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Triassic Hexactinellid Sponges from Patch Reefs in North-Central Sichuan, People's Republic of China

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ABSTRACT

A moderately diverse fauna of reticulosid, lyssacinosid, and hexactinosid hexactinellid sponges occurs in small reef mounds in the Upper Triassic (Carnian) Hanwang Formation in north-central Sichuan, China. Reticulosid sponges, which contain some bundled elements in their skeleton, include *Glossospongia angustoscula* Wu, 1989, and *Glossospongia regulara* n. sp. Lyssacinosid sponges include the bowl-shaped *Keriogastrospongia phialoides* Wu, 1989. Hexactinosid sponges are more diverse and include the euretid sponges *Radioplica stephana* Wu, 1990, a convoluted bowl-shaped form with digitations, and the undulate plate-like new genus and species *Dracospongia undulata.* Craticulariid sponges include the ribbed obconical *Sphenaulax pliopetala* (Wu, 1990), the new species *Sphenaulax infundibuliforma,* and the new genus and species *Scipiospongia columnaria.* Cribrospongiid hexactinosan sponges present include the new genus and species *Tesselospongia fistulosa,* and the possibly related, open funnel-shaped, *Nelumbifolium pectiniforme* Wu, 1990.

Inozoan-like hexactinosoans included in *Casearia* Quenstedt, 1858, are the moniliform *Casearia articulata* (Schmidel, 1780), and *Casearia oblata* (Wu, 1990), and the laterally flattened *Casearia decursiva* (Wu, 1990). *Dracholychnos annulirotatus* Wu and Xiao, 1989, is a funnel-shaped sponge composed of annular chamber-like rings and is considered a related genus.

These sponges make up much of the baffling elements in these deep-water mounds. Some genera were earlier described (Wu, 1990) as of lychniscosan grade but such seems not to be the case. The short initial descriptions of various taxa (Wu and Xiao, 1989; Wu, 1989, 1990) have been expanded and updated, based on new collections from the same exposures along the western margin of the Sichuan Basin.

The new trace fossil genus and species, *Ichnospongiella carnica,* is described from occurrences with the sponges. These burrows have dense, thick walls that contain many sponge spicules and others fossil fragments. Other associated trace fossils, some noted by Wendt, et al., (1989) as similar to *Terebella lapilloides* Münster, 1833, are also figured and briefly described from the same samples.

INTRODUCTION

Extensive collections of upper Triassic sponges have been assembled over the past 20 years from patch reefs in north-central Sichuan (Wu, 1989, 1990). These include the first major collections of Triassic hexactinellids known from China and much of Asia.

Upper Triassic sponge patch reefs are widely distributed in north-central Sichuan, from Mianzhu County to Anxian County, in an area about 20 km long and 6 km wide, at approximately 31° 45′ N. latitude, and 104° 15′ E. longitude (Fig. 1). These patch reefs are exposed intermittently along strike within the Upper Triassic Carnian Hanwang Formation. Twenty-two such sponge patch reefs have been found by Wu and his collaborators since 1975. (Wu, Zhang and Zhu, 1977, 1979; Wu and Zhang 1982, 1983; Wu, 1984; Wendt, Wu and Reinhardt, 1989). Tectonically

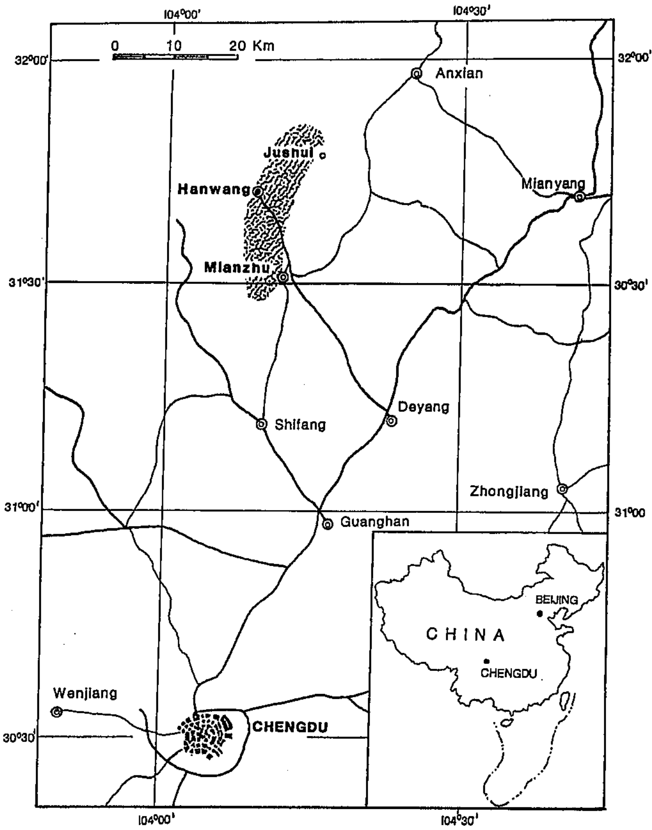

Figure 1. Index map showing broad area of sponge-bearing exposures of the Carnian Hanwang Formation north of Chengdu, in north-central Sichuan. The shaded area shows the general region in which thrust fault-repeated sections of the Hanwang Formation, from which the sponges described here were collected, and associated beds are exposed in the pre-Longmenshan Fold Zone, along the northwestern margin of the Sichuan basin.

these patch reefs are situated in the pre-Longmenshan fold zone. The sponges described here were collected largely from localities at Hanwang, Mianzhu County, and at Jushui, Anxian County (Fig. 1). Samples designated R6-1, R6-2, etc., were collected from various localities in the same area and are from mounds principally in the Jushui area in Anxian County, north-central Sichuan.

These patch reefs are elliptical mounds with longitudinal axes of 100 meters or more and somewhat narrower widths of about 60 meters at their bases. They are 40–60 meters high. Inter-reef distances between the isolated patch reefs range from 100 m to 2 km.

Upper Triassic rocks of north-central Sichuan.—The upper Middle Triassic (Ladinian) Tianjingshan Limestone is overlain by the lower Upper Triassic Hanwang Formation of Carnian age (Table 1, Fig. 2). The Hanwang Formation consists mainly of dark-grey, massive limestones and

Table 1. Upper Triassic formations of northwestern Sichuan

SERIES	AGES	FORMATIONS
	Rhaetic	Xujiahe Formation
	Norian	Xiaotangzi Formation
Upper Triassic	Norian	Shiyuan Formation
	Carnian	Hanwang Formation with sponge patch reefs
Middle Triassic	Ladinian	Tianjingshan Limestone

contains the sponge-patch reefs. The overlying upper Late Triassic Shiyuan and Xiaotangzi formations, of Norian age, are composed of light-grey, grey, and variegated shales, silty sandstones, and sandstones that alternate with limestone beds. Uppermost Triassic Rhaetic deposits are represented by the Xujiahe Formation, which is a typical continental coal-bearing series.

Late Triassic paleogeography of South China.—A widespread regression of the sea set in at the beginning of the late Middle Triassic (Ladinian) over most of southwestern China, because of uplift of what is now Sichuan and northwestern and northern Guizhou provinces (Fan, 1980; Xi, 1985). This restricted the extent of the sea (Fig. 3) and occurred during an early episode of tectonic movement of the Indochina area. In Sichuan, the sea was restricted to the northwestern corner of the Sichuan basin, where up to 428 meters of the distinctive carbonates of the Tianjingshan Limestone were deposited. These rocks consist of light-grey, thick-bedded to massive dolomite and limestone, and probably accumulated in supratidal and intertidal environments on the carbonate platform.

At the beginning of the early Late Triassic, extensive transgressions spread from the Tethyan Sea, in the southwest, and from the Boreal-Circumpacific Ocean, in eastern China. The two seaways were separated in South China (Fig. 3) by a remnant of the landmass that was uplifted during the Ladinian (Xi, 1985).

Two distinct embayments or gulfs are recognized in the Tethys Seaway west of the Ladinian South China landmass. One of these extended from Guanyan, through Mianyang, to Emei in northwestern and southwestern Sichuan, and the other extended from Guiyang to Xingyi, in Guizhou Province (Fig. 3).

Because this part of the Tethys Sea was connected with the main Tethys Sea around the Longmenshan Island Chain, a variety of organisms had access into southern China and flourished in the northern gulf where extensive sponge patch reefs were formed in northern Sichuan. No such reefs have been found in the southern gulf in Guizhou Province.

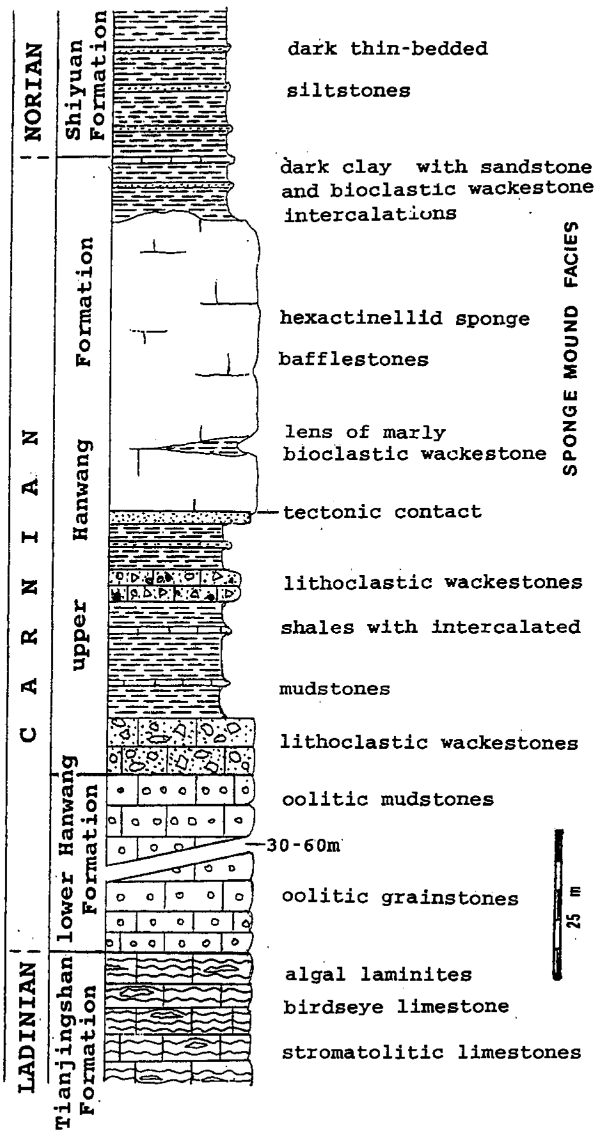

Figure 2. Upper Triassic section exposed near Jushui in Anxian County, in north-central Sichuan (modified from Wendt, et al., 1989).

Later in the middle Late Triassic, these reef-bearing deposits were buried by alternating marine beds and terrigenous clastics that contain occasional coal seams. Triassic sedimentation finally ended after the continental coal-bearing Xujiahe Formation was deposited.

In southeastern China, a transgressive marine succession accumulated in a narrow trough extension of the Boreal-Circumpacific Ocean. The location of that trough was strongly controlled by its paleotectonic setting. A continental coal-bearing series, with minor marine intercalations, accumulated in the trough, but no reefs have been found in these deposits.

Patch reef development.—Growth of Upper Triassic patch reefs in north-central Sichuan can be divided into several stages (Fig. 4), as were differentiated by Wu and Zhang (1982, 1983). These mounds have been also discussed more recently by Wendt, Wu and Reinhardt (1989).

The foundation for reef growth, unit 1 of Figure 4, consists of lower oncolite-oolitic banks, capped by upper skeletal debris banks. The oncolite-oolitic banks are now mainly composed of dark-grey, medium- to thick-bedded grainstones that contain abundant oncolites, oolites and pisolites. Diameters of oncolites range from about 0.2 up to 2 cm. Sparry calcite cement filled in between these grains.

The somewhat younger skeletal debris banks (Fig. 4, unit 2) are mainly composed of dark-grey, medium- to thick-bedded grainstones and intercalated argillaceous mudstones. Diverse skeletal debris in those rocks includes fragments of brachiopods, bivalves, crinoids, echinoids, foraminifers, ostracodes, gastropods, bryozoans, calcareous algae, ammonites and fish scales. Debris amounts to about 50 percent of the total rock volume. These skeletal fragments usually are intermingled with intraclasts of sand- and pebble-size.

Bank deposits are overlain by sponge-bearing limestone of transitional facies. These limestones, facies 3 of figure 4, are mainly dark-grey to light green-grey, massive, sponge-microbial(?) limestones. It was in this stage that sponges began to flourish in the area. They commonly occur *in situ* in the limestones and played an important baffling role in trapping limemud to produce the mounds.

Sponge bafflestones of the patch reef core, facies 4 of figure 4, are mainly dark-grey massive rocks. Sponges usually occur in upright growth position in them, and have been observed in many outcrops. Considerable limemud was trapped between the sponges. Accessory organisms in the bafflestones include brachiopods, bivalves, ostracodes and foraminifers.

Dark-grey to purple-grey reef breccias form reef flank facies around the reef cores, as facies 5 and 6 of figure 4. Breccia fragments are generally 1–5 cm across, although some larger clasts attain diameters of up to 30 cm. The reef flank facies is divided into the inner facies 5 and the outer facies 6. The inner facies is characterized by floatstones that consist of fragments derived directly from reef core rocks. Matrix filling the interstices are lime mudstones that contain smaller intraclasts and skeletal debris. The faunal assemblage of the inner zone is similar to that of the reef core facies, but sponges, brachiopods and bivalves appear to be more abundant than in the reef core.

Breccias in the outer facies 6 are mainly composed of micrite with a matrix of argillaceous rocks and siltstone. Argillaceous rocks and siltstone are more abundant toward the periphery of the patch reefs and in laterally equivalent, near interreef beds.

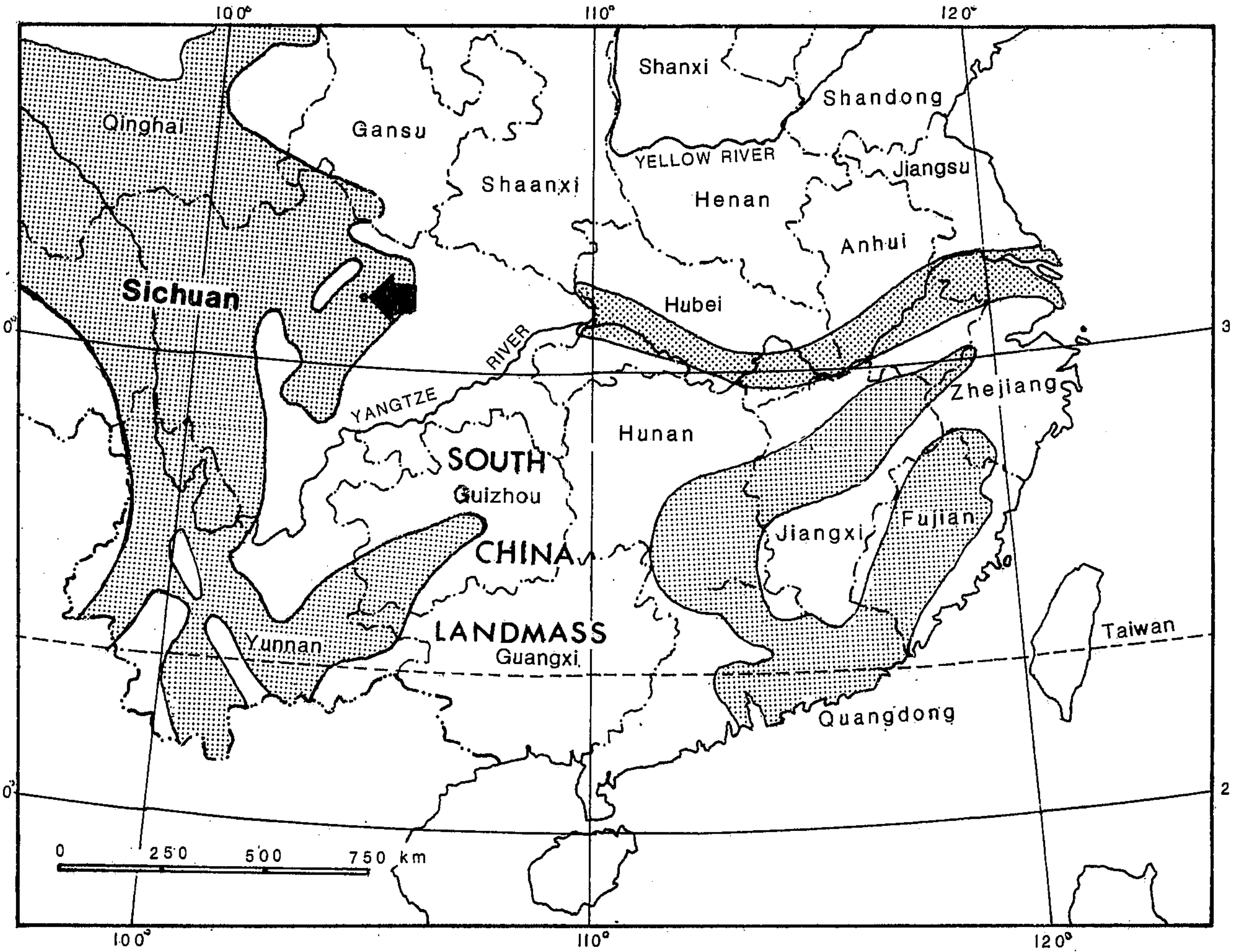

Figure 3. Paleogeographic map showing distribution of marine deposits (stippled) and land mass areas in southern and eastern China (modified from Xi, 1985). Triassic rocks accumulated in the northwestern part of what is presently the Sichuan Basin, where the sponge reefs developed (large arrow). One arm of the extensive transgression from the Tethyan Sea, extended northward into western Sichuan and southern Qinghi provinces. A second arm of that embayment extended northeastward from Yunnan into central Guizhou province, but sponge mounds are not known from there.

Skeletal debris and sponge micrites form the reef top, facies 8 of figure 4. There the main rocks are dark-grey, massive sponge and skeletal debris micrite. Sponges decrease rapidly, vertically, at the same time that other skeletal debris increases, including fragments of brachiopods, bivalves, gastropods, and echinoderms. These rocks mark the end of patch reef accumulation.

Inter-reef deposits in the Hanwang Formation can be divided into two sequences. The lower sequence, facies 7 of figure 4, consists of dark-green and dark-grey, thin- to medium-bedded, argillaceous mudstones interbedded with skeletal sponge limestones. The faunal assemblage of these rocks is similar to that of the outer reef flank beds. The upper sequence, facies 9, is mainly interbedded dark-grey silty mudstones and siltstones, with occasional intercalated lenses of argillaceous limestone and marl. Shallow-water benthonic faunas rapidly decrease, laterally. No sponges have been found in this facies which, instead, contains relatively abundant thin-shelled bivalves and ammonites.

Wendt, et al., (1989, p. 23) called attention to the very common small intergrown or encrusting structure in many of the sponges. They noted that the small tubular structures have dark, dense micritic walls 0.5–1.0 mm in diameter, with a central commonly spar-filled opening 0.2–0.3 mm in diameter. These structures show in many of our figured specimens (Pl. 4, Figs. 3 and 9; Pl. 7, Fig. 7; Pl. 8, Figs. 2, 4, and 5; Pl. 10, Figs. 4, 7, 8, for example). Wendt et al., observed (1989) that these tubes are similar to

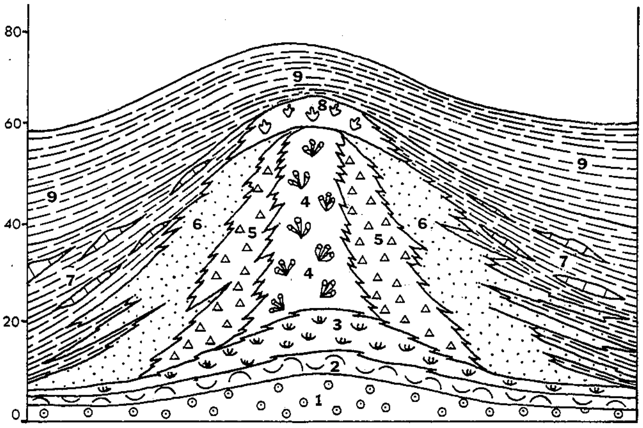

Figure 4. Generalized model of Carnian sponge mounds in the Hanwang Formation in the vicinity of Jushui and Hanwang, north of Chengdu, in Sichuan. Nine facies related to the sponge mound growth and burial have been differentiated. 1, *Oncolite-oolitic grainstones are the foundation for reef growth; and are overlain by,* 2, *grainstones and mudstones with diverse skeletal debris; and* 3, *sponge-algal limestone of transitional facies that is commonly limemud bafflestones and marks the beginning of reef development. Reef facies include:* 4, *dark-grey massive sponge bafflestones of the reef core facies;* 5, *coarse clastic reef-flank facies floatstone that includes fragments of reef core rocks in lime mudstone matrix; and,* 6, *outer reef breccias that are mainly micrite in argillaceous lime mudstone matrix, and that grade laterally into interreef facies.* 7, *Interreef deposits are mainly dark-green and dark-grey argillaceous mudstones with interbedded skeletal sponge limestones, in the lower part, but lack sponges in the upper part. The reef top facies,* 8, *is mainly dark-grey, massive, sponge and skeletal debris micrite.*

Upper interreef deposits and postreef deposits, facies 9, *are mainly dark-grey silty mudstones and siltstones lacking sponges. Differential compaction of the lateral more argillaceous rocks produced drape over the crest of the mound in later beds in the upper part of the Hanwang Formation (modified from Wu and Zhang, 1982).*

Terebella lapilloides Münster, 1833, that is common in Jurassic sponge mounds from southern Germany (Schorr and Kock, 1985; Brachert, 1986) but that these Triassic occurrences have thicker walls. Wendt, et al., (1989) also concluded that these agglutinated tubes were probably produced by annelid worms.

The dark-walled tubes occur both in matrix around the sponges and inside their thick skeletons. Tubes within the sponges appear to have occupied previously open canals rather than to occupy bored new openings in the often compact spicule skeletons.

Other larger lined burrows also occur in matrix around the sponges. Such burrows include common *Ichnospongiella* (Pl. 11, Figs. 1–4), a new genus described below, and also more rare larger-diameter tubes (Pl. 11, Fig. 5) that include ostracod valves and other debris in their walls.

Microbial crusts occur on some sponges, as for example on *Scipiospongia columnaria* n. gen. and n. sp. (Pl. 10, Fig. 1), but such crusts appear to have played relatively minor roles in construction fabrics of the mounds. They were not major binders in the dominantly baffled accumulations.

COLLECTION DEPOSITORIES

Type and reference specimens are deposited in collections at Chengdu Institute of Technology (CIT), in the Sichuan Standard Repository Collections (SSRC) at Chengdu, and in the Institute of Geology, Academia Sinica, at Beijing (IG).

SYSTEMATIC PALEONTOLOGY

Phylum PORIFERA Grant, 1836
Class HEXACTINELLIDA Schmidt, 1870
Subclass AMPHIDISCOPHORA Schulze, 1887a
Order RETICULOSA Reid, 1958
Superfamily DICTYOSPONGIOIDEA
Hall and Clarke, 1899
Family STEREODICTYIIDAE Finks, 1960
GLOSSOSPONGIA Wu, 1989

Emended diagnosis.—Bell-shaped to tongue-shaped, lyssakid hexactinellid sponges with laterally flattened but deep simple spongocoel with thick walls and skeletons composed of crude net of upward-radiating bundles and roughly horizontal bundles of hexactine-based spicules, possibly with additional bundles at right angles, to make three-dimensional net. Areas between bundles, not filled by canals, with skeleton formed of irregularly oriented and spaced small hexactines and hexactine-based spicules around prominent canals, which appear radially oriented and normal to dermal-gastral surfaces. Most distinctive spicules coarse hexactine-derived forms in which one or two of normal six rays aborted to produce long spicules, with fairly short rays normal to bundle trend. Gastral margins with coarse, honeycomb-like exhalant ostia.

Discussion.—In his classic study on the siliceous Permian sponges of the West Texas region, Finks (1960, p. 108–110) described *Stereodictyum orthoplectum* as large, upwardly flaring cones whose skeleton is made of approximately equally spaced bundles in a distinct three-dimensional rectangular net. The bundles are made of parallel spicules composed of a dozen or so long individual rays that appear to be very long monaxons, rather than rays of obvious hexactines. Finks (1960) observed some intersections of rays, which suggested that some of the spicules may be hexactine-based, but was uncertain. Finks (1983) included the family in the Superfamily Dictyospongioidea rather than in the Protospongioidea where he originally placed it. *Stereodictyum* is a distinctly regular sponge, with most of the skeleton made of bundles, rather than having a skeleton like the Chinese *Glossospongia* where bundles are present but make up a relatively minor part of the overall volume of the skeletal net. In the Chinese material, most of the large spicules in the skeleton are clearly hexactines and although many of the coarser hexactines, in particular, have been modified by loss of some rays.

Rigby and Washburn (1972) described *Stereodictyum proteron* from the Pennsylvanian Diamond Peak Sandstone from the southern end of Buck Mountain in central Nevada. These sponges have much in common with *Stereodictyum* from the Permian of Texas, but have bundles composed of obvious modified hexactines rather than of the prominent long spicules characteristic of the Permian genus. The *Stereodictyum* described by Rigby and Washburn (1972) is a thick, discoidal or saucer-like to broad, upward-flaring, obconical form.

Wu (1989, p. 767) named *Glossospongia* for the tongue-, bell-, or scabbard-shaped lyssakid sponges that occur in Carnian rocks of the western Sichuan Basin. He did not recognize the crude net of bundled hexactine-based spicules as an important part of the skeletal structure because they appeared like scratches in the thin sections.

The Chinese *Glossospongia* is a laterally flattened obconical form and contrasts with both species of *Stereodictyum* described from North America in having a skeleton made largely of discontinuous bundles and an intervening irregular mesh of hexactines.

Type species.—*Glossospongia angustoscula* Wu, 1989.

GLOSSOSPONGIA ANGUSTOSCULA
Wu, 1989
Plate 1, Figures 1–9; Plate 2, Figures 1, 5;
Plate 6, Figures 1–3, Plate 9, Figure 1

Glossospongia angustoscula Wu, 1989, p. 765, Pl. 1, Figs. 4–6.

Emended diagnosis.—Upward-flaring, steeply obconical, laterally flattened bell- to tongue-shaped sponges with relatively thick nodose walls composed of moderately reticulate net of bundles composed of hexactines and modified hexactines, with individual bundles discontinuous. Vertically ascending bundles connected at irregular intervals by similar discontinuous(?) horizontal bundles, or bundles at irregular angles. Individual bundles 0.2–0.3 mm in diameter. Intervening space largely occupied by horizontal convergent canals surrounded by numerous irregularly oriented hexactines in unfused lyssakid structure. Gastral layer with numerous coarse exhalant ostia.

Description.—Skeleton composed of mix of bundles and intervening more irregularly oriented and spaced hexactines. Most prominent bundles upward radiating and crossed by crude horizontal bundles, that intersect at angles of less than 90°, all are discontinuous in thin sections of fragment 65 mm high and 36 mm wide.

Vertical bundles generally spaced 2–5 mm apart, diverge upward but may become subparallel. Vertical bundles mostly 0.2–0.3 mm in diameter, but bundles up to 0.5 mm across locally. Horizontal bundles generally 0.2–0.3 mm across. Both types of bundles appear discontinuous and composed of spicules with long, thin rays parallel to bundle. Some spicules, however, with short rays at right angles to long sections but unquestionably hexactines. Vertical bundles generally with 15–20 spicules per cross section, in side-by-side parallel fashion, and not fused. Other bundles composed of only 2–3 widely spaced spicules. Horizontal bundles generally composed of 5–10 spicules with long thin rays as in vertical bundles. Coarse spicules occur irregularly throughout bundles, both in interior and on exterior of bundles, without any particular pattern.

At least three orders of canals apparent in thin section. A few large openings, 1.2–1.5 mm in diameter, occur scattered throughout skeletal fragment. These 4–5 per 25 sq. mm, were most apparent. Intermediate-size, and much more evident, canals generally 0.8–0.9 mm wide and 0.9–1.1 mm high, with distinctly elliptical cross sections, although some also circular and approximately 0.8 mm in diameter. These occur 13–14 per 25 sq. mm as principal openings in skeleton; separated by 0.5–1.0 mm of skeletal material, both horizontally and vertically, and arranged in crude vertical series, although without distinct regularity.

Smaller canals, 0.2–0.5 mm in diameter, commonly lined by spicules with major rays tangent to circumference of canals. Lining generally 0.01–0.02 mm thick and only 1 or 2 spicules thick, made of some of smallest spicules in skeleton. A few canals also with spicules whose major rays parallel to canal length, but most canals lined by spicules normal to long dimensions of openings.

Individual bundles may have large modified hexactines at junctions, although with great irregularity. Skeleton appears as upward-expanding crude net which may be multi-layered and moderately thick. Coarsest individual spicules appear centered within bundles throughout skeletal net and associated with clustered tiny hexactines. These large spicules with basal ray diameters of approximately 0.08–0.10 mm; many with long vertical rays, parallel to bundles, but short lateral rays only 0.5 mm or less long. Rays parallel to bundle, however, commonly 2–3 mm long although some rays up to 9 mm long. These usually taper rather abruptly for proximal 1–2 mm near ray junctions and then less rapidly, becoming subcylindrical for half ray length and then narrow to thin needle-like tips. Some longer spicules may be rhabdodiactines or modified diactines that not hexactine-based. Spicules within tracts generally have lost rays but those in skeletal areas between tracts commonly equal-rayed hexactines. Many spicules with slightly swollen ray junctions.

Smaller hexactine spicules, those with ray diameters of only 0.02 mm or smaller, make up most of bundles and most of skeletal net between bundles, although somewhat larger spicules most evident in skeletal fabric.

None of the spicules are fused.

Discussion.—Dimensions of principal spicules of the skeletal net and of canals are considered to be specific characters, whereas the overall nature of the skeletal net and shapes of the sponges of the species are considered to be principal generic characters.

Material.—Thirty four specimens, including S-1089 to S-1123, are from the Jushui community located in the Carnian reef mound tract of the western Sichuan Basin. Figured sponges include specimens S-1095, 1096, 1098, 1110, 1116, 1117, and 1120, along with thin section IG R6-11.

GLOSSOSPONGIA REGULARIS n. sp.
Plate 6, Figures 4–6; Plate 9, Figure 2

Diagnosis.—Thin-walled, obconical or subtubular sponges with skeleton of weakly bundled hexactines and intervening irregularly-oriented hexactines, with prominent dermal layer of tangential rays of small spicules, but with occasional large, armoring spicules, but not as distinct armored layer. Bundles of skeletal net generally 0.2–0.3 mm in diameter, with vertical, radial and tangential bundles of basically same dimensions, all crudely defined, however, in dominantly irregular, somewhat matted-appearing skeleton. Dermal layer to 1.0 mm thick. Wall 4.0–5.0 mm thick and pierced by numerous regular canals approximately 1 mm in diameter.

Description.—Single transverse thin section of upward-expanding conical to conical-cylindrical sponges is in collection. It has circular-elliptical outline approximately 27 x 38 mm. Thin walls, 4–5 mm thick, surround simple tubular ostium 18 or 19 mm wide, across short axis.

Wall pierced by essentially horizontal radiating canals, mostly 0.8–0.9 mm across. Canals in outer part of skeleton generally 0.75 x 1.0–1.5 mm but expand somewhat to 0.8 x 1.3 mm in diameter in middle of wall and up to 1.0 x 1.2 mm in inner or gastral part of wall. Many canals strongly branching; outer inhalant ostia only 0.25 mm across lead into short canals which converge to produce larger openings, 0.3–0.4 mm in diameter, at inner margin of dermal layer. These expand abruptly to 0.8–0.9 mm across at midwall. Most smaller canals appear merged to form large canals essentially by midwall where there may be additional horizontal concentric series of canals each 0.2–0.4 mm across. Inner part of wall perforated essentially only by canals of large open radial series, each of which expands, funnel-like, to ostia with diameters of approximately 1.3 mm at gastral surface.

Outer part of the skeleton, thus, shows extensive convergence of small canals and inner half shows only a few canals, other than large openings.

Most canals lined by many small spicules tangent to circumference of canal margin and parallel to exterior of sponge. These small spicules, 0.02–0.05 mm in diameter, form compact layer approximately 0.5 mm thick, where spicules occur side by side to define distinctly margined large openings.

Dermal layer of skeleton made of bundled, horizontally-arranged diactines or rhabdodiactines in mat 1.0–1.2 mm thick. Variation in thickness caused by variations in packing of spicules at inner margin. Some spicules in layer are hexactines with rays up to 0.05 mm in diameter mixed with coarser spicules with rays 0.10–0.15 mm in diameter. Many of both series of hexactines with outer rays tangent to exterior of sponge, and with distal rays extending out into enclosing matrix. Many coarser series appear regularly oriented, with principal ray axes vertical and horizontal.

Main parenchymal skeleton made up of irregularly oriented hexactines with basal ray diameters of approximately 0.05 mm, and rays up to 2–3 mm long. Less common, but more obvious, coarser hexactine spicules with basal ray diameters 0.10–0.15 mm and rays up to 1.5 mm long. Spicule distribution in skeleton distinctly bimodal, with most of net composed of smaller spicules. Coarser parenchymal spicules nearly equally distributed throughout skeleton and irregularly oriented with reference to principal dimensions of sponge.

Discontinuous traces of bundles of hexactine-based spicules are 0.2–0.3 mm in diameter and composed of 5–10 parallel rays in relatively open structure. Bundles form structural framework and spaced 1.5–2.0 mm apart where most evident. Rays 0.01–0.03 mm in diameter most common, but range up to 0.10 mm in diameter and to 3 mm long.

Discussion.—*Glossospongia regulara* n. sp. contrasts with the associated *Glossospongia angustoscula* Wu, 1989, in having distinctly coarser spicules as the coarsest elements of the skeleton, in having a more regular canal system, and a well-defined matted dermal layer. The forms are similar, however, in having bundles as characteristic elements within the skeletal structure. Most of the coarse spicules in *Glossospongia regularis,* however, appear to be unmodified hexactines in contrast to the modified major spicules in *Glossospongia angustoscula.*

Etymology.—Regula, L, rule, calling attention to the regular placement of the simple radiating canals in the skeleton.

Type material.—The holotype, and only known specimen of the species, is on thin section IG R6-9 (031), collected from the Jushui locality.

Subclass HEXASTEROPHORA
Schulze, 1887a
Order LYSSACINOSA Zittel, 1877
Family KERIOGASTROSPONGIIDAE
Wu, 1989
Genus KERIOGASTROSPONGIA
Wu, 1989

Emended diagnosis.—Bowl-shaped lyssacine sponges with prominent large exhalant ostia of subradial canals in concentric rings, in shallow spongocoel; walls thick, of irregularly oriented and spaced hexactines and hexactine-derived spicules of several sizes in generally fine-textured skeleton, except for somewhat more consistently oriented coarser hexactines of general brachiospongiid appearance in dermal layer.

Type species.—Keriogastrospongia phialoides Wu, 1989

Discussion.—Keriogastrospongia Wu, 1989, is one of the coarsely canalled, bowl-shaped sponges of the collections. Even fragments are distinguised by the irregularly oriented coarse hexactines of the lyssacine skeleton, and the coarse brachiosponge-like armoring dermal layer. *Glossospongia* Wu, 1989, is bell-shaped or tongue-shaped and has a skeleton composed largely of irregularly oriented fine hexactines but it also has a three-dimensional bundled grid as part of the skeleton, which makes it distinct from *Keriogastrospongia.* Other sponges in the collection have organized dictyonine skeletons and are easily differentiated from *Keriogastrospongia.*

The Pennsylvanian-Permian *Dococlerma* Finks, 1960, from North America, has enlarged hexactine-based dermalia, as in *Keriogastrospongia,* but such dermalia in *Dococlerma* have papillate or otherwise ornamented distal surfaces that may fuse to form a rigid dermal layer. Enlarged dermalia of the related Permian *Carphites* Finks, 1960 are much simpler than those of *Dococlerma,* like in *Keriogastrospongia. Carphites,* however, has interior spicules that include hexactines, oxeas and strongyles in groups of parallel bundles, in a skeletal structure unlike from that in *Keriogastrospongia. Acanthocoryna* Finks, 1960, has dermalia with distal spikes and a bundled skeleton that is a more complex structure than that produced by the irregularly oriented and spaced hexactines in the Triassic *Keriogastrospongia.*

The Jurassic *Stauractinella* Zittel, 1877, is a globular to broadly flattened keg-shaped sponge that has some irregularly oriented large, dermal hexactines or hexactine-based spicules, but its principal spicules are diactines. It might appear superficially similar to *Keriogastrospongia* but has a distinctively different skeletal structure.

KERIOGASTROSPONGIA
PHIALOIDES Wu, 1989
Plate 2, Figures 2–4; Plate 3, Figure 6;
Plate 6, Figures 7, 8; Plate 9, Figure 3;
Plate 11, Figure 3

Keriogastrospongia phialoides WU, 1989, p. 767, Pl. 1., Figs. 1–3

Emended diagnosis.—Obconical to thick-walled, bowl-shaped to goblet-shaped, lyssakid sponges with coarse canals and irregular knobby outer and inner margins of wall; weak dermal armor developed. Set of roughly vertical excurrent canals pierces interior and leads from subradial series of canals into bottom of irregular spongocoel. Skeletal net brachiospongiid with hexactines and hexactine-derived spicules of various sizes irregularly oriented throughout skeleton. Skeleton generally fine-textured, except for armoring layer where hexactine spicules up to 0.18 mm in basal diameter form outer layer approximately 1 mm thick.

Description.—Bowl-shaped commonly asymmetrical sponges with one side bent inward; typical example 75 x 95 mm, oval in plan view across upper margins, and to 35 mm high. Exterior rough with low nodes, and inhalant ostia 1–3 mm in diameter, most 1–1.5 mm in diameter and 3–5 mm apart. Sponges range up to 40 or 50 mm high and 25 to 30 mm in diameter. Most definitive vertical section is of sponge approximately 37 mm high, which expands from rounded base approximately 10 mm wide to maximum width of 23–24 mm in upper part of sponge, near base of spongocoel. Above that, sponge narrows to approximately 18–20 mm in diameter. At rounded oscular margin, wall 9–12 m thick, but to 15–18 mm thick at middle wall, and somewhat less in lower parts. Root tufts or attachment basalia unknown.

Gastral surface with prominent exhalant ostia arranged into roughly concentric rings 5–6 mm apart. Oval ostia more nearly round and 2.5–3.5 mm across in inner half of bowl-shaped crater-like spongocoel, where ostia spaced 1–2 per cm, in individual rings. Ostia in upper half distinctly more oval to flattened, still 2.5–3.5 mm across horizontally but only 1.0–1.5 mm high, radially or vertically. These upper ostia form prominent rings 4–5 mm apart, vertically, in upper part where some ostia more slit-like and concentrically elongate and spaced 2–3 per cm within the rings. Uppermost ostia, in upper 1 cm of wall, smaller and more nearly circular than oval ones below, and grade to openings only 1.0–1.5 mm in diameter near oscular margin, where spaced 5–6 per cm in horizontal ring.

Entire sponge perforated by moderately coarse canals that lead into upper shallow spongocoel, which in characteristic specimen is 12 mm across and ranges from approximately 7 to 10 mm deep because of variation in height of walls. Above spongocoel floor, walls approximately 5 mm thick but thin to 2–3 mm thick at rounded summit of osculum, which is approximately 10 mm in diameter. Essentially same size sponge preserved in IG R6-23(074) where 20–22 mm in diameter and pierced by spongocoel 10 to 12 mm across, bounded by walls 6–8 mm thick. Wall thickness shows considerable irregularity because of widely flaring funnel-like gastral ostia of excurrent canals. They range up to 3 or 4 mm in diameter and produce irregular coarse nodes and lobe-like extensions of dark skeleton into light-colored matrix. Lobes of skeleton, 2–3 mm long, extend as finger- or tongue-like extensions into spongocoel.

Exterior weakly nodose, with mounds 1–3 mm in diameter and high, generally between ostia of incurrent canals. Nodes irregularly placed, as are canals, so entire sponge appears like exterior of a black walnut.

Three series of canals recognizable within skeleton. Coarsest of these part of general subvertical, central series, 1–2 mm in diameter. Canals with irregular undulating, almost braided, appearance where they open into broad pits 2–3 mm across in spongocoel floor. Examples of such canals locally traceable for 4–5 mm in vertical tangential section in IG R6-23(076). Because of their irregularity, they appear as markedly discontinous matrix fillings spaced 1–2 mm apart.

These large canals joined in outer lower part of sponge by subradial to upwardly convergent canals 0.5–1.0 mm in diameter. These canals irregularly spread through outer and middle parts of walls. They converge inward toward subvertical central series and locally may merge to form crude irregular openings up to 3 mm across. They appear arranged in roughly vertical sets 1–1.5 mm apart on exterior, but become more regular in wall interior and merge to help produce distinctly ragged, lobate, gastral margin.

Dense intercanal parts of skeleton pierced by numerous short openings, approximately 0.1 mm across, that interconnect larger canal series. These small openings irregularly oriented and occur throughout wall.

Skeleton brachiospongiid, composed of irregularly-oriented and spaced hexactines of various series that combine to produce moderately even-textured skeleton, but one lacking geometrical pattern, for individual spicules not oriented at any consistent angle with reference to axis of sponge. Spicules not bundled nor fused, nor connected by other skeleton elements into solid net.

Two general skeletal layers recognizable, an armoring dermal layer and an inner endosomal layer. Outer armored layer, 1–1.5 mm thick, contains coarsest spicules in skeleton. These with basal ray diameters up to 0.12 mm across, although most 0.06–0.08 mm in diameter at base of rays. Axial canals common in fibrous calcite replacements. Most rays smooth, long, and show no swollen centers. A few of largest spicules, up to 0.18 mm in basal ray diameter, have somewhat expanded subspherical ray junctions, but these not common.

Coarsest spicules in interior layer with rays approximately 0.10 mm in diameter and with axial canals 0.02 mm in diameter as round openings in fibrous calcite. Most numerous preserved spicules in wall interior 0.02–0.04 mm in ray diameter and with long, thin, smooth irregularly-oriented rays.

Smallest identifiable spicules with rays only approximately 0.01 mm in diameter and up to 0.1–0.15 mm long. Generally speaking, however, small spicules preserved as faint ghosts in moderately densely packed parts of skeleton between canals. Spicules with rays 0.04–0.05 mm in basal diameter most commonly preserved elements in interior of skeleton, although tinier spicules much more abundant in dark, compact, isolated fragments of skeleton. Canals appear as unlined perforations within thatch. Some fragments of ostracods and thin bivalves also incorporated into skeleton. Such foreign material common in Chinese Triassic hexactinellids.

Discussion.—The coarse exhalant ostia in the bowl-shaped sponges, the irregular nodose sculpture and brachiospongiid skeleton with a dermal armor, are diagnostic of *Keriogastrospongia phialoides* Wu, 1989, particularly when combined with the relatively fine-textured skeleton and the unlined canals that have irregular courses through the skeleton. *K. phialoides* contrasts to the moderately large stereodictyid *Glossospongia* that has bundled spicules and regular canals, which appear to be more or less straight radial through the fairly thin-walled, distinctive, scabbard or flattened goblet-shaped form. Sponges included in *Keriogastrospongia* also differ from associated *Radioplica stephana* Wu, 1990, which is crenulate bowl-shaped, has a dictyonine skeleton, and has marginal digitations. *Nelumbifolium pectiniforma* Wu, 1990 is more funnel-shaped and has a dictyonine skeleton.

Material.—The collection includes specimens of the species: S-1064 to S-1071, S-1077 to S-1088, and four thin sections, IG R6-1(8), R6-1(9), R6-23(073), and IG T3-17. Figured specimens include S-1164, 1165, and thin section IG R6-23(073). Specimen S-1064, 1065, and 1067 to 1072 are from Jushui, and S-1066, and 1073 to 1076 are from Hanwang.

Order HEXACTINOSA Schrammen, 1903
Suborder SCOPULARIA Schulze, 1887a
Family EURETIDAE Zittel, 1877
Genus RADIOPLICA Wu, 1990

Emended diagnosis.—Irregular cup-like sponges with longitudinally fluted or convolute margins that may merge to produce upwardly divergent tubular projections or subparallel branches, with walls lacking major canals in markedly uniform three-dimensional dictyonine skeletal mesh.

Discussion.—*Radioplica* Wu, 1990 is perhaps most similar to the Jurassic-Holocene *Verrucocoelia* Étallon, 1859, in having many short cylindrical branches from a common base that may be tubular or broadly obconical. That common base in *Verrucocoelia* is not regularly fluted but it is in *Radioplica.* Walls in both genera may lack canals. *Radioplica* lacks hood-like outgrowths typical of *Verrucocoelia.*

Periphragella Marshall, 1875, is a Cretaceous-Holocene form and may appear similar to *Radioplica* but commonly has divided and anastomosed tubes rather than straight tubular branches; as do many genera included in the Euretidae Zittel, 1877, by Reid (1964, p. cxlvi).

Sections of the small associated *Tesselospongia fistulosa* new genus and species may appear superficially similar, but the *Tesselospongia* has distinct canals in a cribrospongiid pattern. Other sponges in the collections have considerably simpler unbranched skeletons and usually are much larger.

Type species.—*Radioplica stephana* Wu, 1990.

RADIOPLICA STEPHANA Wu, 1990
Plate 3, Figures 4–6; Plate 9, Figures 7, 8

Radioplica stephana WU, 1990, p. 352, 359–360, Pl. 2, Fig. 1, Pl. 3, Figs. 6, 7.

Emended diagnosis.—Same as for genus, with branches 9–10 mm in diameter and spicule nodes 0.2–0.3 mm apart in much of skeleton.

Description.—Irregular to undulaform or crenulate cup-like or bowl-like sponges with upper and outer parts composed of subparallel branching tubes. Sponges at least 20–30 mm high and approximately 9–12 mm in diameter in their principal tubular parts, with growth form similar to *Verrucocoelia,* in which branches rise from common base. Lower walls somewhat thicker than upper ones that generally 2–3 mm thick and rarely up to 4 mm thick. Walls which appear to be 11 mm thick cut in a few diagonal sections probably represent lower parts of sponge. Surfaces of branches appear uniformly smooth to slightly undulating.

Simple tubular spongocoel penetrates virtually full length of each tube. Branches with diameters of 9–10 mm have circular spongocoels approximately 6 mm in diameter that appear circular to slightly elliptical.

No major canals interupt distinctly uniform skeleton and differentiated gastral and dermal layers not developed, so entire skeleton appears uniform, from wall to wall. Generally speaking, primary strands occur near gastral margins and diverge upward and outward at low angles, so strands meet dermal margins at only 10°–20°. Curvature on strands, thus, very low and most appear nearly straight for great distances through wall. This results in transverse lamellae that only gently arched, and generally, nearly at right angles to diverging primary strands. Lacks prominent dermal and gastral layers.

Most distinctive feature of even fragments of markedly uniform three-dimensional grid of skeleton is slightly expanded nodes at centers of dictyonalia. These nodes commonly up to 0.06 mm in diameter, although in some coarser examples, common ray junctions up to 0.1 mm across. Horizontal beams, which form transverse lamellae, 0.14–0.16 mm long between expanded nodes, which results in general separation of 0.2–0.3 mm between nodes in central parenchymal part of wall. Beams in gastral part, however, considerably shorter, only 0.04–0.06 mm long, near surface of divergence of strands. Node separation becomes distinctly uniform short distances from that surface of divergence so that nearly entire skeleton net has rectangular grid-like openings 0.2–0.3 mm across. Most such openings outlined by beams and strands 0.03–0.04 mm in diameter in thinnest part at mid-length.

Because of local moderately coarse replacement and recrystallization, dimensions of individual beams may be slightly expanded. Beams may range up to 0.05 or 0.06 mm in diameter, particularly in vicinity of nodes where all beams expand slightly.

Evidence of diagonal buttresses lacking, so specimens certainly of dictyonine grade. Spacing between transverse lamellae generally 0.2–0.3 mm, but may range up to as much as 0.6 mm or as small as 0.1 mm in various parts of some skeletons. Skeletal regularity is distinctly evident, however, in even smallest fragments of sponge. Where spaces between transverse lamellae high, there is generally incomplete, partial, horizontal or transverse lamina between regular elements, apparently to keep net essentially of uniform dimensions.

Axial canals of spicule rays preserved in a few specimens. These axial canals 0.008–0.01 mm in diameter of opposed rays from adjacent spicules show obvious side-by-side relationships, like generalized structures figured by Reid (1958, figure 12B). Most such preserved canals in *Radioplica* appear circular in cross section, and courses show well through moderately finely crystalline replacements of originally opalline siliceous skeleton.

Discussion.—Comparisons with similar appearing and related sponges were treated in discussion of the genus. The distinct uniformity of the skeletal net, lack of prominent canals piercing the parenchymal skeleton, and the multiple-branching growth form characterize the genus and species and separate them from other dictyonine hexactinellids in the collections.

Materials.—Figured specimens include S-1157, from Hanwang, and thin sections IG R6-2(003), R6-11(035), R6-12(037) and T3(3) from Jushui. Additional reference specimens of the species occur on thin sections IG R6-1, R6-3(005), R6-3(006), R6-3(008), R6-9(027), R6-9(028), R6-24(081), R6-12(036), and R6-15(049), and IG $T3_1$, $T3_2$, $T3_4$–$T3_{10}$. All specimens are from the Carnian mounds tract near the communities of Hanwang and Jushui of the western margin of the Sichuan Basin.

Genus DRACOSPONGIA new genus

Diagnosis.—Undulate plate or broadly obconical sponges with marked regularity in advanced euretoid skeletal structure with primary strands continuing full length or diameter and other strands diverging laterally to both dermal and gastral surface; plates lack canals but with well-defined dermal and gastral layers.

Discussion.—Sponges with euretoid dictyonal frameworks that lack canals were included by Reid (1964, p. cxlv–cxlvi) in the Euretidae Zittel, 1877. Many of the genera included by Reid in the family are funnel-like with tubes or are branched or anastomosed tubes and are clearly separated from *Dracospongia.* Perhaps most similar are such funnel-shaped sponges as *Chonelasma* Schulze, 1887b, *Eubrochis* Schrammen, 1902, or *Wollemannia* Schrammen, 1912. However, *Chonelasma* has some irregularly placed radial canals and apertures in the thick cortical layers on both sides of the thick-walled skeleton. *Dracospongia* is a thin-walled form that lacks distinct canals. *Eubrochis* Schrammen, 1902, is also funnel-shaped to vase-shaped but has transverse beams that form irregular laminae in coarse-meshed skeletons, in contrast to the uniform relatively fine skeleton in *Dracospongia* which has longitudinal strands that diverge uniformly from midwall toward both gastral and dermal thickened layers. *Wollemannia* Schrammen, 1912, has thin cortical layers that appear distinct from the internal skeleton, rather than as thickened continuations of that skeleton. *Dracospongia,* thus, appears to be distinct from these Cretaceous genera.

Porospongia d'Orbigny 1849 includes plate-like to club-like sponges (Pisera, in press) with a uniform skeleton in which dictyonal strands diverge toward both the dermal and gastral margins but toward the dermal margin at a low angle. In the species *Porospongia marginata* Münster, 1829 (in Goldfuss, 1829), the skeleton is very regular and lacks canals but has large meshes. Large circular oscula interupt the dense gastral layer (Mehl, 1992, pl. 13, fig. 6) but do not extend as canals far into the fine mesh of the skeletal interior. Such oscula are not present in *Dracospongia* where the gastral layer is less dense and continuous than in *Porospongia,* as shown in the holotype section of the Chinese sponge (Pl. 3, figs. 1–3).

The distinct regularity of the fine skeleton and lack of canals clearly separate *Dracospongia* from the associated *Nelumbifolium* Wu, 1990. *Dracolychnos* Wu and Xiao, 1989, is also an undulating plate-like dictyid sponge but it has a skeleton composed of discrete annular chamber-like additions, in contrast to the remarkably uniform skeleton in *Dracospongia.*

Bowl-shaped *Keriogastrospongia* Wu, 1989, is a coarsely canalled lyssacinosid sponge and is easily separated from *Dracospongia.*

Type species.—*Dracospongia undulata* new species.

Etymology.—*Draco,* L., dragon; *spongia,* sponge, referring to the dragon-like serpentine appearance of the sponge in vertical sections.

DRACOSPONGIA UNDULATA
new species
Plate 3, figures 1–3; Plate 9, figure 5

Diagnosis.—Undulate funnel-shaped, plate-like or broadly obconical dictyonine sponge with plates 2–3 mm thick and euretoid skeleton with strands divergent from midwall at low angles toward thin dermal and gastral layers. Transverse lamellae 0.5–0.8 mm apart, and strands approximately 0.2 mm apart in midwall.

Description.—Sponge thin undulating plate, flabellate or frond-like form, showing marked skeletal uniformity. Plate 2–3 mm thick and, in cross section, extends up to 70 mm long or in diameter. Upper and lower surfaces smooth and subparallel. Skeleton euretoid, and principal dictyonalia approximately one-third wall thickness in from dermal layer, which results in asymmetric angles of emergence of strands and produces gently arcuate transverse lamellae.

Skeleton fairly simple, with thickened cortices as both dermal and gastral layers. Dermal cortex approximately 0.1–0.2 mm thick and consists of not only thickened elements but additional dictyonalia to produce compact layer. Gastral layer somewhat thicker, 0.2–0.3 mm, also composed of considerably thicker-rayed spicules rather than in parenchymal part of skeleton, which makes up 1.5–2.5 mm of plate.

Primary strands more or less continuous throughout full length of cross section and from these, other strands diverge both towards gastral and dermal margins. Strands emerge at gastral margin at angles of about 60° and at dermal margin at about 20°–30°. Locally, strands closely space and subparallel, often only 0.1–0.2 mm apart in outer 0.5 mm near dermal surface. Strands that diverge toward gastral surface more or less uniform distances apart, but increasingly farther apart as they diverge from plane of separation. Most approximately 0.2 mm apart in middle part of wall and maintain that separation toward gastral surface.

Transverse lamellae formed by beams from strands and most obvious structures in cross section. Lamellae spaced 0.5–0.8 mm apart in middle part of wall, but become somewhat less than that toward gastral and dermal surfaces. In some areas, transverse lamellae almost at right angles to dermal surface where angle of emergence of strands low, but lamellae arch and generally swing proximally in upper or gastral part of sponge. New strands inserted with bases at beams rather than from divergence and thickening of principal primary strands.

Dictyonalia arranged in corresponding patterns so that centers of spicules in strands at same general level. This produces prominent regular transverse structure of skeleton. Rays of dictyonalia with locally well-preserved axial canals, which indicate that rays overlap and that beams are produced by overlap. In some areas, where axial canals not well preserved, spicules appear oriented with some ray tips contacting centers of adjacent spicules.

Sections of strands 0.2–0.4 mm in diameter and roughly circular in cross section. Many with axial canals 0.008–0.012 mm in diameter. Individual segments straight and uniformally spaced. Strand segments decrease in length, particularly toward gastral margin where curvature of strands most apparent. Many spicules with swollen nodes 0.08–0.12 mm across. Uniform smooth beams diverge from centers without additional rays and 0.02–0.04 mm in diameter.

Dermal cortex composed of swollen dictyonalia, with nodes uniformally 0.10 mm across, and closely spaced 0.1–0.2 mm apart so that 2 or 3 occur per transverse lamellar segment. Connecting rays also thickened, up to 0.04–0.06 mm across, and entire skeleton appears composed of stubby elements. Dermal elements considerably more robust than those in parenchymal inner part of wall. Thickening affects principally only outer layer of spicules, but some spicules in outermost skeletal unit of parenchymal layer also may be thickened and dermal layer may be up to 2 centra thick. Dermal rays outline small ostia, approximately 0.06–0.08 mm in diameter, that lead into uncanalled open parenchymal part of skeleton.

Gastral layer with elements of similar size as in dermal layer, but ostia in gastral layer slightly larger, approximately 0.10–0.12 mm across. No marked interruptions of skeleton by canals in parenchymal part of wall.

Transverse lamellae apparently outline positions of growing margins. Where wall flexed gastrally, transverse lamellae meet dermal layer almost at right angles. Where wall curves dermally, transverse lamellae arched and meet gastral layer at 50°–60°. In addition, in zones of curvature, more dictyonalia added on convex side of plate and beams may be shortened on concave side.

Discussion.—The plate-like or flabellate undulating form, the simple uniformity of the skeletal net, and the lack of prominent canals separate this form from other sponges in the collection, as discussed in treatment of the genus, above.

Material.—The holotype, thin section IG R6-20(064), is from Jushui, Sichuan.

Etymology.—*Undulatus*, L., wavy, referring to the undulate or wavy vertical section of the sponge.

Family CRATICULARIIDAE
Rauff, 1893
Genus SPHENAULAX Zittel, 1877

Emended diagnosis.—Steeply to broadly obconical or plate-like craticulariid sponges with distinct ribs on exterior, deep axial spongocoel, and regular uniform fine-textured dictyonine skeleton with distinct dermal and gastral layer produced by thickening of individual elements. Primary strands diverge upward and outward from near gastral margin. Outer layer of pentactines and stauractines may be attached to ribs or to sides of ridges over troughs between ridges by synapticular(?) bridges in well preserved material.

Type species.—*Scyphia costata*, Goldfuss, 1826

SPHENAULAX PLIOPETALA
(Wu, 1990)
Plate 3, Figures 7–13; Plate 6, Figures 9, 10; Plate 7, Figures 1, 2; Plate 9, Figure 4

Calycospongia pliopetala WU 1990, p. 350–351, 358–359, Pl. 1, Figs. 8, 13; Pl. 2, Figs 3, 4; Pl. 3, Figs 2, 3.

Emended diagnosis.—Moderate-sized sponges to over 70 mm high and to 45 mm in oval diameter, with ribs 3–4 mm wide separated by indented vertical rows of inhalant ostia 1.5–2.0 mm wide. Exhalant ostia generally about 1 mm in diameter; fine dictyonine skeletal net with nodes approximately 0.2 mm apart, dermal and gastral layers 0.2–0.4 mm thick, of thickened beams and nodes.

Description.—Steeply obconical intermediate-size sponges with coarse, somewhat irregular vertical ribs separated by sharp indentations produced largely by vertically aligned ostia of inhalant canals. Deep simple spongocoel extends to near base, surrounded by wall 4–5 mm thick in middle and upper part and 2–3 mm thick in lower part.

Largest specimen, S-1029, broken at base but 70 mm high, expands upward from circular base 17–18 mm in diameter to oval diameter of 30 x 45 mm at midheight and 35 x 50 mm at incomplete summit. Weathered walls 7–8 mm thick on one side and 4–5 mm thick on opposite side.

Vertical ribs with rounded crests 3.5–4.5 mm wide at base, trough to trough, and 5–7 mm wide in upper part. Troughs between ridges 1–2 mm wide in upper part and more sharply rounded than ridges. Ridges branch upward to maintain moderately uniform widths.

Inhalant ostia 0.8–1.2 mm in diameter in oval, slightly vertically elongate, pits along interrib troughs. Ostia 3–4 per 5 mm, vertically, along single trough.

Smaller round canal openings, 0.3–0.5 mm in diameter, occur on ridges in vertical rows also, and spaced 1 mm apart, center to center. Some ribs with 1–2 vertical rows of smaller pores in lower part of sponges, where best preserved.

Smaller sponges, S-1025 and S-1030, with more nearly complete obconical pointed bases 5–10 mm in diameter, expand upward to oval cross section 12 x 18 mm in 30 mm or to circular cross section 16–17 mm in diameter in 20 mm. Both with complete, canal-indented oscular margins and that of S-1025 show diplorhysis, with horizontal inhalant canals extending to near gastral margin between ribs, and exhalant canals extending from spongocoel to near dermal margin, or to it, along axes of ribs.

Two horizontal cross sections of same specimen of species, IG R6-18(055) and IG R6-18(056) are in collection. They are tubular or steeply obconical to conical-cylindrical, ribbed sponges that appear like cogged gears in transverse cross section. These sponges with walls 7–12 mm thick.

Thick walls penetrated by inhalant and exhalant canals in full craticulariid diplorhysal development and surround tubular spongocoel, approximately 14 mm in diameter. Typical section shows 14 vertical rows of radial-horizontal exhalant ostia. These rows appear to extend full length of sponge. Canals 0.8–1.1 mm across, and with parallel sides. Most approximately 1 mm across through entire length of 5–10 mm from margin of spongocoel to rounded hemispherical distal ends, where they generally end blindly short of dermal margin.

Convergent horizontal inhalant canals also in vertical rows and with indented ostia 1.5–2.0 mm in diameter between outer rounded ribs, but narrow to only 0.4–0.8 mm in diameter near where they end blindly 1.8–2.0 mm short of spongocoel. Skeletal elements between inhalant and exhalant canals generally 1.8–2.0 mm thick near spongocoel but expand distally to approximately 4 mm thick near dermal surface.

Skeleton regular dictyonine with thickened dermal and gastral layers 0.2–0.4 mm thick. Most of armoring layers appear approximately 0.3 mm thick, although with distinct irregularity.

Parenchymal skeletal structure roughly 8 dictyonalia thick between canals in midwall. Strands appear to arch upward and outward from near spongocoel. Relatively delicate parenchymal net with nodes 0.04–0.06 mm in diameter, spaced approximately 0.2 mm apart, center to center. Beams 0.16–0.14 mm long where uniformly spaced, although may be somewhat shorter where skeleton more irregular. Beams approximately 0.02–0.03 mm in diameter at mid-length, but thicken to approximately 0.04 mm in diameter where joined with nodes.

No axial canals observed within parenchymal spicules because of calcareous replacement, however, some thickened dermal and gastral rays shows overlap of axial canals.

Gastral layer of distinctly thickened dictyonalia lines spongocoel and parts of exhalant canals. Layer with nodes up to 0.12 mm across but with most approximately 0.08–0.10 mm in diameter. Beams between gastral nodes 0.04–0.06 mm in diameter, lengths approximately equal to those in parenchymal area. Differentiation of gastral layer based on thickening of individual elements rather than closer spacing. Gastral layer one to two dictyonalia thick but may range up to 0.03 mm thick in some parts of section.

Less pronounced dermal layer similarly composed of thickened dictyonalia, with nodes 0.12–0.14 mm in diameter, connected by thickened beams approximately 0.06 mm across. Locally, axial canals well preserved in some spicules of dermal layer.

A few free, spiny hexactines occur in both dermal and gastral layers. Such spicules more evident in dermal layer, however, because of curvature of skeleton in ends of ribs.

Transverse lamellae appear to arch gently upward from outer edge of ribs to inner edge of spongocoel and oscular margin.

Discussion.—The ribbed exterior and craticulariid diplorhysal canal system, around a somewhat tubular spongocoel, is characteristic of *Sphenaulax pliopetala* (Wu, 1990). The sponge is also distinguished by thin gastral and dermal layers and by a relatively fine-textured parenchymal net. Primary subvertical strands occur in the ring of skeleton around the tubular spongocoel.

Upper Jurassic *Sphenaulax costata* (Goldfuss, 1826), is a similar appearing, ribbed, craticulariid sponge with ribs to 3.2 mm wide, but it has an outer layer of pentactines and stauractines that may be attached by (?)synapticular bridges over troughs between ribs or to sides of such ridges (Mehl, 1991a, p. 83, 1992, p. 81–82; Pisera, in press). Such structures are not present or not preserved in our specimens. According to Pisera (in press) mesh spaces in the dictyonal skeleton of *Sphenaulax costata* are regularly

0.3 x 0.4 mm, almost double the size of spaces in *Sphenaulax pliopetala.*

Laocoetis Pomel, 1872, from the Jurassic of Germany, is a related craticulariid sponge but it lacks the ribbed exterior of *Sphenaulax* and has a distinctly uniform pattern of ostia quite different from that in the Chinese sponges. *Laocoetis* may have a "colonial" form or a broadly funnel-shaped form with a uniform canal pattern, growth forms distinctly different from that of *Sphenaulax pliopetala* Wu, 1990. The Jurassic *Leptolacis,* Schrammen, 1937, is also a craticulariid sponge but it is plate-like.

Material.—Twelve specimens, S-1024 to S-1036 and three thin sections, IG R6-18 (054), (055), and (056), are all from Jushui in the Carnian sponge mound tract of the western Sichuan Basin. Figured specimens include S-1025, 1026, 1027, 1028 and 1029, and thin sections IG R6-18(055) and (056).

SPHENAULAX INFUNDIBULIFORMA
new species
Plate 4, Figures 1, 3, 7–9; Plate 7, Figures 6, 7; Plate 10, Figure 4

Diagnosis.—Funnel-like to broadly obconical or plate-like sponges with inhalant-exhalant canals, 0.6–0.10 mm in diameter, in crude vertical rows in craticulariid(?) pattern, separated by tracts with fine uniform rectangular dictyonine skeletal net in which primary strands diverge gently upward symmetrically; pronounced thin gastral layer of grossly thickened spicules, dermal layer thicker but less well defined.

Description.—Funnel-like to obconical thick-walled sponges with moderately smooth walls marked by low nodes or by vertical ridges formed largely between rows of indented ostia of vertically stacked radial canals. Cross sections of ribs or nodes somewhat rounded to bullet-shaped. Largest preserved sponge fragments representing heights of curved fronds 6–9 mm high or radii of funnel-shaped sponge over 20 mm in diameter or across and to 6 cm tall where more steeply obconical. Walls to 10–12 mm thick, with some variation and pierced principally by distinct radiating canals normal to dermal-gastral surfaces or inclined slightly upward toward gastral margin.

Cross-sections of radial canals circular to slightly elliptical, elongate vertically, and 0.6–0.7 mm wide in parenchymal middle part of wall. They expand to 1.0–1.2 mm wide at gastral margin. Canals appear irregularly wavy, locally branching, and may merge toward gastral margin.

Canals separated by skeletal tracts 0.5–1.1 mm across, with most tracts approximately 0.7–0.8 mm across, both vertically and horizontally, canals help produce fairly uniform-textured skeletal net, where 4 to 6 canals and intervening skeletal tracts occur per cm, measured vertically along single series. In same area 6–8 vertical series of canals occur per cm, measured horizontally. Canals with distinct, although crude, vertical stacking but similar horizontal lines of canals lacking. Canal pattern not grid-like but more or less uniformly spaced throughout skeleton. Canals not lined by spicules, but appear as smooth interruptions in skeleton.

Skeleton net well organized with dictyonalia spaced to produce rectangular, locally triangular, skeletal pores 0.12–0.16 mm across fairly uniformally throughout skeleton. Spicules slightly thickened in dermal layer about 1 mm and 7–8 dictyonalia hick. Contrasts to gastral layer only 0.2–0.3 mm thick of grossly thickened elements.

Normal parenchymal skeleton of dictyonalia, with nodes slightly expanded to 0.04–0.05 mm in diameter and with beams 0.10–0.14 mm long. Most beams 0.02 mm in diameter in middle, but may expand up to 0.03 mm in diameter where flared to common ray junction at nodes. Many spicules show axial canals approximately 0.008–0.010 mm in diameter as uniform, circular, beaded impressions.

Much of skeleton in reticulate net with uniform rectangular pattern. Elements of net thicken slightly in dermal area where nodes expand up to 0.06–0.08 mm across with some irregularity. Beams essentially same length as in parenchymal skeleton, but some up to 0.2 mm long. Beams in dermal dictyonalia commonly 0.02–0.04 mm across, although some up to 0.06 mm in the outermost part of the skeleton. Most beams approximately 0.15 mm long, but some irregularity most apparent in tangential sections, as in IG R6-21(067) and (065). There extraneous free rays, some apparent synapticulae, and perhaps dictyonalia of intermediate ranks produce more irregular-appearing skeleton.

Gastral layer 0.4–0.5 mm thick, composed of grossly thickened elements that may be beam-like, comma-like or finger-like. These generally 0.12–0.20 mm in diameter and up to 0.3–0.4 mm long. In some areas, however, gastral dictyonalia not enlarged and only one-quarter that size. Thickened nodes 0.2–0.5 mm apart, center to center, although openings between thickened grotesque elements 0.2–0.3 mm wide. Some coarse gastral spicules also show axial canals, indicating that somewhat enlarged net is merely increase in dimensions of dictyonalia rather than increase of number of dictyonalia to produce thin armoring layer.

Low vertical, bark-like, ridges on exterior with radial relief of 1 mm or less above horizontal tracts that separate canals of vertical rows. Sponges appear somewhat like *Ventriculities* Mantell, 1822, but skeletal net of *S. infundibuliforma* not lychniscoid but only dictyonine.

Discussion.—*Sphenaulax pliopetala* (Wu, 1990) is the most closely related species but it is a steeply obconical sponge with coarse distinct ribs and it lacks the prominent coarsely spiculed gastral layer of the new species *Sphenaulax infundibuliforma.* Parenchymal skeletal structures of the two species are similar, but *S. pliopetala* has a much more regular, radiating canal pattern.

The associated *Nelumbifolium pectiniforme* Wu, 1990, is also funnel-shaped, but that genus has a coarse dictyonine skeleton rather than the fine one characteristic of *Sphenaulax. Glossospongia* and *Keriogastrospongia* may appear similar, particularly as fragments, but both these genera have lyssacinosid skeletal structure of largely irregularly oriented hexactines and are easily differentiated because of that diifference.

Dracospongia new genus, may be funnel-shaped but it has a coarser euretoid skeleton largely lacking canals. *Dracolychnos* is also a broad funnel-shaped to broadly obconical sponge but it is composed of annular chamber-like segments in a skeleton which contrasts to that seen in *Sphenaulax infundibuliforma* new species.

Material.—Most of the distinctive characteristics of the species and genus are shown in thin section IG R6-5(015), the holotype. Paratype specimens include S-1143, 1147, 1148 and 1151. A vertical paratype section, IG R6-17(053), shows distribution of the canals. In addition to these, paratype thin sections IG R6-5(016) and R6-5(017) show partial horizontal or transverse sections. Vertical or nearly vertical paratype sections are included on sections IG R6-28(088) and T_3(10). Smaller tangential surfaces are cut in reference thin sections IG R6-6(08), R6-7(1), R6-11(1), R6-11(2), R6-17(052), R6-17(053), R6-21(065)(67), R6-28(087), R6-28(088), R6-28(089) and R6-28(93). All of these are from Jushui Triassic mound localities in Sichuan Province. Specimens S-1024 to S-1026, S-1029, S-1031 to S-1033, and S-1036 are from Hanwang, and specimens S-1027, S-1028, S-1030 and S-1034 are from Jushui.

Etmology.—*Infundibuliformis,* L., funnel-shaped, in reference to the common form of the species.

Genus SCIPIOSPONGIA
new genus

Diagnosis.—Steeply obconical, thick-walled dictyonine sponges with vertical rows of inhalant-exhalant canals in craticulariid(?) patterns, cross connecting to longitudinal, upward-divergent canals, separated by distinct tracts in which thickened primary strands form vertical rods at canal boundaries and remainder of net of girder-like tract composed mainly of short beams and synapticulae producing dominantly triangular skeletal pores.

Discussion.—*Scipiospongia* new genus appears similar in gross skeletal-canal structures to *Sphenaulax* Zittel, 1877, but the latter has a uniformly rectangular skeletal structure lacking the thickened long strands and the largely triangular skeletal pores of the former. Similarly, *Nelumbifolium* Wu, 1990, appears similar in growth form in some fragments but has a coarser rectangular-based skeleton than that in *Scipiospongia.*

Bowl-shaped *Keriogastrospongia* Wu, 1989, and the somewhat more obconical *Glossospongia* Wu, 1989, both have lyssacinosid skeletons composed largely of irregularly oriented and spaced hexactines rather than the distinctive dictyonine skeleton characteristic of *Scipiospongia.*

Etymology.—*Scipio,* L., staff or wand; *spongia,* sponges, calling attention to the staff-like strands in the skeleton.

Type species.—*Scipiospongia columnaria* n. sp.

SCIPIOSPONGIA COLUMNARIA
new species
Plate 7, Figures 8–10;
Plate 10, Figures 1–3

Diagnosis.—As for genus, with radial canals to 0.8 mm wide and 1.2 mm high, cross connected to vertical canals approximately 1 mm in diameter and separated by upward-divergent or branching skeletal tracts 0.5 mm across along branches, but usually about 1 mm across between canals; skeletal pores to 0.25 mm across where rectangular and to 0.20 mm across where triangular, defined by beams and synapticulae 0.02–0.03 mm in diameter and rod-like strands to 0.06 mm in diameter.

Descriptions.—Longitudinal and tangential sections of distinctive steeply obconical, probably gently ribbed, aligned nodose, dictyonine sponges occur in collection. Sponges at least 8 cm tall as seen in available sections IG R6-21(065) and (067), holotype and paratype sections. Walls around deep open spongocoel about 10 mm thick in lower part and to 20 mm thick in upper part.

Walls pierced by upward-divergent canals, approximately 1.0 mm in diameter, that parallel skeletal tract. Tract with continuous thick primary strands cross-connected by similarly thick short beams and synapticulae that produce girder-like skeletal net with mainly triangular skeletal pores.

Radial horizontal inhalant-exhalant canals in vertical rows separated by 0.5–1.0 mm wide skeletal tracts. Canals commonly oval and 0.6–0.8 mm wide and 0.8–1.2 mm high, spaced so 5–7 canals occur per 5 mm in vertical rows. Canals in probable craticulariid pattern.

Primary strands 0.4–0.7 mm apart, mostly approximately 0.5 mm apart, and divergent upward so greatest separation near where new strands inserted. Strand segments traceable to 5–6 mm in thin sections before cut, but probably considerably longer rod-like elements. Strands 0.025–0.06 mm in diameter as coarsest longest elements in net. Axial canals commonly preserved and 0.005–0.015 mm in diameter in calcareous replacements. Strands commonly border girder-like tracts and vertical canals and commonly lack beams or rays on canal side, or such may be present as nodes or short free rays.

Cross-connecting short beams and synapticulae 0.02–0.03 mm in diameter, but may swell to 0.04–0.05 mm across where joined to each other or strands, define triangular skeletal pores 0.10–0.20 across, where triangular, or 0.20–0.25 mmm across, where rectangular. Beams commonly with traces of overlapping axial canals that 0.004–0.006 mm in diameter.

Strands diverge asymmetrically from near midwall and meet gastral surface at 60°–70° and dermal surface to 20°–30°.

Discussion.—*Scipiospongia columnaria* is currently the only species in the genus. Specific characters are considered to be dimensions of the canal series and their spacings, as well as dimensions of elements of the girder-like skeletal structure.

Material.—Holotype, thin section IG R6-21(065); and paratype sections IG R6-21(066) and R6-21(067), from Jushui, Sichuan. Reference specimens from Jushui include IG R6-17(052), R6-25(084) and T_3(10).

Etymology.—*Columnaris,* L., pillarlike, referring to the cross-braced skeletal columns characteristic of the sponges.

(?)Family CRATICULARIIDAE
Rauff, 1893
Genus CASEARIA Quenstedt, 1858

Type species.—*Casearia articulata* Schmidel, 1780.

CASEARIA ARTICULATA
(Schmidel, 1780)
Plate 5, Figure 5

Spongia articulata SCHMIDEL, 1780, p. 19, Pls. 4, 5.
Casearia articulata QUENSTEDT, 1858, p. 680–681, Pl. 82, Fig. 9.
Caesaria articulata DE LAUBENFELS, 1955, p. 82.
Casearia articulata MÜLLER, 1974, p. 1–19, Pl. 1–4.
Innaccoelia pamirica BOIKO, 1990, p. 126, Pl. 42, Figs. 4–6, Pl. 43, Figs. 1–4.
Innaecoelia Kurtekia BOIKO 1990, p. 126, Pl. 40, Figs. 3, 4.
Casearia articulata PISERA, (in press), Pl. 11, Fig. 3, Pl. 35, Figs. 6–9.

For a more exhaustive synonymy see Müller (1974, p. 3–4), and Mehl (1991a, p. 79; 1992, p. 78).

Description.—Small conico-cylindrical to cylindrical moniliform chambered sponges. Fragments S-1037 and S-1038, 9 and 12 mm high, latter composed of 3 and former of 4 bead-like segments with moderately well-defined inhalant ostia 0.4–0.5 mm in diameter. These ostia not aligned but uniformly spread about 0.5–0.6 mm apart, center to center, separated by skeletal segments about 0.2 mm wide, so 5–7 ostia occur per 5 mm vertically, horizontally and diagonally.

Larger fragment with lower chambers 10 mm in diameter and upper chamber 12 mm in diameter. Central spongocoel 3 mm in diameter in lower chamber and 5 mm in diameter in upper one.

Longitudinal section of S-1044, a fragment 2 chambers high, shows chambers with walls 3–4 mm thick, with dense dermal-interwall layer 0.3–0.4 mm thick. This layer of dense fine structure between ostia of canals. Structure of non-rectangularly arranged short elements, 0.04 mm in diameter, that surround small pores 0.06–0.08 mm in diameter in uniform cellular structure of "tracts" between ostia.

Chambers generally increase in diameter and height upward so in S-1037, chambers 2, 2, 2.5 and 3 mm high and 4, 4.5, 5, and 6 mm in diameter. In S-1045 chambers 3, 4, 5, and 4 mm high and 4, 6, 6, and 7.5 mm in diameter. Base broken but rounded spongocoel wall complete in part and round. Spongocoel only 1 mm in diameter in broken base 3 mm in diameter, and 2 mm in diameter in top chamber where walls 2.5 mm thick.

Discussion.—Three species of *Casearia* occur in Triassic collections from the western margin of the Sichuan Basin. The cylindrical specimens of these are here included in the type species, *C. articulata* (Schmidel, 1780), based on general morphology and size rather than on clear identity of the internal skeletal and canal patterns so fully documented by Müller (1974) in specimens collected from the Upper Jurassic of Germany.

Casearia oblata (Wu, 1990) includes small sponges with bead-like subspherical chambers, which abruptly increase in dimensions upward. *C. decursiva* (Wu, 1990) is a laterally-flattened subcylindrical form with uniform oval, ring-like chambers that surround an oval, almost slit-like deep spongocoel. The chambers are approximately 5 mm high, uniformly, in the upper adult part of the sponge.

Pisera (in press) noted that *Casearia depressa* Kolb, 1910, should be maintained as a separate species rather than placed in synonymy with *Casearia articulata*, as was done by Mehl (1991a, p. 79, 1992, p. 78).

Material.—Samples of the species in our collections include S-1037 and 1044, which are from the Carnian mound tract at Hanwang, and S-1038, 1042 and 1045 from Jushui. Figured specimen is S-1038.

CASEARIA OBLATA
(Wu, 1990)
Plate 5, Figures 6, 7, 10;
Plate 8, Figures 6 and 7

Monilispongia oblata WU, 1990, p. 354–355, 361, Pl. 1 Figs. 1,5; Pl. 2, Figs 5; Pl. 3, Figs 9, 15

Emended Diagnosis.—Moniliform small to medium-sized sponges with subspherical chambers to 27 mm across in sphinctozoan-like form, with deep spongocoel to 6–7 mm in diameter that extends to near base, chambers increase in diameters and heights upward. Exterior without prominent ostia in reticulate dictyonine dermal skeleton, where rectangular skeletal pores 0.08–0.12 mm across.

Description.—Moniliform small to medium-sized sponges composed of bead-like, subspherical, chambers around central retrosiphonate tubular spongocoel. Chambers increase in size upward near base but may produce annulate cylindrical upper parts in larger sponges. Representative form in collection includes three complete chambers, 8, 12 and 19 mm in diameter above a minor fragment of a fourth near-basal chamber. These chambers 6, 6, and 10 mm high. Central spongocoel 4 x 6 mm across on fractured upper surface and 2 mm in diameter in broken base. Spongocoel defined by coarser gastral layer of dictyonalia.

Fragment of larger sponge with 2 chamber 25–27 mm in diameter shows cylindrical upper part, chambers 13–14 mm high, with axial spongocoel 6–7 mm in diameter.

Exteriors of these larger sponges without prominent ostia but locally with reticulate dermal layer of fine dimensions, with skeletal pores generally 0.08 mm in diameter between beams 0.04–0.05 mm in diameter and with nodes of dictyonine net 0.12–0.16 mm apart. Some areas of net regularly rectangular, other areas more irregular but with same general spacing and beam dimensions.

Discussion.—*Casearia oblata* (Wu, 1990), differs from the more uniformly annulate, steeply obconical to subcylindrical *Casearia decursiva* (Wu, 1990), in having larger bead-like, upward expanding chambers instead of more or less uniform ring-like chambers in its skeleton. *C. oblata* includes distinctly larger and more abruptly upward-expanding sponges than those specimens included in *Caseara articulata* (Schmidel, 1780), which is also a more nearly subcylindrical to gently upward-expanding species.

Wu (1990, p. 354, 361, Pl. 1, Figs. 1, 5; Pl. 2, Fig. 5; Pl. 3, Figs. 9, 15) described and figured the species and concluded, as earlier noted by Wendt et al., (1989, Figs. 6, 10c), that these are lynchniscoid sponges. Mehl (1991a, p. 80) observed that the skeletal structures shown by them and those in *Casearia* are not lychniscs but are pseudolychniscs (Mehl, 1991a). Pisera (in press) also noted the occurrence of pseudolychniscs in *Casearia articulata* (Schmidel, 1780). Piserra's figured specimen (in press, Pl. 11, Fig. 3) of *C. articulata* is considerably more conicocylindrical and has more uniform-sized chambers than those in *C. oblata* (Wu, 1990) described here. It is more like the sponge we have termed *Casearia articulata* in our collections.

Material.—Samples S-1039, 1040, and 1046 from Hanwang, and S-1041 and 1043 from Jushui, in the Carnian mound tract. Figured specimens include S-1039 and 1040, and figured thin section IG T3(12).

CASEARIA DECURSIVA
(Wu, 1990)
Plate 5, Figures 14–16; Plate 8, Figures 8–10;
Plate 11, Figure 6

Segmented lychniscid sponge, WENDT, WU AND REINHARDT, 1989, Figs. 6, 10c.
Monilispongia decursiva WU, 1990, p. 355, 361, Pl. 3, Figs. 10, 16, 17, 21. S
Monilispongia obconcava WU, 1990, p. 356, 361, Pl. 1, Figs. 4, 7; Pl. 3, Fig. 8.

Emended diagnosis.—Moniliform, laterally flattened, annulate sphinctozoan-like sponge with deep spongocoel with ovate cross sections and uniform ring-like chambers 3.0–3.5 mm high in adult stages. Dermal and gastral layers of thickened dictyonine elements, skeleton in interior of chambers delicate, although with nodal spacing of approximately 0.02 mm as in dermal layer.

Description.—Steeply obconical to conical-cylindrical moderate-sized sponges with distinct laterally flattened, annular chambered construction. Exterior with annulate appearance produced by ring-like chambers of more or less equal height. Deep simple spongocoel weakly annulate, extends to oscular margin from near base.

Most complete specimens in collection 55–60 mm tall, distinctly oval in transverse section and 15 x 26 (S-1050) or 16 x 20 (S-1049), with spongocoel 5 x 13 at oscular margin where walls 4–6 mm thick in S-1050.

Chambers and annulations 2.5–3.0 mm thick in juvenile part of sponge and 3.0–5.0 mm high in upper part. Chambers ring-like, as in calcareous sphinctozoan *Amblysiphonella*, and rise 1–2 mm above indentations between chambers on exterior, produced by inward arching of upper chamber wall, below junction of base of wall of succeeding chamber.

Dermal layer of thickened dictyonalia in weathered-out sponges with beams 0.04–0.06 mm in diameter and 0.16–0.20 mm long, between expanded nodes 0.08–0.10 across. These form skeletal pores to 0.20 mm across. Internal skeletal made of more delicate elements but with same general spacing, with beams only 0.02 mm in diameter.

In longitudinal section, chambers upward crescentic in cross sections, with dermal and gastral parts of walls and "interwalls" between chambers clearly defined by layers of thickened dictyonalia. Walls flexed abruptly downward around spongocoel in retrosiphonate structure.

Canals not well defined in chambered interiors where some ghost-like matrix fills canals 0.4–0.5 mm in diameter traceable parallel to arched interwalls, parallel transverse beams in sections T-3(1). Transverse sections of some canals of same or smaller dimensions also occur as matrix fills. Inhalant ostia 0.2–0.3 mm across where seen as breaks in dermal and interwall nets in the same sections. Similar canals occur in outer parts of chambers in Section T-3(2) but are not seen connecting to exhalant canals.

In Section T-3(2), exhalant canals 0.5–0.6 mm across interupt the thickened gastral layer. These apparently extend to at least midchamber, based on ghosts of matrix fills seemingly unmodified by considerable bioturbation.

Diagonal thin section, Section T-3(2), of flattened annulate tubular dictyonine sponge approximately 18 mm tall, with elliptical upper cross section. Tangentially-cut annulations show along margin. These annulations approximately 3 mm high and separated by 2–3 mm of matrix or indented impressions. Elliptical spongocoel most consistent reference point and at cut is 13 mm long and 8 mm wide, flanked by walls 6.5–7 mm thick, along long axis, and 3.5–4.0 mm thick along short axis. Margins of spongocoel marked by gastral ostia, 0.4–0.7 mm across, as gaps in thickened armoring gastral layer. That layer approximately 0.5 mm thick and more pronounced and wider than somewhat coarser dermal layer, which only 0.1–0.2 mm thick, as judged from available diagonal section.

Nodes in coarse dermal layer average 0.15–0.16 mm in diameter but with great variation. These cross-connected by beams approximately 0.04–0.06 mm in diameter and generally 0.15–0.20 mm long. Spicules of gastral layer, on other hand, with expanded central nodes 0.06–0.10 mm in diameter, expanded from beams approximately 0.03–0.04 mm across and 0.14–0.20 mm long. Parenchymal parts of skeleton somewhat more delicate, though not as delicate as in *Tesselospongia fistulosa* n. sp. In this specimen expanded nodes 0.04–0.05 mm across and connecting beams and possible strands 0.015–0.025 mm across, with most in lower size ranges. They, like other beams, approximately 0.20–0.22 mm long where measurable in middle part of parenchymal layer.

Whether euretoid skeletal structure symmetric or asymmetric uncertain because orientation of section through annulate tubular sponge uncertain.

Discussion.—The annulate species *Casearia decursiva* (Wu, 1990), contrasts with *Casearia oblata* (Wu, 1990), in growth form, for the latter is made of only a few subspherical chambers that increase in size upward, in contrast to the more uniform smaller ring-like chambers in the former. This results in a more uniform, laterally flattened tubular growth form in *C. decursiva.*

The oval cross section and the ring-like chambers in *C. decursiva*, also contrast to the distinctly cylindrical *C. articulata* (Schmidel, 1780) (see Müller, 1974; Mehl, 1991a, Pl. 13, Fig. 2, 1992, Pl. 13, Fig. 2). *Casearia articulata* has distinctly keg- or barrel-shaped chambers in the cylindrical species.

Material.—Representatives of the species in the collection include thin sections T_3(1), T_3(2) and R6-8-025 and samples S-1035, and S-1047 to S-1056, and S-1130, from Carnian sponge mounds. Samples S-1047, 1048, and 1054 are from Hanwang, and S-1035, 1049, 1050, 1051, 1052, 1053, 1055, and 1056 and 1130 are from Jushui, all from the Carnian mound tract. Figured specimens include S-1047, 1049, and 1050, and thin sections IG T3(A), T3(2) and a section of sample S-1035.

Genus DRACOLYCHNOS
Wu and Xiao, 1989

Emended Diagnosis.—Low funnel-shaped to broadly obconical, thin-walled, plate-like sponges composed of annular ringed segments, each with distinct dermal-gastral layer of thickened dictyonine skeletons, often appearing as double layer in horizontal sections; chamber-like rings produce annular ridges on both top and bottom surfaces.

Type species.—*Dracolychnos annulirotatus* Wu and Xiao, 1989

Discussion.—The distinctive annulate, broad, plate- to funnel-like chambered growth is unique among Triassic hexactinellids from Sichuan. *Casearia depressa* Kolb, 1910, is an annulate steeply obconical sponge whose "construction resembles a pile of dishes with lids" (Müller, 1990). Each "dish and lid" is composed of a series of stacked annular ring- or chamber-like additions added at the growing upper margin, chambers whose circumferences enlarge in lower broadening parts of the annulations and shrink in upper parts where the turret-like sponge contracts. A single upper or lower wall of an annulation might appear similar to *Dracholychnos* but the latter is a one layer plate- or funnel-like sponge rather than an annulate subcylindrical to steeply obconical sponge such as a *C. depressa* Kolb, 1910.

Nelumbifolium Wu, 1990, has a similar funnel-like shape but lacks the annular chambered skeletal structure. *Lecanocoelospongia* Wu, 1989, also has a broadly funnel-like form but it too lacks the distinct annular growth form and chambers. In addition it has a lyssakid irregular skeleton in its moderally thick walls, and a rough dermal surface and a gastral surface marked by canals and large ostia.

Placotelia Oppliger, 1907, from the Jurassic of France, is also a broadly obconical sponge but it lacks the annular chambers and the ringed surfaces, but may look superficially annular because of concentric rings of coarse ostia on the gastral surface. Internally the skeletal structure lacks the chambers and, even on the surface, the European sponge has a radiate rather than concentric structure.

Tremaphorus Schrammen, 1936, is also grossly similar in form but lacks the chambered structure and morphology.

Some sponges from the European Jurassic (Oppliger, 1907; Schrammen, 1936; Pisera, in press) may have wrinkled dermal surfaces but all lack the chambered growth form of *Dracolychnos.*

DRACHOLYCHNOS ANNULIROTATUS
Wu and Xiao, 1989
Plate 5, Figures 8, 9, 11–13, 17, 18;
Plate 8, Figures 5, 11, 12; Plate 9, Figure 6.

Dracholychnos annulirotula WU AND XIAO, 1989, p. 13, Pl. 1, Figs. 1–3.
Dracholychnus annulirotatus WU, 1990, p. 352–353, 360, Pl. 1, Figs. 2, 3, 6; Pl. 3, Figs. 19, 20.
Dracholychnus catenatus WU, 1990, p. 353, 360, Pl. 1 Fig. 4; Pl. 2, Fig. 2; Pl. 3, Fig. 4.
Dracholychnus ruidicostatus WU, 1990, p. 353–354, 360, Pl. 3, Figs. 1, 18.

Emended diagnosis.—Funnel-shaped with surfaces ornamented with annular rings produced by chambers 1–5 mm high, radially, in walls generally 5–6 mm thick in inner parts, but up to 2–2.5 cm thick in outer parts; most to 50 mm in diameter but rarely to 66 cm in diameter. Skeleton dictyonine with prominent dermal layer of expanded beams, curved to form successive chambers filled with more delicate dictyonine skeleton with nodes regularly 0.10–0.14 mm apart in chamber interiors.

Description.—Low, obconical to funnel-shaped or broad, open fan-like sponges with simple, smooth open spongocoel and thin walls built of radially concentric chamber-like sections. Sponges to at least 10–12 cm in diameter, in specimens available and in type specimens (Wu, 1990, p. 353), but may range to 660 mm in diameter, although most 20–50 mm in diameter. Sponge walls generally 4–5 mm thick, and commonly 1.8–5.1 mm thick, but one large sponge 66 cm in diameter with walls 42 mm thick (Wu, 1990, p. 353).

Skeletons built of irregularly ring-like, locally asymmetric chambered additions. These irregularly and weakly lobate, 2–3 mm wide and up to 1 mm high, radially, as defined by thickened dictyonalia that make dermal layer and transverse lamellae where cut in sections. These lamellae generally spaced 2.0–3.5 mm apart, although some only 1.0 mm apart, indicating peripheral ring-like additions of that general dimension during growth.

Dermal layers generally composed of two irregularly thickened subparallel layers of dictyonalia. Dermal layers extend in concentric ring-like structures out from margin of shallow spongocoel in horizontal sections. Some may converge, laterally, and show growth not totally radial and uniform, but radial growth generally characterisitic.

Coarse skeletal nodes of dermal layer most commonly preserved parts of skeleton, and 0.06–0.10 mm in diameter, with most approximately 0.08 mm across. They form parallel layer generally 0.2 mm apart, with considerable irregularity. Nodes within single dictyonalia layers 0.2–0.3 mm apart. Beams commonly 0.10–0.13 mm long, but may be up to 0.30 mm long in dermal interwall layer, and may be up to 0.08 mm in diameter, but most approximately 0.06 mm across or slightly smaller. They show great irregularity in dimensions, as well as moderate irregularity in placement.

Interwalls commonly 0.2–0.4 mm thick, usually with two strands arching to produce transverse lamellae in what must be unusual euretoid skeleton. Strands not traceable for any distance in skeleton, for chamber skeletons not well preserved and only coarse upper and lower radial walls well preserved. Beams within interwalls approximately 0.25–0.3 mm long, center to center, and 0.04–0.05 mm in diameter. Spicule nodes irregularly developed and approximately 0.10 mm in diameter, from which extend beams that make up interwall. Free rays also radiate from nodes, most commonly into more distal chambers, rather than proximal ones, although both occur. Free or unattached rays may extend 1.5–2.0 mm into distal chambers, but only about half that distance in proximal ones of sponge.

Parenchymal skeleton, except for transverse lamellae, very fine-textured and not well preserved, although irregularly present as patches in each ring-like chamber addition to skeleton. There small nodes, 0.02–0.03 mm in diameter spaced approximately 0.10–0.14 mm apart, concentrically and radially. Related beams generally 0.015–0.02 mm in diameter, smooth, and approximately 0.1 mm long. Beams preserved in available thin sections principally as cross sections. Apparently fine-textured skeleton broke apart easily, even when protected within chambers formed by thickened dermal layers.

Spicules characteristic dictyonalia and their junctions appear overlapping within single transverse lamellae. Other types of junctions also occur and include irregular and perhaps ray tip-to-node or to middle of beam from one layer to another within transverse lamella. Irregular synapticulae also developed where beams that connect strands short and where rays side by side. Walls between chambers, consequently, 0.2–0.4 mm thick in center of distalmost part of wall. Walls gradually thin as two layers of beams that make up transverse lamellae merge so that lateral walls principally made of single dictyonaliid layer.

Pores between double dictyonalia of principal inner chamber walls 0.15–0.25 mm in diameter. Most round or broadly elliptical, but others may be irregular, though rounded, where seen in vertical sections of wall. Perforations through chamber walls in parenchyme 0.2–0.25 mm in diameter, in general, and openings through gastral and dermal layers mostly approximately 0.25 mm across.

Discussion.—Dracolychnos annulirotatus Wu and Xiao, 1989, is characterized by the chambered-appearing, somewhat lobate, irregular ring-like additions of the skeleton and by the very fine parenchymal skeletal net between the coarse lamellar rings. Fine dictyonine skeletal structures are not preserved in organized fashon within many of the chambers and some of those spicule fragments in the openings could also be foreign elements because the sponges and matrix within the chambers commonly have been intensely burrowed and contain obviously foreign fragments of ostracods, gastropods, foraminifera, etc. The sponges have a low conical to broad funnel-shaped, thin-walled, growth form, that may or may not have had a stalk.

Dracholychnos annulirotatus Wu and Xiao, 1989, is a funnel-shaped sponge with a lower stalk. Wu (1990, p. 353–354, 360) also described *Dracholychnus catenatus* and *Dracholychnus rudicostatus* as new species and differentiated them from the type species, based on differences in shape, cupulate-discoid or elliptical discoid, and on the lack of a root or stalk in the latter two species. All three have upper and lower surfaces marked by annular rings produced by the concentric chambered growth of the sponges. Our review now suggests that the three should be considered as growth variants of a single species, the type species. *D. catenatus* and *D. ruidicostatus* are thus subjective junior synonyms of *D. annulirotatus* Wu and Xiao, 1989.

Material.—The holotype is specimen CIT 121 deposited in the Data Center of the Chengdu Institute of Technology. Other figured specimens designated as holotypes of *D. catenatus* Wu, 1990, (Plate 2, Fig. 2), and *D. ruidicostatus* Wu, 1990 (Plate 3, Fig. 1) are also in the Data Center of the Institute. Figured specimens from our collections include specimens S-1057, 1059, 1060 and 1061, and thin sections IG R6-11(018), R6-18(057), R6-18(058), R6-25(085) and IG T3(A). Reference specimens include IG R6-8(23 and 24), R6-19(060), R6-20(062), R6-23(075), R6-24(080), R6-25(086). All are from the Hanwang-Jushui Triassic mound tract north of Chengdu, in north-central Sichuan province. Samples S-1058, 1062 and 1063, and S-1160 and S-1161 are also included here. Specimens S-1158, 1160 and 1163 are from Jushui, and S-1057, 1059, 1060, 1161 and 1162 are from Hanwang.

Family CRIBROSPONGIIDAE
Römer, 1864
Genus TESSELOSPONGIA
new genus

Diagnosis.—Small conico-cylindrical sponges with deep simple spongocoel and smooth walls with cribrospongiid diplorhysal canal system in well organized, uniform, simple, euretoid dictyonine skeleton with primary strands near gastral margin, skeletal structure diverges upward and outward to dermal margins where dermal cortex well-defined and thicker than gastral layer.

Discussion.—Cribrospongia d'Orbigny, 1849, and *Tremaphorus* Schrammen, 1937, include plate-like cribrospongiid sponges and, thus, are clearly different from the tubular *Tesselospongia. Ramispongia* Quenstedt, 1878, a Jurassic European genus, is a branching small form. Most similar genera are the tubular-conical or cylindrical European Jurassic sponges *Walcotella* de Laubenfels, 1955, and *Ordinatus* de Laubenfels, 1955. The latter, however, is a large sponge in comparison to *Tesselospongia* and has much coarser canals and skeletal structure. *Walcotella pertusa* (Goldfuss, 1833) is a variable species, and the only species described of the genus (Pisera, in press). It includes some sponges of essentially the same shape as *Tesselospongia,* though somewhat larger sponges with much larger canals and a somewhat coarser skeleton.

Etymology.—Tessellatus, L., inlaid with small square stones; *spongia*, sponge; referring to the regular rectangular appearance of the skeleton.

Type species.—Tesselospongia fistulosa new species.

TESSELOSPONGIA FISTULOSA n. sp.
Plate 4, Figures 4–6; Plate 7, Figures 3–5;
Plate 10, Figures 5, 6

Diagnosis.—As for genus and with inhalant ostia 0.30–0.50 mm in diameter in dictyonine net of dermal layer with square skeletal pores 0.16–0.18 mm across; exhalant ostia to 0.60 mm in diameter. Primary strands approximately 0.2 mm apart in middle of wall, cross-connected by beams spaced approximately 0.2 mm apart, and 0.015–0.020 mm in diameter.

Description.—Steeply obconical to conico-cylindrical small sponges, each with simple deep tubular spongocoel. Characteristic specimens gently to moderately curved, with horn coral-like appearance, to 20–25 mm high. Sponges expand upward, with faint growth lines and minor annulations 3–5 mm high, in generally smooth surface otherwise marked by small inhalant ostia.

Inhalant ostia round to elongate vertically and oval-shaped, range 0.30–0.50 mm in diameter with most approximately 0.35–0.40 mm across and high. Ostia not aligned, neither vertically nor horizontally, but more or less uniformly spaced 0.20–0.30 mm apart so 2 or 3 occur per mm vertically, horizontally and diagonally. Small round ostia, probably dermal openings of exhalant canals in diplorhysal canals, occur in skeletal tracts between larger inhalant ostia on dermal surface, such openings approximately 0.10 mm in diameter, in cribrospongiid canal pattern.

Skeletal pores rounded between beams in dermal exposure, where pores 0.04–0.06 mm in diameter in tracts between ostia.

Walls 1.8–2.3 mm thick around spongocoel 4 x 5 mm in diameter where sponge 7 x 9 mm in diameter at oscular margin on S-1002. S-1005 with diameter of 8 mm and walls 2.0 mm thick around spongocoel 3.5–4.0 mm in diameter at top of small sponge.

Dictyonine net shows well on weathered surface of S-1005, with square skeletal pores 0.16–0.18 mm across, defined by calcareously replaced beams 0.02–0.03 mm in diameter. Nodes 0.04–0.06 mm across and preserved as calcite spar in expanded part of skeleton with pseudolychniscs. Uniform dictyonal net with strands that gently diverge from gastral surface and curve to meet dermal surface at up to 20°.

Transverse section of complete oscular margin of S-1005 shows uniform reticulate quadrangular net, as does transverse section of broken base. There rectangular skeletal pores 0.12–0.16 mm across, with nodes and beams like exposed on dermal surface.

Vertical thin section of sponge fragment 47 mm tall expands upward from subspherical base approximately 2 mm across to diameter of 8 mm in short distance above base and near base of spongocoel. Sponge continues to widen upward to near top, where approximately 13 mm in diameter before narrowing in somewhat tangential cut.

Spongocoel extends for virtually full length, from rounded base to uppermost tangential margin. It expands from approximately 3 mm across, at rounded hemispherical base, up to maximum width of about 5 mm, 10 mm below upper surface.

Gastral margins of walls smooth, except for broad pits of ostia of radial canals. Walls approximately 2 mm thick near base, thicken up to 3 mm at mid-height, and up to approximately 5 mm of maximum thickness near top of sponge. Exterior shows weak annulae up to 0.9 mm high or wide, 10–13 mm apart, but such irregularities not at same levels in sections of both walls. General surface, however, smooth and armored so that even incurrent ostia pits obscured.

Horizontal section shows well-defined radial canals, at least beneath dermal cortex. Canals approximately 0.4–0.5 mm across interrupt relatively fine-textured skeleton.

Radial canals may be in crude vertical or horizontal rows. In vertical series, 6 occur in 5 mm, separated by 0.3–0.6 mm of skeletal material. Rows are separated by skeletal material 0.7–1.0 mm wide in middle part of wall, and in the well-defined gastral layer. Convergence of some large canals at about midwall suggested, and maintains spacing and diameter of these excurrent openings.

Well-preserved gastral ostia, 0.5–0.6 mm in diameter, occur regularly around margin of spongocoel. Ostia separated by 0.75–1.0 mm of skeletal material that thickened slightly in the gastral layer.

Parenchymal skeleton simple, euretoid dictyonine, with primary strands at gastral margin. Strands curve symmetrically upward and outward to emerge at the dermal cortex at angles of approximately 70°–80°, but locally up to approximately 90° to sponge surface. Primary strands approximately 0.015–0.018 mm thick and clearly defined immediately inside gastral layer. They thicken slightly to 0.018–0.02 mm near midwall and retain diameter of approximately 0.2 mm through rest of traverse out to base of thickened dermal cortex. Centers of dictyonalia somewhat expanded, with diameters of approximately 0.03–0.04 mm.

Strands with varying separation, but 0.16–0.20 mm apart within 0.5 mm of gastral margin and remain essentially 0.2 mm apart through middle and outer parts of parenchymal skeleton. They are cross-connected with beams of similar dimensions, spaced uniformly approximately 0.2 mm apart, producing reticulation of moderately fine spicules through much of skeleton. Skeletal openings approximately 0.2 mm across and high.

Armored dermal layer or cortex 0.1–0.2 mm thick, along most of vertical cross section, but ranges up to 0.3–0.5 mm thick in transverse section. There layer also somewhat thicker and up to 2 dictyonalia thick. Nodes of spicule junctions up to 0.08 mm in diameter, with individual short beams 0.25 mm long and up to 0.04–0.06 mm across at mid-distance between expanded centers. These relatively coarse elements surround small ostia that generally elliptical or crudely triangular, 0.08 mm long and 0.04–0.06 mm across. Dermal layer not interupted by larger radial canals.

Gastral layer up to 0.2–0.3 mm thick in upper part of transverse section and approximately 0.3 mm thick in horizontal section. Skeletal elements somewhat less thick than in pronounced dermal layer, but ray junctions of spicule nodes up to 0.05–0.06 mm in diameter, and with beams approximately 0.03 mm in diameter and 0.2 mm long.

Parenchymal skeletal net considerably more delicate than either in gastral or dermal layers, with strands and beams both 0.015–0.020 mm in diameter. Latter approximately 0.2 mm long and with both tangential and radial elements that connect adjacent strands. Beams of parenchymal spicules enlarged up to 0.03 mm in diameter only in vicinity of gastral canals. Beam lengths remain essentially same throughout skeleton, except in zone of rapid divergence of primary strands near gastral margin. There elements somewhat shorter, that is subradial elements somewhat shorter, but tangential beams essentially same lengths as farther out in parenchymal layer of skeleton.

Discussion.—The distinctive features of the new species *Tesselospongia fistulosa* are the relatively uniform delicate skeletal net, the asymmetric expansion of the skeletal net from the gastral margin, the thick dermal layer and somewhat less thick gastral layer. Ostia and radial canals in the cribospongiid canal pattern are apparent in both the thickened gastral and thick dermal layers. Dimensions of canals, their spacing and sizes, and dimensions of the skeletal net are considered to be specific characters.

Material.—Holotype, Sample S-1001, and paratypes S-1002 and S-1009 from Hanwang, and S-1005 from Jushui; and paratype thin sections IG T3(1), T3(2) and T3(4), R6-8(022), R6-15(051), R6-19(061) and R6-24(078) from the Hanwang-Jushui mound tract. Additional reference specimens includes S-1003, 1007, 1010, 1011 and 1013, and thin sections IG R6-9(30), R6-15(48), R6-24(77), R6-10(34), R6-3; and IG T3(3) from Jushui; and specimens S-1004, 1006, 1008, and 1012 from Hanwang.

Etymology.—*Fistulosus,* L, porous, in reference to the porous cribrospongiid skeleton.

Genus NELUMBIFOLIUM Wu, 1990

Emended diagnosis.—Broad, open funnel-shaped, thin-walled sponges with prominent ostia of exhalant-inhalant canals, about 2 mm apart in moderate concentric and radial series in rough to nodose gastral and dermal surfaces. Discontinuous concentric and radial midwall canals in coarse, somewhat irregular, open skeleton where radial strands most prominent, with second- and third-order subdividing elements commonly appearing spinose or with free rays or small hexactines or with synapticulae near nodes.

Discussion.—*Keriogastrospongia* Wu, 1989 is an associated open bowl-shaped sponge, but it has large exhalant ostia in the shallow spongocoel in a lyssacid skeleton and is clearly different from *Nelumbifolium pectiniforme* Wu, 1990. Similarly, fragments of the bell- or scabbard-shaped *Glossospongia* Wu, 1989, may appear superficially similar but it is also clearly differentiated by its skeletal structure where some hexactine elements are bundled but separated by irregularly oriented hexactines, in a non-dictyonine skeleton.

Dracospongia new genus, is an undulate plate-like sponge but it has a markedly regular euretoid skeleton largely lacking canals, in a structure distinctly different from that seen in *Nelumbifolium. Dracholychnos* Wu and Xiao, 1989, is a broad funnel-shaped sponge but it is composed of annular, ring-like chambers, rather than a radially arranged skeletal net.

Type species.—*Nelumbifolium pectiniforme* Wu, 1990.

NELUMBIFOLIUM PECTINIFORME Wu, 1990
Plate 4, Figure 2; Plate 5, Figures 1–4;
Plate 8, Figures 1–4; Plate 10, Figures 7, 8

Nelumbifolium pectiniforme WU, 1990, p. 356, 362, Pl. 1, Fig. 12, Pl. 2, Figs. 6, 8.

Emended Diagnosis.—Same as for genus and with inhalant ostia to 1.2 mm in diameter and exhalant ostia to 1.5 mm in diameter, in dictyonine skeleton with coarse primary quadrules about 2.0 mm across, concentrically, and high, radially. Subdivided irregularly by second- and third-order, often spinose-appearing elements.

Description.—Broad open funnel-shaped to broadly obconical, thin-walled sponges usually preserved as fragments of curved wall, commonly with rounded outer or upper oscular margin. Both upper gastral and lower dermal surfaces rough, nodose or locally marked by irregular to faint upward divergent to subparallel radial, discontinuous, ridges. Ridges occur between ostia of inhalant and exhalant canal series. Ridges on gastral surface 1–2 mm wide and locally capped by nodes that project downward toward centers of gastral depression or broad spongocoel. Such tapering nodes commonly 1.0–1.5 mm wide and to 2 mm long.

Exhalant ostia on S-1142, 1.0–1.5 mm in diameter, with most 1.2–1.3 mm across in shallow pits between nodes or ridges. Such ostia 2.0–2.5 mm apart, center to center concentrically and laterally, parallel sponge margin. Ostia commonly 2.0 mm apart, center to center, in radial series at right angles to margin of spongocoel or wall between ridges.

Inhalant ostia on dermal surface commonly 0.8–1.2 mm in diameter, and separated by low ridges 1.2–1.5 mm wide, so ostia about 2 mm apart, center to center, both radially and concentrically. Such ostia also crudely aligned at right angles to rounded oscular margin.

Sponge walls range from 5 mm thick in small sponges to 10–11 mm thick in larger sponges. Smaller forms with preserved oscular widths of 7–8 cm and incomplete heights of 15 mm. Larger but more incomplete fragments suggest sponges to 20 cm across and heights of 3–4 cm. Some fragments suggest some sponges more steeply obconical and funnel-like in early growth stages but flared and nearly subhorizontal in later stages.

Thin sections of coarsely and regularly canalled, palmate, thick-walled, plate-like sponges characteristic. IG R6-6(18) is tangential section of specimen approximately 4.7 cm high and 6 cm wide. In it three series of prominent canals occur in rectangular interrelationships and include radial canals normal to dermal-gastral surfaces, one longitudinal series in midwall, and another series concentric in midwall. Most evident ostia or cross sections of horizontal radial canals normal to dermal-gastral surfaces, range from 0.8 up to 1.8 mm across, although most approximately 1 mm across where circular. Where ostia slightly elliptical, may be up to 1 mm across and 2 mm high.

These canals regularly spaced in radial and concentric series and generally separated by approximately 1 mm of regular skeletal material; so that 5–8 canals occur per 10 mm, measured horizontally parallel to coarse horizontal and concentric midwall canals, and occur 4–5 per 10 mm parallel to principal strands in skeletons. Canals of that radial series converge to either concentric or vertical midwall canals that somewhat less extensive. Latter radial series with canals approximately 0.2 mm high, with irregular ragged margins. Both radial and midwall concentric canals expand where merged. Horizontal concentric midwalls canals most prominent and about 1 cm apart, vertically. They arch parallel to rectangular horizontal tracts of skeletal material. Vertical or longitudinal radial midwall canals of approximately same dimensions, 0.1–0.2 mm across. Vertical series distinctly less continuous than horizontal series and appears more or less as interruptions between two or three of vertically stacked radial series.

Skeleton between canals moderately irregular recticulate grid based on radial primary strands, spaced 0.7–1.4 mm apart in straight radiating series. New strands probably inserted, for no strands seen to branch. These vertical or radial primary strands appear most continuous elements and cross-connected by horizontal beams at intervals of approximately 1.5–2.0 mm. Numerous free rays and smaller beams occur throughout skeleton.

Beams of principal radial and concentric strands produced by overlapping rays, as indicated by overlap of some locally preserved prominent axial canals. Axial canals of the primary strands are coarse, most 0.005–0.008 mm in diameter but may be up to 0.015 mm in diameter. Generally speaking, however, most dictyonalia now composed of relatively coarse, radial fibrous calcite or of blocky sparry calcite, with no evidence of internal structure.

Primary nodes of major dictyonalia approximately 0.10–0.18 mm in diameter, although locally to 0.25 mm in diameter. Rays 0.08–0.1 mm in diameter away from nodes, but up to 0.14 mm across near nodes. These rays or beams taper irregularly and with lumpy margins where smaller second-order and third-order hexactines and irregular free rays, 0.02–0.03 mm across, attached to primary strands. This tends to produce an undulating structure when viewed in detail. Skeleton formed of dictyonalia fused, both laterally and vertically, where rays overlap.

Secondary strands, 0.03–0.04 mm in diameter, subdivide large, radially elongate rectangles between primary strands into secondary openings, 1.0–1.5 mm across, in somewhat irregular base. In some areas, secondary dictyonalia fused to principal beams at acute angles and produce some triangular openings between major skeletal elements. These secondary junctions generally with tips of dictyonalia fused to mid-beams of primary structure. These strands, like primary elements, appear spinose or thorny where third-order beams and free rays attached.

Third-order elements generally 0.02–0.03 mm across, where most evident at bases of attachment. Some of these form free hexactines with small rays 0.10–0.13 mm long. Such rays moderately smooth and taper irregularly to sharp points where seen in few spicules. Some elements joined by diagonal synapticulae that 0.02 mm or smaller in diameter.

Specimen IG R6-18 (059) probably vertical section that includes parts of diagonal section across base and parts of vertical wall. Sponge has fairly regular dictyonine skeleton, but with regularity and sizes of skeletal elements, including double-layered irregular transverse lamellae, characteristic of species. Uniform radial pattern of skeleton is fairly distinctive. Vertical midwall canals show where coarse skeleton interrupted, but with no evidence of coarse horizontal, concentric midwall canals because these openings at right angles to section. Circular openings in midwall appear to be oriented in this direction, but not pronounced disruptions of skeletal pattern, which not surprising because of coarseness of skeleton.

Discussion.—Comparisons with similar sponges have been discussed under the genus above.

Material.—Figured specimens of the species include S-1140 to S-1142 and 1150, and thin sections IG R6-2(2), R6-2(4), and R6-6(018). Reference specimens include S-1143 to S-1149, S-1151 to S-1154 and thin sections IG R6-1(16), R6-2(4), R6-2(20), R6-2(42), R6-16(044), R6-16(046) and R6-18(059), all from Jushui, Sichuan. Specimen S-1141 is from Hanwang.

TRACE FOSSILS

Genus ICHNOSPONGIELLA new genus

Diagnosis.—Small branching tubular fossils with thin walls that lack distinct canals. Walls include irregularly oriented and variously sized monactines, hexactines, and hexactine-based spicules, lacking bundling, generally with dominate horizontal patterns but with some rays tangent to the curved wall.

Etymology.—*Ichnos* Gr., footprints, track or trail; *spongia*, sponge; *ella* little, in reference to the sponge-like trace-fossil appearance of the small fossils.

Type species.—*Ichnospongiella carnica* new species.

ICHNOSPONGIELLA CARNICA
new species
Plate 11, Figures 1–4

Diagnosis.—Same as for genus.

Description.—Several specimens occur in S-1158, holotype, and in thin sections which cut main stems and some bases of branches of tubular form.

Holotype includes many transverse sections and one moderately long sublongitudinal section of fossil. Longitudinal section with complete upper end but base not clearly preserved in somewhat undulate specimen 0.5 mm long or high. It is pierced by single tubular opening 1.5 mm across near base, but expanded up to diameter of approximately 4 mm at upper end. Inner surface of walls smooth throughout.

Walls dense and 1.5–2.0 mm thick. Outer surface somewhat diffuse and irregular on small scale in both longitudinal and transverse sections in holotype block and paratype.

Various stages of branching shown in holotype block from where cross sections attached and crudely 8-shaped openings, to clearly separated tubes where openings separated by simple wall, to complete isolation and independent walls.

Block also with transverse sections of stages of development from small, near-basal parts only 1.6 mm across, with matrix-filled openings 1 mm in diameter surrounded by walls 0.3 mm thick, to intermediate-sized sections 3–4 mm in diameter. These commonly with walls 0.5–1.0 mm thick and central openings to 1.5 mm in diameter. More numerous sections of cylindrical upper part with central openings 4–5 mm in diameter and walls 1.5–2.0 mm thick, producing tubes 8 or 9 mm in diameter.

Diagonal section on R6-6(20) approximately 9 mm long and with basal width of approximately 2.5 mm. Tube expands upward to approximately 3.5 mm across at point of divergence of two branches, both approximately 2.2–2.5 mm across. Larger main branch pierced by central opening 1.4 mm across, where cut in ellipse, and small branch with a central opening 1.2 mm across in elliptical section, a measure of true diameter of opening. Walls in both branches range 0.4–0.6 mm thick, with walls slightly thicker near junction of branches than in distal parts of specimen. Inner surface of central tube moderately smooth.

Surface of tubular fossil weakly nodose, with small rounded mounds or irregularly lobate nodes approximately 0.3–0.4 mm across and 0.1–0.3 high. Nodes spaced 0.5–0.7 mm apart, where seen in cross sections along wall margin.

Walls of tube include loose, unfused, irregularly oriented monactines, hexactines and perhaps hexactine-derived spicules in thatched dense, mass of irregularly packed spicules and other debris. Some spicules with rays subparallel to outer and inner surfaces. Packing of spicules nearly equal through wall.

Rays of spicules cut in thin section range up to 0.15 mm in diameter. Ray junctions relatively rare in sections but some with rays approximately 0.10–0.11 mm in diameter. Most spicules in wall approximately 0.06–0.08 mm in diameter. Rays smooth and appear to taper moderately uniformly from expanded ray junctions to sharp tips.

Rare ostracod valves incorporated into wall and oriented basically parallel to dermal and gastral surfaces of sponge.

Discussion.—The small size of the branching trace and its dense layered skeleton that includes sponge spicules and other debris seem to be diagnostic of the species.

Holotype.—Holotype S-1158 from Locality JASC at Jushui, and paratype thin sections, IG R6-6(20) and R6-40(09), and reference thin sections IG R6-4(11), R6-4(12), and R6-9(26), are all from the Carnian Jushui-Hanwang mount tract.

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PLATE 1

Glossospongia angostoscula Wu, 1989, from the Hangwang Formation, Sichuan.
All are figured specimens and are x1.

Figures *1, 2, 4,* Laterally flattened, steeply obconical specimen showing the irregular nodose exterior, relatively thick walls, and the central slit-like spongocoel characteristic of the species, specimen S-1095; *1,* side view; *4,* view from above but inverted from that of Figure *1. 2,* View from above of a large specimen of the species showing characteristic thick walls, broken in the lower part, that surround the slit-like spongocoel, specimen S-1096. *3, 6,* Intermediate-size specimen showing the nodose exterior and laterally flattened, steeply obconical, form characteristic of the species, specimen S-1120; *3,* side view with attached bivalves and worm-like trace fossils particularly apparent in the lower part; *6,* view from above. *5,* Oblique view of somewhat smaller, more rounded, obconical form of the species showing thick walls and spongocoel filled with dark matrix in the upper surface and narrowed stalk at the base, specimen S-1110. *7,* Side view of small specimen showing slipper-like form of some representatives of the species, with tilted oscular margin showing thick walls around the spongocoel filled with dark fine-grained matrix, specimen S-1117. *8, 9,* Side and vertical views of specimen S-1116, a relatively small representative of the species and somewhat less laterally compressed than larger specimens, so that the spongocoel is more oval than slit-like.

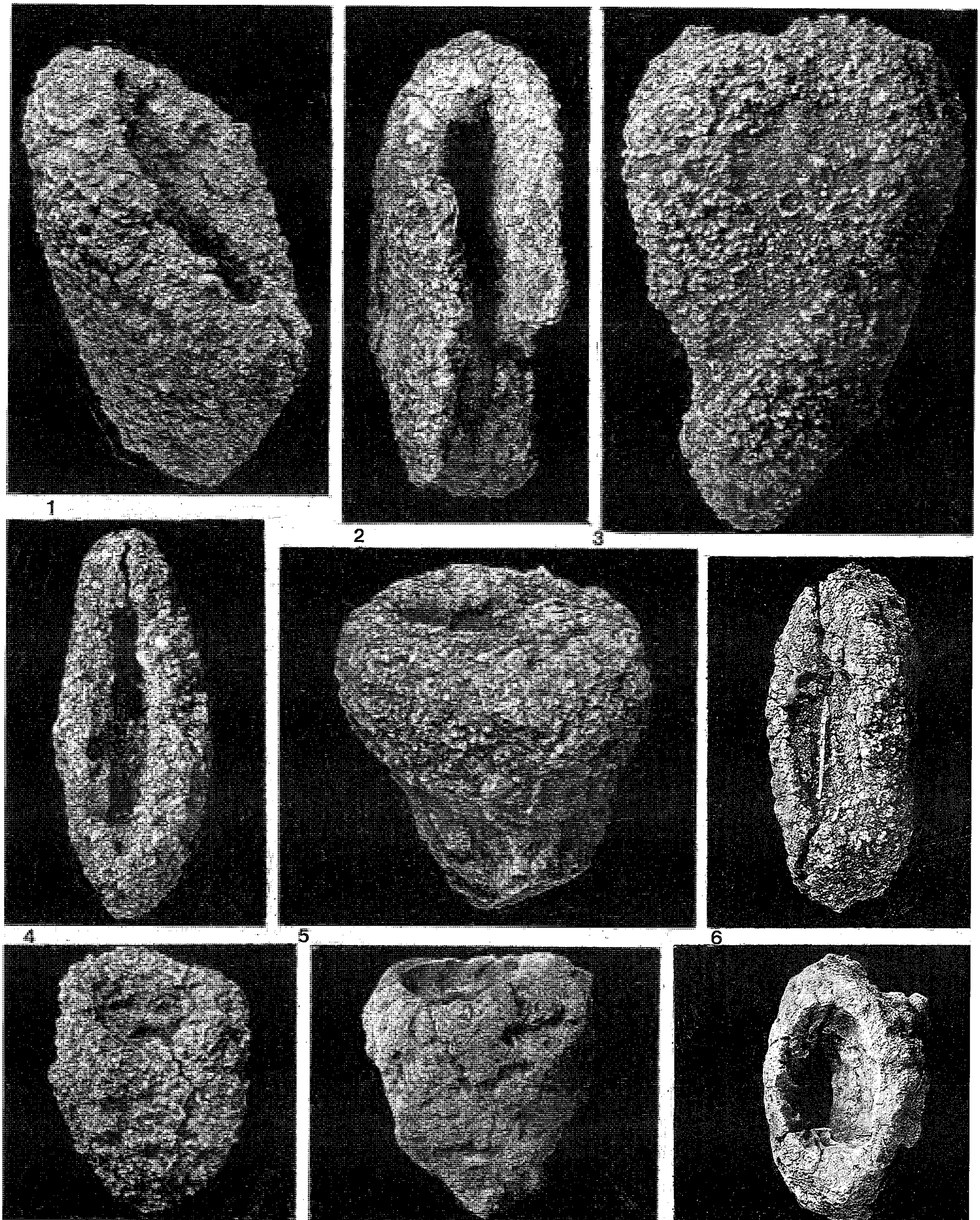

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PLATE 2

Glossospongia angustoscula Wu, 1989 and *Keriogastrospongia phialoides* Wu, 1989

Figures *1, 5, Glossospongia angustoscula* Wu, 1989, figured specimen S-1098, *1,* view from above of the large specimen with an oval transverse section showing the thick walls broken across in the upper right, but obscured and weathered on the left. The oval-shaped spongocoel is largely filled with coarse bioclastic debris, x1; *5,* lateral view showing the somewhat tongue-shaped form of many specimens of the species, with coarse inhalant ostia as dark matrix fills and indented areas on the exterior, with darker bioclastic matrix fill of the spongocoel forming the summit of the specimen, as viewed from this angle, x 1/2.

Figures *2, 3, 4, Keriogastrospongia phialoides* Wu, 1989, figured specimens, all x1; *2, 3,* Figured specimen, S-1164; *2,* view from above showing the broad spongocoel surrounded by relatively thin walls, on the right and toward the top, but with the lower left wall folded into the spongocoel; gastral surface is marked by large ostia of exhalant canals that are arranged in ring-like pattern; lower canals are nearly circular and upper canals have distinctly flattened almost slit-like exhalant apertures; *3,* side view showing the shallow bowl-shaped nature of the sponge and the nodose exterior, x1. *4,* View of the weathered exterior of specimen S-1065 showing the irregular bowl-shaped form of the species and distribution of exhalant canals, here matrix filled. That matrix filling is weathered into nodose relief in the central and right parts but only shows as light grey matrix fill in the darker grey skeletal structure on the left. The eroded surface must be near the bowl-shaped gastral surface. As a result much of the specimen is a filling of the spongocoel with only a thin layer of the skeleton, specimen S-1065, x1.

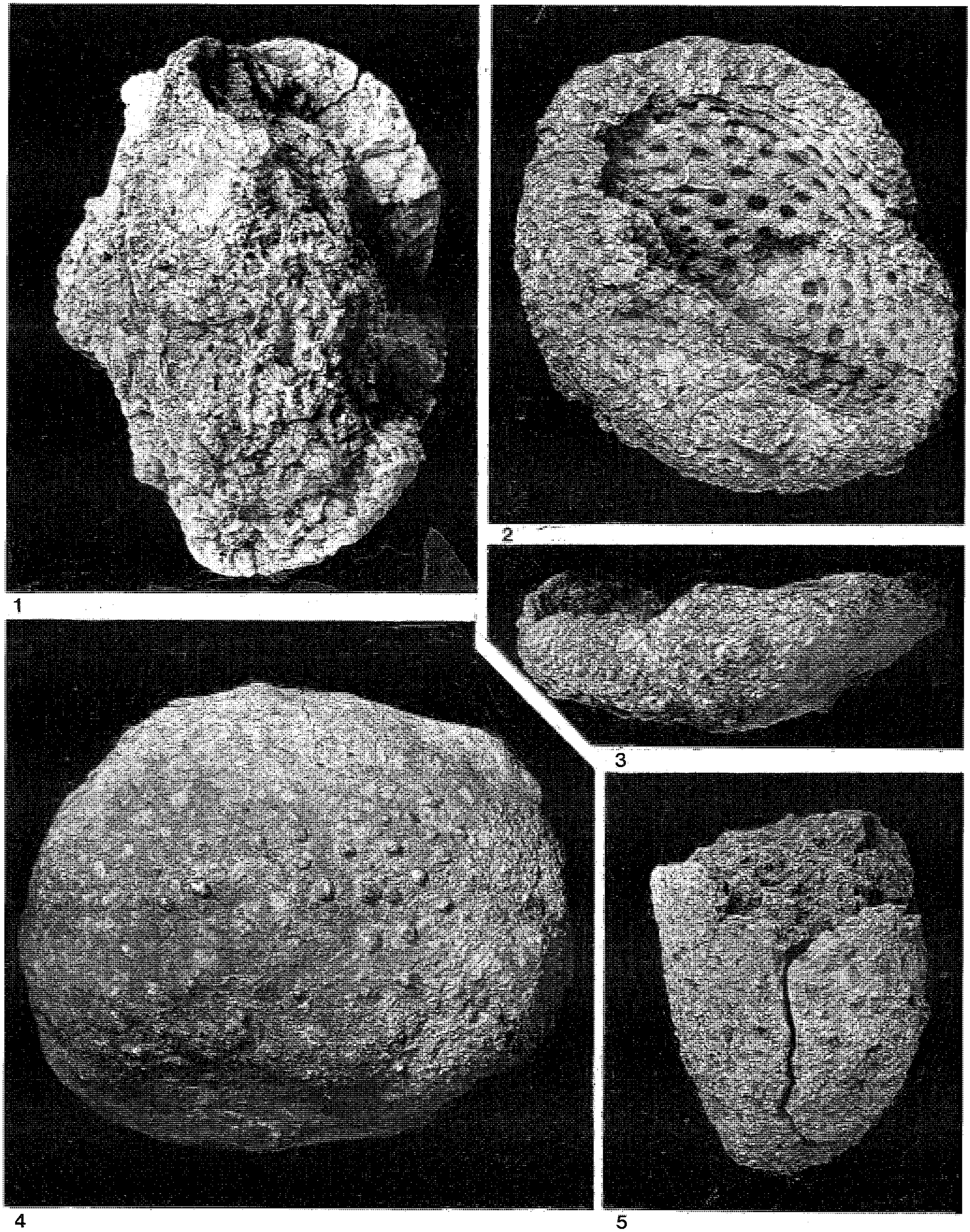
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PLATE 3

Dracospongia undulata n. sp., *Radioplica stephana* Wu, 1990,
Keriogastrospongia phialoides Wu, 1989, and *Sphenaulax pliopetala* (Wu, 1990)

Figures *1–3, Dracospongia undulata* n. sp., holotype IG R6-20(064), from the Triassic of Sichuan. *1, 3,* Photomicrographs of vertical sections showing the undulate nature of the plate-like sponge, with a pronounced dermal layer at the bottom and a gastral layer at the top; primary strands diverge toward the right and meet the gastral margin, at the top, at angles of up to 60° and the dermal margin, below, at a somewhat smaller angle. Transverse lamellae form arcuate bands in the direction of growth, toward the right, both x10; *2,* enlargment of some of the right part of Figure *1,* showing axial canals in some rays and with crosses of the canals preserved in others, particularly in the upper center, x20.

Figures *4–6, Radioplica stephana* Wu, 1990, figured specimens; *4,* longitudinal section of a tubular extension, with a central axial spongocoel and skeletal structure of the walls moderately well preserved on either side, showing the uniform, even, texture of the skeleton that lacks canals and in which dermal and gastral layers are not developed. Primary strands diverge gently upward from the gastral margin and horizontal beams form upward arcuate transverse lamellae, thin section IG R6-2(003), x10. *5,* Longitudinal section of a particularly well preserved part of the wall of the undulate sponge showing upward divergence of the primary strands from the gastral margin, on the right, toward the dermal margin, on the left, in the well-defined dictyonine skeleton, thin section IG T3(3), x10. *6,* Figured specimen showing a section through the fluted undulate margin of the bowl-shaped sponge, in the lower part and left (arrow), with sections of fragments of *Keriogastrospongia phialoides* Wu, 1989, (K) in the lower right and upper center, specimen S-1157, x1.

Figures *7–13, Sphenaulax pliopetala* (Wu, 1990), figured specimens. *7,* Side view of relatively small specimen showing laterally flattened, upward expanding growth probably near the base of a young sponge, with prominent ribs particularly evident near the top, specimen S-1026, x1. *8, 12,* Vertical and side views of a laterally flattened small specimen of the species, showing prominent aligned exhalant ostia in the gastral surface of the spongocoel, which has a distinctly lenticular cross section, characteristic ribs show on the exterior in the side view, specimen S-1027, both x1. *9, 13,* Small steeply obconical specimen in vertical and side views, showing the moderately coarsely ribbed nature of the exterior and the relatively small oval-shaped spongocoel, now filled with matrix, specimen, S-1025, both x1. *10,* Side view of a relatively large specimen of the species showing the characteristic ribbed exterior, partially obscured by attached osters, microbial crusts and crinoidal debris in the matrix; inhalant ostia are circular openings in indentations between ribs and show moderately well in the lower central part of the sponge, specimen S-1029, x1. *11,* Side view of a gently curved specimen with a weathered surface that shows vertically aligned, darker, matrix-filled ostia of inhalant canals in indentations between the ribs, particularly prominent in the upper half of the small sponge, specimen S-1028, x1.

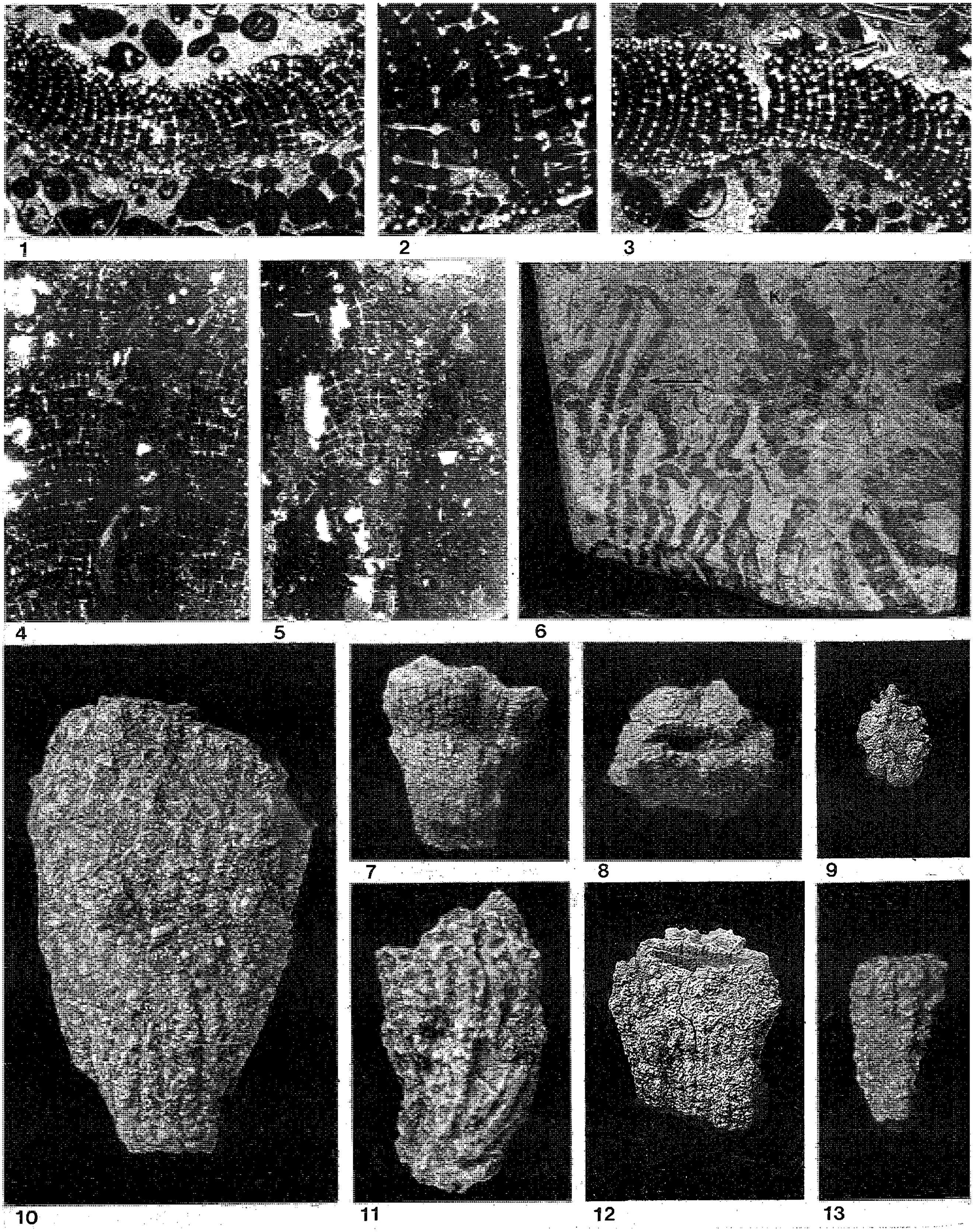
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PLATE 4

Sphenaulax infundibuliforma n. sp., *Nelumbifolium pectiniforme* Wu, 1990, and *Tesselospongia fistulosa* n. sp.

Figures *1, 3, 7–9, Sphenaulax infundibuliforma* n. sp., *1,* paratype fragment of funnel-like form showing relatively smooth gastral surface with upper margins indented by matrix-filled canals, particularly evident at the top and upper left, lower part of the specimen may be encrusted by microbial overgrowths, specimen S-1151 x1; *3,* gastral surface of fragment of the species showing nodose microbial-encrusted lower part, but aligned canals and small nodes in the middle left part and surface overgrown with encrusting and burrowing worm-like tubes similar to *Terebella lapillodes* Münster, 1833, like those observed by Wendt, et al., (1989), specimen S-1148, x1; *7,* dermal surface with weak, faint annular ridges and moderately aligned impressions of inhalant ostia, best expressed in the upper left and near the upper rounded oscular margin, lower right part microbial-encrusted, specimen S-1147, x1; *8, 9,* paratype specimen; *8,* view from above of the funnel-shaped fragment showing the irregular canals piercing the walls in a moderately regular fashion; gastral surface on the left is encrusted and partially matrix-covered, S-1143, x1; *9,* side view of the gastral surface encrusted by *Terebella* and microbial crusts, sections show general thickness of the wall in the upward-expanding funnel-like fragment, S-1143, x1.

Figure *2, Nelumbifolium pectiniforme* Wu, 1990, gastral view of the fragment showing the characteristic, very coarse, aligned ostia of the exhalant canals, separated by low nodes in the lower part, but with the surface encrusted and obscured in the upper part; regular canals not well shown in the diagonally fractured sides of the fragment, specimen S-1150, x1.

Figures *4–6, Tesselospongia fistulosa* n. sp., type specimens, all x2; *4,* paratype showing characteristic form of the species with prominent inhalant ostia of the radial subhorizontal canals; a round matrix-filled spongocoel shows in the summit and as a round node in the fractured base; the exterior is marked by weak annulations or growth lines and by the more or less horizontally aligned ostia, particularly prominent in the upper part; specimen S-1002, x2. *5, 6,* Holotype, specimen S-1001; *5,* side view showing the weakly annulate, curved, subcylindrical sponge with prominent inhalant ostia comprising much of the area of the dermal surface of the wall, x2; *6,* view of the broken summit showing the central circular spongocoel, traces of the radial horizontal canals, and a diagonal view of the lower part of the cylindrical species, x2.

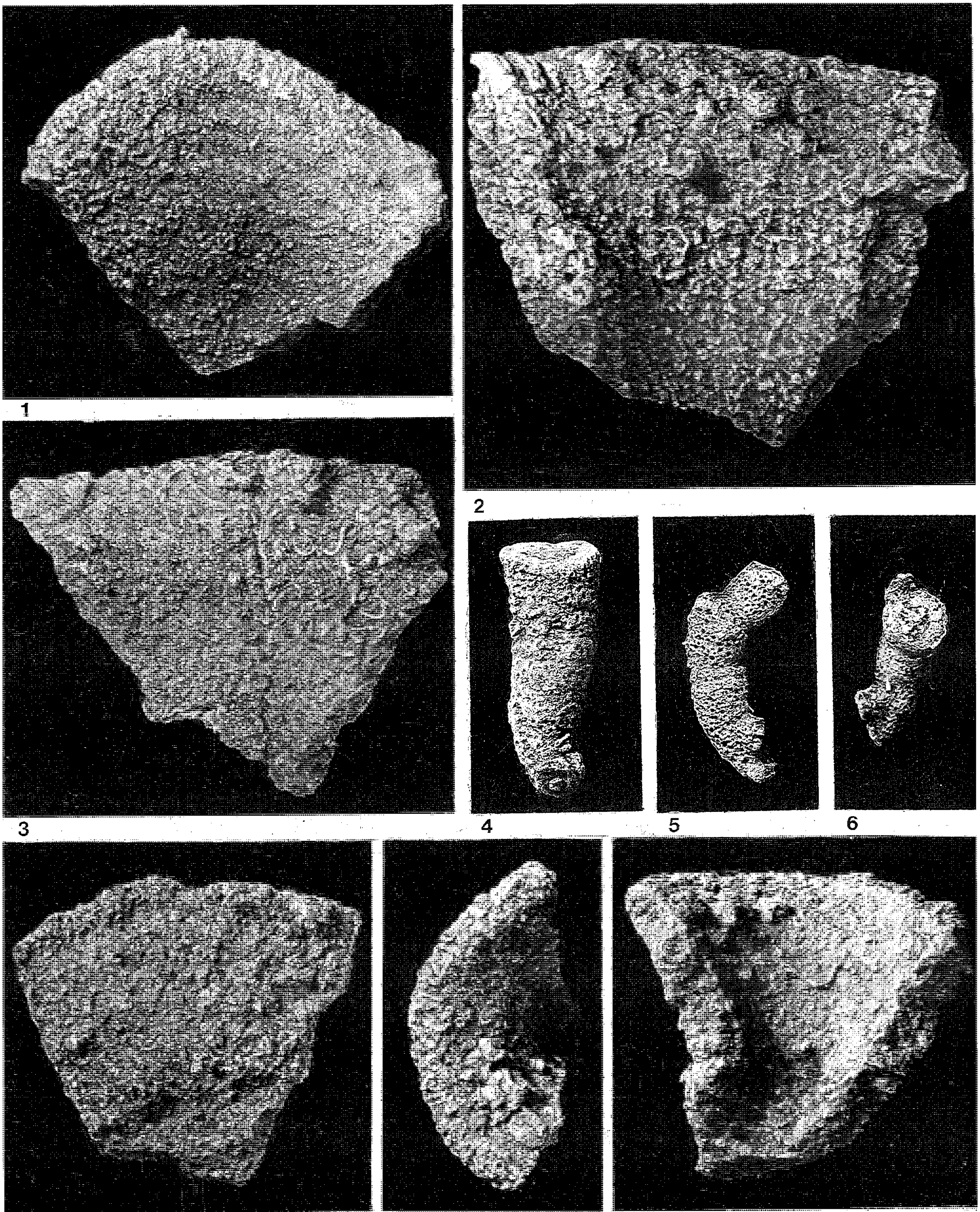
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PLATE 5

Species of *Nelumbifolium, Casearia* and *Dracholychnos*

Figures *1–4, Nelumbifolium pectiniforme* Wu, 1990; *1, 2,* figured specimen S-1142, *1,* view from above into the funnel-shaped sponge, with a broken upper margin and base, but showing the aligned skeletal structure and canal pattern in the central part, a pattern obscured by nodose microbial crusts in the upper part of the thin-walled sponge, x1; *2,* side view showing the abruptly expanding funnel-like form of the specimen, but with a broken base and only partially complete rounded oscular margin; exterior with nodular microbial crusts, x1; *3, 4,* figured specimen S-1141, a small thin flaring plate of the species; *3,* view from above into the funnel-like gastral opening, and with prominent regular canals indenting the rounded oscular margin at the top, x1; *4,* side view of the broken margin showing the characteristic upward flaring profile of the species, in this very thin-walled specimen, x1.

Figure *5, Casearia articulata* (Schmidel, 1780), figured specimen, side view showing the general dimensions of the small, cylindrical sponge with prominent chamber-like construction, specimen S-1038, x1.

Figures *6, 7, 10, Casearia oblata* (Wu, 1990), figured specimens; *6, 7,* specimen S-1039, *6,* specimen seen from above showing rounded transverse sections and ill-defined oval cross-section of the spongocoel suggested by the white, narrow line, x2; *7,* side view showing the abruptly upward expanding chamber-like form of the basal part of the sponge, also showing increases in diameters and heighths of chamber-like elements in the basal part of the sponge, x2; *10,* side view of the large specimen of the species composed of two chambers of the upper cylindrical part of the sponge, specimen S-1040, x1.

Figures *8, 9, 11–13, 17, 18, Dracolychnos annulirotatus* Wu and Xiao, 1989, figured specimens. *8, 12,* Specimen S-1059, *8,* view from above showing the irregular annular ringed chambers characteristic of the genus and species, with a central depression, partially matrix-filled at the base, and with the gastral surface obscured locally by encrusting tubes like *Terebella,* x1; *12,* oblique view showing the basal stalk of ring-like segments and the upper funnel-shaped part of the sponge composed of annular irregular rings of chambers, x1. *9, 13,* Specimen S-1057, *9,* view from above showing ring-like chambers somewhat obscured by overgrowths, but best defined in the lower part of the conical depression, x1; *13,* side view showing the basal stalk and the upper funnel-like part of the sponge in a typical growth pattern, x1. *11, 18,* Specimen S-1060, *11,* view from below showing the prominent annular chambers above the broken stalk in the skeletal structure characteristic of the species, x1; *18,* view of the upper gastral surface in the shallow conical depression produced by upward expanding, funnel-like growth of the sponge; ring chambers are particularly pronounced in the lower part, x1. *17,* Specimen S-1061, side view showing a nearly complete steeply obconical basal part of the sponge, just below the abrupt outward flaring upper part, x1.

Figures *14–16, Casearia decursiva* (Wu, 1990). *14,* Side view of specimen S-1050 showing the flat side and annular vertical, ring-like chambers typical of the species, from a nearly complete rounded base to the rounded upper oscular margin; moderately uniform dimensions of the chambers is characteristic of the species, x1. *15,* Side view of specimen S-1049, showing the characteristic form of the species, with a skeleton composed of relatively low annular ring-like chambers, stacked in uniform succession to produce the columnar skeleton, x1. *16,* Side view of a relatively small specimen, S-1047, but with chamber dimensions essentially the same as larger specimens of the species; with chambers showing some irregularity in the upper part of the fragment, as in the upper part of specimen in Figure *15,* x1.

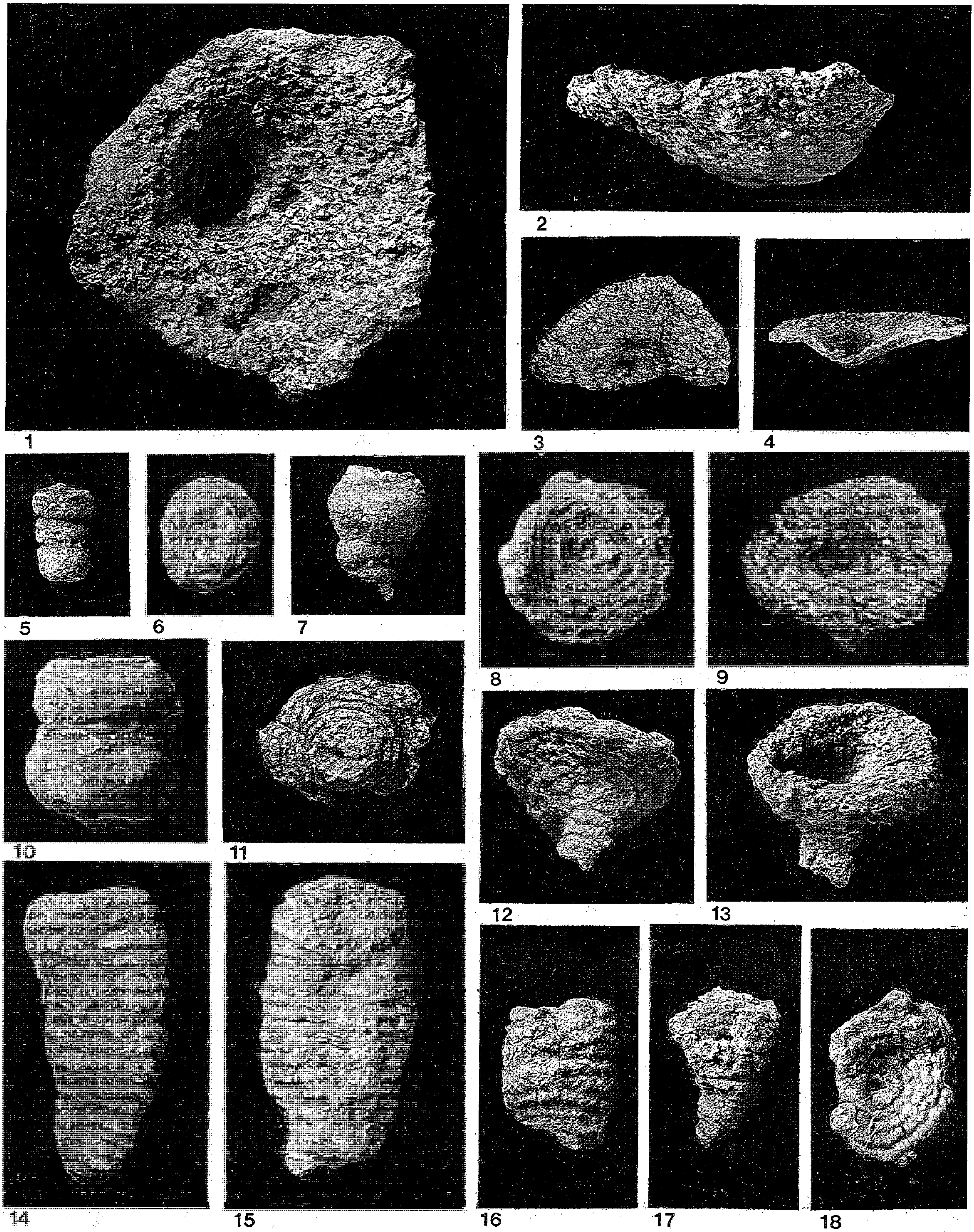
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PLATE 6

Photomicrographs of species of *Glossospongia, Keriogastrospongia* and *Sphenaulax*

Figures *1–3, Glossospongia angustosula* Wu, 1989, thin section IG R6-11, a longitudinal, tangential section; *1,* characteristic bundle of clustered hexactine rays near the center (1), showing ray intersections of the moderate-sized hexactines; small dots are sections of spicule rays showing their relatively uniform distribution in the skeletal structure, which is interrupted by a prominent circular canal opening in the upper left and by smaller canal openings largely filled with dark, dense, worm-tube structures in the lower center, x10; *2,* section showing a more less continuous vertical bundle (1) that continues to near the base of the figure, and is cross-connected by a less distinct horizontal bundle (2) that also connects to a less continous vertical bundle above and to the right of the two, showing the three-dimensional gridwork of the basic skeleton of bundled elements, with irregularly oriented hexactines shown in various ray sections filling the spaces between the bundles, except those spaces occupied by canals, like the spar-filled openings on the right, x10; *3,* vertical bundle of spicules in the right center, toward which converge relatively long bundle segments from the left center; light dots are sections of irregularly oriented hexactine rays between girder-like bundles, x10.

Figures *4–6, Glossospongia regularis* n. sp., holotype, thin section IG R6-9(031); *4,* transverse part of the section showing large, dark matrix-filled exhalant canals toward which converge smaller inhalant canals leading from the dermal margin, on the left; weak bundle sections occur in the upper center and bundled dermal layer shows in the left center; large hexactines are irregularly oriented in the intervening area and make up much of the volume of the skeleton, x10; *5,* transverse section showing exhalant canals emptying into the spongocoel, on the right, with small to moderately large inhalant canals interrupting the dermal surface on the left; bundled spicules of the dermal layer (1) show well in the upper left and parallel spicules of the internal bundles show in the lower center (2), x10; *6,* tangential section through the wall, showing the relatively regular placement of the large canals, now filled with dark matrix, interrupting the intermediate grey skeleton where various sections of large irregularly oriented hexactines appear as light dots; sections of parallel bundles show in the upper center (1) and upper right (2), with a diagonal orientation; the bundle in the upper right is traceable as a discontinous element almost into the central part of the figure; the matted dermal layer shows on the exterior at the left at the contact with the dark-grey matrix; absence of a distinct gastral layer is marked by continuity of the normal skeletal structure to the spongocoel margin, with is filled with sparry micrite in the lower right, x10.

Figures *7, 8, Keriogastrospongia phialoides* Wu, 1989, thin section, IG R6-23(073), longitudinal section; *7,* part of the section showing the gastral margin, on the right, interrupted by medium grey matrix in one of the large exhalant canals in the center and right center, largely defined by dark skeletal material in which irregularly oriented hexactine rays are circular or oval light-grey dots, only locally are ray intersections evident, as in the upper center and upper right and left center where coarser spicules show; lighter debris, near the right margin, is part of the matrix fill of the spongocoel, x10; *8,* longitudinal section showing coarse irregular oriented hexactines, with some showing swollen ray junction and ray segments, but most rays are evident only as transverse sections of rays; light-grey matrix fills part of an exhalant canal in the upper center, leading into the light-grey debris-filled spongocoel margin on the right; somewhat larger black rings around light ovals in upper left are sections through the *Terebella*-like worm-tubes that occupy some of the canals, x10.

Figures *9, 10, Sphenaulax pliopetala* (Wu, 1990), figured specimens. *9,* Horizontal transverse section showing a large matrix-filled exhalant canal, defined by a gastral layer of thickened spicules around the dark grey, fine-grained filling in the lower part and the partial sparry filling in the upper center; the regular dictyonine skeletal net shows well in the center, where horizontal beams form the dominent reticular structure; primary strands are seen elsewhere as circular cross-sections of elements vertical to the plane of section, thin section IG R6-18(056), x20. *10,* Transverse section showing the nature of the wall, with a dark matrix-filled exhalant canal in the lower center, and with a moderately well-defined gastral layer of thickened spicules around that canal, but with a prominent dermal layer of thickened spicules around the upper end of the radial rib; the regular skeletal structure shows particularly well in the upper part where horizontal beams show as grey interconnections between the light-grey circular cross sections of primary strands, which are normal to the plane of the thin section, thin section IG R6-18(055), x20.

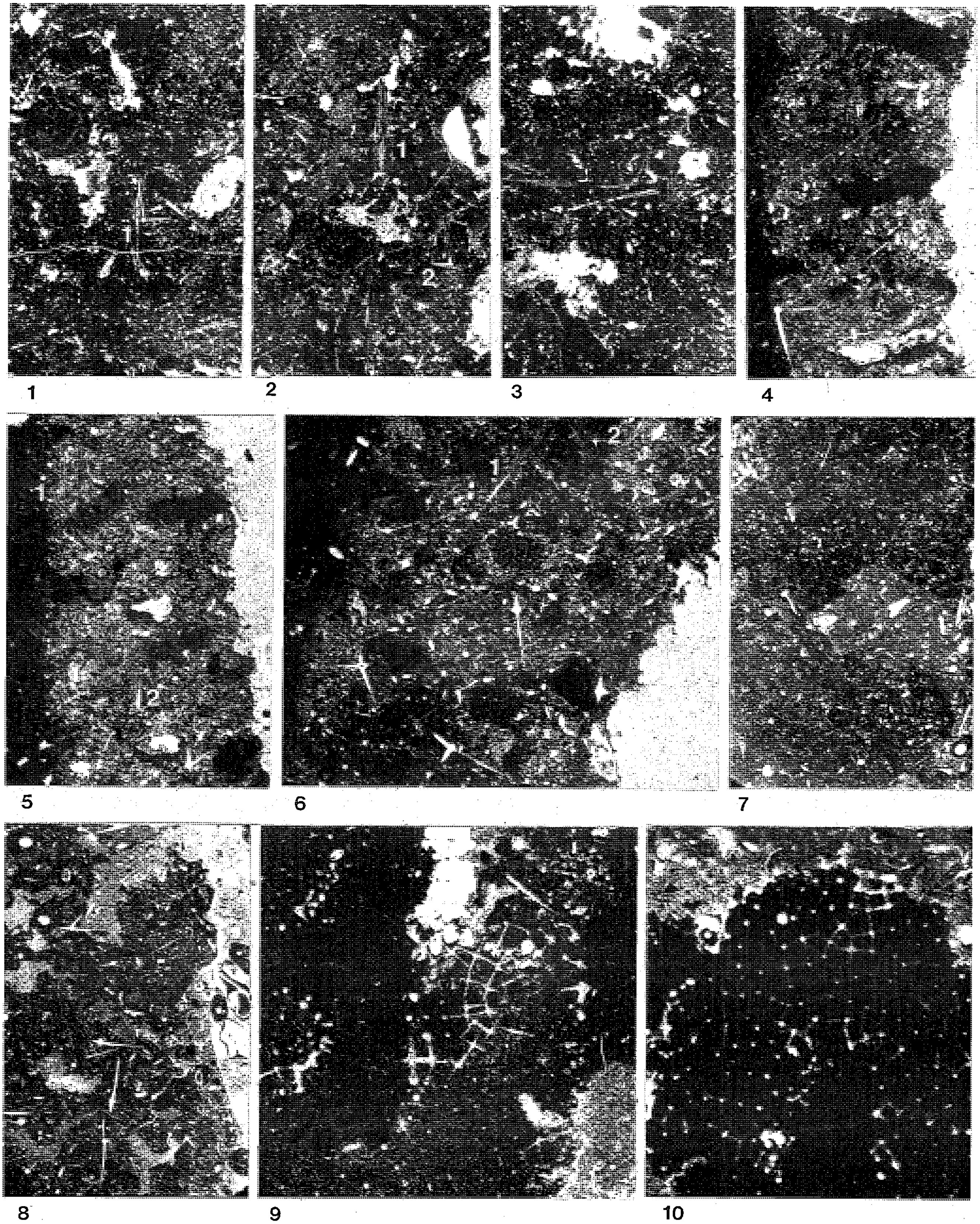
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PLATE 7

Photomicrographs of *Sphenaulax pliopetala* (Wu, 1990), *S. infundibuliforma* n. sp., *Tesselospongia fistulosa* n. sp., and *Scipiospongia columnaria* n. sp.

Figures *1, 2, Sphenaulax pliopetala* (Wu, 1990), thin section IG R6-18(055); *1,* horizontal transverse section through a major rib showing a matrix-filled exhalant canal, in the center, of nearly equal width to that of walls, on either side; thickened spicules of the skeletal net in the gastral layer separate the canal filling from the wall structure; a thickened dermal layer is only moderately well defined in the upper left; light-grey dots in the walls mark positions of primary strands that are cross-connected at regular intervals by horizontal beams which show best in the upper center, light-grey matrix occurs in indented areas between the ribs on both sides in the section, x10; *2,* well-defined skeletal structure in a smaller rib, parallel to the one shown in Figure 1, in which the skeletal structure shows well and where both dermal and gastral layers are defined by thickened spicules; dark matrix fills the exhalant canal in the central and lower central part of the figure; light-colored matrix surrounds the upper end of the rib and extends partly into the inhalant canal that parallels the rib in the right central part, below the sparry fill above the linear dark matrix of the inhalant canal, the upper part of the rib is shown in Plate 6, fig. 10, somewhat enlarged, x10.

Figures *3–6, Tessselospongia fistulosa* n. sp., paratypes. *3,* Transverse section showing the distinctly canalled wall with a prominent dermal layer of thickened spicules, on the left, interrupted by ostia of inhalant canals that may merge laterally or converge with other canals to produce larger exhalant openings that empty into the matrix-filled spongocoeol on the right, thin section IG T3(2), x10. *4,* Longitudinal section showing upward and outward divergence of primary strands toward the dermal margin on the left; slight divergence toward the gastral margin shows in the strands and aligned spicules in the lower right. The relatively simple dictyonine skeleton is interrupted by canals that are largely filled with dark, fine-grained matrix, thin section IG T3(1), x10. *5,* Longitudinal section showing well-defined, rectangular, simple, dictyonine skeleton interrupted by dark matrix-filled canals, upward divergence of primary strands indicated by general expansion of the structure; horizontal connecting beams extend from somewhat swollen nodes throughout the figure, thin section IG T3(4), x10; *6,* paratype with prominent expanded nodes and rays of dictyonine elements in the dermal layer, with skeletal elements of more normal dimensions showing in the upper right, thin section IG R6-19(61), x20.

Figures *7, Sphenaulax infundibuliforma* n. sp., holotype, showing general dimensions of the uniform skeleton net, interrupted by large matrix-filled canals, some of which have also been occupied by dark ringed, spar-filled, worm tubes that have also penentrated into the skeleton tracts. The prominent gastral layer of grossly expanded spicules occurs near the left margin of the figure, and expanded thickened spicules of the dermal layer show near the right margin in the lower part. Dimensions of the dictyonine skeletal net and its uniform character show well in the lower and upper center of the figure, thin section IG R6-5(015), x10.

Figures *8–10, Scipiospongia columnaria* n. sp. *8,* Paratype, vertical longitudinal section showing upward divergent tracts of relatively uniform dictyonine structure in which primary strands form long rod-like elements, generally adjacent to canal margins in the girder-like skeletal structure. The symmetric upward divergence of the tracts is characteristic of the species, thin section IG R6-21(066), x10. *9,* Holotype, thin section showing characteristic skeletal structure of complex girder-like elements in which rod-like vertical strands are parallel to vertical canals in the skeletal structure, thin section IG R6-21(065), x10. *10,* Paratype showing upward divergence and abrupt curvature of the primary strands, particularly pronounced in the right part of the figure, with vertical branching of one of the major canals in the center around girder-like, cross braced, and synapticulae-bound, dictyonine skeletal elements, thin section IG R6-21(067) x10.

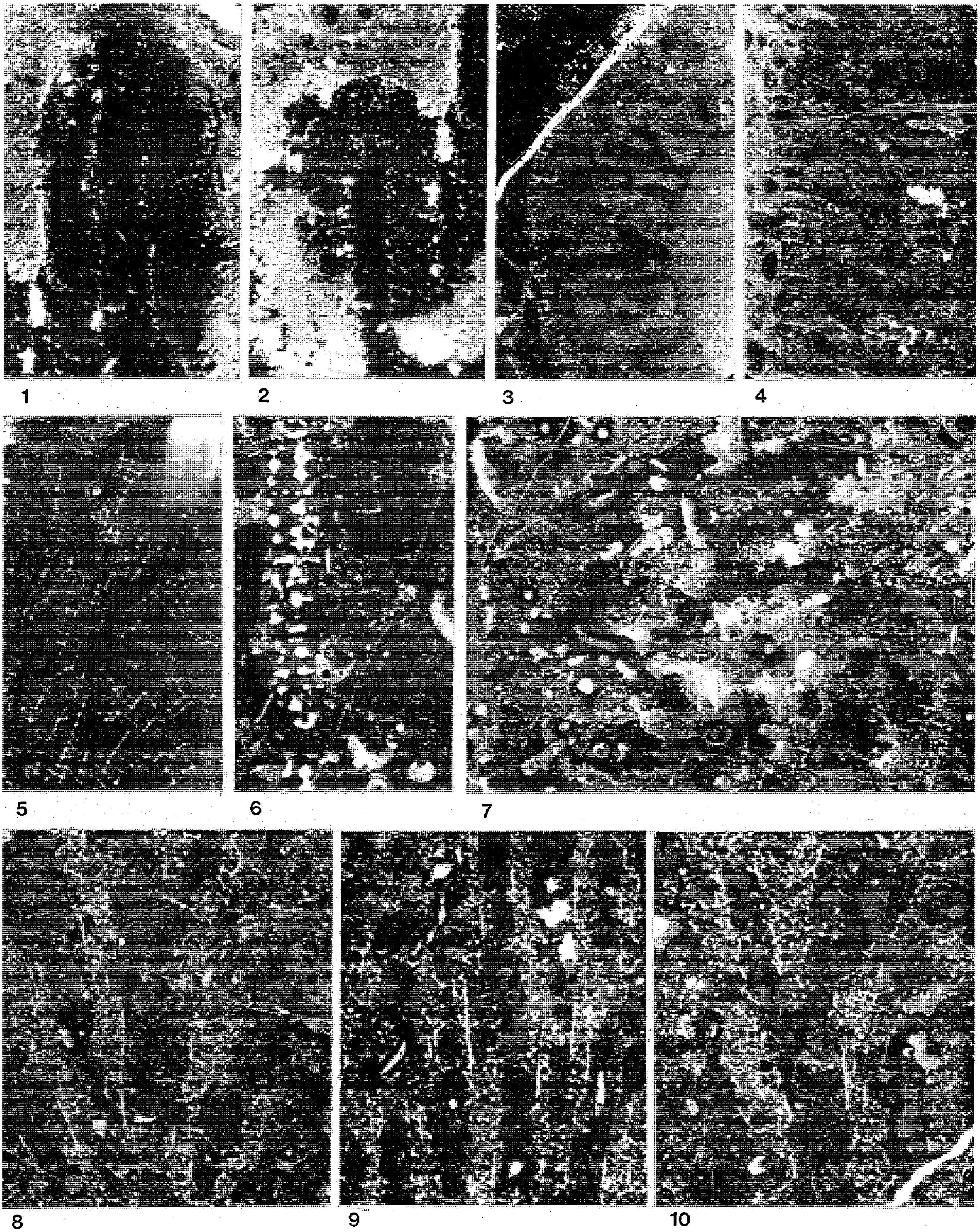
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PLATE 8

Photomicrographs of *Nelumbifolium pectiniforme* Wu, 1990, *Casearea oblata* (Wu, 1990), *Casearia decursiva* (Wu, 1990), and *Dracholychnos annulirotatus* Wu and Xiao, 1989

Figures *1–4, Nelumbifolium pectiniforme* Wu, 1990. *1,* Relatively open dictyonine-grade skeletal grid, showing large hexactines as primary elements producing quadrangles interrupted by second- or third-order spicule elements and with synapticulae attached to some of the rays; dense-walled worm tubes perforate some of the rectangles, thin section IG R6-2(2), x10. *2,* Coarse skeletal net showing prominent web-like construction of synapticulae in the lower left, with the skeleton perforated by worm tubes with dense, organic-rich, dark rims, thin section IG 6-2(4), x10. *3,* Part of the skeletal net showing large hexactines, like those of the right center, and smaller second-order elements, like the small partial hexactine in the lower right, united into a web by attached synapticulae, like the spinose processes attached to the horizontal ray in the left center; axial canals are preserved in some rays of both first- and second-order skeletal elements, thin section IG R6-6(018), x20. *4,* Prominent strands are vertical elements in the tangential section and are cross-connected by less continuous transverse rays, as preserved in this section, and show minor secondary spinose elements attached to the strands and also synapticulae developed in ray junction areas, particularly prominent in the left. Common sections of rays of hexactines normal to the plane of the section are light dots throughout the skeleton, except in areas of canals, some of which are occupied by worm tubes, thin section IG R6-2(2), x10.

Figure *5, 11, 12, Dracholychnos annulirotatus* Wu and Xiao, 1989, *5,* longitudinal section showing upward-arched, main chamber walls and moderately long, upwardly divergent, radiating primary strands in the relatively coarse skeletal structure. Fine structure between the chamber walls has been largely destroyed by burrowing organisms, like the common worm tubes present throughout. Expanded coarse spicules of the principal walls define the chamberlets, thin section IG T3(A), x10. *11,* tangential view of an interwall on the right, and of the normal intrachamber skeletal structure on the left, which is only rarely preserved in the interior of the chambers. Synapticulae are prominent in the grossly enlarged spicular elements of the skeletal interwalls on the right. Axial canals of spicules are locally preserved, for example, in interchamber spicules in the upper left, thin section IG R6-25(085), x20. *12,* Longitudinal section showing thick interwall elements and lack of preservation of skeletal structure within the chambers, which are filled with fine debris but may include fragments of small hexactines. Double-layered structure of the interwalls is characteristic of the species and helps identify even fragments, thin section IG R6-18(058), x 20.

Figures *6, 7, Casearia oblata* Wu, 1990, thin section IG T3(12), *6,* projection print showing the nature of interwalls between chambers of the sphinctozoan-like form in the lower part, with the wall cut transversely to show the nature of spiculation next to the spongocoel in the upper left, x2; *7,* enlarged view of part of the skeletal net shown in the upper left center of Figure *6,* and next to the spar-filled spongocoel, on the right. Small diameters of spicule rays within the chambers show in the lower left and contrast with the large-diameter rays in the interwall, in the central part of the figure, x20.

Figures *8–10, Casearia decursiva* Wu, 1990, *8,* oblique section showing two prominent interwalls of chambers in the upper part of the figure as thickened coarse skeletal elements and a tangential part of the interwall, in the lower part of the figure, that is interrupted by inhalant ostia, now filled with dark matrix, thin section IG T3(A), x10; *9,* oblique section showing curved chamber interwalls through the central part of the figure, but cut tangentially in the lower part of the figure, where elements are thickened and where the section cuts through one of the annulate chambers in the lower central part and into another in the upper part of the figure, thin section IG T3(A) x10; *10,* photomicrograph of an oblique section showing the coarse skeletal elements of a chamber interwall in the lower part, and some finer spicules, within the chamber, in the upper central part, but with much of the skeletal structure in the interior of the chamber destroyed by organic activity, such as the burrowing worm tube in the upper center, thin section T3(2), x20.

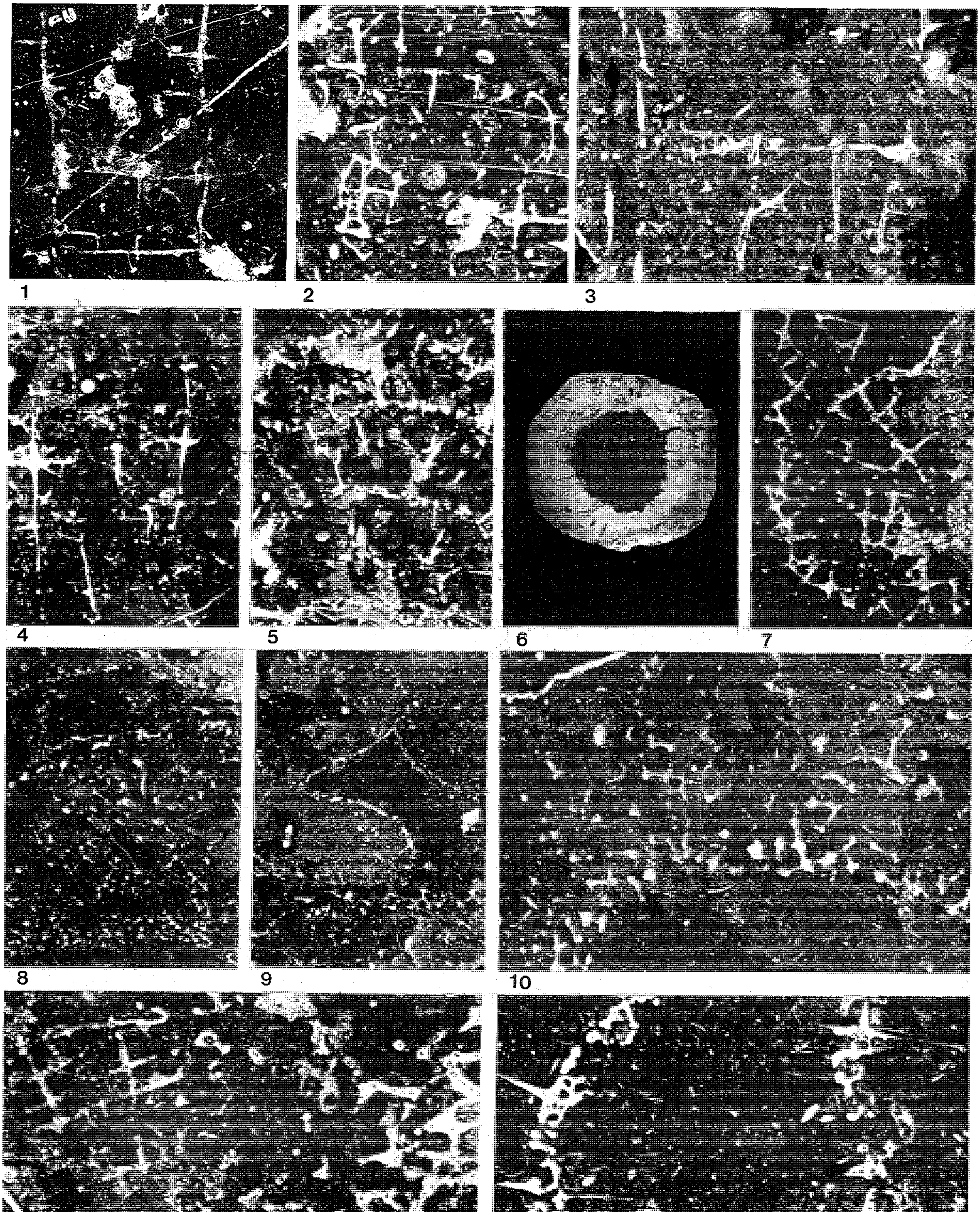
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PLATE 9

Projection prints of species of *Glossospongia, Keriogastrospongia, Sphenaulax, Drachospongia, Dracholynchnos,* and *Radioplica*

Figure *1, Glossospongia angustoscula* Wu, 1989, showing the relatively fine-textured skeleton, where the irregularly oriented hexactines, preserved as spar, are seen only as black dots or locally as linear elements where sections of spicule bundles are preserved; arrows 1, 2, and 3 refer to positions of photomicrographs shown in Figures *1, 2,* and *3,* of Plate 6, thin section IG R6-11, x2.

Figure *2, Glossospongia regulara* n. sp., holotype, a transverse to oblique tangential thin section of the tubular sponge, with prominent exhalant canals most evident in the upper left and with the regular pattern of those exhalant canals shown in the lower right, in an oblique section through the wall. Arrows 4 and 5 show positions of Figures 4 and *5* of Plate 6. Figure *6* of Plate 6 is of the lower part of the wall in the lower right, but rotated approximately 180°, thin section IG R6-9(031), x2.

Figure *3, Keriogastrospongia phialoides* Wu, 1989, longitudinal section showing the relatively massive structure of the thick wall pierced by large exhalant ostia like that at arrow 7, which marks the position of Figure *7,* Plate 6; matrix fills the open broad spongocoel on the right, thin section IG R6-23(073), x2.

Figure *4, Sphenaulax pliopetala* (Wu, 1990), transverse section showing the radiate nature of the skeletal structure, with prominent exhalant canals leading into the largely matrix-filled spongocoel and a more or less ribbed exterior, particularly prominent in the lower right, arrow 1 marks the position of Figure *10* of Plate 6, and Figure *1* of Plate 7, thin section IG R6-18(055), x2.

Figure *5, Drachospongia undulata* n. sp., holotype, showing the annulate plate-like form of the sponge, seen in vertical section, where primary strands diverge symmetrically toward the right and with transverse lamellae, formed by horizontal beams, as the arcuate structure normal to the strands, arcuate toward the right, in the direction of growth, thin section IG R6-20(064), x2.

Figure *6, Dracholychnos annulirotatus* Wu and Xiao, 1989, transverse section showing the regular, radially added chambers arcuate in the direction of growth, and the thin skeletal layers between them, thin section IG R6-18(057), x1.

Figures *7, 8, Radioplica stephana* Wu, 1990. *7,* Transverse sections through cylindrical tube-like sponges showing their uniform skeletal structure, lacking canals and pronounced dermal and gastral layers in the skeleton, thin section IG R6-12(037), x2. *8,* Longitudinal and oblique sections of digitations or flutes in the margin of the bowl-shaped sponge that extend from the wall of the spongocoel, in the lower part of the figure; lack of canals in the hexactinosan skeleton is characteristic, thin section IG R6-11(035), x2.

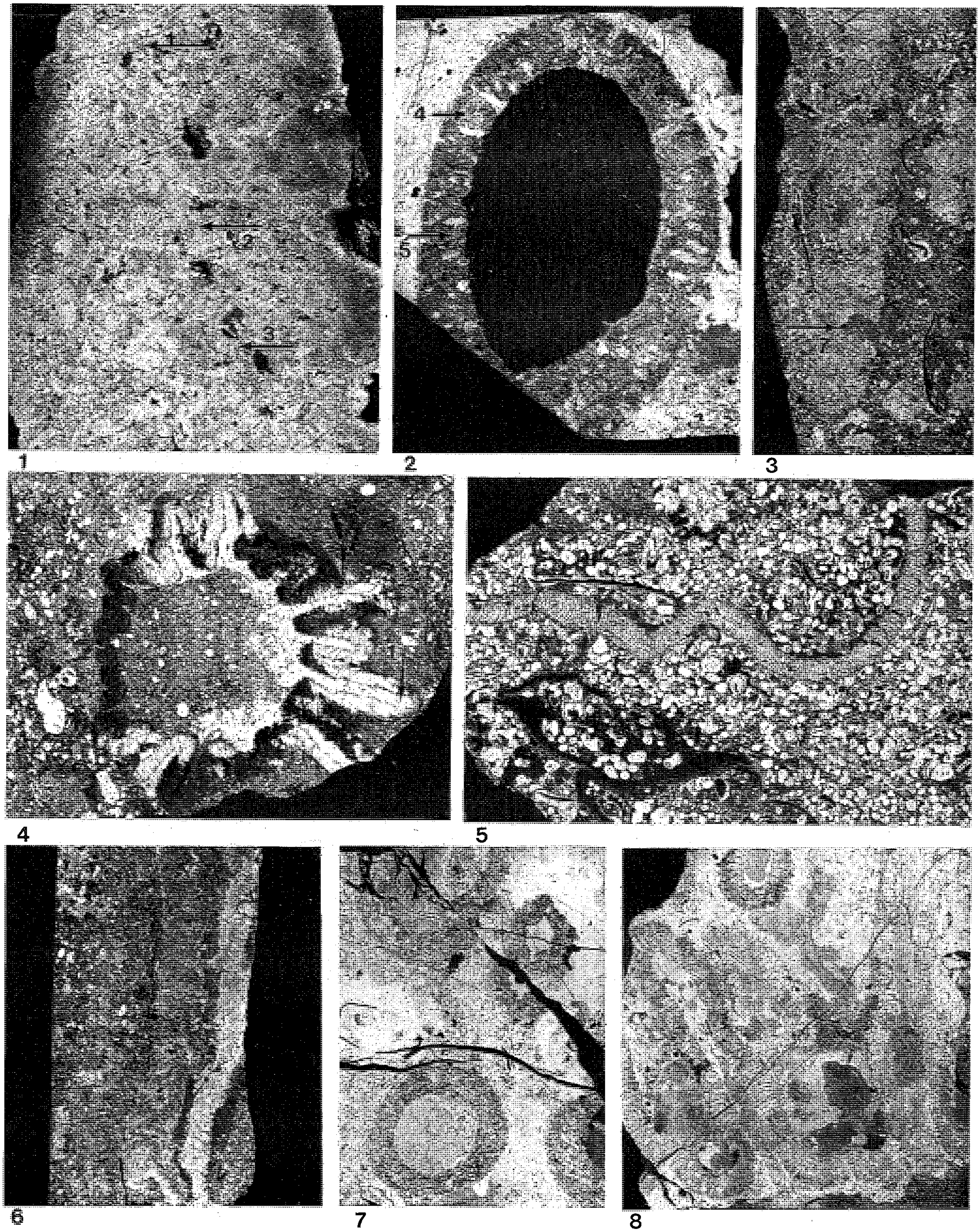

PLATE 10

Projection prints of *Scipiospongia, Sphenaulax, Tesselospongia,* and *Nelumbifolium*

Figures *1–3, Scipiospongia columnaria* n. sp. *1,* holotype showing the prominent matrix-filled vertical canals separated by darker girder-like complex skeletal tracts with crossbraced hexactinosan structure and with vertical strands locally producing long, needle-like rods. Radial canals, like those shown as circular interruptions in the upper central part of the figure, extend from the exterior and connect into the upward-divergent canals in the interior of the wall of the palmate sponges; a thick microbial crust coats the sponge, on the left, and appears light-grey in this projection print, thin section IG R6-21(065), x2. *2,* Longitudinal paratype section showing the upward and outward divergent canal system generally with lighter grey matrix fills, separated by darker grey, upward divergent skeletal tracts. The arrow (10) indicates the position of structure shown in Figure *10* of Plate 7, thin section IG R6-21(067), x2. *3,* Approximately horizontal transverse section through a segment of the wall showing the horizontal to slightly curved radial canals, thin section IG R6-25(084), x2.

Figure *4, Sphenaulax infundibuliforma* n. sp., holotype, transverse section showing the relatively thin walls pierced by distinctively radiating horizontal canals, many of which are occupied by worm tubes that show as light-grey rings around dark fillings in the projection print, thin section IG R6-5(015), x2.

Figures *5, 6, Tesselospongia fistulosa* n. sp., paratypes. *5,* Horizontal transverse sections of cylindrical sponges showing their prominent radial canals, here as light-grey matrix fills in the darker grey skeletal structure. A fragment of *Dracholychnos annulirotatus* Wu and Xiao, 1989, is shown along the right side, as upward arched chamberlets seen in longitudinal section, thin section IG R6-24(078), x2. *6,* Longitudinal section of moderately large sponge with a regular skeleton interrupted only locally with canals, as in the lower right, where they appear as lighter grey and skeletal structure as darker grey, thin section, IG R6-15(051), x2.

Figures *7, 8, Nelumbifolium pectiniforme* Wu, 1990, figured specimens. *7,* Vertical sections in approximately midwall of the broad plate-like or saucer-like sponge showing the regular canals arranged in upward-radial and horizontal-concentric lines of fills of matrix, shown light-grey, between darker grey skeleton-filled areas; as in many sponges in the collection worm-tube structures occupy some of the canals; arrow 3 marks the position of Figure 3 of Plate 8, thin section IG R6-6(018), x2. *8,* Horizontal section through part of a flat funnel-like sponge, in which the spongocoel is filled with what appears as dark matrix in the lower right, with prominent canals arranged in regular rings and radial lines throughout the sponge. The coarse skeletal structure forms a thin, light grid work, particularly pronounced near arrow 1, which shows the position of Figure *1* of Plate 8, and arrow 6, which shows the position of Figure *6* of Plate 8, where the coarse hexactine-based skeletal net is well exposed, thin section IG R6-2(2), x2.

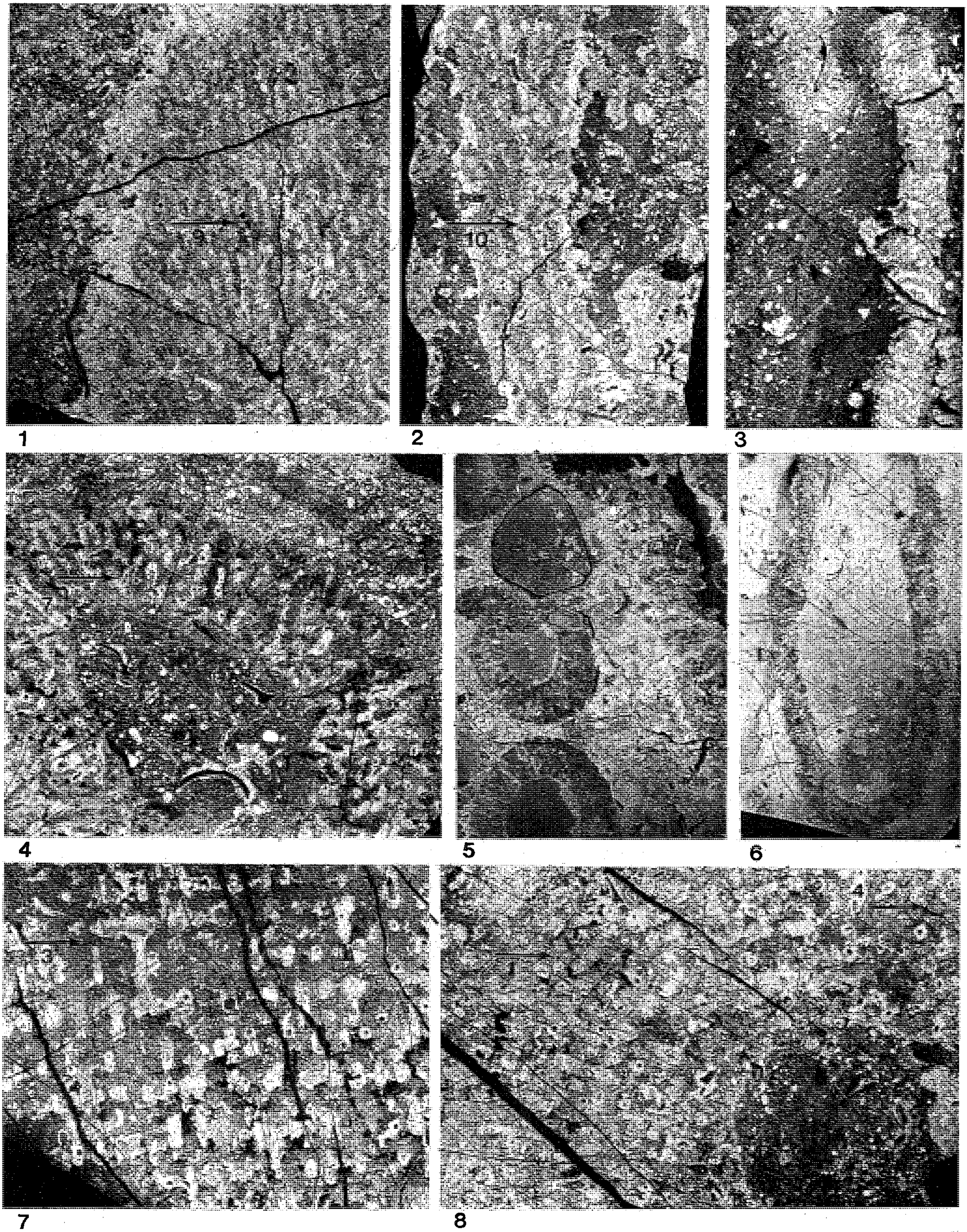
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PLATE 11

Ichnospongiella, Casearia, Dracholynchos, Keriogastrospongia, and an unnamed burrow

Figures *1–4, Ichnospongiella carnica* n. gen. and n. sp., a lined trace fossil burrow. *1,* Holotype showing various sizes of burrows seen in transverse section in the lower center and in sublongitudinal section in the upper center, where the burrows are in place in fine lime mudstone, polished surfaces in reflected light, sample S-1158, x1. *2, 3,* Paratype specimen on thin section IG R6-6(020) showing the bifurcation, as well as the commonly spiculiferous organic-rich lining, which here appears dark grey in transmitted light, the characteristic irregular exterior surface, and the smooth interior surface show in the oblique section, x10; *3,* projection print of the thin section showing the branched paratype in wackestone matrix, associated with tubes of *Terebella*-like fossils in the lower part and a fragment of *Keriogastrospongia phialoides* Wu, 1989, (K) on the right, x2. *4,* Longitudinal section in transmitted light showing the compact wall of the tube with the smooth interior surface, marked by the light line and the irregular outer surface on the right; light-grey elements within the wall are principally horizontally arranged rays of spicules cut in diagonal section, thin section IG R6-4(09), x2.

Figure *5,* Unnamed lined boring, projection print, showing large openings with thick irregular walls that contain numerous ostracode valves and fragments of bivalves shells in the organic-rich wall, here shown as light-grey, around the tube filling of matrix, which appears darker grey in the interior, thin section IG R6-2(04), x2.

Figure *6, Casearia decursiva* Wu, 1990, longitudinal section, projection print, showing the upward arcuate chamberlets, many with double-layered skeletal interwalls, appearing dark-grey, that bound chambers filled with matrix that appears to be light-grey; coarse skeletal debris fills the spongocoel, here cut obliquely, thin section of specimen S-1035, x2.

Figure *7, Dracholynchos annulirotatus* Wu and Xiao, 1989, projection print of horizontal section showing a small matrix-filled spongocoel, in the lower center, and the distinct annular, somewhat undulating, rings of chambers successively arranged around the circular spongocoel; the skeletal structure shows here as dark-grey and matrix as light-grey in the approximately midwall to tangential section of the thin-walled, funnel-like sponge, thin section IG R6-11(018), x2.