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PERMIAN CORALS FROM NEVADA AND CALIFORNIA

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ABSTRACT—Seven species of rugose corals are described from Permian (mostly Leonard Series) strata in the Basin and Range Province of Nevada and California. *Caninia trojana, Lithostrotionella mokomokensis, Lithostrotionella dilatata, Diphyphyllum connorsensis, Thysanophyllum princeps, Lonsdaleia illipahensis,* and *Lonsdaleia cordillerensis* are named. The corals occur in thick successions of commonly cyclical alternations of limestone and sandstone near the eastern margin of the Cordilleran geosyncline. Local distribution and biostromal development can be used in subdividing and mapping the Permian strata of east-central Nevada.

INTRODUCTION

THICK deposits of marine strata of Permian age crop out in the Basin and Range Province in California, Nevada, and Utah. Although paleontologists have devoted some attention to the fusulinids in these Permian beds, much more descriptive work is needed on all phases of paleontology. The purposes of this paper are to describe some species of corals from the area and to show their stratigraphic occurrence in the Permian System.

Permian corals have been discovered infrequently in North America, partly because of the restricted nature of Permian seas and partly because of seemingly adverse environments for growth of corals in those seas. Known Permian faunas include several corals which have been described from the midcontinent by Moore & Jeffords (1941), who also (1941, p. 67,68) review the previous works in that area. Permian corals from British Columbia have been described by Smith (1935); from Oregon, by Merriam (1942); and from California, by Langenheim & McCutcheon (1959).

Corals are locally very abundant in Permian strata of the Basin and Range Province. Indeed, they may comprise biostromes a foot or more in thickness. Moreover, some species are widespread, ranging north-south over a distance of at least 500 miles from northeastern Nevada to southeastern California. It is probable that the corals occupy an east-west zone at least 200 miles wide in the region between the Confusion Range of west-central Utah and the Eureka district of east-central Nevada. Thus, a coralline facies of the marine Permian strata seems to have been deposited along the eastern or continental side of the Cordilleran geosyncline.

It has been the good fortune of the writer to be able to study and to collect from numerous successions of Permian strata in the Cordilleran region. This work was begun in 1947 and has continued through most of the succeeding summers. During parts of five summers the writer was engaged in mapping with students enrolled in the summer field geology courses conducted by the University of Southern California in White Pine County, Nevada. Several summers were spent in paleontologic and stratigraphic studies of Permian and other strata on other projects. It is a pleasure to acknowledge my indebtedness to numerous students, faculty colleagues, and to various other geologists for assistance in the field work. Collections described herein which were originally made in the course of field investigations for Union Oil Company of California have been deposited at the University of Southern California through the kindness of Dr. J. C. Hazzard.

STRATIGRAPHY

Corals are described from two Permian localities in the southern part of the Basin and Range Province. The detailed stratigraphic succession of Permian rocks in the Providence Mountains of southeastern California has been published by Thompson & Hazzard (1946), and the general sequence of Permian strata in the Spring Mountains of southwestern Nevada has been discussed by Longwell & Dunbar (1936).

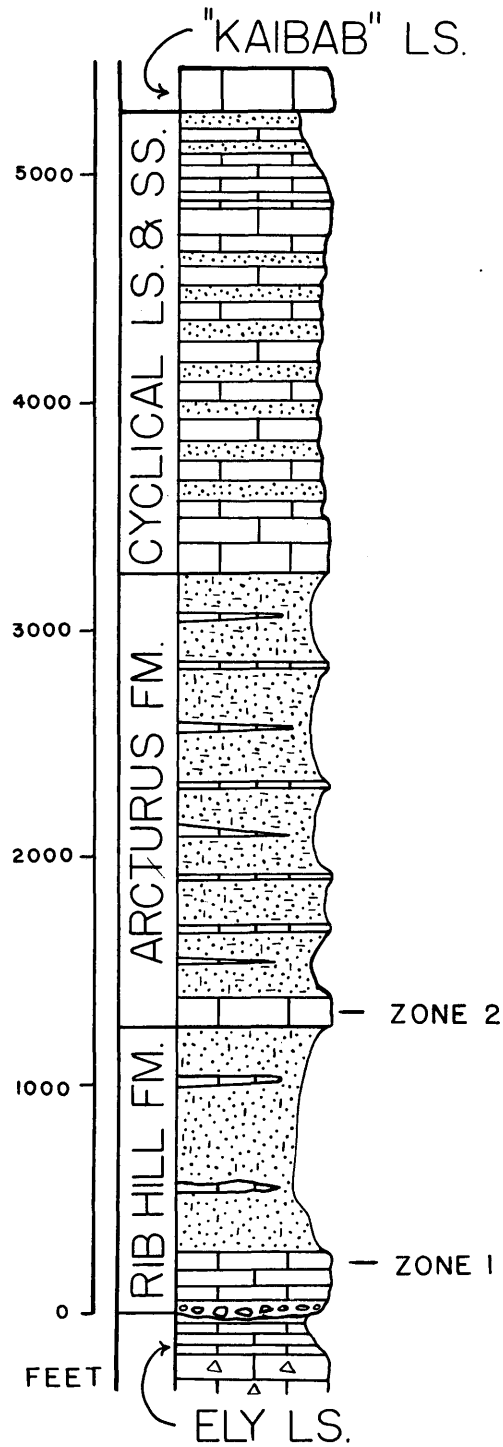
Only part of the thick Permian succession in east-central Nevada has been published

in detail. Knight (1956) has published graphic sections of two stratigraphic successions of Leonard strata in White Pine County. Additional detailed measurements are available for somewhat lower strata in the same county through unpublished research by Ehring (1957). Most of the corals to which reference is made herein were collected from Permian strata in White Pine County.

The Permian succession in east-central Nevada is one of the thickest discovered in North America. It is possible that over 7000 feet of Permian strata are represented there, of which at least 5000 feet are referable to latest Wolfcamp and Leonard Epochs. Corals have not been discovered in the latest Leonard or in the Guadalupe strata in the areas studied.

The Permian succession pertinent to this report is depicted schematically in text-figure 1. Thicknesses are only approximated because the section is a composite of outcrops at several localities. The region is one of considerable structural complexity, in addition to which the western outcrops in the region represent a more carbonate-rich facies than is present in the eastern outcrops. Solution of some perplexing structural and stratigraphic problems has been materially assisted by use of corals in a block of quadrangles consisting of the Ely, Illipah, Illipah 1 advance sheet, Treasure Hill, Pancake Summit, Green Springs, and Buck Mountain quadrangles.

The most nearly complete and readily accessible locality in which the Late Paleozoic rocks can be studied in the area lies along U. S. Highway 50 in the east half of the Illipah quadrangle, about 30 miles (airline) west of Ely, Nevada. The Illipah section has been studied by many geologists engaged in exploratory programs of oil companies in Nevada between 1948 and the present. The section lies within the region mapped during several summers by students at the summer field geology camp of the University of Southern California.



TEXT-FIG. 1—Schematic and composite stratigraphic section of the coral-bearing Permian strata in White Pine County, Nevada.

Permian strata in the area rest with apparent concordance upon the Ely limestone of Early Pennsylvanian age. The Ely limestone consists of about 1500 feet of massive to platy, grey limestone. Detailed information on the stratigraphy and paleontology of the Ely limestone will appear in a future number of this journal in an article by Bernard O. Lane.

The basal unit of Permian rocks mapped by us is the Rib Hill formation. Its lower limit is determined by the presence of a thin, chert pebble conglomerate. The succeeding limestones account for as much as 300 feet of section at some localities, but more generally only the uppermost bed of coralline limestone about 30 feet thick is present. This massive unit locally is almost a biostrome of colonial corals. It comprises zone 1 of the coral succession. The remainder, and principal part, of the Rib Hill formation consists of pink to yellow sandstone in the eastern facies but becomes increasingly calcareous and evenly buff in color westward. The arenaceous portion of the Rib Hill formation is about 1000 feet thick.

The Arcturus formation overlies the Rib Hill formation conformably and comprises about 2000 feet of strata. In its eastern facies near the type section (as on the west grade leading up to Murry Summit) the Arcturus formation consists of numerous beds of pink to yellow sandstone intercalated with grey limestone in crudely cyclical alternations. The western facies, however, is even less cyclical in appearance and the sandstones are more uniformly buff and are very calcareous. Toward the western margin of the mapped areas the Rib Hill and Arcturus formations become difficult to differentiate. The base of the Arcturus formation, however, is a widespread, massive succession of limestones which contain biostromes of corals referred to herein as zone 2. Corals occur less abundantly in other limestone beds within the Arcturus formation, particularly in the lower strata.

The uppermost strata containing corals discussed herein comprise a strikingly cyclical sequence of criquina, grey sandstone, and fusulinid-rich, buff limestone. The whole succession produces prominent cliffs and bench-and-bluff topography in the high ridge north and south of Moorman Ranch in the Illipah quadrangle. It is probable that this un-named unit is 2000 feet thick, although the upper part is inadequately known. Knight (1956) has published on the fusulinids in the succession. Corals occur in some of the limestone beds.

Overlying the foregoing sequence at some places is a massive, white limestone about 200 feet thick. It is referred to in text-figure 1 as the "Kaibab" limestone because of its position in section. It occurs between strata of Leonard age and strata containing the Phosphoria fauna. Corals are not known from so-called Kaibab limestone.

FAUNAL ANALYSIS

The most unusual feature of the Permian coral fauna from the Basin and Range Province is the abundance of compound corals belonging to groups with a tendency for the development of some sort of axial structure. In *Lithostrotionella* and *Lonsdaleia* the axial structure may be conspicuous, whereas it is reduced in *Diphyphyllum* and is absent in *Thysanophyllum*. *Lithostrotionella* is noteworthy because this genus is widespread in Meramec strata (Middle Mississippian) from the Appalachian to the Cordilleran ranges. On the other hand, *Lithostrotionella* has been reported from Pennsylvanian and Permian strata of several countries, including Canada (Smith, 1935). Merriam (1942) was the first to report *Lithostrotionella* from Permian strata in the United States (Leonard of Oregon).

A second notable feature is the localized abundance of very large specimens of *Caninia*. *Caninia* is common in Late Paleozoic strata in many regions of the world, including North America, but never before (to the writer's knowledge) did species attain the breadth of the species described hereafter.

A third, but negative, phenomenon is the apparent absence of species of *Waagenophyllum* in the collections. *Waagenophyllum* is widespread in Leonard strata of other countries, and has also been reported from Oregon and British Columbia. Perhaps its presence will be proved by slicing of specimens from future collections in the Basin and Range Province.

Faunal elements associated with the corals are meager. Fusulinids may be

locally abundant in coralline beds, but at other localities they are absent. A few specimens of the large gastropod, *Omphalotrochus*, have been collected, particularly in the Arcturus formation. *Dictyoclostus ivesi* also occurs here and there in these Leonard strata, but is rarely common. At a few localities large, ramose fronds of stony bryozoans and the spines and plates of the echinoid, *Echinocrinus*, occur with the corals. Crinoid ossicles, although tremendously abundant in many other beds, are not common in the coralline beds proper.

The corals themselves may be conspicuously abundant, as in zones 1 and 2, where they approach the nature of biostromes. Specimens of the colonial corals range in diameter from an inch or two up to elongate colonies eight feet long and a foot or two in height. Most colonies are from six inches to a foot in diameter. Specimens are infiltrated and replaced by calcite in all cases, whereupon they appear as white masses against the grey matrix of the limestone bed. Surficial silicification has affected some colonies so that the nature of the calices is revealed and the axial structures can be inspected with a hand lens in the field without resorting to preparation of thin sections or polished surfaces.

In many instances the colonies are planoconvex and lie in their positions of growth with the convex side up. In structurally complex areas, however, the entire stratigraphic sucession may be inverted, in which case the corals assist in determining the true orientation of the strata. At several localities there is abundant evidence of disruption of colonies by current action. Large colonies two or three feet in breadth are lying on their sides with fragments of the colonies strewn about in the matrix. Coralla with cylindrical corallites are naturally poorly compacted and are therefore particularly prone to be broken apart. Reworked colonies, of course, cannot be used for determination of stratigraphic tops, but the lineation of the fragments reveals the directions in which currents flowed.

STRATIGRAPHIC DISTRIBUTION

Zone 1 is commonly dominated by the presence of *Thysanophyllum princeps*. It has been found at essentially every outcrop of the basal Rib Hill limestone examined, and is particularly abundant in the eastern portion of the region. It occurs much less commonly in the lower limestone beds of the Arcturus formation. Here and there in zone 1 occur *Diphyphyllum connorsensis*, *Lithostrotionella dilatata*, and *Lonsdaleia cordillerensis*, particularly in the western portion of the region.

Zone 2 contains all seven species of corals described herein, but it is characterized by two species. *Caninia trojana* is confined to the top of zone 2 in east-central Nevada, although it seems to occur at a lower level (in the Wolfcamp Series) in the Spring Mountains of southern Nevada. The most conspicuous coral at most localities, however, is *Lonsdaleia cordillerensis*. Its fasciculate colonies may comprise most of the mass of many beds, and fragments of this species may occur in beds which seem to lack the corallites proper. The species also is present in limestone of Wolfcamp age in southeastern California. *Lithostrotionella dilatata* is also a rather common element in the lower Arcturus strata.

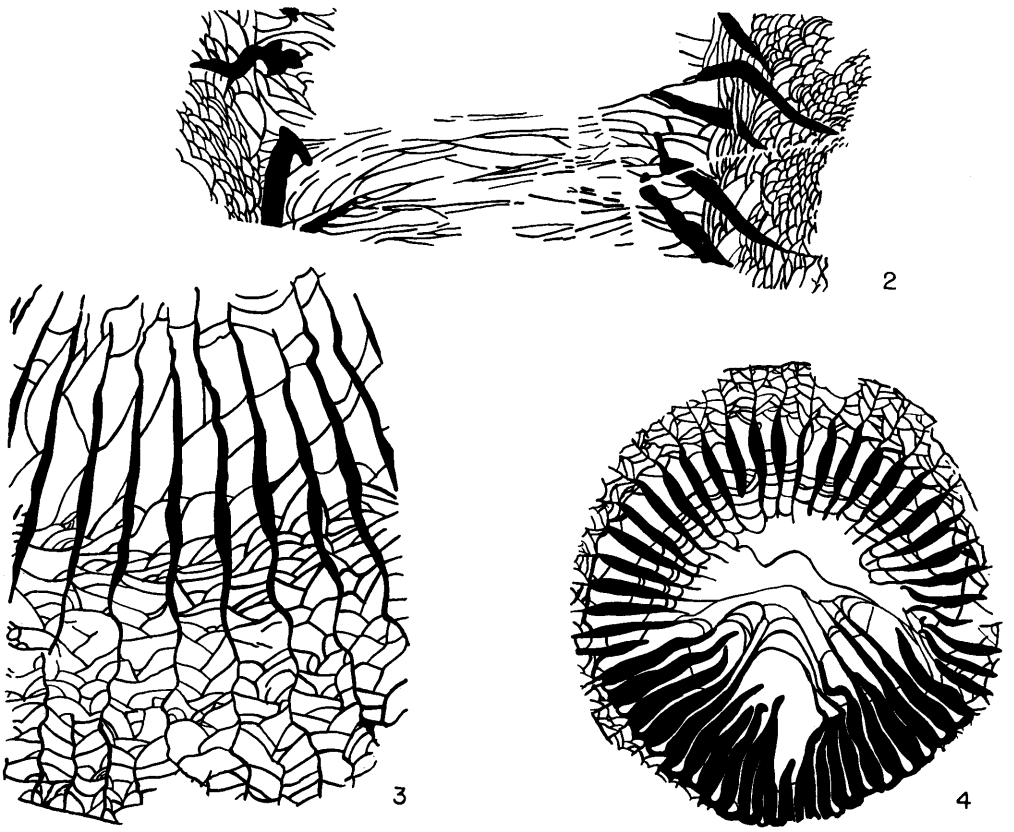
The upper cyclical limestone and sandstone sequence does not comprise a distinct faunal zone such as occurs in lower beds. Corals are less abundant than in lower strata and the fauna is more meager. *Lonsdaleia illipahensis* is rather consistently present in the sequence, although not strictly confined to it. The species is less common in the Arcturus formation. Specimens of *Lonsdaleia cordillerensis* which occur at a few places in the sequence seem to be a variety with unusually broad corallites.

The localities from which the corals were collected are described in a register appended to this report.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA
Subclass RUGOSA
(TETRACORALLA)
Family CYATHOPSIDAE Dybowski, 1873
Genus CANINIA Michelin in Gervais, 1840

Diagnosis.—Caninia comprises solitary cyathopsids whose septa reach the center in early stages but retreat from the axis in



TEXT-FIGS. *2–4—Caninia trojana. 2*—longitudinal section of paratype in mature region, USC 5015, locality 330, ×1.3; *3*—Transverse section of late mature region, paratype, USC 5016, locality 330, ×4; *4*—Transverse section in early maturity, paratype, USC 5017, locality 330, ×1.3.

amplexoid fashion in maturity; septa normally are dilated in the tabularium; minor septa are short and are confined to the dissepimentarium; the cardinal fossula is distinct but the alar pseudofossulae are indistinct; the dissepimentarium is narrow to wide, mostly consisting of herringbone dissepiments between septa; lonsdaleoid dissepiments may be present near the periphery.

Remarks.—Caninia is particularly comcom in North America in Pennsylvanian strata. For instance, it occurs as minor biostromes in the Ely limestone of Nevada. The following species is noteworthy for its large diameter. It is the first species of *Caninia* described from the Permian of the Basin and Range Province. *Caninia* has also been referred to as *Campophyllum* and *Pseudozaphrentoides* in American literature.

CANINIA TROJANA n. sp.
Text-figs. 2–4

Exteriors.—Corals are simple, very large, curved, and have an apical angle of about 50°. The theca is very thin and either is smooth or bears faint septal grooves. The calyx is deep and is essentially flat-floored. The holotype, which is the largest relatively complete specimen, is 12 cm. long and is 9 cm. in diameter at the widest place; if this specimen were complete it would be about 15 cm. long. The deep axial portion of the calyx is about one-third as wide as the diameter of the coral. The cardinal fossula is on the concave side of the coral.

Transverse sections.—At the earliest observed stage of one specimen (diameter about 17 mm.) there are about 36 long major septa which are dilated until they essentially close off the intervening loculi and come within 2 or 3 mm. of meeting at the axis. About 5 major septa lie in each cardinal quadrant. Minor septa are not present. Possibly one rank of dissepiments is present. At a slightly later stage of the same specimen (diameter about 20 mm.) 2 or 3 ranks of herringbone dissepiments are present in a few loculi but minor septa are not present.

In early maturity (diameter 43 mm.) about 50 dilated major septa extend to within 5 mm. of the axis. Approximately 8 or 9 major septa lie in each cardinal quadrant. The short cardinal septum occupies a conspicuous fossula. Alar pseudofossulae are indistinct. Minor septa are absent. A dissepimentarium of 3 or 4 ranks of herringbone dissepiments is as much as 4 mm. wide and is broadest on the counter side of the coral. Loculi are not closed off by dilation of septa.

It is estimated that in late maturity (diameter about 90 mm.) 70 major septa are present in the holotype, of which possibly 10 may lie in each cardinal quadrant. Septa are less dilated than in earlier stages and they leave an open space on the tabularium about 25 mm. in diameter. The dissepimentarium is as broad as 15 mm., which is half the length of the septa. Dissepiments are almost entirely herringbone, except in the outer edges at a few places where slender minor septa up to 5 mm. in length are present; whereupon a concentric pattern is assumed by dissepiments. From 18 to 20 ranks of dissepiments may be present.

Longitudinal sections.—Apical regions are devoid of dissepiments but the dissepimentarium appears shortly and widens distally. Long axes of dissepiments lie essentially vertically or are inclined apically and inwardly as much as 15°. Dissepiments are mostly 2 or 3 mm. long, but here and there one attains a length of 5 mm. From 10 to 12 incomplete tabulae occur in 10 mm. in mature regions where they may be slightly concave axially. In youthful stages where the dissepimentarium is thin to lacking, only 4 or 5 tabulae are present in 10 mm. Tabulae near the periphery slope outward and apically. Tabulae in the axial region of adult specimens are essentially horizontal and are slightly more numerous than in youthful stages.

Comparison.—*Caninia trojana* is distinctly the broadest caninoid coral yet discovered in North America, and possibly is the broadest known to science. Some phases of *Caninia torquia* from the Pennsylvanian of Illinois approach 60 cm. (2 feet) in length, but the broadest specimen there measured only 5.2 cm. (Easton, 1944, p. 127).

Caninia trojana is larger than typical *C. torquia*, has more major septa in maturity, has less well developed minor septa, and has a less well developed dissepimentarium which is not introduced until late in the ontogeny.

Another unusually large caninoid is the Upper Mississippian species, *Caninia nevadensis* (Meek, 1877) from the Brazer formation of Stansbury Island in Great Salt Lake and from the Chainman shale of the Confusion Range, both localities being in Utah. Specimens with about 70 long septa attain a breadth of 7.5 cm. and may have been 25 cm. in length, if they were complete. *C. nevadensis* is essentially cylindrical instead of flaring.

Although caninoid corals occur locally in Late Paleozoic deposits in the Cordilleran region, the other species are all more cylindrical than flaring, and are less broad than *C. trojana*.

Occurrence.—USC localities 330 (type locality), 331, 346, 348, 349.

Material.—Holotype, USC 5104. Paratypes, USC 5105-5110. Topotypes, USC 5111. Other specimens, USC 5131, 5132, 5134, 5137. Collection contains 33 specimens.

Remarks.—Some of the herringbone dissepiments present in *C. trojana* differ somewhat from typical herringbone dissepiments because the present ones commonly consist of a transverse plate like a concentric dissepiment, against which two oblique plates abut across the outer angles.

Strata containing *C. trojana* in White Pine County lie near the base of the *Parafusulina* zone of Leonard fusulinids, whereas strata with *C. trojana* in the Spring Mountains contain Wolfcamp fusulinids.

Family LITHOSTROTIONIDAE
d'Orbigny, 1851

Diagnosis.—Compound rugose corals with the inner end of the counter septum functioning as an axial plate, but axial structures may be lacking in some strains. The dissepimentarium is lonsdaleoid in some groups.

Remarks.—McLaren & Sutherland (1949) have indicated that several genomorphs of *Lithostrotion* can be differentiated on the basis of variation in strength of axial structures, circular or prismatic corallites, and presence or absence of lonsdaleoid dissepiments. Their system is followed in part herein and genomorphs of *Lithostrotion* are indicated by brackets.

LITHOSTROTION [THYSANOPHYLLUM]
PRINCEPS n. sp.
Text-figs. 5,6

Exteriors.—Coralla are composed of prismatic corallites which are mostly 6 mm. in diameter. Coralla commonly attain diameters of 10 to 15 cm. but one mass 240 cm. in length and 20 cm. thick was observed in an outcrop. Calices are rather deep. Calical floors are almost flat or are gently convex.

Transverse section.—Corallites are irregularly polygonal and are separated by ungrooved thecae whose plane of juncture is denoted by a dark line. From 14 to 16 major septa extend across $\frac{2}{3}$ of the radius. Minor septa, when present, commonly are merely short spines which scarcely penetrate one rank of dissepiments. Dissepimentaria commonly are composed of no more than 3 ranks of dissepiments. Marginal dissepiments commonly are lonsdaleoid but are not consistently of that pattern. Inner dissepiments and some marginal dissepiments are almost all concentric. Very few herringbone dissepiments are present. The tabularium is devoid of axial structures in most instances, but in a few sections there are isolated segments which might be either broken tabulae or median plates.

Longitudinal section.—The theca is only slightly contorted. Dissepiments are consistently globose and seem mostly to comprise one vertical series in which 12 dissepiments occur in 1 cm. Tabulae are mostly complete and are broadly arched distally. About 17 tabulae occur in 1 cm. No trace of an axial plate was observed.

Comparison.—Lithostrotion [Thysanophyllum] princeps differs from *Thysanophyllum orientale* (Thomson, 1876), from the Lower Carboniferous of Europe in having narrower corallites, about half as many septa, less well developed lonsdaleoid dissepiments, and in having more closely spaced tabulae.

The dissepimentarium of *Thysanophyllum princeps* resembles that of *Lonsdaleia illipahensis*, but *Thysanophyllum princeps* does not have an axial complex. *Lithostrotionella mokomokensis* has merely an axial plate for a columella, which might not be present in some sections, but *L. mokomokensis* has much coarser lonsdaleoid dissepiments than *T. princeps* has.

Occurrence.—USC localities 334 (type locality), 330, 335, 340, 341, 345, 348, 352, 360.

Material.—Holotype, USC 5112. Other specimens, USC 5113–5116, 5130, 5141, 5142, 5148. Collection contains 9 specimens.

Remarks.—Slight crushing of some specimens causes rupture and displacement of skeletal elements. Thus, isolated segments

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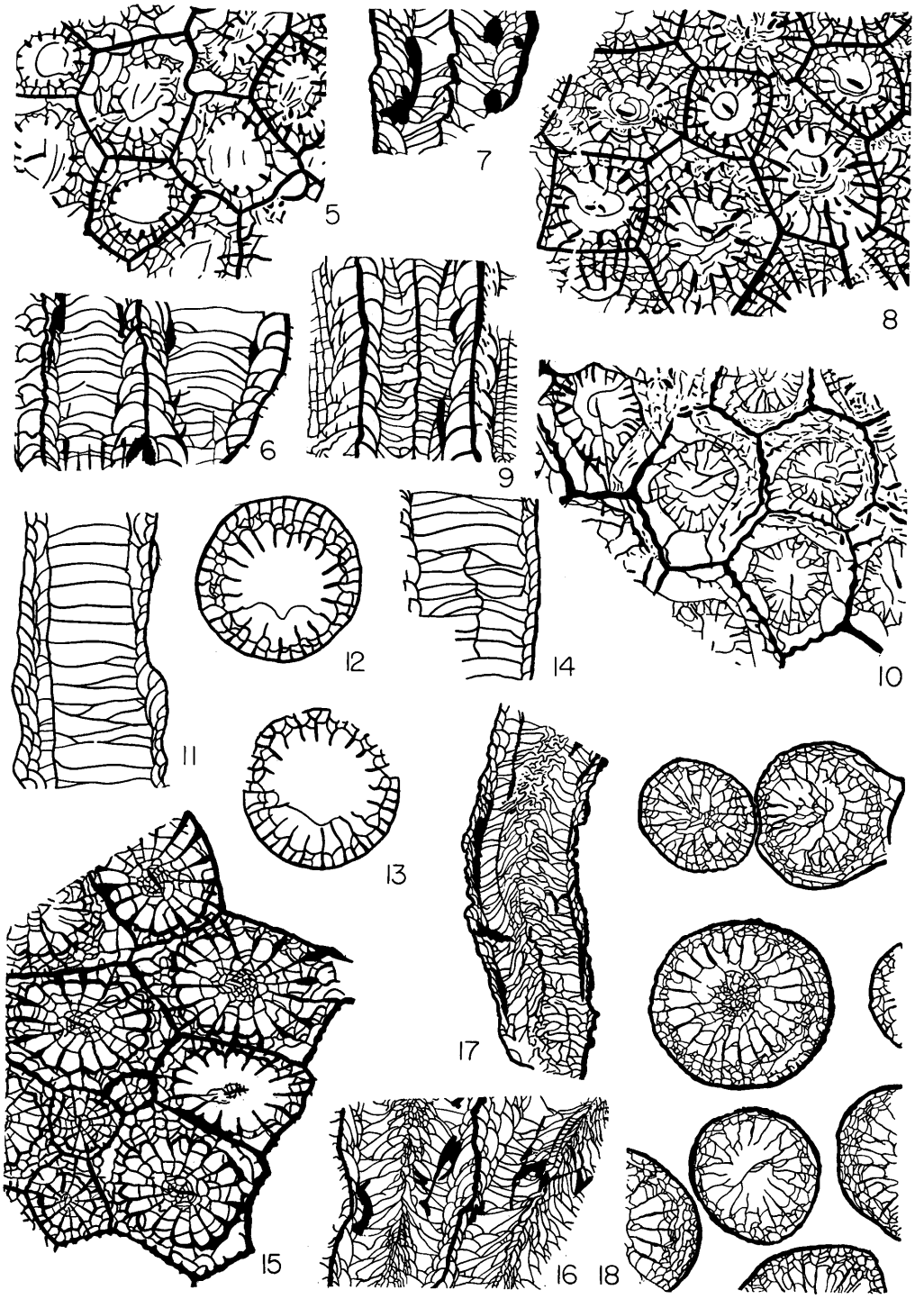
TEXT-FIGS. *5–18—5–6, Lithostrotion [Thysanophyllum] princeps.* Transverse and longitudinal sections, holotype, USC 5112, locality 334; *7,8, Lithostrotion [Lithostrotionella] dilatata.* Longitudinal and transverse sections, holotype, USC 5117, locality 340; *9,10, Lithostrotion [Lithostrotionella] mokomokensis.* Longitudinal and transverse sections, holotype, USC 5119, locality 330; *11–14, Lithostrotion [Diphyphyllum] connorsensis.* Longitudinal and transverse sections of four corallites, holotype, USC 5120, locality 332; *15,16, Lonsdaleia illipahensis. 15*—Transverse section, holotype, USC 5122, locality 336. *16*—Longitudinal section, a paratype, USC 5123, locality 337; *17,18, Lonsdaleia cordillerensis.* Longitudinal and transverse sections, holotype, USC 5127, locality 342. All figures ×3.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of tabulae in some corallites illustrated in text-figure 5 resemble the median plate of an axial structure.

LITHOSTROTION [LITHOSTROTIONELLA] MOKOMOKENSIS n. sp.
Text-figs. 9,10

Exteriors.—Corallum massive, sub-hemispherical to flattened, about 20 cm. in diameter (reconstructed) and at least 5 cm. thick. Mature corallites are mostly about 7 mm. in diameter and are 5- or 6-sided. The common wall between corallites projects above the conspicuously convex dissepiments in calices. Axial ends of septa penetrate the nearly vertically disposed inner slopes of dissepiments. Floors of calices are mostly domed and may retain the trace of the axial plate. Calices are 4 to 5 mm. deep.

Transverse sections.—Calical walls bear a distinct, median, dark line and commonly retain interseptal ridges. Calices are sharply divided into dissepimentaria and tabularia at a prominent inner wall. The dissepimentarium commonly consists of only 1 or 2 ranks of large, lonsdaleoid dissepiments which may be surmounted by few to many septal spines. The tabularium is subrounded to irregularly polygonal. Mature calices mostly contain 15 thin major septa, of which only one (the presumed counter septum) reaches and even slightly passes the axis. The axial end of the long septum is not dilated. Minor septa are present alternately with the majors but only extend half as far across the tabularium as the majors do.

Longitudinal section.—A single row of large, globose dissepiments normally lines each side of the tabularium. About 10 dissepiments occur in 1 cm. The tabularium is divided in half by the somewhat sinuous axial plate. Complete and incomplete tabulae are both present, there being from 15 to 20 in 1 cm. Tabulae rise slightly at the periphery to meet the dissepiments.

Comparison.—The best known clisiophylloids from North America are species of *Lithostrotionella* from the Mississippian System. *L. mokomokensis* resembles *L. tubifera* Hayasaka, 1936 from Montana in size of corallites, number of septa, and distinction between tabularium and dissepimentarium, but lacks the prominent ring-like juncture of septa with steeply-inclined tabulae which Hayasaka likened to a tube.

L. mokomokensis seems to be related to *L. berthiaumi* Merriam, 1942 from the Permian of Oregon. Both species have unusually large dissepiments, but *L. berthiaumi* has concave tabulae, more septa, and a stronger axial structure.

Occurrence.—USC localities 330 (type locality), 347, 349.

Material.—Holotype, USC 5119. Other specimens, USC 5133, 5136. Collection contains 3 specimens.

Remarks.—Although *Lithostrotionella* is confined to rocks of Meramec (Middle Mississippian) age in the midcontinent, it occurs from Mississippian into Permian strata in the Cordilleran region. Thin sections commonly are required in order to differentiate the various species. As a rule of thumb the Mississippian species seem to have rather more distinctly developed minor septa than are present among the Permian species.

LITHOSTROTION [LITHOSTROTIONELLA] DILATATA n. sp.
Text-figs. 7,8

Exteriors.—Coralla at least 15 cm. in diameter, rather spherical, and composed of prismatic corallites. Calices moderately deep and floored by a convex tabula from which projects a short but prominent axial plate.

Transverse sections.—Thecae smooth and separated one from another by a dark central line. About 16 or 17 major septa extend $\frac{2}{3}$ of the radius and are thickened within the tabularium. Minor septa are inconspicuous spines or septal crests near the periphery. Dissepimentarium consists of 1 to 5 ranges of mostly irregular concentric and herringbone dissepiments. A few lonsdaleoid dissepiments occur, particularly in recesses formed in the angles of the polygonal corallites. Columella consists of a single, slightly dilated plate. Elliptical outlines of tabulae surround the axial plate.

Longitudinal sections.—Thecae are slightly contorted. Dissepiments are somewhat elongate and slope inward at about 40°. About 20 dissepiments occur in 1 cm. along the theca. Tabulae are arched distally

at about 30° to meet the sinuous axial plate. From 14 to 18 tabulae occur in 1 cm. in the outer portion of the tabularium.

Comparison.—*Lithostrotion* [*Lithostrotionella*] *dilatata* differs from *L. mokomokensis* in having only sparse lonsdaleoid dissepiments, dilated major septa, and in having a dilated axial plate which is separate from the counter septum. Dissepimentaria of *Thysanophyllum princeps* and *Lonsdaleia illipahensis* are constructed similar to those of *L. dilatata*, but *T. princeps* lacks all trace of axial structure, and *L. illipahensis* has an arachnoid columella. All of the foregoing species construct coralla of prismatic corallites, hence they resemble each other at first glance.

Occurrence.—USC localities 340 (type locality), 345, 349–351, 332.

Material.—Holotype, USC 5117, Paratype, USC 5118. Other specimens, USC 5138–5140, 5149. Collection contains 6 specimens.

Remarks.—Assignment of this species to a genus raises questions which need to be investigated much more than in this introductory study. *Lithostrotionella dilatata* can be interpreted as a relative of *Lithostrotion* [*Thysanophyllum*] *princeps* which retains its axial plate, or it can be interpreted as a relative of *Lithostrotionella mokomokensis* which retains a simple dissepimentarium but has dilated septa and a dilated axial plate. Inasmuch as assignments are made herein on purely morphologic features, this species is referred at this time to the genomorph *Lithostrotionella*.

LITHOSTROTION [DIPHYPHYLLUM] CONNORSENSIS n. sp.
Text-figs. 11–14

Exteriors.—Coralla composed of loosely fasciculate corallites from 8 to 10 mm. in diameter. Coralla range up to at least 15 cm. in diameter. Corallites are cylindrical. Thecae bear faint septal grooves.

Transverse sections.—The theca is very thin. From 18 to 20 thin major septa extend up to ½ the radius. Short minor septa can be distinguished between some major septa. The dissepimentarium consists of 1 to 3 ranks of mostly concentric dissepiments.

Longitudinal sections.—The theca is locally wrinkled. Dissepiments are mostly rather globose, although a few elongate ones may be present. From 12 to 15 of the globose disseopients occur in 1 cm. Tabulae are thin, very slightly convex distally, and are complete (with rare exceptions). About 11 tabulae occur in 1 cm.

In one section (text-fig. 14) an axial plate can be traced over a sinuous course for 6 mm.

Comparison.—*Lithostrotion* [*Diphyphyllum*] *connorsensis* resembles *Lonsdaleia cordillerensis* in being composed of loosely fasciculate corallites, but *L. connorsensis* lacks an axial structure. *L. connorsensis* resembles corals of similar form in the Monte Cristo formation (Mississippian) of the Basin and Range Province which seem to be referable to *Lithostrotion* [*Siphonodendron*] sp. (Easton, 1957, p. 619), but the Mississippian coral normally retains its axial plate and tent-like tabulae, whereas *L. connorsensis* normally lacks an axial plate and has simply-arched tabulae.

Occurrence.—USC localities 332 (type locality), 334, 349, 355, 357.

Material.—Holotype, USC 5120. Other specimens, USC 5121, 5135, 5143, 5145. Collection contains 5 specimens.

Family LONSDALEIIDAE Chapman 1893
Genus LONSDALEIA M'Coy, 1849

Diagnosis.—Mostly compound corals with arachnoid columellae, major and minor septa, one order of essentially transverse tabulae, and an outer zone of lonsdaleoid dissepiments.

Remarks.—Hudson (1958, p. 178) has commented on the recent tendency to assign *Lonsdaleia*-like Permian corals to genera such as *Waagenophyllum* and *Wentzelella*. These genera have transverse inner tabulae but have steeply-inclined outer tabulae (clinotabulae), and some of them have a tertiary order of septa. The material at hand, however, seems to represent the orthodox morphology of *Lonsdaleia*. Inasmuch as *Waagenophyllum* is definitely known from Cordilleran deposits through the researches of Smith (1935) and Merriam (1942), it is possible that the genus will be discovered among the rich coral faunas of the eastern part of the Basin and Range Province.

LONSDALEIA ILLIPAHENSIS n. sp.
Text-figs. 15,16

Exteriors.—Coralla are composed of prismatic corallites which mostly are from 7 to 10 cm. in diameter and are depressed hemispherical. Calices are rather deep with sloping inner margins and a low, dome-shaped, axial boss on the calical floor.

Transverse sections.—Corallites are irregularly polygonal. Thecae have smooth margins and are joined along a dark median line. From 12 to 17 rather sinuous major septa traverse as much as $\frac{2}{3}$ of the radius of a mature corallite. Minor septa are present near the periphery but rarely traverse more than two ranks of dissepiments. The dissepimentarium occupies approximately $\frac{1}{3}$ of the radius. Outer dissepiments are irregularly concentric. Commonly 4 or 5 ranks of dissepiments are present. The axial structure is distinctly arachnoid and may occupy most of the tabularium. As many as 2 or 3 ranks of tabellae surround a slightly thickened median plate. Lamellae transect the tabellae and may correspond in number and position with the major septa; or lamellae may be reduced in number until they are almost lacking. Major septa may touch the axial structure at some points and may even be confluent with some lamellae.

Longitudinal section.—Thecae are somewhat sinuous. Dissepiments are rather elongate and occur in 1 to 3 ranks. About 12 to 14 dissepiments occur in 1 cm. Tabulae slope peripherally at only about 15° to 30°. Some incomplete tabulae are present and approximately 22 tabulae of both kinds occur in 1 cm. The axial complex is composed of closely-spaced tabellae which slope distally at very steep angles and may be vertical or even overhang slightly. The median plate is broadly sinuous, as are the lamellae.

Comparison.—*Lonsdaleia illipahensis* resembles species of *Lithostrotionella* from the Mississippian of North America which have prismatic corallites, but *L. illipahensis* has an arachnoid columella, whereas the columellar structure of *Lithostrotionella* consists merely of a median plate.

Lonsdaleia illipahensis resembles *Thysanophyllum princeps* externally, but has an arachnoid columella instead of no columella. *L. illipahensis* also resembles *Lithostrotionella mokomokensis* externally, but has a more complicated columella and lacks the broad lonsdaleoid dissepimentarium of the latter species.

Occurrence.—USC localities 336 (type locality), 332, 337–339, 359.

Material.—Holotype, USC 5122. Paratype, USC 5123. Other specimens, USC 5124–5126, 5147. Collection contains 6 specimens.

Remarks.—*Lonsdaleia illipahensis* varies somewhat in strength and number of major septa. A specimen from the lower part of the Arcturus formation has about 14 or 15 major septa and they mostly do not reach the axial complex. On the other hand, a specimen from the cyclical beds above the Arcturus formation has about 17 septa in each corallite, and the septa mostly reach the axial complex.

LONSDALEIA CORDILLERENSIS n. sp.
Text-figs. 17,18

Exteriors.—Coralla are composed of loosely fasciculate corallites about 10 to 12 mm. in diameter. Diameters of coralla range from about 10 cm. up to great masses which approach a meter in diameter. Calices are deep, lined with prominent septal ends, and are occupied by a very prominent axial boss on which traces of tabellae are preserved.

Transverse sections.—Mature calices of the holotype at a diameter of 9 mm. contain from 22 to 28 thin major septa, a few of which reach the axial structure. Most major septa reach the theca. Minor septa are inconspicuous and short; moreover, they may not be present in all quadrants. Dissepimentaria occupy as much as $\frac{1}{3}$ of the radius and consist of about 5 ranks of dissepiments when best developed. Dissepiments are mostly herringbone. Although a few lonsdaleoid dissepiments may be present at some positions in some calices, they are not consistently present.

The axial structure is a well-developed arachnoid columella which occupies almost the entire tabularium in its most highly developed condition. On the other hand, corallites of mature dimensions may bear only feebly developed columellae. Tabellae and lamellae are somewhat sinuous and irregularly disposed, thus rendering the

axial structure both complex and variable. Moreover, calices as much as 7 mm. in diameter and containing 20 major septa may lack all traces of a columella. The theca is thin and lacks distinct septal grooves.

Longitudinal section.—The theca is wrinkled conspicuously. Dissepiments are closely packed and of various shapes, but are mostly hemispherical. From 25 to 30 tabulae occur in 1 cm. and mostly slope away from the axial complex at 15° to 30°. The axial complex consists largely of tightly-packed, sinuous tabellae which slope away from the center at angles up to about 70°. The median plate is sinuous and thin, as are the traces of lamellae.

Comparison.—Lonsdaleia cordillerensis resembles species of *Waagenophyllum* such as *W. columbicum* Smith, 1935 in cylindrical shape of corallites and presence of an arachnoid columella, but *L. cordillerensis* has transverse tabulae instead of some transverse tabulae and some clinotabulae.

L. cordillerensis also resembles species of *Waagenophyllum* described from the Permian of Oregon by Merriam (1942) in similar growth habit, but has lonsdaleoid dissepiments and lacks clinotabulae.

Diphyphyllum connorsensis also has cylindrical corallites, but it generally is devoid of any axial structure.

Occurrence.—USC localities 342 (type locality), 332, 343, 344, 356, 358, 360.

Material.—Holotype, USC 5127. Other specimens, USC 5128, 5129, 5144, 5146, 5150, 5151. Collection contains 7 specimens.

Remarks.—This species is referable to *Lonsdaleia* with doubt in some instances because corallites seem to lack the characteristic lonsdaleoid dissepiments. On the other hand, clinotabulae are not present so it can scarcely be referred to *Waagenophyllum.*

In its typical occurrence the corallites are only about 8 mm. in diameter, but in the cyclical sediments overlying the Arcturus formation the corallites attain diameters of perhaps 15 mm. Perhaps it will be advisable to differentiate these varieties in future studies.

LOCALITY REGISTER

USC 330. Buff, fine-grained, silty, thick-bedded limestone in the lower part of the Arcturus formation. Outcrops extend north-south along the synclinal crest of Mokomoke Ridge in the southwest part of the Illipah quadrangle, Nevada, along a line about 500 feet west of the centers of sec. 4, T. 16 N., R. 58 E., and sec. 33, T. 17 N., R. 58 E. The ridge crest can be reached by a rough vehicle trail which ascends the south end of Mokomoke Ridge northward from a point on the gravel road about 1 mile east of Hamilton.

USC 331. Grey, massive limestone of the Bird Spring formation along the crest of the ridge which strikes N. 55° E. and lies 6 miles S. 80° W. from the intersection of Lee Canyon (Nevada Highway 52) and the Indian Springs road (U. S. Highway 95) about 27 miles northwest of Las Vegas, Clark County, Nevada. The locality can be reached by driving 2.5 miles cross-country up the alluvial fan southwest from U. S. Highway 95. The locality lies 2300 feet stratigraphically above the contact of the Bird Spring formation upon the Monte Cristo formation (Mississippian). This zone is at the base of the Permian System (Wolfcamp) in the section referred to by Longwell and Dunbar (1936).

USC 332. Base of 125 foot dark grey limestone comprising the lower part of the Arcturus formation. Outcrops form prominent, partly overhanging bluff and road cut on the north side of former U. S. Highway 93, about 1.2 miles east of the summit of Connors Pass and about 23 miles southeast of Ely, Nevada. Probably near SE cor., sec. 26, T. 14 N., R. 65 E.

USC 333. Light grey, sandy, buff-weathering limestone in the lower part of the Arcturus formation. Outcrops are located on the west side of U. S. Highway 6, about 3 miles SW of Ely, Nevada. Sec. 25, T. 16 N., R. 62 E., Ely quadrangle.

USC 334. Buff limestone at the base of the Rib Hill formation, forming bluff about 200 yards north of U. S. Highway 50 at a point 1 mile east of the Hamilton road. Near cen., sec. 7, T. 17 N., R. 59 E., Illipah quadrangle.

USC 335. Grey limestone 140 feet thick, lying 40 feet stratigraphically below sandstone beds of the Rib Hill formation, due west of 2 large water tanks at the SE end of the north ridge of Rib Hill, 1 mile SW of

Ruth, Nevada. Near SE cor., sec. 16, T. 16 N., R. 62 E., Ely quadrangle.

USC 336. Bluff of brown limestone overlying white limestone on north side of dry valley where unimproved road crosses creek bed, 1.1 miles west of Ruby Valley Truck Trail (Ruby Marsh Road) and 6 miles north of U. S. Highway 50. SE, SW, SW, sec. 8, T. 18 N., R. 59 E., Illipah quadrangle.

USC 337. Grey limestone cropping out 2200 feet along forest road running northwest of Murry Summit about 6 miles southwest of Ely, Nevada. Cen., S½, sec. 27, T. 16 N., R. 62 E., Ely quadrangle.

USC 338. Buff limestone 300 feet stratigraphically above the base of measured section 2 published by Knight (1956, p. 776). About 600 feet above U. S. Highway 50, on north side of road, about 0.3 mile west of Moorman Ranch. Cen., E½, NW, sec. 9, T. 17 N., R. 59 E., Illipah quadrangle.

USC 339. Grey limestone 13 feet thick cropping out in road cut on the north side of U. S. Highway 6, 200 yards west of Murry Summit, about 6 miles southwest of Ely, Nevada. NE, NE, NE, sec. 34, T. 16 N., R. 62 E., Ely quadrangle.

USC 340. Upper 10 feet of 125 foot bluff of limestone at locality 332.

USC 341. Prominent outcrop of biostromal limestone alongside the rough road through Indian Pass, Confusion Range, Utah. Outcrops are probably in the Arcturus formation. Locality is 1400 feet NW of benchmark 5970.

USC 342. Bluff of coralline limestone on the low spur extending southwest from the prominent hogback on the south side of Rib Hill, about 2 miles south of Ruth, Nevada. Basal limestone of the Arcturus formation. Cen., SW, sec. 22, T. 16 N., R. 22 E., Ely quadrangle. Can be reached on faint vehicle trails leading southwest from the main road into the center valley of Rib Hill.

USC 343. Grey, cherty, bluff-forming limestone 7 feet thick, a short distance up hill from locality 335 but 70 feet stratigraphically below that locality. Basal limestones of probable Wolfcamp age beneath the main sandstone body of the Rib Hill formation.

USC 344. Low bluff of limestone overlying light grey dolomite. On the east face of the Providence Mountains at the juncture of two prominent spurs due west of the Gilroy Mine, San Bernardino County, California. Locality is about ½ mile north of Mitchell's Caverns.

USC 345. Same limestone described in locality 332, but comprising a faulted extension to the north but offset about 500 feet westward and cropping out on the north side of old U. S. Highway 93.

USC 346. Prominent bluff of limestone along the southwest face of the hills north of the deep canyon draining westward in the NE, SE, sec. 12, T. 18 N., R. 57 E., Illipah quadrangle. Can be reached from roads in the Pancake Summit quadrangle. Basal limestone of the Arcturus formation.

USC 347. From steep slope of limestone about 20 feet above the rim of the prominent bluff described in USC 346.

USC 348. Rounded slopes developed on the basal limestone of the Arcturus formation in the cen., E½, NE, sec. 3, T. 19 N., R. 57 E., Buck Mountain quadrangle.

USC 349. Prominent bluff of limestone in the lower part of the Arcturus formation cut by Circle Wash about 100 feet south of the road and down the slope from benchmark 7633. Near NW, sec. 33, T. 15 N., R. 59 E., Treasure Hill quadrangle.

USC 350. Limestone bluff in the lower part of the Arcturus formation where Circle Wash cuts southeastward through the hills about 200 yards south of Circle Wash reservoir. Probably cen., W½, sec. 26, T. 15 N., R. 59 E., Treasure Hill quadrangle.

USC 351. Steeply west-dipping limestones about 100 yards east of Circle Wash Road in a V-shaped gully with dry falls of bold outcrops. Probably sec. 22, T. 15 N., R. 59 E., Treasure Hill quadrangle. Basal limestones of the Rib Hill formation.

USC 352. Low ridge of Arcturus limestone about ½ mile west of USC 349 and on the west side of the road south from benchmark 7633. W line, sec. 33, T. 15 N., R. 59 E., Treasure Hill quadrangle.

USC 355. Basal limestone of the Arcturus

formation on a prominent shoulder on the inverted mountain at a point 2100 feet south and 2850 feet east of NW corner of Illipah #1 (SE) advance sheet.

USC 356. From third distinctly resistant limestone about 275 feet stratigraphically above the base of the Arcturus formation on the west face of the inverted mountain. 2800 feet south and 2450 feet east of NW corner of Illipah #1 (SE) advance sheet.

USC 357. Limestone at the base of the Rib Hill formation on a prominent shoulder on the west side of the inverted mountain. 1200 feet due east of hill 8028 on Illipah #1 (SE) advance sheet.

USC 358. From lower massive limestone of cyclical beds overlying the Arcturus formation on the first knoll at the south end of the SW-trending low ridge at a point 7450 feet west and 3800 feet north of the SE corner of Illipah #1 (SW) advance sheet. Easily reached by old road SE from Moorman Ranch across Jake's Valley, then south along base of hills and up the slope on an old sheep camp trail.

USC 359. From massive, grey, coralline limestone at the base of the Arcturus formation on a ridge crest about 100 feet south of a small but very prominent outcrop on a knoll 5700 feet west and 9650 feet north of the SE corner of Illipah #1 (SW) advance sheet.

USC 360. Bluff of limestone (strike 078, dip 25 SE) lying about 50 feet down the north face of the knoll half a mile south of U. S. Highway 93, in NW, NW, sec. 36, T. 14 N., R. 65 E., Ely quadrangle. This is the lower limestone of the Arcturus formation and is the continuation a long strike southward from USC 332.

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