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SPONGES FROM THE LOWER CRETACEOUS MURAL LIMESTONE IN ARIZONA AND NORTHERN MEXICO

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ABSTRACT—*Corynella mexicana* n. sp. and *Lymnorella encrusta* n. sp. from the Lower Albian part of the upper limestone member of the Mural Limestone of northern Sonora, Mexico, and southern Arizona, are the first Lower Cretaceous calcareous sponges described from North America. All collected specimens of both species are heavily silicified. *Corynella mexicana* encrusts corals and other fossils in the *Actinastrea* and *Microsolenia*-stromatolite communities in small reefs. *Lymnorella encrusta* is associated with monopleurids, pachydont bivalves, on the flank of one of the coral-stromatolite reefs.

INTRODUCTION

A FEW heavily silicified but still identifiable sponges have been recovered from the Lower Cretaceous Mural Limestone from the northwestern end of the Chihuahua Trough in southern Arizona and northern Mexico (Text-fig. 1). These are the first Lower Cretaceous calcareous sponges described from North America. A calcareous sponge has been identified from Lower Cretaceous rocks in Venezuela and described under the name *Corynella? aquilerae* by Wells (1944). He also noted older reports of undescribed sponges from Lower Cretaceous rocks of Mexico. However, none of these latter specimens have been described to our knowledge.

The Mural Limestone is exposed in the isolated basin-and-range mountains of southeastern Arizona and northeastern Sonora. The formation is divided into an upper and a lower member (Scott and Brenckle, 1977). The lower member ranges from 91–165 m thick and is interbedded, thin-bedded limestone, shale, and sandstone. The upper member contains the reefs in which the silicified sponges occur and is 50–75 m thick in southern Arizona. Northernmost outcrops which produce the sponges are those at Paul Spur, approximately 19.3 km (12 miles) west of Douglas, Arizona and only a few miles north of the Arizona-Mexico border (Text-fig. 1).

Corynella mexicana n. sp. encrusted corals and other fossils in the reef core of the *Actinastrea* community and in the *Microsolenia*-stromatolite communities, as differentiated by Scott and Brenckle (1977, p. 184–185). The sponges are silicified and stand in relief above the laminar corals, many of which are also encrusted by stromatolites. *Corynella* sp. cf. *C. mexicana* also is found in reef facies in the Middle Albian Stuart City Limestone of the Comanchean shelf margin in core from the Shell No. 1 Chapman, Waller County, Texas at a depth of 5,340.4–.7 m (17,521–2 feet) and 5,361.7–5,362.0 m (17,591–2 feet). *Lymnorella encrustata* n. sp. grew within a bed of thick-walled monopleurids, *Petalodontia felixi* Douvillé, which formed upon the flanks of the coral-stromatolite reefs. The sponges appear to be related to intermediate and pioneer communities in reef development as described by Scott and Brenckle (1977). In general, coral-stromatolite paleocommunities dominate these Early Cretaceous patch reefs within the Mural Limestone and contrast with the better known rudistid reef assemblages from other localities in Cretaceous rocks of the Gulf Coast and northern Mexico. Limestone in which the sponges occur represents the maximum transgression of Aptian and Early Albian carbonates in the western end of the Chihuahua trough (Hayes, 1970).

SYSTEMATIC PALEONTOLOGY

Class CALCISPONGIA De Blainville, 1834
Order PHARETRONIDA Zittel, 1878
(?) Suborder CHALARINA De Laubenfels, 1955
Family LELAPIIDAE Dendy and Row, 1913
Genus CORYNELLA Zittel, 1878
CORYNELLA MEXICANA n. sp.
Pl. 1, figs. 1, 2, 4–6, Text-fig. 2a

Diagnosis.—Small subcylindrical to top-

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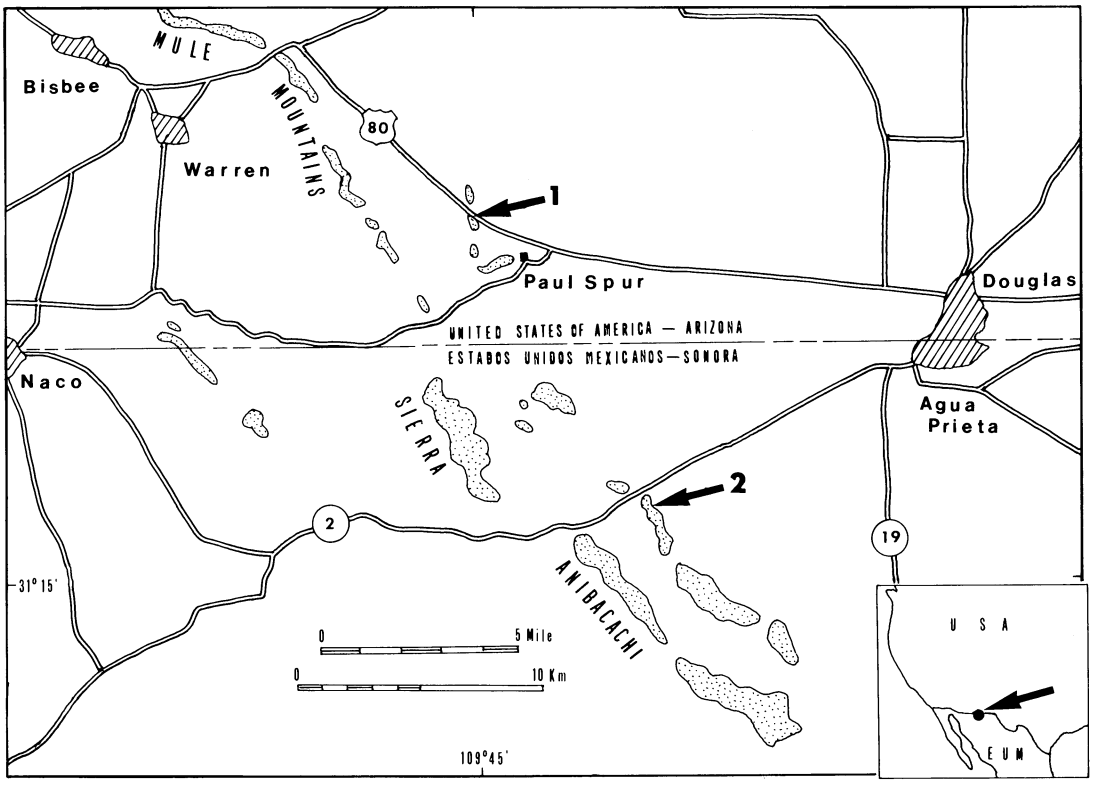
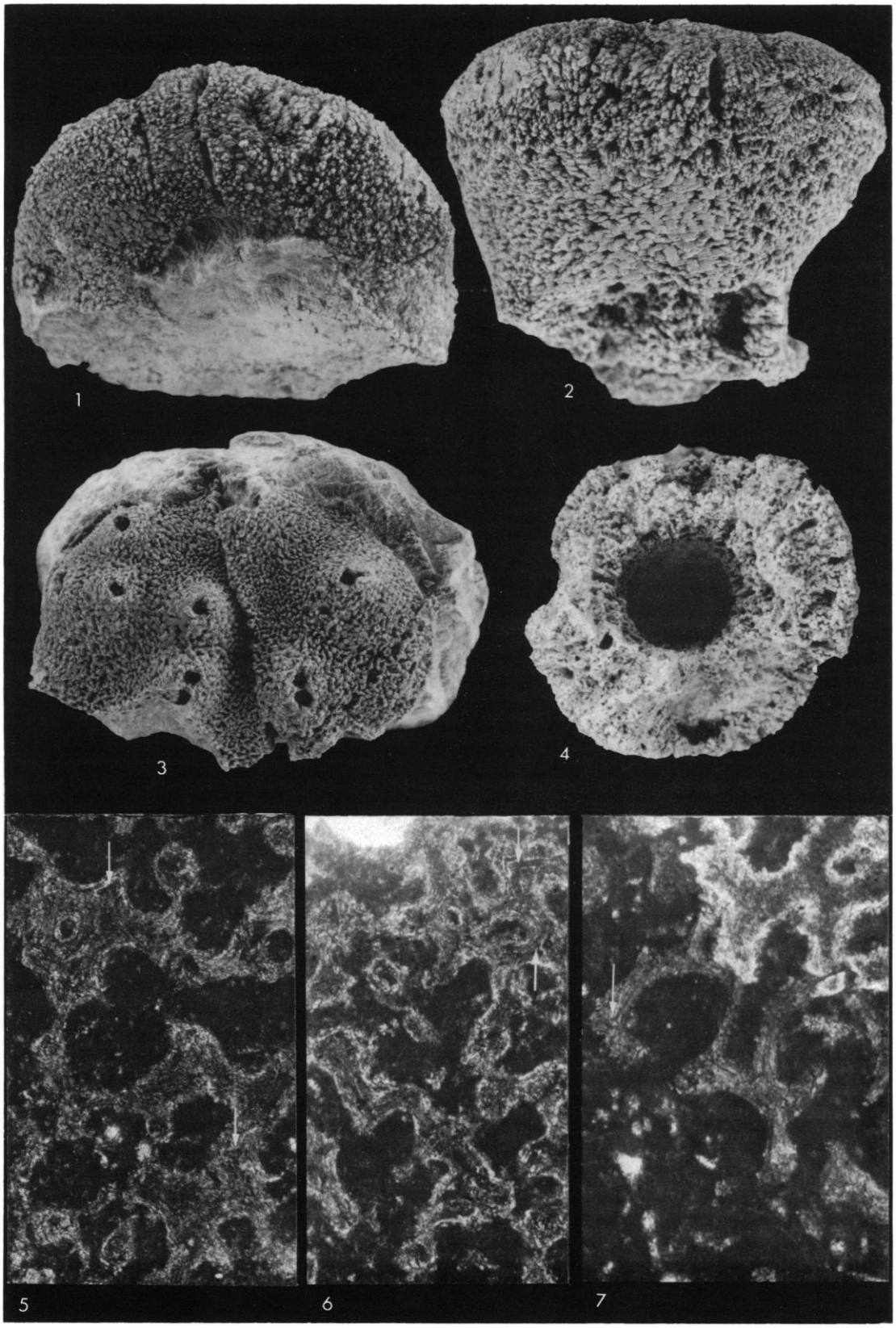


TEXT-FIG. *1*—Index map to sponge localities in the upper Mural Limestone. Locality 1 is along a hogback, 2.5 km west of Paul Spur, directly south of U.S. Highway 80. Locality 2 is on the eastern edge of Sierra Anibacachi, 1.2 km south of Mexico Highway 2.

shaped or turbinate sponges with simple deep spongocoel extending to near the base of the sponge. Walls smooth, except pitted by ostia of the principally radiating incurrent canal system. Some forms have stalks but others appear to be distinctly cylindrical. Skeleton without marked radial pattern but with prominent, radial, subhorizontal canals cross-connecting with a concentric series of horizontal canals that are like circular rings around the spongocoel, in the middle and inner parts of the sponge wall. Canals of concentric system approximately 1 mm in diameter and those of the radial system approximately 0.4–0.7 mm in diameter. All are cross-connected and feed to excurrent canals that are approximately 0.5–0.8 mm in diameter and lead into the spongocoel. Both horizontal systems are interconnected with somewhat ill-defined and finer textured vertical canals that are approximately 0.3 mm in diameter and are certainly much less prominent than either the concentric or radiating horizontal system. Entire sponge is perforated by small skeletal openings that are 0.1–0.2 mm across between the spicule tracts so that the sponge has an irregular open porous pattern.

Skeletal tracts meandriform, cross-connected, and somewhat lumpy, without distinct radial or vertical pattern. Individual tracts range from 0.08–0.16 mm in diameter in their thinnest parts, but all tracts develop globose, rounded, expansions where they join with adjacent tracts. These expansions are commonly 0.2–0.3 mm in diameter and are spaced 0.3–0.4 mm apart. Gastral and dermal thickening of individual tracts produce armored layers, 0.5–1.5 mm thick, the thickness depending, in large part, upon the size of the specimen. Small specimens have relatively thin layers and the larger specimens have thicker layers. The dermal layer is markedly thicker than the gastral layer, in intermediate top-shaped specimens. Skeletal net composed of numerous



elongate straight, to gently curved oxeas (?), with larger axial triacts that occur principally at junctions of the stubby tract segments. Triacts with rays 0.02–0.04 mm in basal diameter and up to 0.3 mm long. Monaxial spicules are small averaging 0.005–0.015 mm in diameter and up to 0.1 mm long.

Description.—Three, nearly complete, three-dimensional specimens, plus thin sections of an additional six specimens, are in the collection. The specimens range from a small subcylindrical fragment, approximately 20 mm tall and 18 mm in diameter (Pl. 1, fig. 4), to a large, more nearly complete specimen, approximately 47 mm long and 30 in diameter. The latter is still partially covered in matrix.

A nearly complete and exposed small specimen, the holotype, is a conical top-shaped form (Pl. 1, figs. 1, 2), approximately 20 mm tall and 25 mm in maximum diameter. This particular specimen has a flared attachment base that narrows to a short stalk, 3 or 4 mm high and 15–16 mm in diameter, above which the sponge expands abruptly to a maximum diameter of 21–22 mm shortly below the oscular rim. The sponge then narrows and rounds abruptly, across the curved upper part of the wall, into the osculum.

The exterior of the holotype is moderately smooth, except for irregular, vertically elongate, weak ribbing produced by the somewhat regularly spaced ostia of the incurrent canal system. The exterior on this particular specimen, however, has been modified by intense overgrowths of small hexagonal quartz crystals and by somewhat coarse silicification of the entire skeletal net. Beneath the overgrowths, however, details of the skeletal net are moderately well preserved in the interior of the lumpy skeletal tracts.

In the holotype the walls are 6–10 mm thick at the maximum diameter of the sponge. The osculum is slightly elliptical, 10.5 × 8.5 mm wide, and has a vertical to slightly overhanging upper lip, but the spongocoel becomes conical in the middle and lower part of the sponge, paralleling the general exterior profile. In general, the spongocoel appears to form approximately one-third of the total diameter, particularly in the upper cylindrical parts of the sponge.

Four series of canals or skeletal openings are

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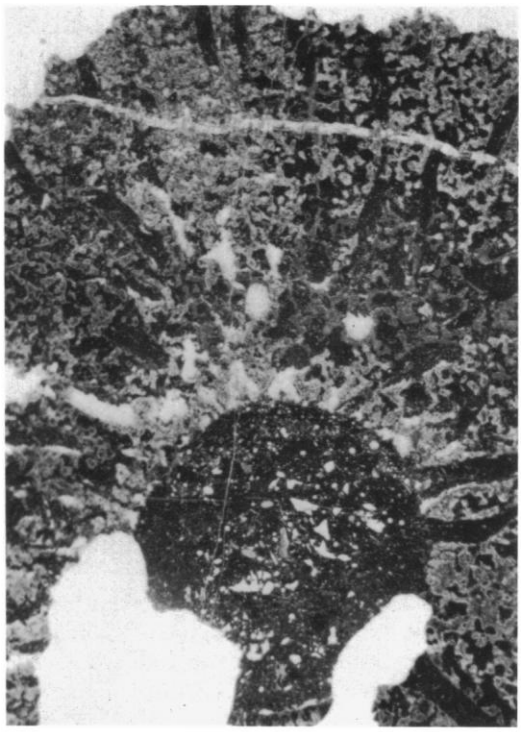
EXPLANATION OF PLATE 1

Corynella mexicana n. sp. and *Lymnorella encrusta* n. sp.

FIGS. *1,2,4–6*—*Corynella mexicana* n. sp. Locality 2 of Text-fig. 1, upper limestone member of Mural Limestone, Lower Albian, Sonora, Mexico. *1,* Vertical view of the holotype showing its relatively thick wall, circular spongocoel partially filled with matrix, and radiating canals that indent the surface. Skeleton shows heavy overgrowths of hexagonal quartz. Lower surface is fractured. USNM 304039, ×3. *2,* Side view of the holotype, an upward expanding cone with a somewhat pedicled base, ostia of the radiating canals, and the gentle rounded upper margin of the sponge. The base is fractured. USNM 304039, ×3. *4,* Paratype, vertical view showing the prominent, radiating, subhorizontal canals and the circular deep spongocoel. Somewhat open-textured middle part of the wall is produced by intersections of both vertical and concentric horizontal canals characteristic of the species. USNM 304041, ×3. *5,6,* Photomicrographs of paratype, USNM 304042, showing the somewhat fibrous nature of the short skeletal tracts cored by relatively coarse triactines (arrows) that are blanketed by diactines, possible oxeas, that make up most of the tract. ×80.

3,7—*Lymnorella encrusta* n. sp. *3,* Holotype from the side showing the gently mounded, subhemispherical to irregularly tuberescent shape of the sponge. Small volcanolike mounds commonly perforated by two excurrent openings. USNM 304043. Upper limestone member of the Mural Limestone, Lower Albian, Paul Spur, Locality 1 of Text-fig. 1. ×3. *7,* Photomicrograph of a thin section of a paratype, USNM 304045, showing the fibrous nature of the skeletal tracts, locally cored by rare triactines but composed principally of bundled diactines, possible oxeas. Light areas in the upper part are quartz overgrowths on the silicified skeletal tracts. Calcified tracts are darker and in the center of the photograph. Still darker areas are matrix that has filled canals. Upper limestone member of the Mural Limestone, Locality 2 of Text-fig. 1, in the Sierra Anibacachi, Sonora, Mexico. ×80.



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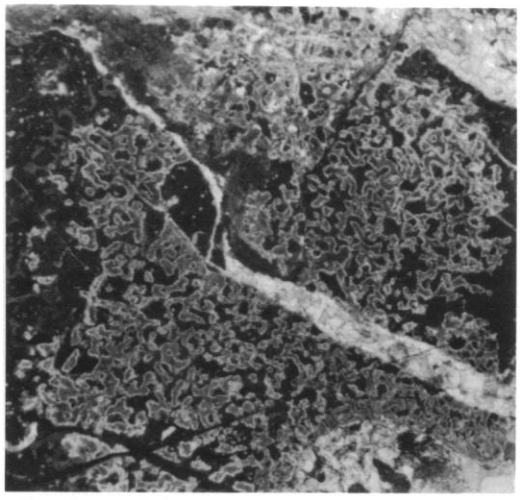

B

TEXT-FIG. 2—*A, Corynella mexicana* n. sp., photomicrograph of a horizontal section showing the prominent spongocoel and the radiating canals. Circular matrix-filled openings near the center of the wall mark vertical canals common in the species. Paratype, USNM 304042, upper limestone member of the Mural Limestone. Locality 2 of Text-fig. 1, from the Sierra Anibacachi, Sonora, Mexico, ×5. *B, Lymnorella encrusta* n. sp., horizontal section near the base of a paratype showing the irregular small skeletal tracts and the essentially imperforate base of the sponge, particularly in the upper right of the photograph. Paratype, USNM 304045, from the upper limestone member of the Mural Limestone at Locality 2 of Text-fig. 1 in the Sierra Anibacachi, Sonora, Mexico, ×5.

apparent. Most obvious are large horizontal radiating canals (Text-fig. 2a) that are cross-connected with somewhat less obvious vertical canals, and with large horizontal canals that are concentrically arranged parallel to the spongocoel margin. Smallest openings are the irregular perforations between the small tracts within the skeletal net and they cross connect between all of the three larger canal series.

Large radiating canals are straight to somewhat weakly sinuous openings that are essentially horizontal to slightly arched. Arcuate canals are more common in the upper part of the sponge. In the lower part of the sponge radiating canals rise upward and inward; some extend completely through the sponge wall into the spongocoel. Radial canals commonly cross connect with the concentric or vertical series. These several canals generally range from 0.4–0.7 mm in diameter. Most canals on the exterior, as seen in thin sections, are 0.4–0.5 mm in diameter, but most of the openings in the spongocoel wall are 0.5–0.6 mm. Some of the canals flare markedly in the last 0.5 mm before they empty into the spongocoel. Most appear to be circular to slightly elliptical, with the long axis of the cross section vertically oriented. Elliptical ostia are particularly apparent in the exterior in the lower part of the sponge. This may be related, in part, to their more upward trend there than in the upper cylindrical part of the sponges. Individual radial canals are spaced from 0.5 mm to as much as 1.5 mm apart in the exterior and intermediate parts of the sponge wall but are approximately 0.5 mm apart at the spongocoel margin. When traced from the exterior into the interior they converge and merge so that canal spacing is essentially maintained.

In the lower part of the spongocoel in some of the smaller specimens, radiating canals are separated by only 0.1–0.2 mm of skeletal material. Virtually only a single skeletal tract occurs between these closely spaced openings so

that 4–6 canals occur in 2 mm, as measured horizontally around the wall.

Radiating canals on some of the larger specimens are distinctly upwardly arched, apparently forming initially as radial indentations across the curved spongocoel margin. These indentations were subsequently roofed over as the sponge grew vertically. This produced, in some, smooth sweeping canals that arch upward from the exterior, become nearly horizontal at the midwall, and then arch downward slightly toward the gastral margin.

The concentric canal system is considerably less regularly developed and much less obvious, particularly in the subcylindrical part of the sponge. These canals range from approximately 0.4–0.7 mm across and, where seen in thin section, are approximately 0.5 mm across in the central part of the wall. Only rarely are two of the concentric ring-type canals developed at the same level, horizontally, in the sponge, but they appear to be stacked and spaced at irregular intervals from 1 to as much as 3 or 4 mm apart in the system. They are most common in the middle third of the wall and with the similarly located vertical series produce a moderately open part of the skeletal net.

Vertical canals range from 0.5–0.7 mm in diameter and are spaced generally 0.5–1.0 mm apart in the middle third of the sponge wall. They are rare in the gastral third and the dermal third of the skeleton and may be moderately discontinuous. They cross connect at slightly expanded openings with both the radial and concentric canal series.

The skeletal net is composed of meandering or almost vermiform, cross-connected, short, stubby segments of spicule tracts (Pl. 1, figs. 5, 6, Text-fig. 2a). Individual tract segments are commonly less than 0.5 mm long and most are only 0.3–0.4 mm long between cross connections with other irregularly oriented segments. There is a slight bulbous expansion at the segment junction that may increase the general diameter of the tracts from 0.10–0.15 mm up to 0.25–0.30 mm.

These irregular and short tracts produce a minutely porous skeletal net, with skeletal openings that range from 0.1 up to 0.3 mm in diameter. Most of the openings are meandering, or of irregular orientation so that no distinct radial, horizontal, nor diagonal pattern appears evident. Individual skeletal openings pinch and swell. Most of them, however, are 0.10 mm in diameter in the more distinctly defined parts of the tract but expand to 0.30 mm across where they join with other irregularly oriented openings. All of the openings and the intervening skeletal tracts show great variation in thickness and orientation but the irregularity combines to produce a rather distinctive, somewhat regularly spaced, very open, porous skeleton.

Skeleton tracts expand slightly to form a thickened layer, from approximately 0.5 mm thick up to 1.5 mm thick around both the gastral and dermal margins. Skeletal openings in these parts of the wall are generally reduced to 0.1–0.15 mm in diameter. Apparently most of the circulating water through the sponge wall entered at the large openings.

The skeleton is composed of subparallel small monaxial spicules, with larger triactines as principal axial spicules. Triactines are most evident at the junction of tracts where they are surrounded and blanketed by subparallel oxeas (?). Most evident large triacts have ray diameters of 0.02–0.04 mm. Maximum lengths of individual rays is approximately 0.2–0.3 mm, although in only a few rare spicules it is possible to determine lengths of rays because they are preserved only in the interior of the tracts and are seen only in thin sections.

Most of the tract segment is made of parallel small spicules that are interpreted to be oxeas, although in the spaghettilike dense packing it is virtually impossible to see both tips of any spicule. Some of the apparent taper may be related to how the individual spicules have been cut in thin sections. In general, however, these tiny spicules range up to 0.01 mm in diameter, although most are 0.005 mm in diameter, or smaller, at their maximum diameter. They appear to taper to sharp points and to be interleaved and *en echelon* arranged with adjacent spicules.

The oxeas unite to form solid, minutely spiculiferous, tracts. In any one cross section where the spicules are parallel 10–30 spicules can be identified in the 0.1–0.15 mm wide tracts. Most of the monaxial spicules are gently curved where tangential to the surface of the tract around some of the circular openings. Obviously, those near the exterior are more consistently curved, sometimes through as much as 90°, than are those in the more axial, somewhat straighter, parts of the skel-

eton. Where best preserved they appear to be densely packed so there is little matrix or cement between adjacent spicules, in contrast to some of the other pharetrone sponges where the spicules are virtually floating in minutely crystalline, calcareous material. The *en echelon* arrangement and close packing of the spicules are distinctive of these particular sponges. Even where the skeletal tracts have been silicified and have heavy overgrowths of crystalline quartz, the fibrous, minutely spiculed nature of the skeletal tracts has been preserved in many areas, although somewhat obscured in the particularly heavily silicified exterior.

The triactine rays appear to diverge from each other at approximately 120°. Most of the longer rays, where best preserved, are principally straight but some curve slightly through 10–15° in observed segments. The large triacts appear to make up less than 20% of the total volume of the skeletal net. Where sections are cut at high angles through the rays, individual triacts may not be identifiable. In most, however, single triacts form the tract axis and individual large spicules, up to 0.03–0.04 mm, are blanketed by surrounding, minutely spiculiferous, parts of the tracts. The tracts may be 3 or 4 times as thick as the diameter of the principal triacts. Ray junctions of the large triacts are at junctions of three segments of the net. These individual tract segments also have a common divergence of 120°, initially, but with that symmetry often being largely lost as individual tracts increased in diameter by addition of overlying, minute, monaxial spicules.

In the gastral layer there are also some somewhat smaller triactines, with ray diameters of 0.015–0.020 mm and ray lengths of 0.3–0.4 mm. These also occur at the principal junctions of the tracts. Spicules of this same size may also occur in the main part of the wall but are difficult to identify because of the angle at which the available thin sections cut them. These smaller triactines are also surrounded by somewhat smaller to nearly the same size monaxial spicules in the outer part of the individual tracts. In some areas small spicules up to 0.2–0.25 mm long can be identified in the outer parts of the tracts. Some of these are definitely oxeas and suggest that most, if not all, of the small spicules are probably oxeas.

Discussion.—*Corynella* is one of the most long-ranging and one of the most common of the calcareous sponges. The genus was reported by DeLaubenfels (1955, p. E99) as ranging from the Triassic to the Cretaceous and occurring in Europe, as well as questionably in the East Indies. Hurcewicz (1976, p. 233) noted that the Triassic examples from the northern part of Italy were placed in the genus *Precorynella* by Dieci, Antonaci, and Zardini (1968, p. 28). Numerous species have been included in the genus, with extensive faunas from Poland, Germany, and Great Britain. Rezvoi, Zhuravleva, and Koltun (1962, p. 35; 1971, p. 29) reported *Corynella* as occurring in rocks of from Permian to Cretaceous ages and from western Europe, Mexico, Timor Island, Moluccas, and in southern Tunisia, and from the Jurassic to Cretaceous of the Crimea, USSR. They stated that more than 20 species have been described. As mentioned earlier, the Paleozoic and Triassic forms probably belong to *Precorynella*. This is almost certainly true of the forms reported from the Permian in North America.

Most of the species are small, with few as large as the specimens from Mexico. In addition, many of the species are subcylindrical, with only a few solitary, cone or club-shaped sponges, such as the Mexican form. The new species *Corynella mexicana* is probably most similar to *Corynella langtonensis* Hinde (1893, p. 222–223; Hurcewicz, 1976, p. 240–241) in terms of general size and in size of individual structural elements. However, the Mexican form has a considerably larger spongocoel and the larger specimens are much larger than the Jurassic species from Poland and Great Britain. The Mexican material also has a considerably greater part of the skeletal tract composed of tangential diacts or oxeas (?) than do the Jurassic forms. In general gross appearance, however, the two species are markedly similar. The canal system in the Mexican species is somewhat different; not only are weakly branching radiating canals clearly defined, but vertical and horizontal ringlike canals are also present. In general, the canal system is of distinctly higher organization than that described for the Jurassic species of northern and western Europe.

Type specimens.—Holotype USNM 304039, and paratypes USNM 304040–304042 all from the upper member of the Mural Limestone,

Early Albian of Sonora, Mexico; in the Sierra Anibacachi approximately 1.2 km south of Highway 2 between Agua Prieta and Cananea, approximately 12 to 13 km west of Agua Prieta (Locality 2 of Text-fig. 1). The collections consist of the holotype, three paratypes, and thin sections of five additional reference specimens, all from the same locality.

Etymology.—The species name, *mexicana,* refers to the Sonora, Mexico locality of the sponge.

Family DISCOCOELIIDAE De Laubenfels, 1955
Genus LYMNORELLA Lamouroux, 1821

Remarks.—Hurcewicz (1976, p. 276) discussed the systematic placement of *Lymnorella* and the occurrences of the genus. She placed these sponges in the Discocoelliidae of De Laubenfels (1955, p. E98) with reservations because of the lack of triactines in the principal skeleton. De Laubenfels (1955, p. E97–98) included the genus in the Stellispongiidae, his new family.

The Arizona-Sonora occurrences are the first reports of the genus in North America. Previously it has been recorded from Middle and Upper Jurassic rocks of Poland, England, and southern Germany (Hinde, 1884, p. 184; 1893, p. 238), from France (Lamouroux, 1821, p. 77), Germany (Bronn, 1837, p. 236; Zittel, 1878, p. 128), from England (Hinde, 1884, 1893) and from Poland (Siemiradzki, 1913; Hurcewicz, 1976, p. 278–279). It has also been recorded from the Triassic of western England (Hurcewicz, 1976, p. 276). The North American occurrence, however, is the youngest report of the genus.

LYMNORELLA ENCRUSTA n. sp.
Pl. 1, figs. 3, 7; Text-fig. 2b

Diagnosis.—Small, massive, hemispherical to irregularly tuberescent sponge, lacking spongocoel. Surface pierced by numerous excurrent openings that commonly are paired and are uniformly situated on small nodes on the otherwise moderately smooth surface. Skeletal net irregular vermiform to irregularly meandering and composed of skeletal tracts formed of many subparallel oxeas that surround rare triactines. Small mounds 3–4 mm across, with excurrent openings approximately 0.5 mm in diameter at their summits, commonly in pairs. Where not in pairs, single openings have the same diameter as combined pairs and may represent a mound which has been broken to show a lower level in the interior. Skeletal openings 0.2–0.3 mm across, moderately regularly throughout the sponge, and separated by tracts 0.1–0.3 mm across. Some cylindrical canals, 0.3–0.4 mm in diameter, occur near mid-thickness of the encrusting sponge and subparallel the upper and outer surface but appear to converge to the small excurrent openings. They are spaced approximately 1 mm apart, as seen in section, 2 or 3 mm from the excurrent openings.

Description.—Two small silicified specimens and 1 sectioned partial specimen are in the collection. The largest and best preserved of these, the holotype, is a somewhat elliptical specimen, approximately 20 mm × 15 mm across, and with an arcuate upper surface approximately 5 mm high. The unsectioned paratype (USNM 304044) is nearly circular, approximately 17–18 mm in diameter and 5–6 mm high.

The somewhat cap-shaped sponge has a thickness of approximately 2 mm between the low mounds in the central part of the specimen, but thins to a rounded or tapering edge, approximately 0.5 mm thick, at the outer edge on the holotype.

Both sponges are somewhat hemispherical, with low to pronounced small mounds marking the exterior. These mounds are less clearly defined on the paratype than on the holotype. On the latter specimen, the small volcanolike mounds are 4–5 mm across and rise up to approximately 2 mm above the general arched summit of the sponge. The mounds have rounded gentle slopes that rise to the small craterlike summits that are perforated by either 1 or 2 excurrent openings (Pl. 1, fig. 3). Crests of excurrent mounds on the holotype are more densely silicified and probably had a more compact skeletal net, initially, than the broad lower intervening areas. Individual mounds are 4–6 mm apart, summit to summit, and their rounded bases may either coalesce or be separated by 3 or 4 mm of normal, porous, skeletal material.

Two coequal excurrent openings commonly occur on each mound crest and are 0.6–0.8 mm in diameter on the holotype. They are separated by 0.2–0.5 mm of skeletal material. On two mounds the double opening at the crest

shows one major canal, 0.8 mm in diameter, and a subsidiary smaller one, 0.3–0.4 mm across. In these instances, the skeletal separation is more interior, so that the two occupy a somewhat elliptical common opening at the immediate crest. Some of this variation may be in preservation, however, rather than differences in the skeleton.

The interior canal systems consist principally of short, radiating, large excurrent openings, and subhorizontal circular canals and smaller skeletal openings between the irregular tracts that feed into the large excurrent openings. The latter extend only approximately 2 mm into the sponge and are cross-connected with a subhorizontal series of slightly elliptical openings arranged parallel to the upper surface of the sponge. These openings are 0.2–0.3 mm in diameter, where best seen on the broken margins of the holotype, and are approximately 1 mm apart. They occur in the middle of the platelike sponge, approximately 1 mm below the exterior surface.

Intermediate-sized interior canals are cross-connected, in turn, by openings between the irregular skeletal tracts. These meandering skeletal openings are approximately 0.1 mm in diameter and pierce the entire sponge. These small skeletal openings have moderately regularly spaced ostia on the upper surface of the sponge. In some parts of the broken edge, these small skeletal openings have a distinct radiating pattern, but elsewhere they have an intensely meandering, complexly branching, arrangement. On the exterior they open into elongate small slits, comma-shaped openings, or circular to elliptical openings. In general, these are 0.1 mm across, although the elongate slits and irregularly branching openings may form small branching complexes up to 0.5 mm across. These openings do become significantly smaller, however, and more widely spaced, on the lateral slopes and summits of the small mounds where the skeletal texture becomes dense and infilled.

Blunt ends of the rounded skeletal tracts produce a minutely knobby surface between the volcanolike excurrent canal mounds (Pl. 1, fig. 3). Skeletal tracts on the exterior have been somewhat heavily silicified but, as preserved, the exterior has a slightly more dense skeletal arrangement than does the interior. Individual branching and meandering skeletal segments (Text-fig. 2b) are thoroughly fused at junction points with other adjacent short stubby tracts. In one area where another organism has encrusted the sponge, some of the original exterior is preserved and the small skeletal tracts extend 0.1–0.2 mm above the general sponge surface as small fingerlike stubby knobs. Elsewhere, however, the outer surface is moderately uniformly composed of tangentially arranged short skeletal tracts. These tracts generally are 0.3–0.4 mm long and, on the exterior, are 0.15 to 0.2 mm across. In the interior of the sponge, they are slightly more delicate, generally 0.1–0.15 mm across but of essentially the same length. The thickened dermal layer, as preserved on the holotype, also shows a relatively dense skeletal layer, 0.2–0.3 mm thick. Only a few canals, 0.1 mm in diameter, perforate through the dense basal layer.

The sponge is distinctly more porous in the inner half than in the lower quarter and the upper quarter of the vertical section. The skeletal pattern is particularly well shown in a section through one of the paratypes (USNM 304045). The decidedly non-radial pattern of the sponge is also evident, as is the somewhat dense basal layer where the sponge has overgrown, and perhaps partially bored, a bivalve. Canal openings in the interior on this particular paratype are essentially the same as those seen on the holotype. Moderate-size openings, up to 0.2 mm across, are interpreted to mark the emergence of the large excurrent canal systems. Other somewhat ill-defined linear openings are interpreted as canals feeding from the exterior into that middle layer which shows most porosity on the holotype.

Individual tracts (Pl. 1, fig. 7) are composed of subparallel, somewhat *en echelon,* small monaxial spicules, with as many as 20 or 30 single spicules visible in cross sections, in those sections where the triacts are approximately parallel or tangential to the thin section surface. Coarse silicification has destroyed much of the fine detail of the interior, however, and only in areas where the section is very thin or where the skeletal net is still somewhat calcareous are individual spicules clearly defined. In these areas the tiny individual monaxial spicules that produce the principal ropy texture of the net, are generally 0.010 mm or even smaller in maximum diameter. A few relative-

ly coarse spicules, up to 0.02 mm in basal ray diameter, are identifiable. Most of the spicules are considerably finer.

In only a few areas, on the one available thin section, is there any evidence of axial triactine spicules. These generally have maximum basal ray diameters of approximately 0.02–0.03 mm and maximum ray lengths of approximately 0.20–0.28 mm. They appear to be relatively smooth, to taper moderately abruptly, and to have maximum ray lengths essentially the same as individual tract segments, judging from those few places where triactines are moderately well defined.

Discussion.—The thin, encrusting, mounded habit of the sponge, coupled with the paired excurrent openings and the delicate, ropy, fine-textured spicule tracts are diagnostic of the genus and the species. In one place the sponge may have penetrated into a calcareous bivalve fragment as a substrate. This may be in part an opportunistic filling of a previously existing hole or depression because, elsewhere, the relatively tight basal layer obviously functioned as a barrier to water circulation and sediments.

Variation in mound development, between the moderately highly-mounded holotype and the much lower-mounded paratype, suggests that height and degree of mounding may be only an ecologic variation. Both specimens, however, show the moderately uniform separation of the commonly paired excurrent openings, and the hemispherical, relatively thin sheet-like occurrence of the sponge.

Lymnorella encrusta, n. sp. is most similar to *Lymnorella mammillosa* (Lamouroux, 1821) in terms of general massive growth habit and size of canals and skeletal fibers or spicule tracts. The latter species, however, is finer textured in terms of the small mounds. In addition, the European species has the mounds capped by single circular oscules, unlike the common double openings seen in the Cretaceous species. In addition, spicules of the new Cretaceous species are somewhat coarser than those cited by Hinde (1894, p. 235–236) for the British material.

A somewhat smaller form, also with the mammillary or moundlike excurrent areas is *Lymnorella pygmaea* (Sollas, 1883, p. 549). Here the summits of the little mounds appear essentially the same as those on North American examples, but the excurrent openings, again are single circular ostia that are one to two mm in diameter. This is slightly larger than even the paired opening of *Lymnorella encrusta* n. sp. In gross habit, however, as figured by Hinde (1893, Pl. 18, fig. 4–4B), the species are similar.

Lymnorella inclusa Hinde (1884, p. 185; 1893, p. 236–237) is a much more dense sponge and apparently lacks the prominent surficial excurrent openings which characterize the North American material.

Lymnorella ramosa Hinde (1893, p. 238–239) is a bushy mass, with subcylindrical branches that extend out from the base, and is a growth form significantly different than our Cretaceous species. *Lymnorella ramosa* is also reported from the Polish Jurassic (Hurcewicz, 1976, p. 276–277) and is a distinctly more branching form.

Lymnorella globoconica Hurcewicz (1976, p. 278–279) is a conical form capped by a spherical upper part and with a star-shaped, irregular osculum, a growth form, and canal pattern significantly different from the North American species.

Type specimens.—Holotype USNM 304043 and paratypes USNM 304044 and 304045. The holotype is from the upper limestone member of the Mural Limestone, Early Albian, exposed in a hogback 2.5 km west of Paul Spur, and directly south of US 80 (at Amoco Production Company locality 8314, sample 4) from Chochise County, Arizona, approximately 19.3 km (12 miles) west of Douglas, Arizona (Locality 1, Text-fig. 1). The paratypes are from the upper limestone member of the Mural Limestone, in the Sierra Anibacachi, approximately 1.5 km south of Highway 2, between Agua Prieta and Cananea, about 12 to 13 km west of Agua Prieta, Sonora, Mexico (Locality 2, Text-fig. 1).

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