, root tuft of loosely packed parallel arranged monaxons, mostly bound by matrix; *4,* 99VR4–51, detail of the best-preserved spicules; *5,* 2000VR3–1, root tuft of densely packed coarse monaxons; *6,* 2000VR3–1, detail of the spicules of the root tuft with the largest diameter (>1 mm). Scale: *1, 3, 5,* bar 10 mm; *2, 4, 6,* bar 5 mm.

three-dimensional specimen. Individual spicules solid siliceous elements.

Material examined.—Moderately large fragment, 2000VR3-1, collected from level 1,600 of the Vergaño section (Fig. 3), from the Vergaño Formation, late Moscovian, Upper Carboniferous, at VR3, northeast of Vergaño, Palencia.

Discussion.—This is the coarsest spiculed tuft and is distinctive in the intermingling of these coarse spicules as single elements or as clusters amid the finer-textured spicules. In addition, its spicules are more consistently closely packed than are those of finer-textured Root Tuft B. Root Tuft C is considerably coarser-textured than the finely spiculed, divergent brushlike Root Tuft A.

Class HEXACTINELLIDA Schmidt, 1870
Subclass AMPHIDISCOPHORA Schulze, 1887, emend. Schrammen, 1924
Order AMPHIDISCOSA Schrammen, 1924
Family PELICASPONGIIDAE Rigby, 1970

Type genus.—*Pelicaspongia* Rigby, 1970.

Occurrence.—Lower Ordovician, Silurian, Lower Devonian-lower Upper Carboniferous.

ASTURIASPONGIA new genus

Type species.—*Asturiaspongia aqualiforma* new species.

Diagnosis.—Bowl-shaped, thin-walled, with walls perforated by irregular tubular canals of at least three sizes, all irregularly distributed and separated by relatively thin skeletal tracts of small, irregularly oriented hexactines of several sizes; distinct hypodermal layer of hexactines developed.

Etymology.—Named for Asturias, the region of Spain from where the sponge was collected.

Occurrence.—Arnao, Asturias, Spain; Aguión Formation, late Emsian, Lower Devonian.

Discussion.—The perforate, thin-walled structure to the bowl-shaped sponge is distinctive, particularly where the relatively close, but irregular, packing of the various ranked canals and ostia is evident. Among bowl-shaped genera of the family, the Devonian *Pelicaspongia* differs from the form here in having a thick wall perforated by numerous large cylindrical canals or parietal gaps, and with large hypogastralia. Upper Carboniferous *Arakespongia* Rigby, Chamberlain, and Black, 1970 from Oklahoma is also thick-walled, with numerous large cylindrical canals connected by smaller anastomosing canals, and it has large tuberculate hypodermal spicules. *Calicispongia* Reimann, 1945, from the Devonian of New York, is nodose, saucer-shaped, and has a skeleton with several layers of hexactines. Devonian *Cavospongiella* Rigby, 1986 from Australia is similar in general growth form, but it has two sizes of coarse tubular parietal gaps that pierce the thin wall. *Keriogastrospongia* Wu, 1989, from the Triassic of China, has a shallow spongocoel marked by rings of coarse ostia of subradial exhalant canals in its thick walls. *Larispongia* Carrera, 1998, from the Ordovician of Argentina, is also thick-walled, with closely spaced parietal gaps and a coarse hexactine-based skeleton. *Liscombia* Rigby and Webby, 1988, from the Ordovician of Australia, is thin-walled and cuplike, and the associated *Wongaspongia* Rigby and Webby, 1988 is open-conical to bowl-shaped, but both have distinctive diplorhysal canal systems. *Pseudohydnoceras* Reimann, 1935, from the Devonian of New York, is vase-shaped with large nodes, whereas *Vaurealispongia* Rigby, 1974, from the Ordovician-Silurian of Canada, is bowl-shaped and has numerous dominantly radial parietal gaps.

ASTURIASPONGIA AQUALIFORMA new species
Figure 8.1–8.5

Diagnosis.—Moderate-sized, smooth, bowl-shaped, with thin walls perforated by three series of irregular canals ranging from 1.5–2 mm to 3.5–5 mm in diameter, separated by skeletal tracts 0.2–0.5 mm across; skeleton of small, irregularly oriented hexactines, with hypodermal layer of small hexactines with four rays tangential to dermal surface.

Description.—Holotype approximately one-third of smooth bowl-shaped sponge, 4.5 cm high and 6.5 cm across, includes part of deep open matrix-filled spongocoel (Fig. 8.1). Sponge fragment extends downward from rounded oscular margin of wall, 5–6 mm thick, to broken base, and includes approximately one-third of sponge circumference.

Wall perforated by numerous ostia of three ranks; largest openings sloping funnel-shaped and 3–4 mm, rarely to 5 mm, across at dermal surface and spaced irregularly approximately 1 cm apart. These pores taper inward so 1–2 mm in from exterior, openings 2–3 mm in diameter, and now filled with light matrix. Intermediate ostia 2–3 mm in diameter taper in broadly funnellike openings to only 1.5 mm in diameter 1–2 mm in from dermal surface, where spaced 2–3 mm apart, without determinable pattern other than occurrence between larger and smaller openings. Smallest ostia 1.5–2.0 mm in diameter, 0.2–0.5 mm apart, separated by tracts of skeletal material, range from common circular to irregularly polygonal in transverse section; largely filled with matrix.

Walls also perforated by irregular canals, most of which appear interconnected within wall (Fig. 8.4, 8.5). Some isolated canals regularly tubular and approximately 2 mm in diameter, where exposed in horizontal sections of oscular margin.

Scattered small hexactines apparent where weathered into bas-relief on surface of skeletal tracts near cut end of sponge, arranged with four rays tangential to dermal surface of tracts, but those rays irregularly oriented with respect to adjacent spicules and diagonally to oscular margin, the only certain reference surface. One such well-preserved spicule with smooth tangential rays approximately 0.6 mm long, which taper smoothly to sharp tips from basal ray diameter of approximately 0.04 mm. Distal ray a node 0.06 mm in diameter. Fragments of cylindrical spicules to 1.5 mm long and 0.06 mm in diameter occur on surface in same general area, and may be foreign or parts of hexactines such as those evident in section in interior of sponge.

Irregularly oriented and spaced hexactines, evident in diagonal thin section through wall (Fig. 8.2), range from relatively coarse spicules with basal or near basal ray diameters of 0.14–0.16 mm and rays to at least 2 mm long, to ones 0.04 mm in basal ray diameter with rays approximately 1 mm long. Others with basal ray diameters of 0.06–0.08 mm probably most common, with observed rays to 2.5 mm long. All appear to taper smoothly from ray junctions to sharp tips, although because of their irregular orientation, in available section, even moderately complete rays rarely seen. Neither well-defined gastral nor dermal layer of enlarged spicules present, but variously sized spicules appear distributed in unbundled, or layered texture, around canals, throughout skeletal tracts of thin wall.

Axial canal evident in nearly all spicule sections, range in size but commonly approximately 0.02 mm in diameter in rays 0.10 mm in diameter. Originally siliceous spicules commonly layered, as now preserved. Some spicules with outer layer light gray and coarsely crystalline, with inner layer around axial canal less coarsely crystalline and darker. Elsewhere in section reverse common, with light coarsely crystalline layer next to axial canal. Such relationships probably due to minor differences in diagenetic alteration, rather than original structure.

Larger specimen or paratype with ovoid section approximately 4×6 cm across, which cuts directly across canals in interior, but diagonally through them in outer parts. Largest canals in central part of section to 3–4 mm in diameter, but smaller intervening ones approximately 1 mm in diameter, and more common ones approximately 2 mm in diameter. Larger ones cut diagonally in outer radiating part of section, where matrix-filled openings appear cylindrical and separated by skeletal tracts only 1.0–1.5 mm thick, thinner than those in interior, where tracts to 3 mm thick.

Smaller section through wall and across relatively large, matrix-filled spongocoel, possibly at oscular margin 3.0–3.5 cm across, with wall sections 3–8 mm thick. Walls pierced by radial canals of several diameters, like those in associated section.

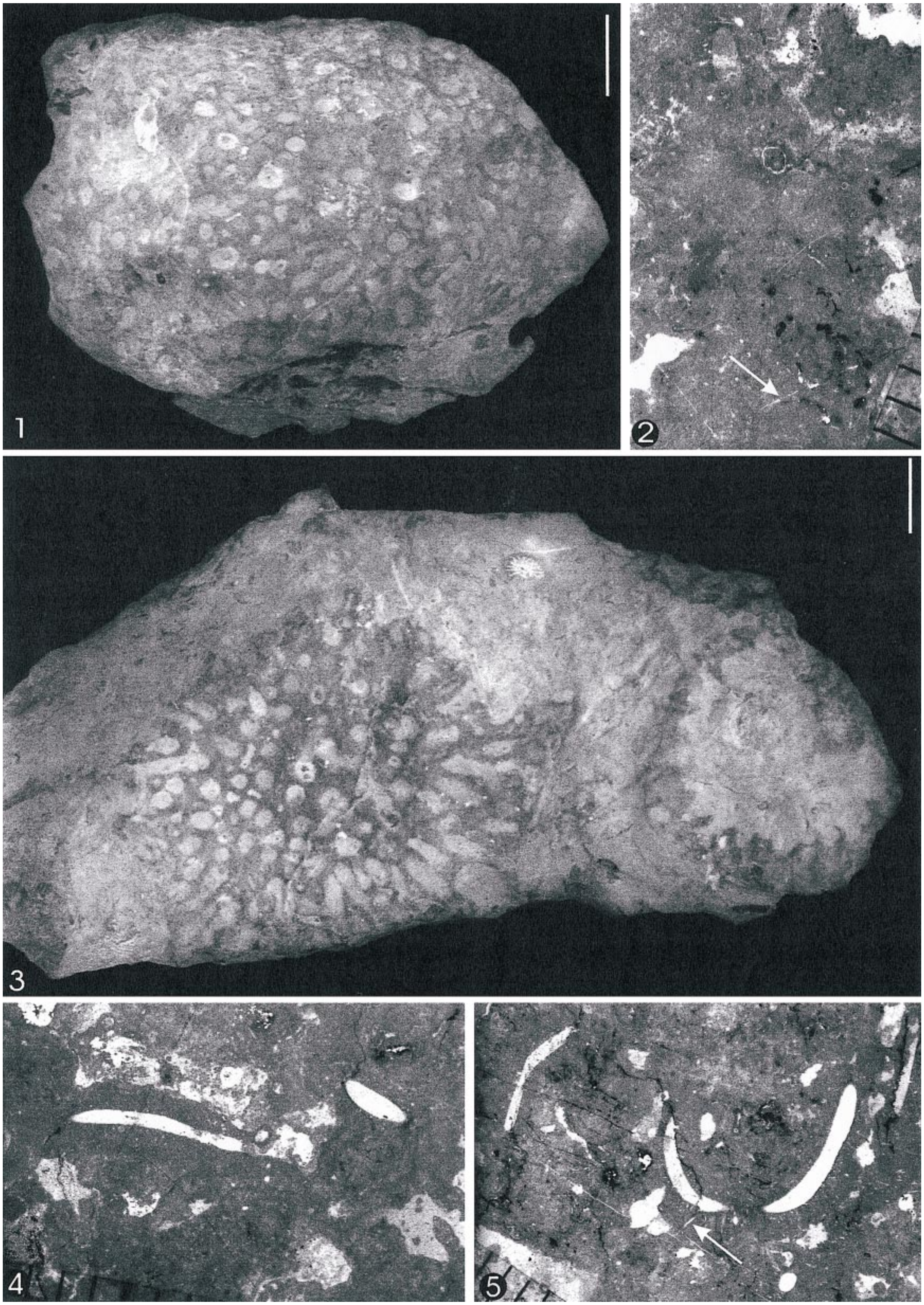


FIGURE 8—*Asturiaspongia aqualiforma* n. gen. and sp., Arnao, Asturias; Aguión Formation, late Emsian, Lower Devonian. *1,* MNCN-I-3565a, holotype, showing the inhalant pores of three different sizes which cover the dermal layer; *2,* MNCN-I-3565a, holotype, detail of thin section, showing irregularly oriented hexactines; *3,* MNCN-I-3565b, paratype, with its two specimens; *4,* MNCN-I-3565a, holotype, detail of thin section, showing interconnected canals; *5,* MNCN-I-3565a, holotype, detail of thin section, showing the disposition of spicules radiating from the canals. Scale: *1, 3,* bar 10 mm; *2, 4, 5,* marks 0.5 mm apart.

Spicules not well preserved in skeletal tracts of calcareous replacement, but overall pattern like that of holotype.

Etymology.—*Aqualis,* Latin, for basin; and *formis,* form or shape, in reference to the bowl-shaped form of the sponge.

Types.—Holotype, MNCN-I-3565a, and paratype, MNCN-I-3565b, as well as a diagonal thin section through part of the wall, and a section of matrix filling the spongocoel made from the holotype, are deposited in the Invertebrate Paleontology collection of the Museo Nacional de Ciencias Naturales (CSIC), Madrid. Paratype includes eroded sections of two different specimens, one appears to be basal part of sponge with distinct radial skeletal and canal structure, and other appears to be upper or oscular margin, possibly of smaller sponge of species (Fig. 8.3). The type specimens were collected at Arnao, Asturias, in the late Emsian (Early Devonian), Aguión Formation (Rañeces Complex), by Dr. Royo Gómez and Dr. Gómez de Llarena in 1934.

Discussion.—Comparisons with related genera have been presented in discussion of the genus, above.

ESTRELLASPONGIA new genus

Type species.—*Estrellaspongia irregulara* new species.

Diagnosis.—Globose, with shallow small spongocoel, with thick walls perforated by irregular, branched, moderately coarse inhalant canals converging to coarse, irregular exhalant canals in interior of sponge wall; interior skeleton of irregularly oriented and spaced small hexactines; with differentiated dermal layer of irregularly spaced, enlarged hexactines with tangential dermal rays irregularly oriented.

Etymology.—Named after the Virgen de la Estrella, which gives the name to the sierra where the sponge was collected.

Discussion.—This is the first pelicaspongiid hexactinellid described from the Lower Carboniferous of Spain, although a representative of the family has been reported from Europe as the small *Prenehydnoceras* Hurcewicz and Czarniecki, 1986 from the Viséan rocks of Poland.

Keriogastrospongia, from the Triassic of China, is similar to the thick-walled *Estrellaspongia*, but it is bowl-shaped, with an open spongocoel into which empty, coarse, moderately uniformly spaced, exhalant canals, and the coarse hexactines of its weak dermal layer are more or less consistently oriented. *Arakespongia*, from Upper Carboniferous Morrowan rocks of Oklahoma, is similar to *Estrellaspongia* in being thick-walled, but it is bowl-shaped and has well-defined coarse canals or parietal gaps that are cross-connected by smaller canals mainly near the gastral surface. Its hypodermalia are coarse and irregularly oriented, as in *Estrellaspongia*, but they have strongly recurved tangential rays. *Pelicaspongia*, from the Frasnian of Alberta, Canada, is a similar bowl-shaped to moderately globose, thick-walled sponge. However, it has relatively simple coarse canals, or parietal gaps, and also has hypogastralia that are thicker and larger than the principal hexactines of the interior skeleton. *Twenhofelella* Rigby, 1974, from the Silurian-Devonian of Quebec and Indiana, is a small, bowl-shaped, thin-walled sponge with enlarged dermalia in the otherwise irregularly arranged, fine-textured skeleton of hexactines.

Vaurealispongia, from the Ordovician-Silurian of Quebec and Indiana, is a similar thick-walled, bowl-shaped sponge with a principal skeleton of irregularly oriented smooth-rayed hexactines, but it has a gastral layer of interleaved enlarged hexactines. *Larispongia*, from the Ordovician of Argentina, is also thick-walled and bowl-shaped, but it has closely spaced parietal gaps and enlarged hexactines in both the dermal and gastral layers of the skeleton.

Other genera in the family are small, have thin walls, and have different shapes ranging from cylindrical to palmate, unlike the thick-walled, irregularly canalled, large globose sponge described here.

ESTRELLASPONGIA IRREGULARA new species
Figure 9.1–9.7

Diagnosis.—Globose, thick-walled, with small, shallow spongocoel; moderately complex irregular canal system, inhalant canals to 2 mm in diameter, converge and increase in diameter inward; exhalant canals commonly 6–8 mm across, but up to 13 mm across. Dermal layer distinct with irregularly spaced and oriented enlarged hexactines. Spicule rays with basal diameters of 1–1.5 mm, and to 14 mm long. Smaller hexactines, oxeas, and styles may be present.

Description.—Holotype globose, thick-walled, approximately 14.5 cm tall and 14.3 × 12.4 cm in maximum diameter at approximately midheight (Fig. 9.2, 9.3), capped by apparently shallow spongocoel, 4 × 3.3 cm across at oscular margin (Fig. 9.1), and approximately 2 cm deep on weathered summit.

Dermal surface relatively smooth, with inhalant ostia small and difficult to identify with certainty on weathered surface. Distinct dermal layer of irregularly spaced enlarged hexactines, with smooth tapering dermal rays (Fig. 9.5–9.7) tangential to that surface and also irregularly oriented. Coarse rays with basal diameters of approximately 1 mm, but range to 1.5 mm in diameter, with observed lengths to 13.8 mm. A few smaller hexactines, with rays 2–4 mm long and basal ray diameters of approximately 0.2–0.4 mm, scattered across dermal surface (Fig. 9.6). In addition, rare spicules, possibly double-pointed oxeas, in outer part of skeleton up to 11.9 mm long and approximately 0.3 mm in maximum diameter. Other associated spicule raylike styles, with one end rounded and the other pointed, to 8 mm long and approximately 1 mm in diameter, but these could be rays of irregularly oriented, coarse, hexactines cut obliquely, for several hexactines at angles to dermal surface appear as three-rayed sections on weathered dermal surface.

Canal pattern moderately complex and irregular (Fig. 9.2), with inhalant canals in outer part of skeleton ranging to 2 mm in diameter throughout holotype (Fig. 9.5). Small diameter, inhalant canals converge and increase in diameter inward, like roots of plant converging toward coarse trunk, and these canals appear to grade into interconnected irregular exhalant canals in inner one-half of sponge. Interior exhalant canals commonly to 6–8 mm across in horizontal section through holotype, at midheight, but locally some exhalant canals to 13 mm across. Even in interior, however, smaller canals intervene between larger openings and help define irregular skeletal tracts only a few millimeters thick.

Paratype fragment weathered, with shallow spongocoel, moderately thick surrounding wall, and irregular canal development throughout wall (Fig. 9.4), and approximately 10–11 cm in diameter and 8 mm high. Central spongocoel with elliptical cross section approximately 7 × 4.5 cm across. Matrix weathered from many canals so openings dramatically demonstrate irregularity of system. Most canals in outer part of wall 1–2 mm in diameter, and those of more gastral part of wall to 3–4 mm across. All with irregular courses and spacing in apparently complex system.

Etymology.—Latin prefix, *in,* meaning not; *regularis*, according to rule, refers to the complex and sinuous canal system.

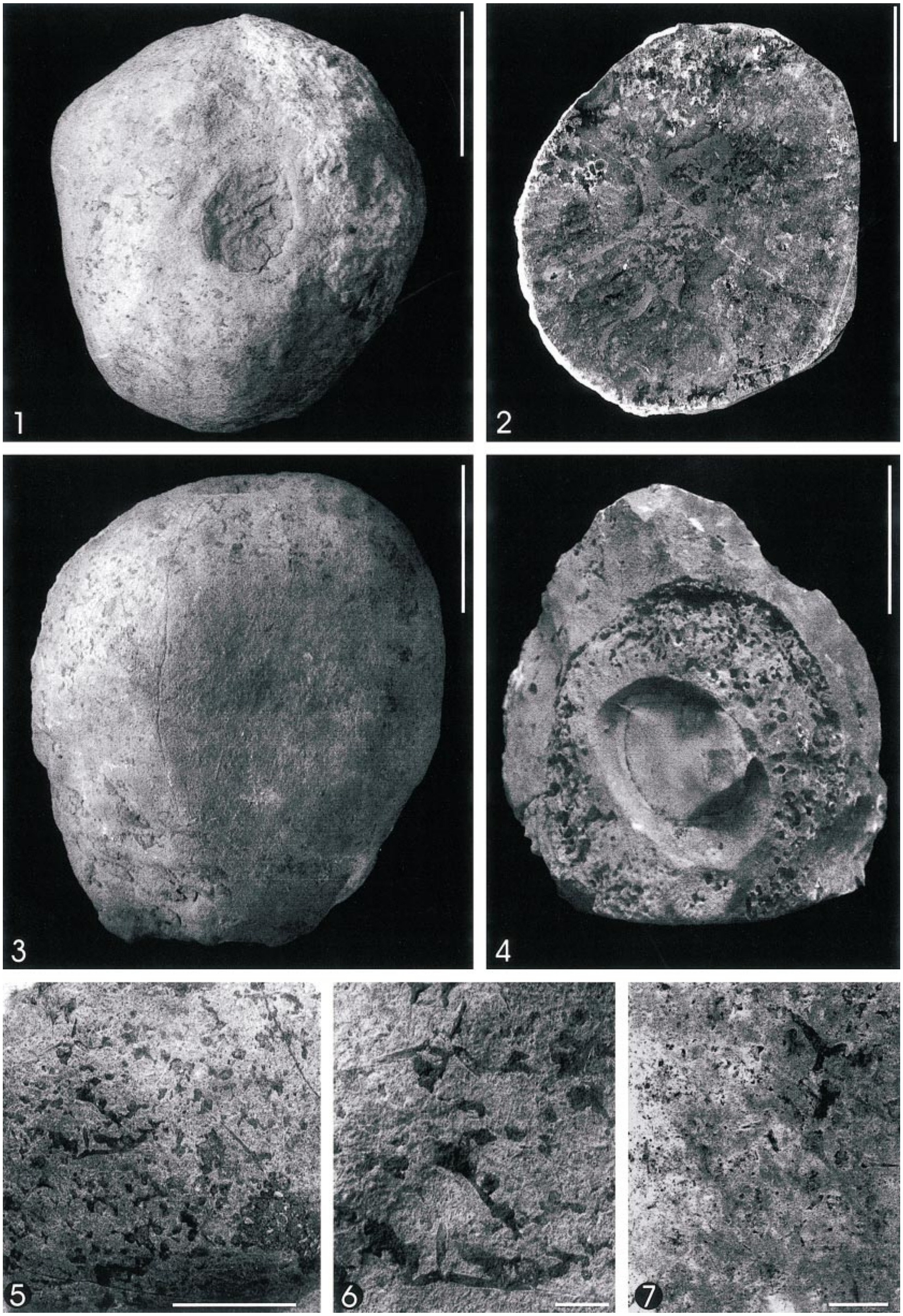
Types.—Holotype, 98 SSEC-1, and paratype, 98 SSEC-2, were both collected by one of the authors from the Sierra de la Estrella, near Espiel, Córdoba, in the Sierra del Castillo Unit, of Asbian/Brigantian age, late Viséan (Early Carboniferous).

Discussion.—Comparisons with related genera have been treated in discussion of the genus above.

HADROPHRAGMOS new genus

Type species.—*Hadrophragmos soleniscus* new species.

Diagnosis.—Bowl-shaped to possibly globose, with thick walls perforated by coarse parietal gaps approximately perpendicular to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gastral and dermal surfaces; skeleton of irregularly oriented and spaced small hexactines; lacks differentiated dermal and gastral layers of enlarged spicules.

Etymology.—Greek, *hadros*, thick or stout; *phragmos*, wall or fence, refers to the thick wall.

Discussion.—*Pelicaspongia*, from the Frasnian of Alberta, Canada, is similar in being a thick-walled sponge with coarse canals or parietal gaps, but it has hypogastralia that are thicker and larger than the principal hexactines of the interior skeleton of the sponge described here. *Arakespongia*, from the Upper Carboniferous Morrowan rocks of Oklahoma, is also similar in being thick-walled, but it has coarse canals or parietal gaps that are cross-connected by smaller canals mainly near the gastral surface, canals that appear to be lacking in the Spanish sponge. It also has large recurved hypodermalia and lacks hypogastralia.

Keriogastrospongia is a similar thick-walled sponge, but has a dermal layer of coarse, consistently oriented, hexactines of general brachiospongiid appearance. *Larispongia*, from the Ordovician of Argentina, is also a thick-walled bowl-shaped sponge, but it has closely spaced parietal gaps and enlarged hexactines in both the dermal and gastral layers of the skeleton.

Twenhofelella, from the Silurian-Devonian of Quebec and Indiana, is small and bowl-shaped with enlarged dermalia in the otherwise irregularly arranged fine-textured skeleton of hexactines. *Vaurealispongia*, from the Ordovician-Silurian of Quebec and Indiana, is thick-walled and bowl-shaped with a principal skeleton of irregularly oriented smooth-rayed hexactines, with interleaved enlarged hexactines in the gastral layer. Other genera in the family are small, have different shapes, and are thin-walled so they should not be confused with the large, thick-walled, sponge described here.

HADROPHRAGMOS SOLENISCUS new species
Figure 10

Diagnosis.—Bowl-shaped, thick-walled; moderately straight parietal gaps generally perpendicular to gastral surface and about 8 mm diameter, but variable; smaller cross-connecting canals may be present. Principal hexactines smooth-rayed, moderately closely packed, with irregular thatched appearance; basal rays diameters of 0.04–0.05 mm and lengths of up to 2 mm. Smaller and larger hexactines less common, irregularly oriented and throughout skeleton.

Description.—Holotype lower central part of bowl-shaped sponge, cut vertically so that internal structure of wall exposed (Fig. 10.1, 10.2). Largest part 10.5 cm wide with wall 6–6.5 mm thick, although dermal surface not preserved and wall could have been thicker. Wall pierced by moderately straight parietal gaps generally perpendicular to gastral surface, to approximately 8 mm in diameter and separated moderately uniformly to 10 mm apart (Fig. 10.3). Diameters of parietal gaps variable because walls rough. Such irregularity suggests smaller canals may cross-connect gaps, but conclusive occurrences not documented. However, transverse section of coarse gap near dermal surface shows that gap connects two adjacent vertical gaps.

Hexactines of skeleton irregularly oriented and spaced (Fig. 10.4–10.6), with most abundant and principal spicules smooth-rayed hexactines with rays where basal diameters 0.04–0.05 mm and lengths may range to 2 mm. Such spicules moderately closely packed in irregular thatched fabric. Relatively rare, finer hexactines, with basal ray diameters of 0.015–0.02 mm, scattered through skeleton. More common coarser hexactines, with rays 0.3–0.4 mm in basal diameter, locally within skeleton as irregularly oriented elements, but not part of either dermal or gastral layer.

Etymology.—Greek, *solen*, pipe or channel, refers to the coarse canals or parietal gaps of the thick wall.

Type.—Holotype, 99VI–9 (A and B), from the San Emiliano Formation, late Bashkirian, Upper Carboniferous, at Villafeliz, León.

Discussion.—Comparisons with related sponges have been treated in discussion of the genus, above. A central part of a large hexactine, with basal ray diameters of 1.1–1.5 mm, occurs as a clast in matrix filling the spongocoel. Lengths of rays are impossible to determine because they are all cut diagonally. Whether this large spicule represents a coarser skeletal layer is unknown because the spicule is isolated.

ASCOSPONGIELLA new genus

Type species.—*Ascospongiella capdevilae* new species.

Diagnosis.—Sack or bag-shaped, moderately thick-walled sponges with broad and deep open spongocoel; walls perforated by straight, radial, closely spaced, parietal gaps or coarse canals cross-connected by smaller canals of relatively uniform dimensions; canals separated by thin walls composed of irregularly oriented hexactines of several ranks; distinct gastral layer locally developed but not uniformly present; dermal layer not developed.

Etymology.—Greek, *ascos*, bag or bladder; and *spongia*, sponge; refers to the globose or bag-shaped form.

Occurrence.—Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous.

Discussion.—Among related pelicaspongiids most genera have distinct dermal layers but lack gastral layers. Perhaps most similar is *Vaurealispongia*, from the Ordovician-Silurian of eastern Canada. It is a bowl-shaped to low vasiform sponge with a well-defined gastral layer of enlarged hexactines, and with circular tubular coarse parietal gaps and smaller canals, which branch or anastomose in the interior of the moderately thick walls. The Spanish genus has only a locally developed gastral layer and its parietal gaps are smaller and cross-connected by smaller distinct tubular canals. *Calicispongia*, from the Devonian of New York, is also a bowl-shaped sponge with enlarged gastral spicules but its skeleton is reported to be composed of layered hexactines and it lacks the coarse canals of the genus described here.

Because most of the available specimens have weathered exteriors, it is difficult to determine whether a dermal layer of enlarged spicules was regularly developed or not. However, a few areas have matrix covering parts of exteriors of some sponges, but these sections do not show enlarged dermal spicules. If such were ultimately discovered in *Ascospongiella* n. gen. its relationship to the thin-walled Devonian *Pelicaspongia*, which

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FIGURE 9—*Estrellaspongia irregulara* n. gen. and sp., Sierra de la Estrella, Córdoba; Sierra del Castillo Unit, Asbian/Brigantian, late Viséan, Lower Carboniferous. *1,* 98SSEC–1, holotype, apical view, showing the central position of the osculum, infilled with sediment; *2,* 98SSEC–1, holotype, transverse section at midheight, showing the intricate net of canals that make up the canal system; *3,* 98SSEC–1, holotype, lateral view, with osculum at the top; *4,* 98SSEC–2, paratype, showing the sinuous canal system and the matrix-filled spongocoel; *5,* 98SSEC–1, holotype, detail of the external (dermal) wall, with pores and spicules; *6,* 98SSEC–1, holotype, detail of the hexactines of the dermal layer. These spicules have been obliquely eroded, losing their hexaradial symmetry; *7,* 98SSEC–1, holotype, detail of the dermal layer with some hexactines. Scale bar: *1–4,* 50 mm; *5,* 25 mm; *6, 7,* 5 mm.

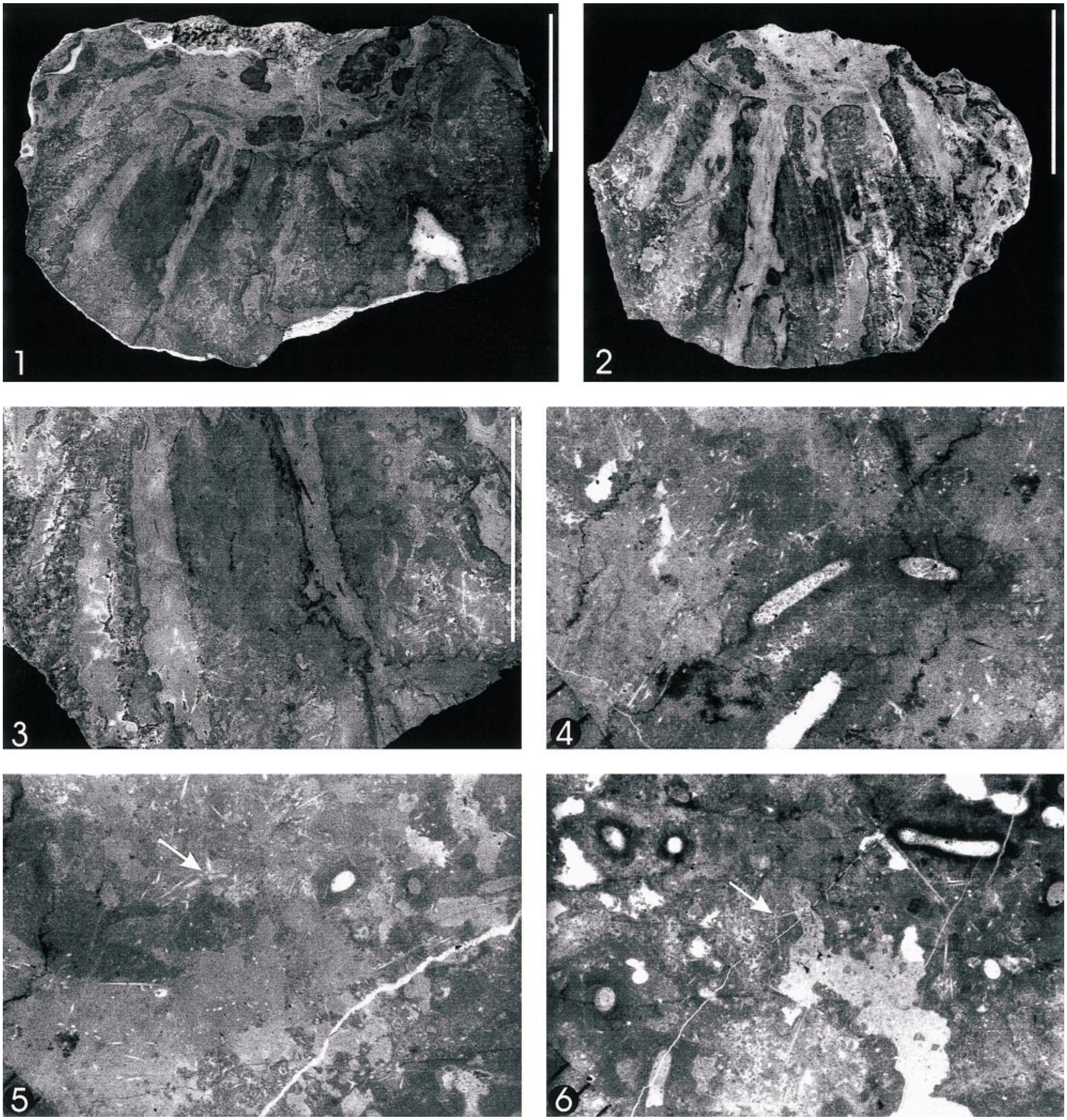


FIGURE *10*—*Hadrophragmos soleniscus* n. gen. and sp., Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *1,* 99VI4–9B, holotype, polished section, showing the matrix-filled spongocoel in the upper part of the image; *2,* 99VI4–9A, holotype, polished section with distinct straight canals perpendicular to the body wall; *3,* 99VI4–9B, holotype, detail of polished section, showing the wide canals cross-connected by smaller irregular canals; *4,* 99VI4–9A, holotype, detail of thin section A, with diagonal sections of rays of numerous, small, irregularly spaced and oriented, light-colored, hexactines; *5,* 99VI4–9A, holotype, detail of thin section A, showing several large hexactines and smaller diagonal ray sections; *6,* 99VI4–9A, holotype, detail of thin section B, where long spicule rays (larger than 15 mm in the upper right) and dark microborings have been cut. Scale: *1–3,* bar 10 mm, *4–6,* marks 0.5 mm apart.

has enlarged hexactines in both gastral and dermal layers, would need to be reviewed. However, there is no suggestion of a coarse dermal layer in the moderately thick-walled sponge described here, and for that reason the two forms are differentiated. The same is true of *Larispongia*, from the Ordovician of Argentina, for it has both gastral and dermal layers and parietal gaps that have thin separating skeletal elements, as in *Ascospongiella* n. gen.

Other genera in the family have different forms, are thin-walled, or lack a gastral layer in their skeletons.

ASCOSPONGIELLA CAPDEVILAE new species
Figure 11

Diagnosis.—Moderately thick-walled, globose to sack-shaped sponges with deep open spongocoel; walls perforated by numerous parietal gaps or coarse canals, 1.3–2.0 mm in diameter, that lead directly through wall and cross-connected by tubular smaller canals; skeleton of irregularly oriented and spaced small hexactines and hexactine-derived spicules of several ranks that range 0.02–0.03 to 0.09–0.12 mm in basal ray diameters; with locally developed distinct gastral layer of enlarged hexactines with tangential gastral rays irregularly oriented and approximately 0.20 mm in basal diameter.

Description.—Sack-shaped, elongate to round (Fig. 11.6); from 8 cm tall and 6.8 cm in maximum diameter, at midheight, to 27 cm tall and 17.7 cm in diameter or 30 cm tall and 20 × 22 cm in diameter in largest specimen. Holotype 13 cm tall with weathered maximum diameter of 9.5 cm (Fig. 11.1), with much of one wall eroded from probable original diameter of over 10 cm. Open circular osculum caps each sponge, ranges from 20 mm (30 mm across in holotype) to 90 mm in diameter; osculum 15 mm in diameter caps deep spongocoel in subcylindrical paratype (12 cm high).

Walls smooth, generally thin upward from maximum basal thicknesses 15–25 mm, to midheight and upper thicknesses of 10–15 mm. Paratype walls 30–60 mm thick around osculum, pierced by parietal gaps (Fig. 11.2) generally normal to gastral and dermal surfaces moderately straight, cylindrical, 1.3–2.0 mm in diameter. Gaps locally cross-connected by smaller tubular canals 0.8-l.0 mm in diameter, 0.5–2.0 mm apart, separated by walls only approximately 0.5 mm thick, or thicker elements to 2 mm thick, interrupted by smaller cross-connecting canals.

Skeletal tracts of irregularly oriented and spaced hexactines of several ranks (Fig. 11.3, 11.4) now largely calcareous impressions, although rare isolated coarse spicules silicified. Coarsest spicules irregularly developed, or preserved, in gastral layer, observed only in scattered sections of polished paratypes. These spicules with basal ray diameters of 0.2 mm and main rays tangential to gastral surface but at irregular angles. Coarsest interior spicules with ray diameters of 0.09–0.12 mm, and ray lengths of at least 2 mm (Fig. 11.5). Intermediate spicules with ray diameters of 0.06–0.08 mm and rays at least 0.6 mm long. Smallest moderately well-preserved spicules in calcareous replacements with ray diameters of 0.02–0.03 mm and ray lengths of at least 0.4 mm. Ghosts of even smaller spicules locally preserved in relatively uniform-textured skeletal tracts. All ranks of interior spicules irregularly oriented and spaced, although some intermediate spicules locally rectangularly arranged, as in sections, around some fine canals (Fig. 11.5, 11.6).

Etymology.—In memory of Dr. María Paz Capdevila, mother of one of the authors (DCGB).

Types.—Holotype, 99VI-7 (A and B), and paratypes 99VI-1 to 6, 8, 10 to 17, 19, 20, 22, 24, 25, 27, 28, 30 to 33, 36 to 40, 42 to 47, 56, 62, 64, 66, 67 (A and B), 73, 74, 96, 2000VI-1, 2, 3, 5 are all from the San Emiliano Formation, late Bashkirian, Upper Carboniferous, at Villafeliz, León.

Discussion.—Comparisons with related sponges have been treated above in discussion of the new genus.

Order RETICULOSA Reid, 1958
Superfamily PROTOSPONGIOIDEA Hinde, 1887
Family PROTOSPONGIIDAE Hinde, 1887

Type genus.—*Protospongia* Salter, 1864.

Emended diagnosis.—Vasiform or spheroidal; skeletal net essentially single layer or thin multiple layers of stauractines and/or pentactines, together with possible rhabdodiactines in some species; spicules typically in parallel arrangement, largest usually in quincuncial arrangement (but sometimes in overlapping quadrate arrangement), smaller spicules of several orders of size subdivide quadrules thus formed, in nonoverlapping quadrate arrangement; however, spicules may be irregularly arranged in some genera; parietal gaps may be present; prostalia (rhabdodiactines?) may be strongly developed about osculum and may project from entire surface; basalia often developed.

Occurrence.—Middle Cambrian-Lower Devonian.

Genus IBEROSPONGIA new genus

Type species.—*Iberospongia globulara* new species.

Diagnosis.—Globular to subspherical, thin-walled, with single-layered lyssacid skeleton of quadrately arranged hexactines that increase in size upward from slightly invaginated base to maximum diameter of sponge, at midheight, as first-order spicules with unfused overlapping rays, second-order hexactines above midheight; upper part of skeleton converging toward oscular margin, but osculum not exposed so nature unknown; coarse basal root tuft developed.

Etymology.—Latin *Iberus*, designated things or people from Iberia, now Spain and Portugal.

Discussion.—Nature of the quadruled skeleton of hexactines suggests that the new small genus should be included within the Protospongiidae. Most genera included in the family are steeply obconical to cylindrical, but a few are ovoid, at least as flattened. For example *Actinodictya* Hall, 1890, from the Devonian of New York and Pennsylvania, is an ovoid form, but it is large and has a skeleton of interlaced spicule bands rather than a quadruled structure. Some examples of *Diagoniella* Rauff, 1894, from the Middle Cambrian to Silurian of Canada, the United States, and Portugal, are ovoid and have quadruled skeletons, but their skeletal pattern is diagonal to principal axes of the sponge, rather than parallel, as in this new genus. *Triticispongia* Mehl and Reitner, 1993, from the Lower Cambrian (Tommotian) of China, is a small ovate sponge, as flattened, but it too has quadrules diagonal to the principal axes of the sponge. *Saetaspongia* Mehl and Reitner, 1993, also from the Lower Cambrian (Atdabanian) of China, is also a small circular sponge, as flattened, but it has a skeleton made principally of plumose diactines, with a few associated small hexactines.

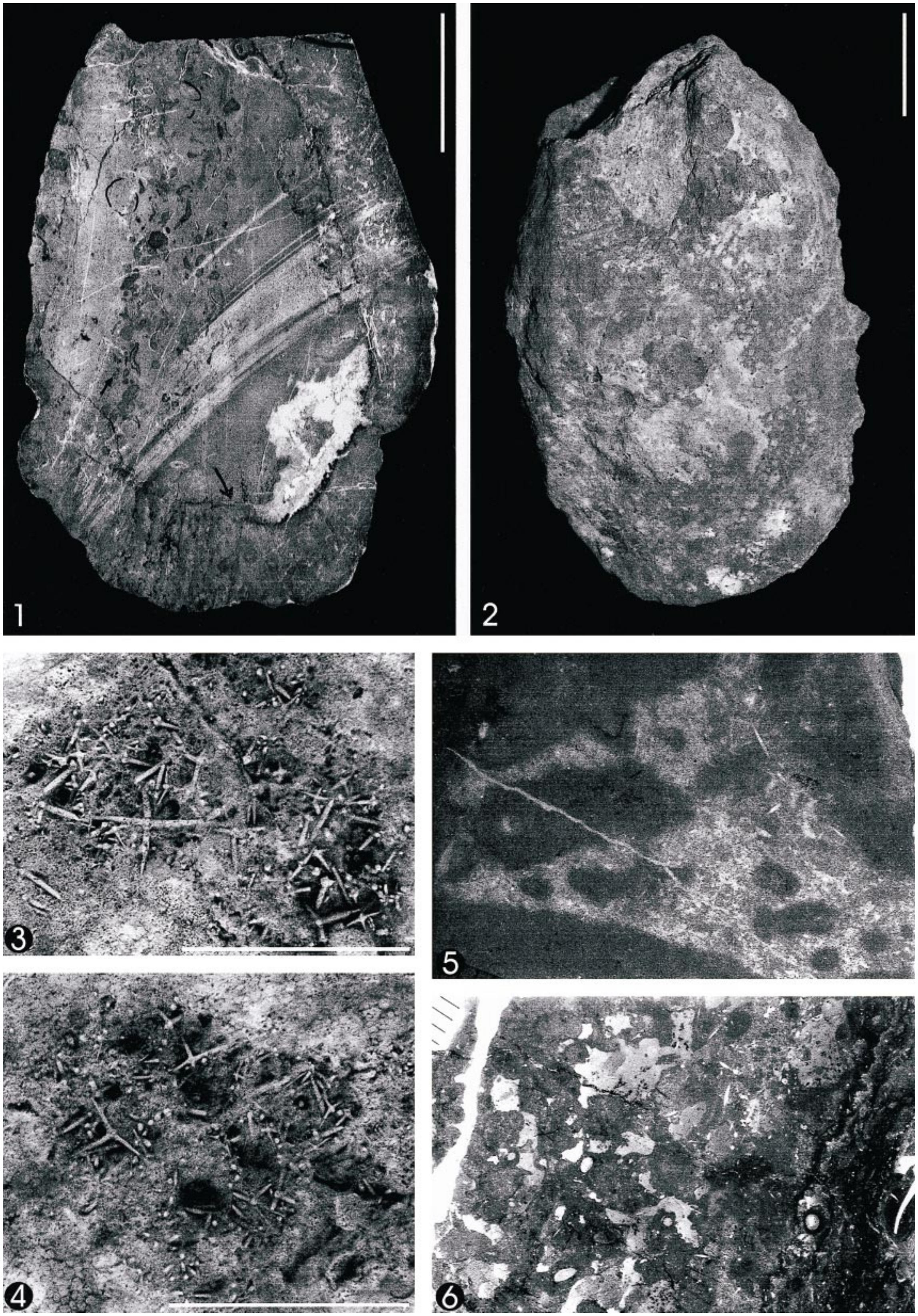
Protospongia iberica Rigby, Gutiérrez-Marco, Robardet, and Piçarra, 1997, from the Silurian of Portugal, is a bowl-shaped protosponge, but it is much larger than *Iberospongia* n. gen. In addition, it has a much coarser skeleton, with first-order quadrules 5–6 mm high and 3.5–4.5 mm wide, several times larger than in the skeleton of *Iberospongia* n. gen. described here.

IBEROSPONGIA GLOBULARA new species
Figure 12

Diagnosis.—Small, ovoid to subspherical, thin-walled; upward-expanding skeleton of quadrately arranged hexactines with overlapping, but unfused, vertical and horizontal tangential ray tips, radial rays well defined; spicule size and quadrule size increasing to midheight; second-order hexactines in upper part; root tuft in central basal part.

Description.—Holotype small, round (Fig. 12.1), with ovoid vertical section (Fig. 12.3), but oscular margin buried in matrix, with maximum diameter 14–14.5 mm at midheight, and 7.5 mm high, as exposed.

Skeleton preserved largely as molds of quadrately arranged hexactines, forming regular upward-expanding rectangular structure produced by longitudinal vertical rays and latitudinal horizontal rays (Fig. 12.2). Proximal rays of hexactines preserved as pointed holes in matrix (Fig. 12.2, 12.4), and bases of distal rays locally preserved as circular openings out from ray junctions of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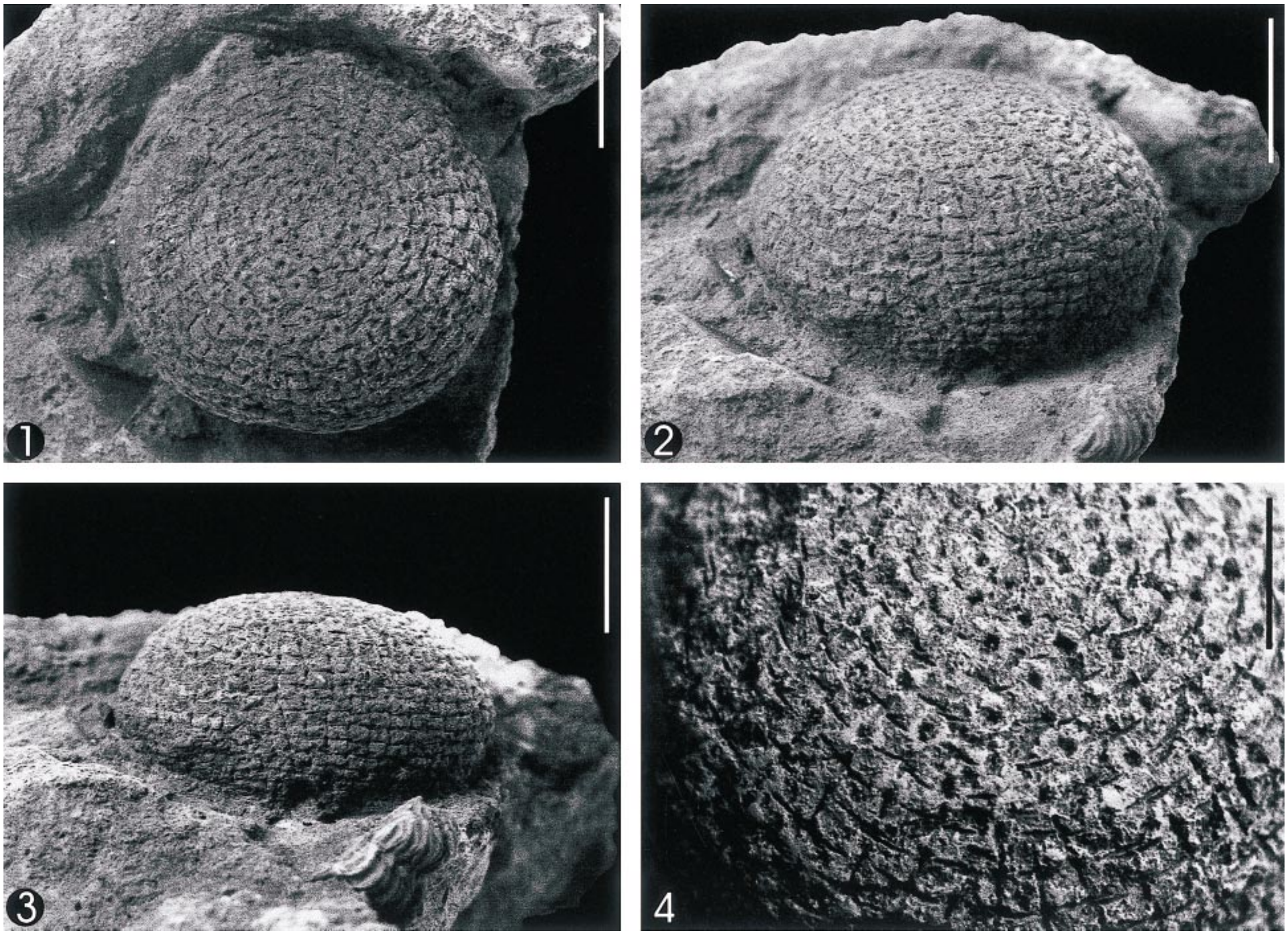

FIGURE 12—*Iberospongia globulara* n. gen. and sp., Polentinos, Palencia; Cortés Member, Abadía Formation, late Zlichovian, Emsian, Lower Devonian. *1,* POL1–1, holotype, aboral or polar view, showing circular outline; *2,* POL1–1, holotype, oblique view, showing hexactines-defined quadrules; *3,* POL1–1, holotype, lateral view, showing the ovoid outline; *4,* POL1–1, holotype, detail of the ''polar'' region, showing the holes left by the dissolved proximal rays of the hexactines. Scale bar: *1–3,* 10 mm; *4,* 5 mm.

spicules. Tangential rays of adjacent spicules not fused, but overlapping and parallel to one another to define quadrules throughout skeleton.

Skeleton radiating uniformly upward and outward from basal ''polar'' region where approximately 16 radial and upward-aligned series of hexactines recognizable 1 mm out from pole. Other vertical series of hexactines inserted between early developed series, beginning 2–3 mm from ''pole'' so 32–36 vertical rows of spicules on sides at midheight.

Spicules in basal part of skeleton with tangential rays approximately 0.4–0.5 mm long and basal ray diameters of approximately 0.05 mm. Holes produced by solution of proximal rays of same general diameter. Spicules near ''pole'' smaller and details of molds poorly preserved but defining quadrangles 0.5–0.6 mm high in basal region (Fig. 12.4). Spicule size increasing radially, so at midheight, tangential horizontal rays 0.7–0.8 mm long and vertical tangential rays 0.5–0.6 mm long, both with basal diameters of 0.06–0.07 mm, tapering smoothly to sharp tips. Skeletal quadrangles 0.6–0.7 mm high and 1.0–1.1 mm wide at midheight on sponge.

Second-order spicules inserted in skeleton in inward-sloping walls of sponge, where quadrangles only 0.4–0.5 mm high and wide, only half size of quadrangles in lower equatorial part of skeleton.

Larger deep cylindrical openings in matrix in basal part (Fig. 12.1, 12.4); coarse root tuft spicules forming stalklike central cluster. These impressions 0.2–0.25 mm in diameter and irregularly approximately 0.5 mm apart in ''polar'' region.

Etymology.—Latin *globulus*, diminutive for ball or bead, in reference to the shape of this sponge.

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FIGURE 11—*Ascospongiella capdevilae* n. gen. and sp., Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *1,* 99VI–7A, holotype, longitudinal section of the specimen, showing the wide open spongocoel and the thickness of the body wall; light-colored, arched, diagonal lines are saw marks; *2,* 99VI–12, paratype, complete specimen, with pores and spicules covering most of the dermal wall; *3,* 99VI–40, paratype, detail of hexactines of various sizes in dermal part of skeleton; *4,* 99VI–40, paratype, detail of pores of two sizes in an area with abundant spicules; *5,* 99VI–7, holotype, thin section where the skeletal tracts are easily distinguished by the presence of light-colored spicules, and canals by their fillings of dark matrix; *6,* 99VI–7, holotype, thin section, with abundant light spicules, mostly hexactines cut at odd angles, in dark tracts, and small, light gray irregular canals. Scales: *1, 2,* bar 50 mm; *3, 4,* bar 5 mm; *5, 6,* ×5.

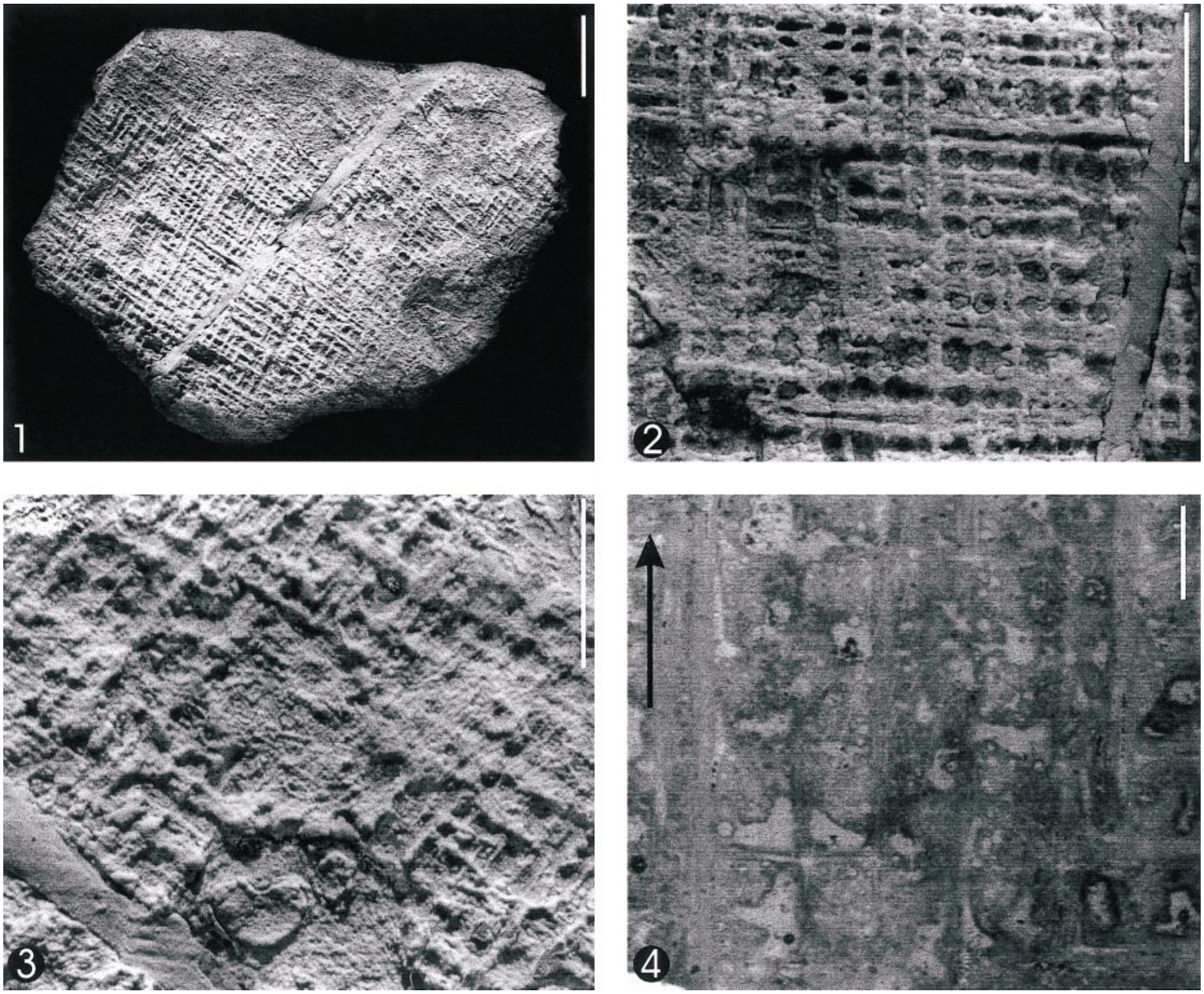

FIGURE *13—Stereodictyum orthoplectum* Finks, 1960, Las Pilitas 2, Badajoz; Asbian/Brigantian, late Viséan, Lower Carboniferous. *1,* LP2/8–1, specimen whitened with magnesium, gastral surface; *2,* LP2/8–1, detail of whitened specimen, showing the pores located between the orthogonally arranged bundles of spicules; *3,* LP2/8–1, detail of whitened specimen with light from a different orientation, which shows the relief of the individual spicules forming the bundles; *4,* LP2/8–1, detail of thin section, showing the lyssacine arrangement of the internal hexactines; arrow points to gastral surface. Scale bar: *1,* 10 mm; *2, 3,* 5 mm; *4,* 1 mm.

Type.—Holotype, and only known specimen, POL1–1, was collected at Polentinos, Palencia, from early Devonian Emsian (late Zlichovian) Cortés Member of the Abadía Formation by Luis Saráchaga and Conchita Segura and was donated to the UCM.

Discussion.—Comparisons with related sponges have been presented in discussion of the genus above.

Superfamily DICTYOSPONGIOIDEA Hall and Clarke, 1899
Family STEREODICTYIDAE Finks, 1960
Genus STEREODICTYUM Finks, 1960

Type species.—*Stereodictyum orthoplectum* Finks, 1960.

Occurrence.—Viséan, Lower Carboniferous—Wolfcampian and Leonardian, Lower Permian.

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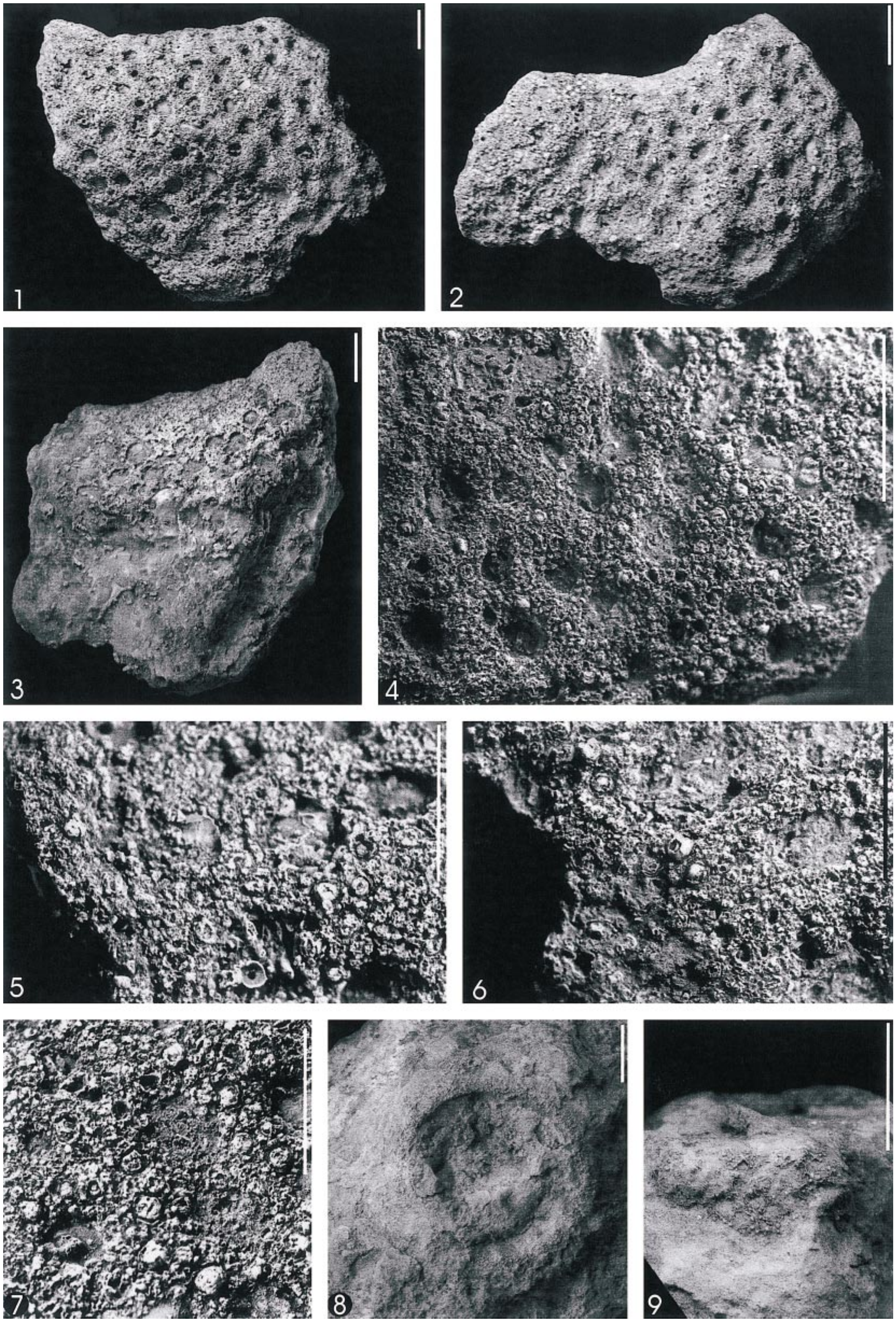
FIGURE *14—Stioderma* Finks, 1960. *1–7, Stioderma perforata* n. sp., Vergaño, Palencia; Vergaño Formation, late Moscovian, Upper Carboniferous. *8, 9, Stioderma* sp. A, Villafeliz, León; San Emiliano Formation, late Bashkirian, Upper Carboniferous. *1,* 99VR4–20, holotype, view of the dermal layer (external), showing inhalant pores of various sizes; *2,* 99VR4–21, paratype, view of the dermal layer, also densely perforated; *3,* 99VR4–20, holotype, view of the upper layer, with large parietal gaps; *4,* 99VR4–20, holotype, detail of the dermal layer showing the spicule arrangement between the pores; *5,* 99VR4–20, holotype, detail of the spicules of the dermal layer with the characteristic swollen distal rays of the hexactines; *6,* 99VR4–21, paratype, also showing the peculiar swollen hexactines of the Family Stiodermatidae; *7,* 99VR4–21, paratype, detail of a couple of small pores, surrounded by the swollen rays of the dermalia; *8,* 99VI–48, apical view of the specimen, showing the circular osculum in its center; *9,* 99VI–48, detail of the spicules arranged around the oscular margin, some of which also show their swollen distal rays. Scale: *1–4, 8, 9,* bar 10 mm; *5–7,* bar 5 mm.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STEREODICTYUM ORTHOPLECTUM Finks, 1960
Figure 13

Stereodictyum orthoplectum FINKS, 1960, p. 108–110, pl. 37, figs. 1–8; pl. 38, figs. 1–7, text-fig. 73.

Description.—Single flat fragment of sponge wall, approximately 10 mm thick, 58 mm high, and 50 mm across (Fig. 13.1), with gently upward divergent, rectangularly arranged skeleton of layered distinct bundles (Fig. 13.2, 13.3). Layers of vertical bundles alternating with layers of horizontal bundles at approximate right angles to each other (Fig. 13.4). Third series of radial bundles roughly at right angles to these layers and helps form three-dimensional lyssacine skeleton, where bundles of all three series in mutual contact.

Horizontal tangential bundles 0.2–0.8 mm, with most 0.4–0.5 mm in diameter, and commonly 0.6–0.8 mm apart (Fig. 13.3). Vertical bundles 0.02–0.6 mm in diameter, smallest where first inserted, or recognizable, as branched element, thickening upward to average diameters of 0.4–0.5 mm, but becoming larger near or below where new bundles initiate or branch from earlier-formed ones. Radial bundles commonly 0.4–0.5 mm in diameter and 0.2–0.8 mm apart, with most 0.5 mm apart. Pores or canal openings between the reticulate bundles cylindrical to suboval in cross section, 0.2–0.8 mm in diameter (Fig. 13.2).

Individual bundles including 20–25 closely packed, side-by-side, spicule rays in cross section near bundle junctions (Fig. 13.4). Individual rays average approximately 0.10 mm in diameter, but range to 0.15 mm in basal ray diameters in coarsest hexactines, with ray junctions near bundle junctions or contacts. Spicule rays to 3 mm long (thin section), but complete rays rarely identified in closely packed, parallel structure.

No series of distinctly larger openings traceable in fragment, although some pores larger in vertical series immediately below where new vertical bundles inserted in vertical growth of sponge.

Fragment faintly concave so exposed surface may have been gastral, but with no other definitive indications of dermal-gastral orientation. No specialized dermal or gastral layers evident.

Material examined.—A single fragment, LP2/8–1, from which a thin section was made, is from Asbian/Brigantian beds, Viséan (Lower Carboniferous), at Las Pilitas 2 (Badajoz). The specimen was collected by S. Falces and donated to the authors for study.

Discussion.—The Viséan occurrence is the oldest reported for the genus and it is also the first report of the genus from Europe, although it has been reported from the Moscovian (Upper Carboniferous) of China (Rigby et al., 1999) and from the Lower Pennsylvanian of Nevada (Rigby and Washburn, 1972) outside of the type area of the Texas-New Mexico region in the United States. Measurements and general structure of the Spanish specimen are similar to the type species, described from the Wolfcampian and Leonardian (Lower Permian) of western Texas (Finks, 1960, p. 108–110). Openings between the bundles are larger in the Texas material, but not of a range that would suggest the fragment described here is of a different species, even though of an older age.

The Spanish sponge lacks the dermal(?) layer distinctive of *Stereodictyum proteron* Rigby and Washburn, 1972 from Nevada as well as the large monaxial, possibly root tuft, spicules. Packing of spicules within bundles was observed to be loose in the Nevada species, in contrast to the close packing in the specimen described here, but possibly more distinctive are the large canals, to 2.0 mm in diameter in the Nevada species, that are not developed in this Spanish specimen.

The Chinese specimens of *Stereodictyum proteron* are finer textured (Rigby et al., 1999), with seven to eight bundles per 5 mm in the larger specimen, measured both vertically and horizontally, but has only five to six bundles per 5 mm in smaller fragments, like the spacing in the present specimen.

In paleobiogeographical terms, the taxon may have originated during the Early Carboniferous in or near Spain, later extending west into Euramerica, where it survived until the Permian, but did not extend north of the equator. Later in the Early Carboniferous, a new species, possibly derived from the North American stock, extended towards the equator, crossing it and expanding north and west along the Euramerican coast, through colder waters, and reaching North China, in the northern rim of the Paleotethys Ocean, during the Moscovian (Late Carboniferous).

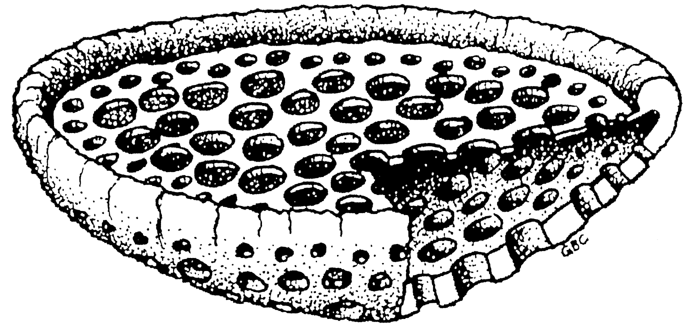

FIGURE 15—Restoration of *Stioderma perforata* n. sp.

Superfamily BRACHIOSPONGIOIDEA Finks, 1960
Family STIODERMATIDAE Finks, 1960

Type genus.—*Stioderma* Finks, 1960.

Occurrence.—?Upper Cambrian, Lower Carboniferous-Upper Permian.

Discussion.—Finks (1960, p. 132) included *Stioderma* Finks, 1960, which he interpreted as including part of *Hyalostelia* Zittel, 1878, ?*Hyalostelia* Zittel, 1878, in part, and ?*Rhakistella* Weller, 1930 in the family.

Genus STIODERMA Finks, 1960

Type species.—*Stioderma coscinum* Finks, 1960.

Occurrence.—Lower Carboniferous-Upper Permian.

STIODERMA PERFORATA new species
Figures 14.1–14.7, 15

Diagnosis.—Thick-walled, bowl-shaped, with distinct coarse parietal gaps in outer and upper wall; upper wall forming cap over broad spongocoel; walls of irregularly oriented hexactines; outer wall with dermal layer of hexactines, with swollen hemispherical distal rays; exhalant parietal gaps in upper wall more closely spaced and larger than in lower and outer wall; dense rim above junction of upper and outer walls, lacking parietal gaps.

Description.—Holotype part of lower outer wall of bowl-shaped sponge, part of upper inner wall, or ''ceiling,'' bridging spongocoel, and part of upper dense rim extending above junction of upper inner wall and outer wall (Figs. 14.1, 14.3–14.5, 15). Specimen extending approximately 6.5 cm along gently curved rim, including adjacent fragment of upper ''ceiling'' wall (Fig. 14.3), approximately 12–14 mm wide; rectangular fragment of upper outer wall approximately 7.3 cm high and 5 cm across (Fig. 14.1). Paratype part of outer wall as irregular fragment 14 cm long and 7 cm across (Fig. 14.2).

Outer wall, 12–13 mm thick in holotype, perforated by small parietal gaps 2.0–3.0 mm in diameter in upper part, but grading to 4–6 mm in diameter in lower parts, where gaps moderately uniformly 3–5 mm apart, though not in rows (Fig. 14.4). Most distinctive dermal spicules hexactines with swollen spherical distal nodes 0.7–1.4 mm in diameter, formed of concentric microlaminae (Fig. 14.5) 0.005–0.01 mm thick. Nodes perched on short basal distal rays 0.2–0.3 mm in diameter. Smaller second-order spherical nodes 0.4–0.7 mm in diameter cap distal rays of smaller hexactines that fill spaces between larger first-order spicules, to produce relatively dense outer layer of skeleton.

Upper ''ceiling'' wall over spongocoel 5–8 mm thick along preserved margin, perforated by large circular parietal gaps mainly 4–5 mm in diameter, and smaller ones 2–3 mm across between larger gaps and in transition margin from dense upper rim, which lacks gaps. Gaps in transition zone in row where eight gaps occur per 50 mm. Next row of larger openings also moderately regularly spaced, in alternating positions, as is less complete third row at broken margin of fragment. Thin walls separate gaps and range one to two spicules to many spicules thick and to 2–3 mm across. These elements generally silicified, however, and their spicular structure not well preserved. Some hexactine spicules with rays tangent to gap surfaces preserved; most such with rays approximately 0.10 mm in diameter, although some up to 0.20 mm across.

Upper dense rim 8–10 mm high (Fig. 14.3), above junction of gap-bearing walls, lacking parietal gaps, but with numerous small canals, between spicule rays, 0.18–0.23 mm in diameter, with most approximately 0.20 mm across in upper part, increasing to 0.5–0.7 mm in diameter in lower transition zone (3–4 mm wide), and adjacent to gap-bearing upper wall.

Spicules of upper rim thick-rayed hexactines, with proximal-distal rays perpendicular to surface. Tangential rays irregularly oriented, even in gastral layer and in smaller spicules throughout. Upper surface lacks major spheroidal distal nodes, so prominent in dermal layer of lower outer wall, although distal rays of few spicules expanded as stubby, rounded truncated rays that taper radially, with basal ray diameters of 0.12–0.16 mm, and lengths of 1.0–1.5 mm. Exposed upper surface packed with rounded tips of distal rays 0.15–0.20 mm in diameter, commonly preserved as outer crusts with solid rods that mark cepidal canals. Other ray parts often missing or show laminar structure. Underlying interior spicules and some interlayered smaller ones also preserved as hollow crusts with ray diameters of approximately 0.10 mm and commonly secondarily fused and silicified.

Spicules of upper edge and distal surface of rim with spheroidal distal nodes to 0.6–0.7 mm in diameter, although most only 0.3 mm in diameter or smaller. These rays commonly side-by-side in compact skeleton.

Paratype (Fig. 14.2, 14.6, 14.7) with numerous parietal gaps in compact skeleton as funnellike depressions 3–5 mm in diameter at top and 1.8–2.2 mm across where filled with matrix at approximately midwall (Fig. 14.6), spaced moderately uniformly 5–7 mm, center to center. Coarse canals, 1.0–1.5 mm in diameter, scattered between gaps but relatively rare. Additional ill-defined and irregularly distributed ostia of canals, 0.2–0.4 mm in diameter, occur between larger openings.

Dermal layer of skeleton with prominent and relatively large hemispherical knobs of distal rays of outer hexactines (Fig. 14.7), approximately 1 mm or less apart, and 0.8–1.5 mm in diameter, with most 0.8–1.0 mm across. Smaller nodes, 0.3–0.5 mm in diameter, between outer hexactines, range from side-by-side to 0.3 mm apart as laminated knobs. Other rays, such as tangential rays, not well differentiated in dermal layer, but as irregularly oriented elements in weathered interior of wall.

Etymology.—Latin *per*, prefix meaning through, *forare*, to bore; related to the numerous wide pores crossing the dermal and upper walls.

Types.—Holotype, 99VR4–20, and paratype, 99VR4–21, were collected at VR4, close to Vergaño, Palencia, (Fig. 1), from the 1,600 level of the Vergaño Formation, late Moscovian, Upper Carboniferous.

Discussion.—Fragments of the sponge suggest that it was a broad, relatively low, bowl-shaped species with a coarsely perforated wall that probably extended across the mouth of the bowl (Fig. 15). The coarse parietal gaps in that ''ceiling'' suggest that the sponge did not have an osculum, but that the gaps functioned as exhalant openings from the broad spongocoel, just as the smaller gaps and canals functioned as inhalant openings in the lower and lateral walls. The upper coarsely perforate part of the sponge is distinctive of the species, particularly when coupled with the characteristic spicule structure of the outer dermal layer and dense rim.

Stioderma coscinum has similar spicule structure and development of parietal gaps. Those gaps in the North American type material all 0.3–6.0 mm in diameter and their spacing of 0.5–9.0 mm overlaps the observed range of gaps and spacing in the Spanish sponge, where gaps appear to be primarily of two distinct sizes, 2–3 mm and 4–5 mm in diameter on the ''ceiling'' and 3–5 mm and 4–6 mm in diameter in the lower outer wall of the bowl-shaped sponge. In addition, *S. coscinum* apparently lacks the probable ''ceiling'' to the spongocoel and the associated dense oscular rim typical of *S. perforata* n. sp. The basal root tuft, developed in *S. coscinum*, is not evident in *S. perforata* n. sp., but our specimens are all relatively small and may be of only the upper part of the sponge. Large dermal spicules in the North American species are reported to have spherical knobs approximately 1.0 mm in diameter and smaller ones to have knobs approximately one-quarter that size. Similar dermal spicules in the Spanish species have coarser knobs that range 0.8–1.5 mm and 0.3–0.5 mm in diameter, although those differences are probably only of minor taxonomic significance.

STIODERMA new species A
Figure 14.8, 14.9

Diagnosis.—Low globe- to bowl-shaped, with narrowed oscular rim surrounded by thin dense upper rim of wall, basal part unknown; wall perforated by numerous ostia, 0.8–1.2 mm in diameter, as interruptions in irregular skeleton of irregularly oriented hexactines of several sizes, but with large dermal spicules with swollen nodular distal rays; nodes of various sizes to 0.5 mm in diameter; tangential hexactine dermal rays to 3 mm long and with basal ray diameters to 0.2 mm.

Description.—Holotype is rim and upper part of wall of bowl-shaped sponge at least 5 cm in diameter, as exposed, but possibly much larger (Fig. 14.8). Upper dense wall around round osculum forming rim 4–5 mm thick of closely spaced hexactine and hexactine-derived spicules. Rim armored by densely packed, spheroidal, distal nodes of hexactines of various sizes (Fig. 14.9), where best preserved. These nodes to 0.5–0.6 mm in diameter, although nodes of many smaller spicules, 0.2–0.3 mm in diameter, help form nearly solid layer. Parietal gaps lacking in rim, but common in lower wall. Parietal openings in main wall round to rounded quadrate, 0.8–1.2 mm in diameter, separated by single spicule rays or tracts to 0.5 mm wide. Smaller circular ostia of canals, 0.5–0.7 in diameter, in tracts between larger gaps, help produce open-textured wall.

Spicules irregularly oriented hexactines range from small spicules, with rays only 0.5 long and basal ray diameters of 0.05 mm, to second-order spicules with rays 1.0–1.2 mm long and 0.15 mm in basal ray diameter (Fig. 14.9). Principal spicules regular hexactines in interior of skeleton, but in dermal layer with distal nodes 0.3–0.5 mm in diameter, on stems to 0.15 mm across, or nodes rest directly on central ray junction of spicules. Coarse first-order spicules with rays to 3 mm long, or longer, and basal ray diameters of 0.2 mm, with distal nodes to 0.6 mm in diameter resting directly on ray junctions, or on short ray segments to 0.2 mm long. Coarse dermal spicules with rays parallel to oscular margin upper rim, but more commonly with tangential dermal rays irregularly oriented in main part of skeleton, or with irregularly oriented spicules of smaller ranks in felted texture in interior of wall, based on limited exposed parts.

Type.—Holotype, 99VI–48, was collected from the San Emiliano Formation, late Bashkirian, Upper Carboniferous, at Villafeliz, León.

Discussion.—This species of *Stioderma* is finer-textured, with smaller spicules and smaller parietal gaps and canals than in *Stioderma perforata* n. sp., from the Vergaño Formation at Vergaño, Palencia. It is also significantly finer-textured than the type species, *Stioderma coscinum*, from the Upper Carboniferous-Lower Permian of Texas and New Mexico in the United States. Because we have only a single, partially buried specimen, we leave the species in open nomenclature.

ROOT TUFT B
Figure 7.3, 7.4

Description.—Root tuft fragment subcylindrical, approximately 60 mm long, 12–20 mm in diameter (Fig. 7.3), composed of long silicified monaxial spicules irregularly from side-by-side to 4 mm apart throughout calcareous matrix (Fig. 7.4). Individual spicule fragments to 5 mm long and 0.25 mm in maximum diameter, although most half that size, exposed on weathered tuft surface. Some isolated fragments with sharp tips and other larger bits with double taper, indicating most oxeas. Traces of axial or crepidal canals, to 0.04–0.05 mm in diameter, preserved in densely silicified spicules, particularly evident in transverse sections exposed on one tuft end, where irregular, moderately close packing of spicules also evident. Most spicules straight to slightly curved, but locally some kinked and broken, apparently result of early shift in host sediments.

Material examined.—The single fragment, 99VR4–51, was collected from level 1,600 of the Vergaño section (Fig. 3), from the Vergaño Formation, late Moscovian, Upper Carboniferous, at VR4, northeast of Vergaño, Palencia.

Discussion.—Scattered fragments of echinoderms, bryozoans, and corals, along with secondary pyrite nodules that encase the earlier silicified spicules, occur through the matrix between spicules. Taxonomic position of the root tuft is uncertain, but it is similar to those associated with various Upper Paleozoic hexactinellid sponges elsewhere, and probably is an hexactinellid tuft. It is a much more coarsely spiculed tuft than Root Tuft A and has a looser texture.

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