Silurian Rugose Corals of the Klamath Mountains Region, California

GEOLOGICAL SURVEY PROFESSIONAL PAPER 738

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By CHARLES W. MERRIAM

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A descriptive, taxonomic, and stratigraphic study of Klamath Mountains Silurian Rugosa

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 72-600033

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1 (paper cover)
Stock Number 2401–2077

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SILURIAN RUGOSE CORALS OF THE KLAMATH MOUNTAINS REGION, CALIFORNIA

By Charles W. Merriam

ABSTRACT

The graywacke-argillite sequence of the northeastern Klamath subregion, Siskiyou County, Calif., includes limestone and limestone conglomerate containing distinctive Silurian rugose corals associated with *Atrypella*, *Conchidium*, and *Encrinurus*.

Part of this sequence has been designated the Gazelle Formation; the type section is on Willow Creek near Gazelle, where it comprises lithologic units 1 through 3 in ascending order. Most of the corals come from unit 2, an argillaceous limestone conglomerate underlying the massive limestone of unit 3. To the west in the Scott River drainage, different coral-brachiopod-molluscan faunas occur in lenticular limestones of the graywacke belt; *Halysites*, absent from the type area of the Gazelle, occurs in the more westerly Silurian facies.

The graywacke-argillite sequence with its localized coralline limestone lenses was deposited in the Pacific Border graywacke belt, which includes the Silurian strata of southeastern Alaska. In Alaska this succession includes volcanic rocks, some of which are pillow lavas. No diagenetic dolomite is known in the Pacific Border Silurian, in sharp contrast to the Great Basin shelf sea strata of this system.

Of 13 rugose coral families identified in the Great Basin Silurian, 10 occur also in the northeastern Klamath faunas. *Wintunastraea*, *Shastaphyllum*, and *Klamathastraea* are new genera of colonial Rugosa, thus far known only in the Gazelle Formation. Most of the Klamath Mountains genera and species of Rugosa differ from those of the Great Basin.

The Klamath Mountains beds share the following rugose coral families: Streptelasmatidae, Kodonophyllidae, Tryplasmatidae, Lykophyllidae, Stauriidae, Kyphophyllidae, and Endophyllidae with the Swedish Gotland beds (Silurian standard) of western Europe. A majority of the families and genera that are present in both the Gotland and Klamath deposits seem to peak earlier in the Silurian at Gotland than in the Silurian at Klamath.

On the basis of correlation with the *Atrypella-Conchidium* beds of southeastern Alaska and of comparison with coral assemblages of the Great Basin, Gotland, Czechoslovakia, and Australia, the Gazelle coralline beds of unit 2 are considered to be of Late Silurian (Ludlovian) age. Older and probably younger coral-bearing strata occur in the Scott River drainage. No coral or brachiopod faunas of Devonian (Kennett Formation) age were recognized in the northeastern Klamath subregion.

The Rugosa of the northeastern Klamath subregion are described, classified, and illustrated.

INTRODUCTION

Coral-bearing limestones of Silurian age form a geomorphically conspicuous but otherwise minor part of structurally and stratigraphically complex rock sequences in the northeastern part of the Klamath Mountains region. Pre-Silurian strata, doubtless present here, remain to be identified paleontologically with assurance. Devonian beds have not been conclusively dated; all rocks in this vicinity previously assigned to the Devonian System on tenuous fossil evidence are now believed to be older. The Devonian is much better known in the southeastern part of the Klamath Mountains region (fig. 1).

In the northwestern states generally, Paleozoic history is obscured by deformation, metamorphism, and cover of younger rocks, especially volcanic rocks. To this the northeastern Klamath subregion is no exception, situated as it is adjacent to the Cascade belt. Here, as on the east side of the Cascades scattered fossiliferous exposures suggest that earlier in geologic history the Paleozoic systems were possibly continuous and fairly complete beneath terrane now occupied by the volcanic chain. Although igneous intrusion and metamorphism are widespread in the Klamath Mountains province, fairly large areas in the eastern half escaped the total ravages of alteration and yield well-preserved fossils.

The rugose corals of these little-known Silurian beds were selected for detailed study because of their taxonomic diversity and good state of preservation, and because they fitted into a long-term research program on western North American middle Paleozoic Rugosa as guides to age determination, correlation, and historical geology. In this connection, associated fossils, particularly tabulate corals and brachiopods, have also been evaluated, in order that the stratigraphic and age conclusions not be based solely on the study of a single fossil group.

OBJECTIVES AND SCOPE

Primary objectives of this investigation are the description, classification, and illustration of Silurian rugose corals from the Gazelle Formation. Dealt with also are Rugosa of strata not included in the Gazelle as that division is restricted in this region; part of these rocks are Early Silurian in age and part may bridge the gap between Upper Silurian and Devonian.

In connection with the descriptive paleontology, the areal distribution and stratigraphy of the fossil-bearing rocks were discussed with the ultimate objective of establishing an integrated Paleozoic sequence and a true stratigraphic order of the several faunas. At present too little is known of the geology and paleontology of this region to make this objective possible; more detailed geologic mapping in conjunction with stratigraphic paleontology is required.

Understanding of the rugose corals and associated fossils of the Gazelle Formation and other units of this region is at present inadequate for more than provisional age determination and geologic correlation with other areas; more positive conclusions await detailed study of associated fossil groups, among which are brachiopods, trilobites, and calcareous algae.

Study of the Klamath Rugosa has been carried out concurrently with research upon Silurian rugose corals of the Great Basin and the Alexander Archipelago of southeastern Alaska. The Silurian rocks of the Klamath Mountains are quite similar to those of southeastern Alaska; both regions lie within the Pacific Border province in which graywacke and volcanic rocks are conspicuous. In the summers of 1961 and 1963 Alaska field parties of the U.S. Geological Survey were visited briefly for the purpose of comparing Silurian marine sections with those of the Klamath Mountains and of enlarging collections of comparative fossil material.

HISTORY OF INVESTIGATION

During the summer of 1884, J. S. Diller of the U.S Geological Survey was engaged in a pioneering geologic study of Mount Shasta and adjacent mountain ranges in Siskiyou County (Diller, 1886). At a base camp on the lower slope of this great volcanic peak, his explorer's curiosity was aroused by early morning sunlight illuminating light-colored crags to the northwest across Shasta Valley. Local residents informed Diller of the fossiliferous nature of the craggy limestones so clearly visible in the foothills of the Scott Mountains. Arrangement was made for a geologic reconnaissance later that year. Diller's brief examination of the limestone area on Willow Creek 3 miles southwest of Gazelle (Edson's Ranch) resulted in a neatly executed geologic structure section and sketch map recorded in his 1884 field notes; his section and map delineate quite accurately the essential stratigraphic relations as they are presently understood. Some of the Silurian rugose corals collected by Diller at that time are described herein.

A preliminary report by Diller in 1886 on the geology of northern California directed attention to newly discovered Paleozoic rocks, including those now known as the Gazelle Formation. These strata were at that time assigned to the Carboniferous, together with upper Paleozoic rocks of the Redding area previously dated correctly by Meek (1864) in a report of the first California State Geological Survey. Initial error in age determination of the Gazelle probably resulted from the exterior resemblance of *Klamathastraea* to a lonsdaleioid coral, the problems of homoeomorphy among Rugosa not then being understood.

In 1893 the Diller party collected additional Gazelle fossils at Willow Creek, and a study of all Klamath Mountains Paleozoic fossils was undertaken by Charles Schuchert. In 1894 the results of this paleontologic investigation were published by Diller and Schuchert as a contribution announcing discovery of Devonian strata in northern California. Schuchert recognized the previous error of Carboniferous age assignment and reassigned the Gazelle to the Devonian System, together with the formation in the Redding area now called the Kennett Formation. Surficial resemblances of certain Gazelle brachiopods to Late Devonian species of the Great Basin and continental interior explain the Devonian assignment.

Diller's (1903) northern California field studies were extended in subsequent years to the south-central and western Klamath Mountains. Fossiliferous exposures, in mostly carbonate rocks, were discovered in association with metamorphic rocks at numerous localities. Although the fossils are for the most part rather scrappy and inadequate for positive identification, these collections from partly altered rocks made possible qualified determinations of age ranging from Devonian to latest Paleozoic.

Diller's most noteworthy achievement was the Redding Folio of 1906, an outstanding contribution describing the geology of a key area in the far west and elucidating its Paleozoic stratigraphy and historical geology. In this work the broader outlines of geologic structure and stratigraphy were convincingly set forth. Although no beds older than the Devonian Kennett Formation were dated by fossils, the pre-Kennett volcanic rocks were correctly identified, and there have been no subsequent major changes in the stratigraphic column of the southeastern Klamath subregion.

In 1930 Stauffer reviewed Schuchert's paleontologic conclusions when he compared the Devonian faunas and stratigraphy of northern California with those of the Inyo Mountains; his findings supported those of previous investigators—that the Gazelle and the Kennett are of Devonian age, together with limestones of the northern Inyo Mountains now considered mainly Silurian and designated the Vaughn Gulch Limestone.

The writer's association with problems of northern California middle Paleozoic dates from 1932. In that year his attention was called to the Gazelle fossil occurrences by the late F. M. Anderson, who had observed the abundantly fossiliferous nature of these rocks while examining properties for the Southern Pacific Railroad. From 1932 to 1935 several collecting trips to the Gazelle Formation in the Chastain Ranch area were made by the writer in the company of R. A. Bramkamp, F. E. Turner, and other graduate students at the University of California in Berkeley. The fossil material then obtained was found to include several species in the Diller collections. With the cooperation and guidance of G. A. Cooper of the Smithsonian Institution the Chastain Ranch material was identified as Silurian (Merriam, 1940, p. 47–48).

About 1946, economic interest in Siskiyou County limestone resources led to geologic mapping by Heyl and Walker (1949) of an area which included the type section of the Gazelle Formation. Like most Silurian limestones of the Pacific Border province, those of the Gazelle are fairly pure and nondolomitic. They have have been quarried for commercial purposes.

During the years from 1946 to 1960, student interest in rocks and fossils of the northeastern Klamath subregion led to recognition of the westerly continuation of the Silurian beds from Shasta Valley near Gazelle to Scott Valley. Among those whose fossil collections and geologic conclusions have come to the attention of the writer are B. J. Westman (1947), J. R. McIntyre (unpub. data), and Michael Churkin, Jr. (1961, 1965). Important fossil discoveries in these rocks at Scott Valley were made by Rodney Gregg of Gregg Ranch.

Following World War II, detailed geologic mapping of the copper districts north of Redding called for a review of the fossil evidence and stratigraphy of the Paleozoic rocks in the southeastern Klamath subregion (Kinkel and others, 1956). These investigations disclosed no strata carrying Silurian fossils beneath Devonian limestones of the Kennett Formation. Concurrent studies in the northeastern Klamath subregion failed to reveal the presence of Devonian strata with Kennett faunas in the Gazelle area.

During the 1950's reconnaissance geologic mapping was conducted by F. G. Wells within the northeastern Klamath subregion under the chromite program of the U.S. Geological Survey. In September of 1951 several days were devoted to field study of fossil-bearing exposures by the writer in the company of F. G. Wells, J. R. McIntyre, and W. C. Smith.

A geologic reconnaissance of little-known parts of the Klamath Mountains by W. P. Irwin and D. B. Tatlock led to the discovery of other Paleozoic rock exposures (Irwin, 1960); this discovery provided further incentive to restudy the Klamath Mountains Paleozoic geology. Of special interest was the finding of a Silurian fauna with *Rhizophyllum* (Helen Duncan and W. A. Oliver, Jr., written commun., 1961; Oliver, 1964, p. 150) in the Weaverville area of the central metamorphic belt (Irwin, 1963).

Discovery of *Monograptus* by Churkin (1965) in the Gazelle Formation on Willow Creek supported a Silurian age for these deposits. Fossil collecting by Maitland Stanley at Willow Creek in the summer of 1967 led to the finding of new rugose corals, including the new genus *Wintunastraea.*

METHODS OF STUDY

Stratigraphic paleontology of the complex Paleozoic rocks in the northeastern Klamath Mountains calls for detailed geologic mapping as a basis for section discrimination and ultimate fossil zoning. Mapping thus far in this vicinity is of a most general nature except for small areas; one of these is the type area of the Gazelle Formation (fig. 3A) on Willow Creek, which was mapped by Heyl and Walker (1949). Some of the fossils are loose float material which was collected from the slopes of Chastain Ridge and Bonnet Rock; other fossils are traceable to weathered exposures of Gazelle unit 2. Other float of this kind undoubtedly comes from small, poorly exposed lower limestone lenses and cobbles of undetermined horizon in the thick Gazelle unit 1 graywacke. Here and at Parker Rock detailed geologic study will eventually provide a better stratigraphic sequence. Only broad generalizations of the stratigraphy, structure, and depositional history of these interesting marine deposits are now possible. Field observations, fossil collecting, and sediment sampling in connection with this study are inadequate for sedimentation analysis or biofacies appraisal.

Concurrent research upon southeastern Alaskan and Great Basin Silurian faunas by the writer has provided the advantage of direct comparison of corals, brachiopods, and other fossils with those of the Klamath Mountains region. Comparison of the Rugosa of the Klamath Mountains with related corals in the important Gotland and Czechoslovakian reference columns has not been satisfactory because of lack of comparative fossil material. Furthermore, most rugose corals of both European regions are in need of complete restudy using modern thin section techniques.

Preservation of Gazelle rugose corals ranges from excellent to poor, although little fossil silicification has taken place in these nondolomitic rocks. Difficulty was experienced in obtaining good photographs of the delicate internal structures, as for example with *Cyathactis gazellensis* and *Petrozium staufferi*. Staining the smoothed surfaces by the alizarine technique aided in differentiating the coral structure from the cloudy matrix, but the stain applied to thin sections did not improve photographic results.

ACKNOWLEDGMENTS

The writer is indebted to the University of California (Berkeley), Department of Paleontology, for use of fossil collections made in the years 1945 to 1949 by J. R. McIntyre at Parker Rock, Grouse Creek, and Gregg Ranch. Use of excellent Gazelle corals collected by Maitland Stanley on Willow Creek in 1967 is greatly appreciated. Thanks are due also to Rodney Gregg of Gregg Ranch for guidance to the collecting sites in that vicinity.

Comparison of the Silurian strata from the Klamath Mountains and Alaska was greatly facilitated by visits to the better sections on Heceta, Tuxekan and Kuiu Islands under the guidance of G. D. Eberlein and L. J. P. Muffler of the U.S. Geological Survey during the summers of 1961 and 1963.

P. E. Hotz, W. P. Irwin, and G. W. Walker of the U.S. Geological Survey read the sections of this paper which deal with stratigraphic geology and made numerous constructive suggestions. The paleontologic section was critically reviewed by W. A. Oliver, Jr., of the U.S. Geological Survey, whose suggestions regarding matters of rugose coral taxonomy and description have been most helpful.

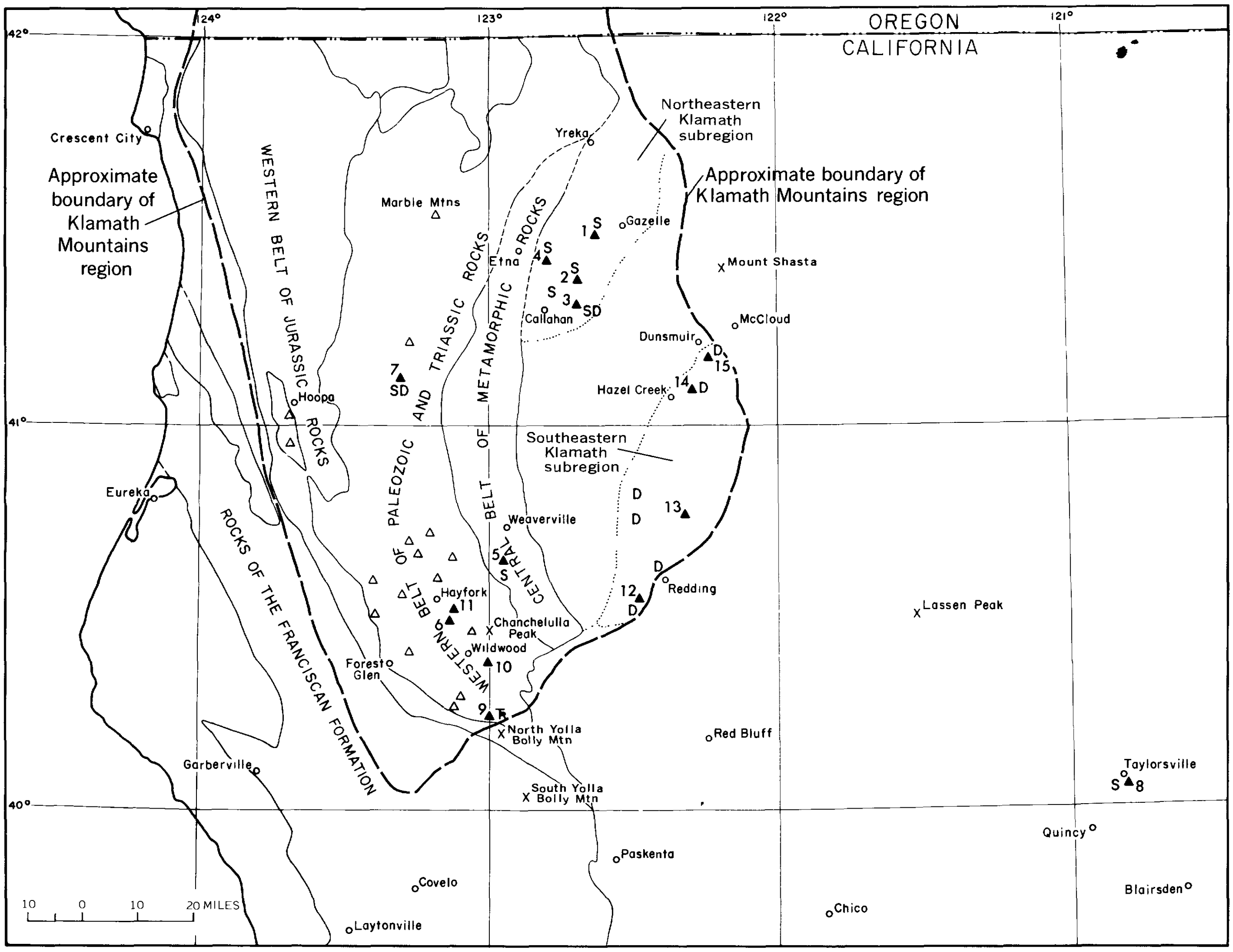
All fossil photographs are the work of Kenji Sakamoto, of the U.S. Geological Survey.

DISTRIBUTION OF PALEOZOIC ROCKS IN THE KLAMATH MOUNTAINS REGION

Paleozoic and pre-Cretaceous Mesozoic strata of the Klamath Mountains region are distributed in north-trending belts of differing rock character, age range, and metamorphism. As delineated by Irwin (1960, fig. 3), an arcuate central belt of prevailingly metamorphic rocks extends north through Weaverville to Yreka, in a sense dividing the Klamath region into western and eastern parts. Paleozoic rocks treated in this report lie east of the central belt of metamorphic rocks, in what is termed the "eastern Paleozoic belt" of Irwin. The Paleozoic rocks of this eastern belt may be further subdivided areally, on the basis of petrologic character, stratigraphy, and paleontology, into the northeastern Klamath subregion and the southeastern Klamath subregion (fig. 1).

Paleozoic rocks of the northeastern Klamath subregion abut on the west against the central belt of metamorphic rocks; those of the southeastern Klamath subregion are separated from the same metamorphic belt by a wide band comprising ultramafic rocks and granitic plutons, blanketed in part by Cenozoic volcanic rocks of the Mount Shasta vicinity and areas to the south. Little is known of Paleozoic bedrock within this intermediate band. The southeastern Klamath subregion, including the Redding and Shasta copper districts, is the more completely mapped and studied geologically; in this subregion, Paleozoic strata ranging in age from Middle Devonian to Permian are dated paleontologically with confidence. Except for the Douglas City area, Silurian rocks have been identified with assurance only in the northeastern Klamath subregion with which this report is primarily concerned.

In rugged, forested areas of the central metamorphic belt and to the west are many scattered, little-known exposures of fossil-bearing limestone, marble, and argillite, some Paleozoic, others of Mesozoic or probable Mesozoic age. Many of these rocks are crinoidal; others contain tabulate corals, stromatoporoids, *Chaetetes*-like remains, and calcareous algae of uncertain affinity. Carbonate rocks with fossils occur along the Trinity River South Fork, in the southernmost Salmon Mountains, and sporadically in a very large area between Chanchelulla Peak and the South Fork Mountains. Several of these southern and southwestern Klamath exposures yield fusulinids and other late Paleozoic fossils; some, like the Whiterock occurrence northwest of North Yolla Bolly Mountain, once believed to be entirely Devonian, are actually of Triassic age in part (N. J. Silberling, written commun., 1958). Conclusively dated strata of Silurian and Devonian ages are, with one exception in the Douglas City area near Weaverville, all situated east of the central metamorphic belt.



EXPLANATION

▲
Fossil-bearing rocks, mainly Paleozoic

△
Limestones and marbles of uncertain age, probably Paleozoic or Mesozoic

Ꝛ
Rocks of Triassic age

D
Rocks of Devonian age

SD
Rocks of Silurian or Devonian age

S
Rocks of Silurian age

FOSSIL LOCALITIES

1 Gazelle Formation, Willow Creek area
2 Gazelle Formation, Parker Rock area
3 Silurian or Devonian, Grouse Creek area
4 Early Silurian, Horseshoe Gulch area
5 Silurian, Douglas City area
6 Limestone cobble with ? *Shastaphyllum*
7 Silurian or Devonian on Knownothing Creek
8 Montgomery Limestone of Silurian age
9 Whiterock fossil area
10 Rocks of probable Permian age
11 Rocks of probable Permian age
12-15 Kennett Formation, Middle Devonian

FIGURE 1.—The Klamath Mountains region, California, showing rock belts and locations of fossiliferous exposures. Adapted from Irwin (1960, fig. 3).

PALEOZOIC STRATA OF THE NORTHEASTERN KLAMATH SUBREGION

The northeastern Klamath subregion (figs. 1, 2) occupies some 800 square miles between Shasta Valley on the east and Scott Valley on the west, extending from the Callahan vicinity north to Yreka. The only Paleozoic strata of firmly established age in this subregion are Silurian (Merriam, 1961); however, Upper Ordovician rocks are reported, and structurally isolated exposures of uncertain stratigraphic position contain faunas of probable Early Devonian age. There is little stratigraphic continuity here because of the complex geologic structure, patchy metamorphism, and intrusion by peridotite and granitoid bodies. Few sections lend themselves to bed-by-bed measurement and systematic fossil collecting for more than a few hundreds of feet.

The more conspicuous outcrops of this subregion are massive light-gray craggy limestones forming geomorphic features like Parker Rock, Mallethead Rock, and Bonnet Rock. Bold isolated limestone masses of this kind give an initial impression of having been formed as marine reefs, which were later entombed by clastic sediments. Although in considerable part of organic origin, these carbonate bodies lack true reef structure. Most of the Silurian corals and other fossils here dealt with come not from these prominent craggy limestone masses, but from partly argillaceous beds which underlie them.

Much more extensive areally than the craggy limestones are clastic siliceous sedimentary rocks, chert, phyllite or schist, and the plutonic rocks. Most abundant among the clastic rocks are graywacke, argillite, and conglomerate.

In this subregion, phyllite and schist, to which the name Duzel Formation has been applied (Wells and others, 1959), are of unknown age. There seems to be no convincing stratigraphic evidence to indicate that they are older than the Silurian rocks. In the Horseshoe Gulch area, these metamorphic rocks include thin unfossiliferous limestone beds. On Willow Creek they are believed to be faulted against the Gazelle Formation and are possibly the upper plate of a thrust in that area (Churkin and Langenheim, 1960, fig. 1).

Systematic fossil collecting has been done in five different areas of the northeastern Klamath subregion (fig. 2). Between most of these areas there is little similarity in faunas and details of stratigraphy, and they are (as presently understood) not paleontologically correlative. To what extent this lack of agreement is a matter of facies change and how much is due to difference of stratigraphic position remains unestablished. At present these faunas have not been arranged in sequential order with confidence. Faunas and stratigraphy of the five separate areas are dealt with separately in the hope that an integrated column may eventually be set up. The five areas are as follows: (1) Willow Creek area (type area of the Silurian Gazelle Formation), (2) Parker Rock area, (3) Horseshoe Gulch area, (4) Grouse Creek area, and (5) Gregg Ranch area. Fossil localities in each area are described in a locality register at the end of this paper.

With some assurance it may be said that the oldest Paleozoic strata of this subregion are in the west at Horseshoe Gulch. Ordovician fossils have been reported in that vicinity, possibly below the Early Silurian fauna here dealt with. The highest beds of the Gazelle Formation at the east edge of the subregion are Late Silurian. In the south at Gregg Ranch and Grouse Creek, the youngest strata recognized thus far are those of possible Early Devonian age.

Detailed geologic mapping, in conjunction with stratigraphic paleontology and studies of metamorphism, still has to be done in this structurally complex terrane before a composite stratigraphic column can be proposed.

GAZELLE FORMATION OF SILURIAN AGE, WILLOW CREEK AREA

The Willow Creek drainage southwest of Gazelle includes the sections at Bonnet Rock, Chastain Ridge, and Mallethead Ridge within the type area of the Gazelle Formation. The geology of this vicinity was first described by Diller in unpublished notes of 1884. In later years the area was partly mapped geologically (fig. 3) by Heyl and Walker (1949) and by Churkin (Churkin and Langenheim, 1960). Two sedimentary rock formations are present—the little-altered Gazelle Formation consisting of limestone, shale and argillite, graywacke, sandstone, conglomerate, and chert, and a schist and phyllite unit of unknown age which is in fault contact with the Gazelle. Locally these metamorphic rocks appear to rest against the Gazelle in a possible thrust fault relationship.

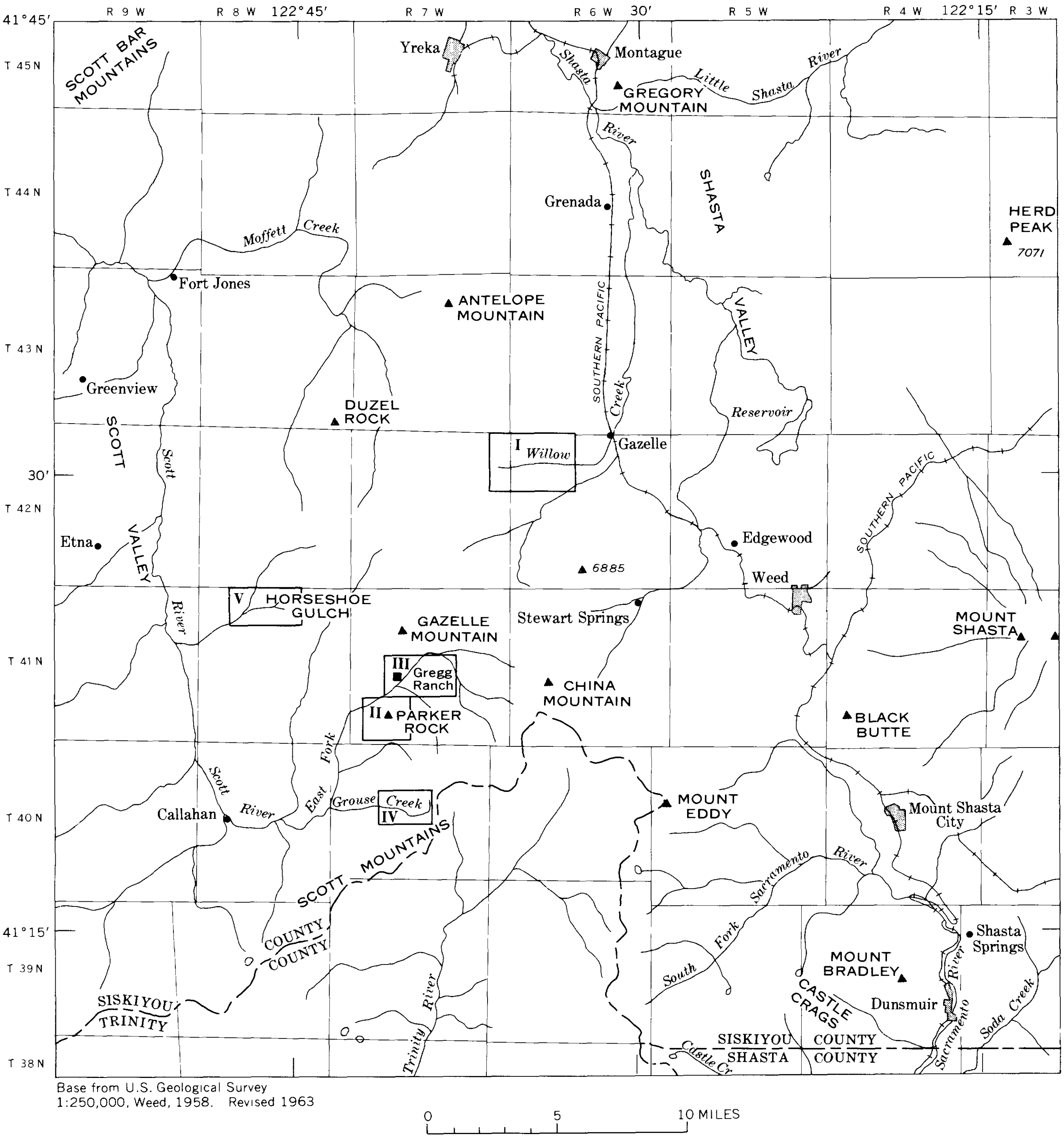
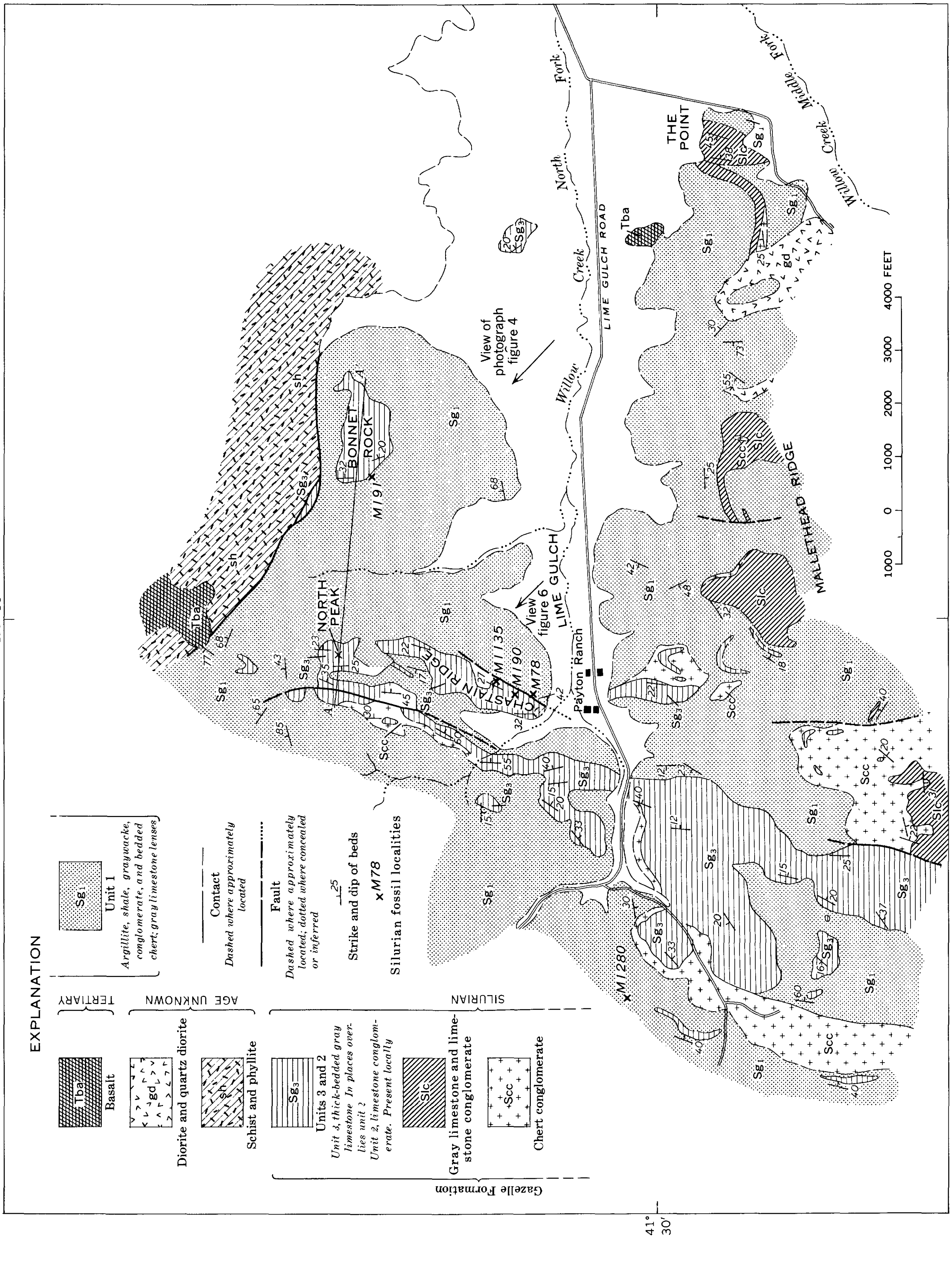
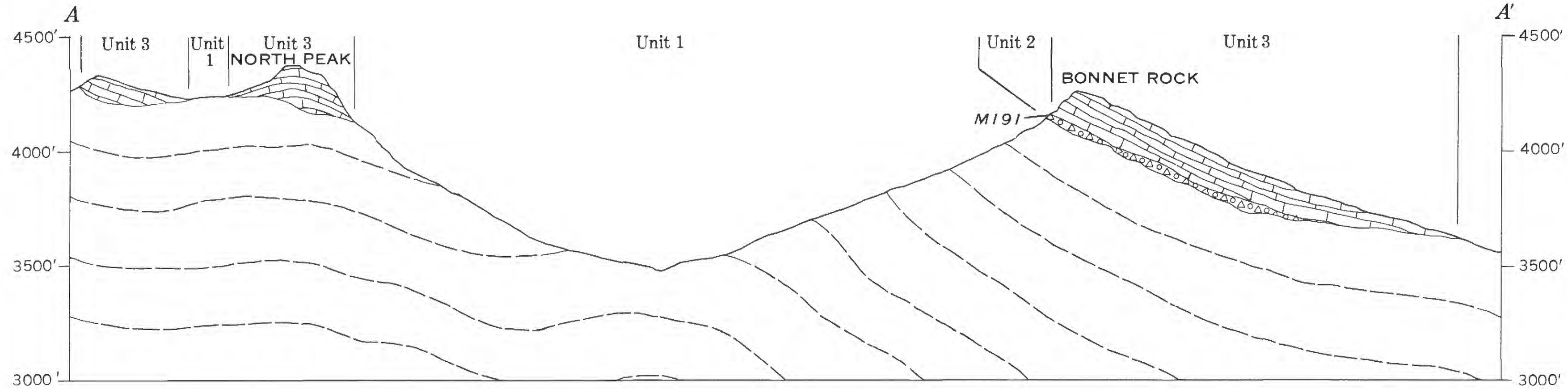


FIGURE 2.—The northeastern Klamath subregion, showing the five separate areas wherein coral-bearing Paleozoic rocks occur: I. Willow Creek area, II. Parker Rock area, III. Gregg Ranch area, IV. Grouse Creek area, V. Horseshoe Gulch area.


EXPLANATION
Tba
Basalt
TERTIARY
gd
Diorite and quartz diorite
sh
Schist and phyllite
AGE UNKNOWN
Sg₃
Units 3 and 2
Unit 3, thick-bedded gray limestone In places overlies unit 2
Unit 2, limestone conglomerate. Present locally
Slc
Gray limestone and limestone conglomerate
Scc
Chert conglomerate
Sg₁
Unit 1
Argillite, shale, graywacke, conglomerate, and bedded chert; gray limestone lenses
Gazelle Formation
SILURIAN
Contact
Dashed where approximately located
Fault
Dashed where approximately located; dotted where concealed or inferred
Strike and dip of beds
Silurian fossil localities
xM78
122° 35′
41° 30′
THE POINT
LIME GULCH ROAD
North Fork Willow Creek
Middle Fork Willow Creek
View of photograph figure 4
View figure 6
LIME GULCH
BONNET ROCK
NORTH PEAK
CHASTAIN RIDGE
MALLETHEAD RIDGE
Payton Ranch
M191
M1135
M190
M78
M1280
1000 0 1000 2000 3000 4000 FEET
A



B

FIGURE 3.—Geologic map and section of the type area of the Gazelle Formation. *A*, Silurian fossil localities and relationships of stratigraphic units in the Lime Gulch area on Willow Creek. Modified from Heyl and Walker (1949, pl. 26). *B*, Section along line *A–A′* between North Peak and Bonnet Rock shows relations of the stratigraphic units.

BONNET ROCK SECTION

The type section of the Gazelle Formation lies on the southwest side of Bonnet Rock, where it comprises three units as follows:

Type section of Gazelle Formation, southwest side Bonnet Rock

Top of section	
Gazelle Formation:	*Feet*
Unit 3. Limestone, fairly uniform fine texture, craggy and cliffy, thick, evenly bedded; weathers medium- to light-gray. Includes contemporaneous limestone breccia-conglomerate lenses; chert pebbles in basal part. Abundantly fossiliferous to bioclastic in pockets	175±
Gradational boundary locally	
Unit 2. Coarse limestone conglomerate and nodular argillaceous limestone with cobbles and subangular clasts of highly fossiliferous medium- to light-gray limestone in a matrix of tan-weathering argillite. Associated argillaceous pockets contain contemporaneous or unreworked fossils	0–25
Possibly disconformable contact	
Unit 1. Predominant shale, dark-gray, weathers tan to maroon, and argillite with graywacke and coarse gritty sandstone. Subordinate beds of siliceous conglomerate and gray chert. Limestone lenses scattered, light-gray, fossiliferous	1,000±
	1,200±
Base unexposed	

Bonnet Rock occupies the east limb of a north-trending asymmetric anticline in which ridge-capping limestone of unit 3 dips east at a low angle (fig. 4). Less competent beds of underlying unit 1 and unit 2 are more deformed and locally show indications of differential movement near the unit 3 boundary. No major shift related to possible thrust displacement of the massive unit 3 was recognized.

Unit 1, having a thickness estimated to be at least 1,000 feet, occupies the axial part of the anticline between Bonnet Rock and Chastain Ridge (fig. 3*B*). Its base is not exposed. This unit is predominantly dark gray and greenish-gray, tan-weathering shale and argillite, which is red or maroon in places. With the argillaceous beds are much graywacke and gritty sandstone; these are probably tuffaceous in considerable part. Subordinate are siliceous conglomerate and dark-gray bedded chert. These highly variable lithologic types are discontinuous laterally. On the west side of Bonnet Rock in the upper 25 feet of unit 1 are lenses of tan and dark-gray argillite, sandstone, and graywacke which change laterally and below to siliceous conglomerate. A 15-foot conglomerate lens in this interval contains rounded to subangular cobbles as much as 10 inches long in a partly laminated argillite matrix; in places this facies is a sort of puddingstone with scattered cobbles. The cobbles include hornfels, chert, porphyritic igneous rocks, graywacke, and limestone. The limestone cobbles are less than 2 percent of the total and have the general appearance of the limestone in unit 3. These cobbles were probably derived from the lower limestone lenses in unit 1 at Mallethead Ridge.

Unit 2, ranging in thickness from a few feet to about 25 feet, is composed of rubbly-weathering nodular limestone and limestone conglomerate with tan to pale-green argillaceous matter as matrix between cobbles or nodules (fig. 5; pl. 4, fig. 13). In small fossil-rich lenses some of the cobbles and nodules are in fact corals and brachiopods which, when they weather free, may be coated by the tan or green argillaceous matter. Scattered lenses of the argillaceous material contain abundant small fossils.

FIGURE 4.—View northwest toward Bonnet Rock and Chastain Ridge, showing bold outcrops of the cap-rock limestone of unit 3 in the type section of the Gazelle Formation. Lower slopes of Bonnet Rock underlain by argillite and graywacke of unit 1. Photograph from Heyl and Walker (1949, fig. 2).

Occurring at the base of the massive limestone of unit 3, these argillaceous-limestone conglomerate beds, being less competent than the beds of units 1 and 3, have been deformed by differential movement and are therefore unsatisfactory for stratigraphic interpretation at their boundaries (fig. 5). However, it is probable that unit 2 has pockety distribution upon an uneven surface of disconformity because here and there the massive limestone of unit 3 rests directly upon unit 1. For example, on the west side of Bonnet Rock a sharp uneven contact with considerable relief locally separates the massive gray limestone of gray unit 3 from the graywacke of unit 1. At other exposures the nodular-conglomeratic limestone of unit 2 appears to grade upward into the normal thick-bedded limestone of unit 3. The lack of lithologic uniformity within unit 2 is further discussed in connection with the exposures at Chastain Ridge.

Several of the better fossil collections from the Gazelle came from unit 2 at Bonnet Rock, where small lenses contain abundant tabulate corals, rugose corals, and brachiopods. Fossils occur in the argillaceous matrix as well as in limestone clasts and nodules.

FIGURE 5. Argillaceous limestone breccia-conglomerate of unit 2, Gazelle Formation. Large boulder in middle foreground is about 15 inches wide, left to right. West side of Bonnet Rock.

Unit 3, the massive crag-forming upper limestone, is estimated to range in thickness from 75 feet to about 150 feet at Bonnet Rock (fig. 4). It is thickly but evenly bedded, of fairly uniform fine texture, and is bluish-gray when fresh and light gray when weathered. Unit 3 includes scattered lenses of limestone conglomerate, chert conglomerate, and gray bedded chert. Corals and brachiopods are numerous in pockets. The limestone of unit 3, which has a very low magnesium content, is fairly pure chemically. (See Heyl and Walker, 1949, p. 519–520 and table 1.)

No rocks younger than unit 3 are known in this area. The relationship of unit 3 to underlying unit 2 is locally gradational, but where unit 2 was not found, it appears to rest disconformably upon unit 1.

CHASTAIN RIDGE SECTION

The thick-bedded limestone of unit 3 is well exposed in Chastain Ridge, which is oriented north-south, and is 0.7 mile southwest of Bonnet Rock. Along the east side of this ridge, no exposures of unit 2 were found, and the contact between unit 3 and unit 1 is mapped as a fault. Fossils which weather out along this fault (fig. 6) appear to have come from unexposed beds of unit 2 or from the upper argillaceous beds of unit 1.

Shales and argillites occur in the upper beds of unit 1 along the lower slopes east of the craggy limestones of unit 3 in this ridge; the shales weather in places from tan to green or maroon. On the southwest side of Chastain Ridge, the lower 30 feet of the massive limestone of unit 3 includes chert pebble lenses. Below unit 3 are chert cobble conglomerates and grayish-green hornfelsic argillite, which are underlain by more chert cobble conglomerate and similar argillite members with graywacke and gritty sandstones. The distinctive fossil-rich rubbly limestone conglomerate of unit 2 at Bonnet Rock was not found here, possibly being absent locally because of a disconformity below unit 3, but faulting is the explanation for some exposures. Heyl and Walker (1949, p. 517) observed siliceous conglomerate grading upward into limestone conglomerate at the base of unit 3, with progressive increase of carbonate cement and limestone clasts.

The largest fossil collections from the Gazelle came from the south end of Chastain Ridge on the east side (loc. M78). Here the fossils weather out of argillaceous beds along the fault contact with the massive limestone of unit 3. Silurian graptolites reported by Churkin (1965) were collected from unit 1 about a mile west-southwest of locality M78.

MALLETHEAD RIDGE SECTION

The prominent craggy limestone of unit 3 has been mapped south from Chastain Ridge into the western part of Mallethead Ridge, which extends eastward from Mallethead Rock to The Point (fig. 3*A*). Disconnected limestone exposures in the eastern part of this ridge have the lithologic appearance of unit 3, but they were not identified as such by fossils. On the south slope of Mallethead Ridge where outcrops are poor, the strata appear to be Gazelle Formation unit 1; the strata consist of argillite, graywacke, gray bedded chert, siliceous conglomerate, and subordinate gray limestone with abundant crinoidal debris and favositid corals. Vertical stratigraphic order could not be determined within this sequence; it is several hundreds of feet thick, and scattered fossiliferous limestone bodies are seemingly distributed throughout its extent. Gray limestone cobbles in the upper part of unit 1 at Bonnet Rock could readily have been derived from the limestone in some of these lower lenses.

Diagnostic Silurian rugose corals of the genus *Mucophyllum* were collected from a limestone lens at the foot of Mallethead Ridge on the south side, 2½ miles southwest of The Point. Near this limestone exposure a significant trilobite assemblage was collected from shales by Churkin (1961).

GAZELLE FORMATION AT PARKER ROCK

Parker Rock, an important collecting locality of Silurian corals, brachiopods, and mollusks, lies on the east fork of Scott River 6 miles northeast of Callahan near the old Parker Ranch site (fig. 2). Like Bonnet Rock on Willow Creek, Parker Rock is capped by low-dipping massive limestone of the Gazelle Formation. This limestone caprock, probably the equivalent of unit 3 in the Willow Creek area, is underlain by weaker rocks which include deformed argillaceous siltstone and rubbly weathering breccia-conglomerate limestone (pl. 4, fig. 13) corresponding to beds of the unit 2 and topmost unit 1 interval at Bonnet Rock. In places at Parker Rock, tongues of the conglomeratic limestone with argillaceous matrix like unit 2 pass upward into the thick-bedded equivalent of unit 3. These tongues suggest possible marginal reef talus features and are discussed elsewhere in this regard. *Halysites* and other corals are common in the lower beds of the massive caprock, but most of the coral and brachiopod material was collected from underlying conglomeratic and argillaceous limestone from which they weather free, as they do in unit 2 at Bonnet Rock.

Collections of well-preserved fossils made by J. R. McIntyre from the Parker Rock vicinity appear to have come mainly from strata below the upper massive limestone and probably represent the interval equivalent to unit 2 and the higher beds of unit 1.

FIGURE 6.—View northwest toward Chastain Ridge, which is underlain by the Gazelle Formation. Limestone caprock of unit 3 is in fault contact with unit 1 on east. Collecting locality M78 in middleground left.

SILURIAN OR EARLY DEVONIAN LIMESTONES OF THE GREGG RANCH AREA

The Gregg Ranch area lies on the east fork of Scott River northeast of Parker Rock between Rail Creek and Houston Creek (fig. 2). Fossil-rich Paleozoic limestone outcrops in this vicinity appear to be lenses scattered in a predominantly argillite-graywacke sequence lithologically similar to unit 1 of the Gazelle Formation in the Willow Creek area. The exposures are, however, poor, and the absence of continuous outcrop precludes the determination of stratigraphic sequence. Fossil evidence reviewed elsewhere suggests that some of the Gregg Ranch limestones are younger than those in Gazelle unit 3; it is possible that the strata here include a higher continuation of that succession, thus ranging upward from Silurian into the Devonian System. In general, the faunas of the Gregg Ranch area differ from those of neighboring Parker Rock. How much of the difference is related to depositional and faunal facies and how much reflects differences of stratigraphic horizon has not been established.

Greenstones with limestone lenses on the east side of the Gregg Ranch area (Wells and others, 1959, p. 648) have previously been considered to be of possible Devonian age.

SILURIAN OR EARLY DEVONIAN STRATA OF THE GROUSE CREEK AREA

The Grouse Creek area lies on Grouse Creek west of Cooper Meadow, 6½ miles east of Callahan (fig. 2). Well-preserved brachiopods, corals, and Mollusca occur here in dark-gray calcareous siltstone and silty limestones in an isolated belt of very poor exposures in forested terrain where the sedimentary rocks were extensively penetrated by peridotite and other basic intrusives.

Lithologically these fossil-rich Paleozoic rocks do not resemble those in other parts of the northeastern Klamath subregion and no stratigraphic sequence has been observed. Corals from the Grouse Creek area have their nearest analogs in the Gregg Ranch area, but in general the Grouse Creek faunas are quite different from other assemblages of this subregion.

EARLY SILURIAN AND ORDOVICIAN(?) DEPOSITS OF THE HORSESHOE GULCH AREA

Paleontologic evidence strongly suggests that older strata of the northeastern Klamath subregion lie to the west in the Horseshoe Gulch area (fig. 2), within the westernmost outcrop belt of the Duzel Formation (Wells and others, 1959, pl. 1). Poorly exposed rocks of Horseshoe Gulch, an east branch of McConnahue Gulch, consists of deformed graywacke, phyllite, limestone, and marble within which no stratigraphic order has been determined. Fossils collected here have previously been dated provisionally as Ordovician(?), Early Silurian, and more doubtfully as Devonian. These fossils have come from isolated, relatively little altered, but fractured, variably iron-rich limestone quite unlike the thick-bedded light-gray limestone of Gazelle unit 3 at Willow Creek. Structural and stratigraphic relationships of these fossil-bearing limestones to the much more extensively exposed Duzel phyllites have not been established. Duzel phyllites of this vicinity include thin unfossiliferous limestone or marble layers.

That Duzel phyllite and associated rocks of Horseshoe Gulch are actually equivalent to the phyllite and schist faulted against the Gazelle Formation on Willow Creek remains to be demonstrated. At Bonnet Rock these metamorphic rocks differ in appearance and are not known to have limestone intercalations like the Duzel phyllite of Horseshoe Gulch. Fossils and age of the Horseshoe Gulch beds are discussed below.

RUGOSE CORALS AND ASSOCIATED FOSSILS OF THE NORTHEASTERN KLAMATH SUBREGION

Rugose corals of the five areas within this subregion (fig. 2) are associated with other fossils, nearly all of which are undescribed. Some were previously referred to Devonian species to which they are unrelated. Because these associated fossils are important in establishing age and correlation, they are listed here, mostly as genera unless otherwise known to resemble previously described species, as for example certain Alaskan brachiopods of Silurian age.

Only in the Willow Creek area is the stratigraphy sufficiently well known to make possible a treatment of the faunas in terms of stratigraphic position. Here, however, most of the material comes from a 50-foot interval bracketing Gazelle unit 2, the topmost beds of unit 1, and the basal beds of unit 3. Fossils from this interval are considered together as the *Atrypella* fauna. The type section for the Gazelle Formation on the southwest side of Bonnet Rock has yielded a good representation of the fauna from this interval, and it was probably here that most of Diller's collections were made. Most of the material collected by the writer and his associates in later years came from localities along the southeast edge of Chastain Ridge, from what is regarded as the same 50-foot interval. Here the fossils weather free along the fault contact of Gazelle unit 3 and unit 1, the unit 2 limestone conglomerate not being exposed (fig. 6). At Parker Rock the Silurian section is similar to that of the Willow Creek area, but detailed

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mapping is needed to elucidate the stratigraphic sequence.

ATRYPELLA FAUNA OF THE WILLOW CREEK AREA

The *Atrypella* fauna is so named because of the abundance of this smooth spiriferoid so characteristic of the higher Silurian of the circumboreal belt from Alaska to Greenland. In the Willow Creek area this fauna characterizes unit 2 of the Gazelle Formation, extending up into basal beds of unit 3 and occurring in the topmost beds of unit 1. Table 1 shows rugose corals and associated fossils collected from this interval at Bonnet Rock and Chastain Ridge.

As noted below, the Silurian beds of Parker Rock include some species of the *Atrypella* fauna, but the coral, molluscan, and trilobite facies differ.

TABLE 1.—*Fauna of the* Atrypella *zone, Gazelle Formation, Willow Creek area*

Species	Bonnet Rock		Chastain Ridge		
	M191	USGS 586 M1132	M190	M78	M1135
Rugose corals:					
? *Orthophyllum* sp					×
Syringaxon sp					×
?*Palaeophyllum* sp. G				×	
Wintunastraea stanleyi n. gen., n. sp					×
Zelophyllum sp. G			×		
Cyathactis gazellensis n. sp	×				
Cystiphyllum sp. c	×			×	
?*Kyphophyllum*				×	
Petrozium staufferi n. sp	×	×			
Shastaphyllum schucherti n. gen., n. sp		×		×	×
Klamathastrea dilleri n. gen., n. sp		×			
Tabulate corals:					
Heliolites	×		×	×	
Plasmopora				×	
Favosites (massive)	×			×	
Stromatoporids				×	
Brachiopods:					
?*Isorthis*	×				
Conchidium			×	×	
Gypidula	×			×	×
Barrandella	×				
Atrypa	×			×	
Atrypella cf. *A. tenuis*	×		×	×	
Plectatrypa	×			×	
Alaskospira cf. *A. dunbari*				×	
?*Stricklandia* or *Cymbidium*				×	
stropheodont	×				
Trilobites:					
Bumastus				×	
Encrinurus	×			×	×

FOSSILS OF UNIT 1 OF THE GAZELLE FORMATION, WILLOW CREEK AREA

Topmost beds of unit 1 contain the *Atrypella* fauna, but most of this thick unit has yielded no significant fossil evidence from beds of known stratigraphic position. Limestone float with tabulate corals is fairly common within the outcrop area of unit 1, but it cannot be determined with certainty that this material was not derived from Gazelle unit 3.

Monograptus, collected by Churkin (1965) in upper Lime Gulch (loc. M1280), probably occurs in the upper part of unit 1 below the *Atrypella* zone. Possibly much lower in unit 1 are the trilobite and coral occurrences (loc. M87) on the south side of Mallethead Ridge. Along this slope from the top of the ridge south to the middle fork of Willow Creek, coral-bearing limestone float probably came from lenses within unit 1. At locality M87 the horizon of the limestone bed containing the diagnostic rugose coral, *Mucophyllum mcintyrei*, is possibly close to that of the shale which yielded a trilobite assemblage (Churkin, 1961). This fauna, identified by Churkin, is listed below:

Trilobites:

- *Leonaspis* (*Acanthalomina*) *minuta* (Barrande)
- *Dicranopeltis* sp., cf. *D. decipiens* (Weller)
- *Trochurus* sp. indet.
- *Scutellum* sp. indet.
- *Proetus* sp. indet.
- *Cheirurus* cf. *C. insignis* Beyrich
- *Encrinurus* (*Cromus*) *beaumonti* (Barrande)

Brachiopods:

- *Leptaena rhomboidalis* Wilckens?
- *Atrypa reticularis* Linnaeus var. *orbicularis* Sowerby?
- *Atrypella scheii* (Holtedahl)?
- *Gypidula* sp.

SILURIAN FOSSILS OF UNIT 3 OF THE GAZELLE FORMATION, WILLOW CREEK AREA

The massive light-gray, ridge-capping limestones of unit 3 are quite fossiliferous or biogenic in places, but thus far have yielded few well-preserved fossils because of the difficulty of extraction. Silicified material is uncommon, perhaps because dolomitization, which often accompanies fossil silicification, did not take place here. Other than debris of crinoids, tabulate corals, and algae, the only forms generically identified are small *Atrypella*-like brachiopods and the rugose corals *Kodonophyllum* and *Zelophyllum*.

Calcareous algae, probably important limestone builders of unit 3, have been listed and figured by Johnson and Konishi (1959, p. 136) from the type area of the Gazelle ("Graystone area"). Among these are the following:

Parachaetetes sp.
Vermiporella cf. *borealis* Høeg
Girvanella problematica Nicholson and Etheridge
Dasyporella norvegica Høeg

It is likely these algae were collected from the massive limestones of unit 3. Because of the resemblance of the algae from the type Gazelle to those from the Early Silurian of Horseshoe Gulch, the former were also considered Llandoverian by Johnson and Konishi (1959, p. 158, table 3).

SILURIAN RUGOSE CORALS AND ASSOCIATED FOSSILS OF THE PARKER ROCK AREA

Table 2 lists fossils collected by the writer in 1951 and 1956 and by J. R. McIntyre during the years 1945 to

1949. In the main, the Parker Rock material is believed to represent the Gazelle Formation and the interval of the *Atrypella* fauna, although *Atrypella* is itself poorly represented.

The distinctive colonial Rugosa of the Gazelle at Willow Creek were not found at Parker Rock. However, *Cyathactis gazellensis* is present, as are the brachiopods *Conchidium*, *Plectatrypa*, and small spiriferoids provisionally assigned to *Alaskospira*. Also abundant are the tabulates *Heliolites*, *Favosites*, and *Halysites*. A significant facies difference is absence of *Halysites* at Willow Creek. Absence of the Gazelle colonial Rugosa at Parker Rock is also ascribed to facies difference. In other regions coralline biofacies of the Silurian not uncommonly lack *Halysites* where other tabulates may be abundant.

The biofacies at Parker Rock favored the gastropods to a greater extent than the biofacies at Willow Creek, to judge from the number of genera represented. Attention is called to the amphineuran plates; these are the only known occurrence of such fossils in western North America of Silurian age.

TABLE 2.—*Silurian fossils from the Gazelle Formation, Parker Rock area*

Species	M1028	M1029	M1030	M81	M83	M84	M85	M86	M90
Rugose corals:									
?pycnostylid			X						
Mucophyllum cf. *M. mcintyrei* n. sp			X						
Cyathactis gazellensis n. sp			X				X ?		
Tabulate corals:									
Favosites (massive)	X	X	X	X					X
Heliolites				X					
Halysites (*Catenipora*)			X	X					X
Syringopora				X					
Brachiopods:									
Hesperorthis								X	
Dalmanella							X		
?*Skenidioides*						X			
stropheodont								X	
Camarotoechia cf. *C. reesidei* Kirk and Amsden								X	
?*Glassia*								X	
Atrypa							X	X	
?*Plectatrypa*							X		
?*Atrypella*				X					
?*Alaskospira* cf. *A. dunbari* Kirk and Amsden							X	X	
?*Trematospira*								X	
Howellella							X		
Conchidium sp				X					
Conchidium cf. *C. biloculare* (Linneaus)				X			X	X	
?*Pentamerus*	X								
Amphineurans:									
Gryphochitonid plates					X				
Gastropods:									
Platyceras								X	
bellerophontid (large)							X		
Holopea								X	
Prosolarium or *Pseudophorus*				X					
Rotellomphalus cf. *R. tardus* Perner					X				
Hormotoma				X					
Ruedemannia cf. *R. lirata* Ulrich and Scofield				X					
Raphispira cf, *R. plena* Perner					X				
Eunema cf. *E. strigillatum* Salter					X	X			
Mesocoelia cf. *M. janus* (Perner)				X					
Stylonema						X			
Murchisonia				X					
Pelecypods:									
Nuculites or *Palaeoneilo*					X				
Conocardium (small)					X				
Ostracods:									
Leperditia						X			
Trilobites:									
Calymene				X					
Pseudocheirurus								X	
cheirurid pygidia						X	X		

FAUNAS OF THE GREGG RANCH AREA

The Gregg Ranch faunas include few rugose corals—*Kyphophyllum greggi* being the only representative. More numerous are the tabulates, with *Favosites* and *Cladopora*. A list of fossils from the Gregg Ranch area follows:

Favosites sp.
Cladopora sp.
Kyphophyllum greggi n. sp.
Hesperorthis sp.
Skenidioides sp.
Howellella n. sp., cf. *H. smithi* Waite
Eunema or *Lophospira* cf. *L. bicincta* (Hall) Lindström
Progalerus or *Cyrtospira* sp.
Murchisonia? sp.
Loxonema? sp.
Holopea cf. *H. symmetrica* Hall
Beraunia cf. *B. bifrons* Perner
Hercynella cf. *H. bohemica* Barrande

The gastropod *Beraunia* and the peculiar helmet-shaped *Hercynella* are associated with *Kyphophyllum greggi* at locality M82. At locality M89 rugose corals provisionally assigned to *Kyphophyllum greggi* are associated with *Favosites*, *Cladopora*, and the small spiriferoid brachiopod, *Howellella*. The *Howellella* resembles, but is not conspecific with *H. smithi* Waite of the Lone Mountain Dolomite of Late Silurian age in the Great Basin (Merriam, unpub. data); *Howellella* is abundantly represented by other distinctive species in the Lone Mountain and in the Rabbit Hill Limestone of Early Devonian age in that province.

At locality M80 the brachiopods, *Hesperorthis* and *Skenidioides*, occur in a gastropod association lacking corals. The abundant gastropods are medium- to high-spired forms of small and medium size resembling some of those in gastropod assemblages from Parker Rock and Grouse Creek. *Conchidium* and *Atrypella*, which establish a Silurian age at Parker Rock and Willow Creek, are conspicuously absent at the Gregg Ranch localities.

RUGOSE CORALS AND ASSOCIATED FOSSILS OF THE GROUSE CREEK AREA

Rugose corals are uncommon in the facies at Grouse Creek (fig. 2) where the fossils were collected. Most numerous here are the gastropods and brachiopods. A list of fossils from locality M1134 follows:

Favosites sp. (massive)
Cladopora sp. (slender)
Kyphophyllum cf. *K. greggi* n. sp.

Zelophyllum? sp. (solitary?)
Lingula sp. (large form)
Pholidops sp.
Schizophoria? cf. *S. bisinuata* Weller
Stropheodonta (*Brachyprion*) cf. *B. seretensis* Kozlowski
Camarotoechia? sp.
Cyrtina sp. (coarse ribbing)
Ambocoelia? sp. (ventral valves only)
Glassia? sp.
Nucleospira cf. *N. ventricosa* Hall
Whitfieldella? sp.
Conocardium sp. (small)
Murchisonia cf. *M. bilineata* (Dechen)
Stylonema cf. *S. potens* (Perner)
Cyclonema carinatum Sowerby
Cyclonema cf. *C. bilex* (Conrad)
Proetus sp.
stromatoporoids
tentaculitids

The abundant brachiopods are *Stropheodonta* and the *Schizophoria*-like form. Compared with Weller's "*Schizophoria bisinuata*," the latter presents a superficial resemblance to *Isorthis* of the Silurian but differs by possessing a broad ventral valve sulcus anteriorly and lacks the brachial valve sulcus of the genus *Isorthis*. Small gastropods placed in *Cyclonema* resemble Silurian species from Gotland that were described by Lindström (1884). Except for the corals and some of the gastropods, this fauna shows no close resemblance to others in the northeastern Klamath subregion.

RUGOSE CORALS AND ASSOCIATED FOSSILS OF THE HORSESHOE GULCH AREA

Three fossil collections from Horseshoe Gulch, made in 1950 by F. G. Wells and G. W. Walker, give evidence of possible range in age from Late Ordovician to Devonian (J. M. Berdan, written commun., 1957). Of these collections, two (GWW–9A–50, GWW–12–50) include branching *Favosites*, which are almost certainly younger than Ordovician. Collection GWW–10–50 is reported upon by Miss Berdan as follows:

> *Catenipora* sp., horn coral, undetermined tubular organisms, undetermined immature brachiopods. *Catenipora* ranges from Ordovician to the end of the Silurian. The horn coral is very close to *Grewingkia*, which is an Upper Ordovician genus, but as it is coarsely silicified and as similar forms occur in the Silurian, it is not possible to make a precise identification. The age of this collection may be, therefore, either Upper Ordovician or Silurian.

Collection GWW–10–50 with *Catenipora* and a *Grewingkia*-like rugose coral was the basis for the subsequent Late Ordovician(?) age assignment of the entire Duzel Formation (Wells and others, 1959).

Calcerous algae collected in Horseshoe Gulch by L. R. Laudon were identified by Johnson and Konishi (1959, p. 135–158); their findings are considered below under correlation and age. The algae are as follows:

Parachaetetes sp.
Vermiporella cf. borealis Høeg
Vermiporella høegi Johnson and Konishi
Girvanella problematica Nicholson and Etheridge
Dasyporella norvegica Høeg

Most of the algae from Horseshoe Gulch are reported also by Johnson and Konishi from Gazelle beds on Willow Creek. Because these Gazelle beds are believed to be considerably younger than the Horseshoe Gulch beds, it seems possible that the calcareous algae in question are better indicators of environment than of precise geologic age.

A Silurian type of colonial pycnostylid rugose coral (pl. 1, figs. 8–10) was collected from light-gray limestone in Horseshoe Gulch by A. J. Boucot in 1964.

Silicified corals and brachiopods, collected by Merriam in 1951 and 1956, came from a small isolated exposure of fractured, mildly altered, irony limestone near a reservoir in upper Horseshoe Gulch (loc. M1131). The identifiable fossils follow:

Halysites (*Catenipora*) sp.
Plasmopora cf. *P. follis* Edwards and Haime
Striatopora? cf. *S. gwenensis* Amsden
Syringopora or *Romingeria* sp.
Dalmanophyllum sp. h, cf. *dalmani* (Edwards and Haime)
Palaeophyllum sp.
Zelophyllum? sp. (solitary form)
Hesperorthis? sp.
Schizoramma sp. cf. *S. nisis* (Hall and Whitfield)
?calcareous sponges of the *Heterocoelia* type, with seivelike partitions

It is possible that the collection from the Wells and Walker locality, GWW–10–50, with *Catenipora*, *Grewingkia*?, and undetermined tubular organisms, may have come from the same horizon as the Merriam collection at locality M1131. *Catenipora* is present in both assemblages, and the streptelasmid coral, *Grewingkia*, possesses generic features in common with the related *Dalmanophyllum*.

Nothing is known of the relative stratigraphic horizons of the several fossil collections made thus far in the Horseshoe Gulch area; it is possible that these collections may represent a considerable time-stratigraphic range. With little doubt, however, the faunules containing *Catenipora* and the small solitary streptelasmid corals are the oldest found thus far in the northeastern Klamath subregion but have little in common with Gazelle fossil assemblages from Willow Creek and Parker Rock.

The question of possible Late Ordovician age of the GWW–10–50 faunule of Horseshoe Gulch cannot be resolved on the basis of existing fossil collections. As noted below, the paleontologic evidence from locality M1131, possibly the same horizon as GWW–10–50, seems to favor somewhat an Early Silurian assignment for the strata at that locality.

GEOLOGIC CORRELATION OF THE NORTHEASTERN KLAMATH SUBREGION PALEOZOIC ROCKS

Within the graywacke province on the Pacific Border of North America, few other areas of Silurian and Devonian rocks have been sufficiently studied paleontologically to make possible definitive correlation. A Silurian fauna comparable to that of Gazelle unit 2 has been collected in the Douglas City area near Weaverville; the fauna of the Montgomery Limestone from Taylorsville, Calif., may be compared to one of the faunules from Horseshoe Gulch. Otherwise the most meaningful comparisons at present are with the Silurian and Devonian strata of southeastern Alaska.

Although there is no direct paleontologic support, it appears not unlikely that some part of the northeastern Klamath subregion Paleozoic section is equivalent to volcanic rocks called Copley Greenstone and Balaklala Rhyolite, which underlie the southeastern Klamath subregion Devonian strata (Albers and Robertson, 1961, p. 10).

Correlations which serve to establish the age and stratigraphic position of the Paleozoic rocks from the northeastern Klamath subregion are based to a considerable extent upon paleontologic comparison with distant sections, including those of the Great Basin, Gotland, England, eastern Europe, and Australia.

CORRELATION WITH SILURIAN ROCKS OF THE DOUGLAS CITY AREA

Silurian fossils collected by W. P. Irwin of the U.S. Geological Survey on the Trinity River west of Douglas City came from limestone blocks seemingly derived from a conglomerate interpreted as part of the Mississippian Bragdon Formation (Irwin, 1963). Irwin (written commun., 1969) regards the Bragdon of this exposure as an outlier upon rocks of the central metamorphic belt. Among the fossils are *Spongophylloides?*, *Zelophyllum?*, *Tryplasma?*, heliolitids, and *Rhizophyllum* sp. C (Helen Duncan and W. A. Oliver, Jr., written commun., 1961). The *Rhizophyllum* (Oliver, 1964) supports a Silurian age, which may be the same age as that of *Rhizophyllum*-bearing beds of southeastern Alaska. In southeastern Alaska *Rhizophyllum* occurs in the *Atrypella-Conchidium* zone, which is believed to be approximately correlative with the *Atrypella* zone of the Gazelle Formation.

If the limestone blocks yielding the Silurian fossils are associated with the Bragdon, they are reworked; if not, the Mississippian Bragdon may rest unconformably upon older Paleozoic beds within the outlier. As noted above, fossiliferous limestone conglomerate like that of Gazelle unit 2 is characteristic of the Silurian marine column in the Pacific Boarder province. It is not unlikely, therefore, that the conglomerate with Silurian fossils near Douglas City may have been derived from thus far undiscovered strata equivalent to the Gazelle Formation and possibly equivalent to some part of the Copley volcanic sequence in areas east of Douglas City and Weaverville.

CORRELATION WITH OLDER PALEOZOIC ROCKS OF THE TAYLORSVILLE AREA, CALIFORNIA

Diller (1908, p. 13–19), describing the important Taylorsville Paleozoic section (fig. 1), applied the name Montgomery Limestone to a 30-foot-thick fossiliferous gray limestone within a thick siliceous clastic sequence consisting of shale or slate, quartzite, and minor conglomerate. Silurian fossils are common in the Montgomery, but none of diagnostic value were found in the clastic rocks below it or above. By inference, the shale, quartzite, and conglomerate between the Montgomery and higher beds considered Carboniferous were questionably assigned to the Devonian by Diller.

Stratigraphic investigations by V. E. McMath (written commun., 1959) cast doubt upon the continuity of the succession, but his Montgomery fossil collections bear out the initial Silurian assignment. As a generalization, it may be said that predominance of siliceous clastics and possible equivalence of the Montgomery and the Early Silurian limestone of Horseshoe Gulch suggest that these beds at Taylorsville were also deposited in the Pacific Border province as an outlying part of the graywacke suite, rather than within the intermediate limestone belt of the Great Basin province to the east.

The fauna of the Montgomery Limestone may be compared to fossil assemblages from Horseshoe Gulch in the northeastern Klamath subregion. Present in the Montgomery and comparable to forms occurring at Horseshoe Gulch locality M1131 are *Halysites* (*Catenipora*) sp., *Plasmopora* sp., *Dalmanophyllum?* sp., *Palaeophyllum* sp., and brachiopods assigned to *Hesperothis* and *Schizoramma*. Also in both assemblages are the problematic nodose-tubular organisms resembling the calcareous sponge *Heterocoelia*. The Montgomery Limestone contains the brachiopods *Dicaelosia* and *Skenidioides* not found at Horseshoe Gulch. *Grewingkia*-like streptelasmid corals in the Montgomery may be compared to those of Horseshoe Gulch locality GWW-10-50, which may be the same horizon as the fauna at locality M1131. As noted below, the *Dalmanophyllum-Palaeocyclus* beds of coral zone A (Early Silurian) from the Great Basin are believed to be correlative with the Montgomery and with limestones of Horseshoe Gulch.

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CORRELATION WITH SOUTHEASTERN ALASKA SILURIAN AND EARLY DEVONIAN SEQUENCES

Silurian marine rocks of southeastern Alaska, some 20,000 feet thick, provide the best reference sections for the North American Pacific Border province. These strata have been described by Kindle (1907), Wright (1915), Burchard (1920), and in more comprehensive terms, by Buddington and Chapin (1929). In recent years Silurian beds of this region have been mapped and studied in greater detail by geologists of the U.S. Geological Survey, among whom are Michael Churkin, Jr., W. H. Condon, G. D. Eberlein, L. J. P. Muffler, and A. T. Ovenshine. Fossil studies by Kindle (1907) and Kirk and Amsden (1952) establish provisional age and correlation of some units.

Silurian beds of the northeastern Klamath subregion have their nearest analogs petrologically and faunally in the southeastern Alaska column. For example, the brachiopod genera *Atrypella* and *Alaskospira* indicate a fairly specific correlation of Gazelle unit 2 with an horizon in the upper-middle part of the Heceta-Tuxekan Island sequence.

G. D. Eberlein's mapping and stratigraphic investigations of the Alexander Archipelago (written commun., 1963) and those of Eberlein and Churkin (1970) show that the Heceta-Tuxekan marine rocks of Silurian age are over 20,000 feet thick in places. Graywacke-type clastics are especially well represented in the lower and upper divisions of this column; the largest limestone bodies lie in the upper-middle part, accompanied by thick lenses of limestone breccia, conglomerate, and sandstone. The lower graywackes, according to Eberlein, consist mainly of volcanic detritus in a marine sequence which includes andesitic and basaltic flows; some have pillow structure.

Like the pure massive limestones of the Gazelle Formation, those of the Heceta-Tuxekan section are nondolomitic, having at most a very low magnesium content. Many of these Silurian limestones from Alaska are relatively pure and of commercial quality. No bedding structures indicating reef origin have been recognized, as in the more southerly Gazelle. Rugose corals and calcareous algae seem to be numerically less important in the Alaskan carbonate deposits although the tabulate corals are abundant. The brachiopod biofacies are perhaps better developed than in the Klamath Mountains.

The Silurian graywackes of the Klamath Mountains do not disclose interbedded lavas like those of southeastern Alaska; however, the petrologic similarity of the Gazelle graywackes to those of Alaska, and the occurrence of interbedded chert leave no doubt of the volcanic environment. As in Alaska also, the abundance of fairly coarse siliceous conglomerate in the Klamath seaway supports a theory of contemporaneous deformation in concert with vulcanism.

Study of Silurian Rugosa and associated fossils of the Heceta-Tuxekan Island area, including the south shore of Kosciusko Island together with those of Kuiu Island (Muffler, 1967) sheds light upon the correlation and age of the Klamath Silurian beds. Somewhat younger deposits at Kasaan Bay on the east side of Prince of Wales Island are of interest in connection with age determination of the Gregg Ranch beds wherein the fossil evidence is more suggestive of an interval bracketing the Silurian-Devonian boundary.

HECETA-TUXEKAN ISLAND AREA

Silurian limestone and calcareous shale of northernmost Heceta Island and the south shore of neighboring Kosciusko Island contain abundant brachiopods (Kirk and Amsden, 1952) and tabulate corals. Conditions were evidently not especially favorable for the Rugosa because *Zelophyllum* is the only genus abundantly represented. Among other Rugosa in the collections are *Tryplasma*, *Salairophyllum?*, *Cystiphyllum*, and an undescribed *Entelophyllum*-like genus with a very narrow dissepimentarium having several columns of unusually small dissepiments. *Rhizophyllum* sp. A (Oliver, 1964) occurs in these beds on Kosciusko Island. None of the distinctive colonial Rugosa of the Gazelle were found in the Heceta-Tuxekan beds. *Rhizophyllum* has not been found in the Gazelle; *Zelophyllum* and *Cystiphyllum* are the two genera common to both regions. Of these, *Zelophyllum* sp. G of the Gazelle is similar to the species well represented in the Heceta-Tuxekan brachiopod facies. Brachiopod genera common to the Gazelle and to the southeast Alaskan beds are *Atrypella*, *Atrypa*, *Alaskospira*, *Howellella*, *Isorthis*, and *Conchidium*. The Gazelle *Conchidium* does not belong in the same taxonomic subgroup with *Conchidium alaskense*, the most distinctive fossil of the *Atrypella-Conchidium* beds from the Heceta-Tuxekan. *Conchidium alaskense* is closer to *C. knighti* of the British Ludlovian (Aymmestry). Of the remaining distinctive Alaskan pentamerids (*Brooksina*, *Harpidium*, and *Cymbidium*), none were identified with assurance in the Gazelle although an incomplete coarse-ribbed ventral pentamerid valve has heavy ornamentation suggesting that it belonged to either *Cymbidium* or *Stricklandinia*.

The *Atrypella-Conchidium* beds of the Heceta-Tuxekan section with which Gazelle unit 2 is correlated represent an interval in the upper middle part of the very thick Silurian column. These beds are considered Ludlovian mainly on the basis of the similarity of *Conchidium alaskense* to the British *Conchidium knighti*. The possibility of higher Wenlockian being represented in this interval is not eliminated (Kirk and Amsden, 1952).

For most of the Heceta-Tuxekan beds of the Silurian below the *Atrypella-Conchidium* zone, there is as yet no basis for meaningful paleontologic comparison with the older Gazelle beds of unit 1 or with the Lower Silurian rocks of Horseshoe Gulch. The middle and lower parts of the Alaskan sequence have yielded little fossil evidence other than a few graptolites in the lower graywacke.

KUIU ISLAND

The Kuiu Limestone of Late Silurian age (Muffler, 1967, p. 11) contains somewhat more diverse coral faunas than the approximately correlative beds of the Heceta-Tuxekan area to the south. The compound Rugosa, *Petrozium* and *Entelophyllum*, were collected here in addition to *Zelophyllum*, *Salairophyllum?*, *Cystiphyllum*, *Microplasma* and lykophyllids of the *Phaulactis* type. The stratigraphic position of the Kuiu coral beds was not determined because of faulting and other factors which obscure these relations. *Conchidium alaskense* and *Zelophyllum* indicate probable equivalence to the fauna from the northern part of Heceta Island that has this large pentamerid and *Atrypella*. A distinctive columellate, *Petrozium* from Kuiu (pl. 7, figs. 7, 8), is specifically different from the Gazelle *Petrozium;* the resemblance is perhaps closer to *P. dewari* of the British Early Silurian. It seems likely the Kuiu faunas may include species of Wenlock as well as Ludlow age.

KASAAN BAY AREA, ALASKA

The faunas from Long Island, Kasaan Bay, assigned by Kindle (1907) to the Devonian, are significant for the dating of the Gregg Ranch strata which bear *Hercynella*. Kindle's material came from massive limestones which he subdivided into lower and upper divisions (Wright, 1915, p. 70–72; Buddington and Chapin, 1929, p. 99–101). Large specimens of *Hercynella*, found only in the lower division, were assigned by Kindle to the European species *H. bohemica* and *H. nobilis*. The Gregg Ranch *Hercynella*, associated with *Kyphophyllum*, resembles *H. bohemica* of the Czechoslovakian Early Devonian. *Kyphophyllum* was not found in the Long Island *Hercynella* beds.

The genus *Hercynella* has a reported range from mid-Silurian to mid-Devonian in the Old World (Perner, 1911; Gill, 1950; Termier and Termier, 1950); it peaks in Early Devonian at about the stage of *H. bohemica*. In eastern North America other species of *Hercynella* occur in the Bertie Limestone of Late Silurian age (Grabau, 1910, p. 195; O'Connell, 1914, p. 96). Confirming evidence of Devonian age from fossils other than *Hercynella* was not obtained from Kindle's lower limestone of the Long Island section.

Kindle's upper limestone unit at Long Island yielded a large fauna in which Devonian elements appear to be associated with others which might almost be interpreted individually as Silurian. Oliver (1964, p. 150) has restudied Kindle's coral material, identifying the rugose forms as *Eddastraea?*, *Rhizophyllum* sp. B, *Pseudamplexus* sp. cf. *P. princeps* Etheridge, and stauriid Rugosa. Other fossils listed by Oliver are *Amphipora*, *Aulocystis*, *Favosites*, and *Thamnopora*. *Eddastraea?*, *Thamnopora*, and *Amphipora* would seem at first to favor a Middle or Late Devonian age, judging from ranges of *Amphipora* and *Thamnopora* in the Great Basin. Although *Rhizophyllum* has survivors in the Devonian of eastern Europe and Australia, its great evolutionary burst worldwide is in the Silurian. *Pseudamplexus*-like corals range from Middle Silurian to Late Devonian; the stauriids range upward from Ordovician to Late Paleozoic. In the late Middle and Late Devonian of the Cordilleran belt, *Amphipora* is a limestone-builder. However, the reliability of this branching stromatoporoid as a Devonian indicator in southeastern Alaska is questionable. G. D. Eberlein and C. W. Merriam in 1961 found *Amphipora* abundantly represented at the north end of Heceta Island, where it occurs in beds which appear on the map to be continuous with those containing *Conchidium alaskense*. *Amphipora* from this locality (M1157) is structurally quite typical of the genus, possessing the characteristic axial canal.[1] At locality M1157 *Amphipora* is directly associated with *Microplasma* and corals of the *Zelophyllum* type. Russian reports of *Amphipora* in Silurian rocks, of which there are several, have not been evaluated in the available literature (Khodalevich, 1939). In Japan digitate stromatoporoids of the Silurian assigned by Sugiyama (1940, p. 114, pls. 14, 16, 19) to *Amphipora* do not show the axial canal convincingly and, as pointed out by Oliver (written commun., 1968), are somewhat more suggestive of the genus *Clavidictyon*.

It is not possible at present to evaluate fully the age significance of these Alaskan fossils; further collecting and field stratigraphic observation are necessary in the Long Island section. Weighing available fossil evidence from the massive Long Island limestone beds yielding *Hercynella*, *Rhizophyllum*, and *Amphipora*, it may be said that the presence of possible Silurian elements somewhat weakens, but does not eliminate, a Devonian assignment for the entire unit. These Alaskan strata

[1] W. A. Oliver, Jr., has confirmed the generic identification (written commun., July 11, 1963).

and the possibly equivalent Gregg Ranch beds containing *Hercynella* and *Kyphophyllum* are viewed provisionally as falling within an indefinite zone which brackets the Late Silurian and Early Devonian.

CORRELATION WITH SILURIAN ROCKS IN THE GREAT BASIN

Coral-bearing strata of Silurian age in the Great Basin are distributed in two major marine rock belts of contrasting lithofacies: the intermediate limestone belt and the eastern dolomite belt. In describing the Silurian rugose corals of the Great Basin province[2] five Silurian coral zones have been proposed, lettered A through E in ascending stratigraphic order. Coral zone A is of Llandovery age, B and C are considered Wenlockian; D and E are Ludlovian.

The oldest Silurian fauna of the northeastern Klamath subregion, that of Horseshoe Gulch, includes *Dalmanophyllum*, *Catenipora*, and *Plasmopora;* this assemblage is correlated with coral zone A of the Great Basin which contains *Dalmanophyllum*, *Palaeocyclus*, and *Arachnophyllum* as well as the common tabulate corals of the Early Silurian. In the Great Basin, beds carrying the coral zone A assemblage rest conformably upon Late Ordovician strata containing a Richmondian fauna; coral zone A has been recognized in both the intermediate limestone belt and the eastern dolomite belt.

Equivalents of coral zones B and C of the Great Basin have not been identified in the northeastern Klamath subregion although the two rugose coral groups present in Gazelle unit 2 are present also in coral zone B of the Great Basin. These are solitary lykophyllids of the *Cyathactis-Ryderophyllum* group and the phaceloid *Petrozium*. Different species are found in the two regions. Overall fossil evidence in Gazelle unit 2, particularly the brachiopod correlations with Alaska, favor a Ludlovian age and correlation with coral zone E of the Great Basin. In the Panamint Mountains, where coral zone B is best shown, zone B is low in the Silurian column and is considered early Wenlockian.

Coral zone E of the Great Basin is known only in the intermediate limestone belt. None of the Rugosa from unit 2 is conspecific with a form from coral zone E of the Great Basin. The closest ties are the Endophyllidae, represented in unit 2 by *Klamathastraea dilleri*, and an evolutionary parallel classified in a new subgenus of *Australophyllum* from coral zone E. The rugose coral genus *Kyphophyllum* (pl. 8, fig. 6) is present in Great Basin coral zone E and in the Gregg Ranch beds, herein designated as Silurian or Early Devonian. Gazelle unit 2 has yielded a questionable *Kyphophyllum*. The massive coralline limestones of Gazelle unit 3 contain *Kodonophyllum*, which resemble those from coral zone E.

Mucophyllum mcintyrei of Gazelle unit 1 differs specifically from an undescribed *Mucophyllum* from coral zone E in the Great Basin.

Rugose corals are greatly affected by their environment. The rugose corals in higher beds of the Great Basin eastern dolomite belt differ from those of Silurian coral zones D and E of the intermediate limestone belt to such an extent that they can not at present be correlated paleontologically. The Ludlovian beds of the eastern dolomite belt carry an *Entelophyllum* fauna which also includes an abundance of the small spiriferiod *Howellella*. These eastern dolomites represent the upper Laketown–Lone Mountain biofacies. *Atrypella*, a genus characteristic of the Late Silurian in the Pacific Border province, has been recognized also in the eastern dolomite belt of the Great Basin (Johnson and Reso, 1964).

Among associated brachiopods, comparable species of *Plectatrypa* occur in coral zone E of the Great Basin Silurian and in unit 2 of the Gazelle. The large *Conchidium* of Gazelle unit 2 externally resembles brachiopods of this Silurian genus in beds which range upward from coral zone B to coral zone E.

Whereas calcareous algae are well represented in the Gazelle Formation and older Silurian beds of the Klamath Mountains (Johnson and Konishi, 1959), it is worthy of note that the large and distinctive dasycladacean *Verticillopora*, so abundant locally in the Silurian of the Great Basin, has not been recognized in the Klamath region.

CORRELATION WITH EASTERN NORTH AMERICA, EUROPE, AND AUSTRALIA

EASTERN NORTH AMERICA

Meaningful correlation of the Silurian and Early Devonian beds of the Klamath Mountains with the eastern standards by means of Rugosa and associated fossils is not yet feasible. The more complex colonial rugose genera of the Gazelle Formation and younger beds are thus far unknown in the East, where their ecologic niches may be occupied by species of *Entelophyllum*, a genus not recognized in the Klamath Mountains region. Solitary forms of the rugose families occurring both in the Klamath deposits and in the eastern Silurian deposits are Streptelasmatidae, Kodonophyllidae, Lykophyllidae, Tryplasmatidae, and Cystiphyllidae. Of these, the first three are the more significant.

Dalmanophyllum of the Streptelasmatidae, present in Early Silurian beds of Horseshoe Gulch and low in the Gotland column, ranges upward into the Louisville

[2] Merriam, C. W., unpublished data.

Limestone of Kentucky (Stumm, 1964, p. 17) which is Wenlockian or Ludlovian.

Lykophyllids comparable to but not conspecific with *Cyathactis gazellensis* of Gazelle unit 2 are represented in the Brownsport Formation of Kentucky (Amsden, 1949) by *Cyathophyllum pegramense* (Foerste) and in the Henryhouse Limestone of Oklahoma (Sutherland, 1965 by *Micula? catilla.* These formations are considered Wenlockian and therefore are probably older than Gazelle unit 2, which is regarded as Ludlovian. Similar lykophyllids assigned to *Phaulactis* occur in the Mont Wissick Formation of Quebec (Oliver, 1962a, p. 12) which is of Wenlock or Ludlow age. *Phaulactis* is also reported by Stumm (1962, p. 2) in the Cranbourne Limestone of Quebec, which probably has about the same age range as the Mont Wissick Formation.

Kodonophyllidae of the Gazelle Formation are *Kodonophyllum* and *Mucophyllum.* In the East, a colonial *Kodonophyllum* was described by Oliver (1962b, p. 23) from beds in Quebec of Wenlock or Ludlow age. The Klamath *Kodonophyllum* is in Gazelle unit 3 of probable Ludlow age. This genus is present also in the Louisville Limestone of Kentucky (Stumm, 1964, p. 26).

Mucophyllum, although not itself recorded from the East, has a related and parallel genus, *Schlotheimophyllum*, in the Louisville Limestone (Stumm, 1964, p. 25). The Gazelle species, *M. mcintyrei*, comes from Gazelle unit 1 in beds of probable Wenlock age and perhaps roughly equivalent to the Louisville of Kentucky.

Of the higher strata in the northeastern Klamath subregion, the Gregg Ranch and Grouse Creek beds of Silurian or Early Devonian age contain the rugose coral genus *Kyphophyllum*, which is thus far unreported in the eastern Silurian or Early Devonian. Abundant in these Grouse Creek beds is a small orthoid brachiopod resembling (?)*Schizophoria bisinuata* Weller, a species characterizing the Coeymans Formation of New Jersey of Early Devonian age.

EUROPE

The coral-rich Silurian strata of Gotland, Sweden, provide a satisfactory carbonate facies reference column for western Europe. Rugosa occur in nearly all the 13 major map divisions spanning this geologic system (Hede, 1921; Regnéll and Hede, 1960). The rugose coral families identified both in Gotland and in the Klamath Mountains of Silurian and Early Devonian age are: Streptelasmatidae, Kodonophyllidae, Tryplasmatidae, Lykophyllidae, Stauriidae, Kyphophyllidae, and Endophyllidae.

Of the Streptelasmatidae, *Dalmanophyllum* of Early Silurian age from the Horseshoe Gulch beds, coral zone A, of the Great Basin, and the Montgomery Limestone of Taylorsville, Calif. is matched by *Dalmanophyllum dalmani* of the Gotland Högklint Group (earliest Wenlockian).

In Gotland, *Kodonophyllum* ranges through the Wenlockian into Ludlovian, but it is known only in Gazelle unit 3 (Ludlovian) of the Klamath region. The *Mucophyllum* group of this family has a more restricted range in Gotland, where it is represented by *Schlotheimophyllum patellatum* in the upper Visby Marl (early Wenlockian). *Mucophyllum* occurs in Gazelle unit 1 probably higher in the Wenlockian.

Among the Tryplasmatidae, *Zelophyllum* is Wenlockian in Gotland. This genus is present in Gazelle unit 2 and in more or less equivalent Ludlovian strata of southeastern Alaska.

Beginning with late Llandovery *Phaulactis*, the Lykophyllidae from Gotland range through most of the Silurian; they are especially numerous in lower to middle Wenlock. In the Great Basin this family is well represented in coral zone B (early Wenlock); in the Klamath region *Cyathactis* of the Lykophyllidae is Late Silurian (Ludlovian), occurring in Gazelle unit 2.

Regarding the Stauriidae, *Stauria favosa*, the common Gotland species, is an occupant of the Slite Group of the later Wenlockian. There are few records of Stauriidae in the American Silurian. *Wintunastraea* of this family comes from beds either at the top of Gazelle unit 1 or in unit 2. This genus is perhaps slightly younger than Stauria of the Slite Group.

The Gotland species of *Kyphophyllum* are from beds of early and middle Wenlockian age, but in the Klamath region this genus occurs in higher beds of Late Silurian or Early Devonian age at Gregg Ranch. In the Great Basin *Kyphophyllum* is in coral zone E which is Late Silurian.

Silurian Endophyllidae are generally Ludlovian, for example, *Klamathastraea dilleri* of Gazelle unit 2 (Ludlovian) and the undescribed complex *Australophypllum* subgenus of coral zone E in the Great Basin. In Gotland *?Australophyllum rectiseptatum* (Dybowski) of probable Ludlovian age seemingly belongs in this family.

In summary, of the rugose coral families and genera here considered, a majority seemingly peak in the Gotland Silurian at stratigraphic horizons geologically older than their peak in the Klamath region. This is especially true of lykophyllids, kyphophyllids, and kodonophyllids. Agreeing more or less in stage or range are representatives of the poorly known endophyllids, the stauriids, and the streptelasmatids.

Hede (1942) has correlated the standard Silurian column of Britain with that of Gotland by means of graptolites. Several of the rugose genera from Gotland are reported in the British section, among which *Phaulactis* of the Lykophyllidae is of special interest here. *Phaulactis* in the Valentian (Llandovery) of Shropshire agrees with the early appearance of this genus in Gotland, but differs from the later occurrence of lykophyllids in Gazelle unit 2. *Petrozium dewari* Smith (1930, p. 307), the type of this genus, comes from Valentian (Llandovery) Early Silurian beds of Shropshire, thus being older than *Petrozium staufferi* of Gazelle unit 2, which is considered to be Ludlovian.

The inadequately known rugose coral faunas from Czechoslovakia of Late Silurian and Early Devonian age (Počta,1902) include the common Gotland chonophyllid, *Ketophyllum*, and possible Lykophyllidae. In general these rugose assemblages from eastern Europe seem less diverse taxonomically than those of Gotland. The endophyllid, *Australophyllum fritschi* (Novak) of Czechoslovakia (Late Silurian "Kozel e2"), is of special interest because it parallels *Klamathastraea dilleri* of Gazelle unit 2. *Cyathophyllum prosperum* Barrande of "Tachlowitz e2" and presumably also Late Silurian is probably a lykophyllid because it shows internal features similar to *Cyathactis gazellensis* of Gazelle unit 2.

AUSTRALIA

In Australia the Silurian Rugosa of the Yass-Bowning area (Hill, 1940, 1954, 1958) include at least three forms resembling Gazelle genera, but none are conspecific. *Klamathastraea dilleri* of Gazelle unit 2 shares some features with both *Australophyllum spongophylloides* (Foerste) and *Yassia enormis* (Etheridge); the lykophyllid *Hercophyllum shearsbyi* only remotely resembles *Cyathactis gazellensis.* Of the Kodonophyllidae, *Muchophyllum crateroides* (Etheridge) is quite similar to *M. mcintyrei* of Gazelle unit 1. The Yass-Bowning coral beds are probably about equivalent to the upper part of Gazelle unit 1 and to unit 2. According to Hill (1940, p. 388), these Australian strata are probably of later Wenlockian to early Ludlovian age.

GEOLOGIC AGE OF PALEOZOIC ROCKS IN THE NORTHEASTERN KLAMATH SUBREGION

Comparison of fossils in the Gazelle Formation with the nearest described species of the central Great Basin (Diller and Schuchert, 1894) led inevitably to Devonian assignment of the beds on Willow Creek; these were earlier identified erroneously as Carboniferous (Diller, 1886, p. 21). When Schuchert's paleontologic examination was made in 1894 (table 3), little progress had been made in the description and illustration of fossils from the western middle Paleozoic. The figures and descriptions of the few species from the Eureka mining district, Nevada, and White Pine mining district, Nevada, that were available in the literature provided scant opportunity for meaningful paleontologic comparison and evaluation. Later researchers have demonstrated that the suggestive similarities of *Gypidula*-like brachiopods of the Gazelle to Late Devonian pentamerids of the White Pine district are surficial only. The Gazelle colonial rugose corals in question are not congeneric with Late Devonian forms described by Meek (1877) from White Pine to which they were referred by Schuchert on the basis of external appearance. Although Schuchert did not evaluate the Gazelle corals in accordance with modern thin-section standards, he recognized the endophyllid affinity of a large cerioid coral herein named *Klamathastraea* by external examination alone; it had earlier been confused with Carboniferous *Lithostrotion.* The presence of *Endophyllum*, as this family of corals was construed in 1894, favored Devonian age.

Other than the doubtful *Conchidium* in Schuchert's faunal list, fossils which would be accepted today as unequivocal Silurian indicators were presumably absent from the original Diller party collections or, as is more likely, had not been generically differentiated at the time of the Diller-Schuchert report. Among these are the spiriferoid brachiopods *Atrypella* and *Alaskospira*, the rugose coral *Zelophyllum*, Silurian coral genera herein proposed, and the diagnostic trilobite *Encrinurus.* Schuchert's "terebratuloid cf. *Newberria*" (table 3) is possibly a variant of *Atrypella.* Later collections from Willow Creek have contained better *Conchidium* material. The diagnostic *Halysites*, which supports a pre-Devonian age, was discovered, not on Willow Creek, but in correlative beds at Parker Rock.

Schuchert's homologizing of Gazelle fossils with the Upper Devonian species from the central Great Basin led Diller and Schuchert to the erroneous conclusion that the Gazelle was younger, not older, than the more firmly dated Middle Devonian strata of the Redding district. Today the Gazelle is believed to predate the Kennett Formation of the Redding district in the southeastern Klamath Paleozoic subregion.

Stauffer's findings (1930, p. 98), after more collecting and reappraisal of all paleontologic data, were essentially in accord with Schuchert's Devonian assignment.

Table 3 presents the writer's evaluation of Gazelle fossil identifications by previous workers.

Gazelle fossils which were collected by University of California field parties during the 1930's were identified by the writer in collaboration with G. A. Cooper of the U.S. National Museum (Merriam, 1940, p. 48). *Conchidium*, *Atrypella*, *Encrinurus*, and illaenid trilofites indicated probable Silurian, rather than Devonian age. Further support of Silurian age came with the discovery of *Monograptus* by Churkin (1965) and with the current results of coral investigations.

TABLE 3.—*Identification of fossils in the Gazelle Formation by previous workers*

	Diller and Schuchert, 1894	Stauffer, 1930	Merriam, this report
1	*Favosites*, 4 species		favositids (massive).
2		*Favosites basalticus*? Goldfuss.	Do.
3		*Favosites polymorpha*? Goldfuss.	Do.
4		*Favosites turbinata* Billings	Do.
5		*Favosites* sp	Do.
6		*Cladopora labiosa* Billings	*Cladopora* sp.
7		*Alveolites multilamella*? Meek.	*Alveolites* sp.
8	*Diphyphyllum fasciculum* Meek.	*Diphyphyllum fasciculum*? Meek.	*Petrozium staufferi* n. sp.
9	*Acervularia pentagona* (Goldfuss) Meek.		*Shastaphyllum schucherti* n. gen., n. sp.
10	*Endophyllum* n. sp		*Klamathastraea dilleri* n. gen., n. sp.
11		*Tabulophyllum* sp	*Zelophyllum* or *Cyathactis*?
12		*Stromatopora* sp	stromatoporoids.
13	*Gypidula* cfr. *comis* Owen.		*Gypidula* or *Barrandella* n. sp.
14	*Gypidula lotis* Walcott		*Gypidula* n. sp.
15	*Conchidium*? (small, strongly plicated).		*Conchidium* n. sp.
16	terebratuloid cf. *Newberria*.		?*Atrypella* cf. *A. tenuis* Kirk and Amsden.
17		*Cranaena*? sp	?*Atrypella*.
18	*Loxonema* cf. *delphicola* Hall.		?*Loxonema* sp.
19	*Murchisonia*	*Murchisonia* sp	*Murchisonia* sp.
20	*Bellerophon* cf. *septentrionalis* Tschernyschew.		bellerophontid.
21	*Mytilarca* sp		?*Mytilarca* sp.
22	*Orthoceras*		*Orthoceras*.
23	crinoid columnals (large).	crinoid stems	crinoid columnals (large).

Most of the Gazelle fossils come from a position high in the formation, a 50-foot stratigraphic interval bracketing Gazelle unit 2, the topmost beds of unit 1, and the basal beds of unit 3. This interval is characterized by the *Atrypella* fauna, so designated because of the abundance of this smooth spiriferoid brachiopod.

A review and analysis of age ranges of the various faunal elements in the *Atrypella* assemblage suggest that it is probably no older than late Wenlockian and is more likely Ludlovian. Among the more significant fossils in this regard are *Atrypella*, *Alaskospira*, *Conchidium*, and the endophyllid coral *Klamathastraea*. It should at this point be mentioned, however, that in this fauna occur rugose coral genera to be expected lower in the Silurian System. Among these are the colonial *Petrozium* and lykophyllid Rugosa such as *Cyathactis*. Both belong to taxonomic groups which became established in Europe by late Early Silurian time; in Gotland the lykophyllids differentiated early to reach a peak in the Wenlockian. *Petrozium* and the lykophyllids are thus far known only in the early Wenlockian coral zone B of the Great Basin.

The genera *Atrypella*, *Alaskospira*, and *Zelophyllum* link paleontologically the *Atrypella* fauna of the upper Gazelle with that of the *Atrypella-Conchidium* beds of Heceta Island, Alaska. These southeastern Alaskan strata are probably no older than late Wenlockian. Because of the similarity of the large ornate *Conchidium alaskense* to *Conchidium knighti* from the British Aymmestry (Ludlovian), these Alaskan *Atrypella-Conchidium* beds are here considered to be late Silurian.

Conclusive paleontologic evidence of Silurian age is provided by study of the Parker Rock section, where the higher beds correspond lithologically to combined unit 3, unit 2, and the upper beds of unit 1 of the Gazelle. As at Bonnet Rock on Willow Creek, the *Atrypella* fauna of Parker Rock occurs beneath a massive, craggy caprock limestone like unit 3. *Halysites*, unrecognized in the Willow Creek area, is abundant in the basal part of the unit 3 equivalent. Corals of the Parker Rock *Atrypella* fauna include *Cyathactis gazellensis* and *Mucophyllum*.

A large general collection of fossils from Parker Rock which probably represents the *Atrypella* interval was made in the years 1945 to 1949 by J. R. McIntyre, while he was a graduate student at the University of California. This material includes brachiopods and trilobites not found elsewhere in the Gazelle. Among these are *Camarotoechia* cf. *C. reesidei*, *Hesperorthis* sp., ?*Glassia* sp., *Trematospira* sp., and two species of *Conchidium*. One *Conchidium* resembles *C. biloculare* of the Gotland Klinteberg Group. Among the Silurian trilobites are *Pseudocheirurus* sp. and other cheirurid genera. Like corresponding fossil assemblages at Willow Creek, these assemblages also probably are of Ludlovian age.

The greater part of the type area of the Gazelle section on Willow Creek is undated paleontologically. Except for the topmost beds of unit 1, no fossils have been collected from an established stratigraphic position in the 1,000 feet or more of structurally deformed argillite, graywacke, conglomerate, and chert which make up most of this division. Exposures on the south side of Mallethead Ridge which yielded *Mucophyllum mcintyrei* and a Silurian trilobite assemblage (Churkin, 1961) are believed to occupy horizons well below the top of unit 1. Although these fossils have been dated no more precisely than Wenlock or Ludlow, it is reasonable to assume that the greater part of unit 1 of the Gazelle Formation is Wenlockian, and that the formation as a whole ranges in age from Middle through Late Silurian.

Limestones at Horseshoe Gulch locality M1131 are dated provisionally as Early Silurian (Llandoverian) mainly on the basis of the small solitary rugose coral *Dalmanophyllum* sp. h cf. *D. dalmani*, associated *Plasmopora*, and *Catenipora*. Moreover, the fossils of this locality agree in general with those of the Silurian Montgomery Limestone at Taylorsville, Calif. Except possibly for calcareous algae described by Johnson and

Konishi (1959), there is no paleontologic evidence linking the limestones of Horseshoe Gulch with other beds of the northeastern Klamath subregion.

Faunas containing possible Devonian as well as Silurian elements and accordingly interpreted at present as Late Silurian or Early Devonian are those from the Gregg Ranch and Grouse Creek areas. The Gregg Ranch assemblages include *Kyphophyllum*, which resembles those of coral zone E of the Great Basin (Late Silurian), in association with the large helmet-shaped gastropod *Hercynella*, which is comparable to Early Devonian *Hercynella bohemica* of eastern Europe. The small spiriferoid, *Howellella*, of Gregg Ranch is somewhat more suggestive of *H. smithi* Waite from the Late Silurian upper beds of the Great Basin Lone Mountain Dolomite than of a subspecies of *H. cycloptera* which characterizes the Early Devonian Rabbit Hill Limestone of that province.

The Grouse Creek fauna differs in overall content from those of Gregg Ranch, but it includes a similar *Kyphophyllum* (pl. 8, fig. 7) and a possible *Zelophyllum*. The most distinctive fossils are an abundant small *Schizophoria*-like orthoid brachiopod resembling ?*Schizophoria bisinuata* Weller of the Early Devonian Coeymans Formation of New Jersey, a small coarse-ribbed *Cyrtina*, and the trilobite *Proetus*. Further study of the numerous brachiopod and molluscan species in this well-preserved assemblage may show it to be entirely Devonian.

Calcareous algae from the Horseshoe Gulch vicinity reported upon by Johnson and Konishi (1959, p. 157–158) were dated by them as Lower Silurian (Llandoverian) although the flora gave evidence of Upper Ordovician affinity. That these algae have greater value as facies indicators than evidences of age is suggested by the fact that Johnson and Konishi list some of the same and comparable forms in the type Gazelle ("Graystone area"), where the limestones which yielded them are no older than Middle Silurian (Wenlockian) and are probably for the most part Ludlovian.

DEPOSITIONAL ENVIRONMENT AND ORIGIN OF THE NORTHEASTERN KLAMATH SUBREGION CORAL-BEARING DEPOSITS

Limestone and limestone conglomerate are the principal coral-bearing Silurian and possible Early Devonian rocks of the northeastern Klamath subregion. In these sections carbonate deposits are volumetrically subordinate to the poorly sorted siliceous clastics, which consist of graywacke and gritty sandstone, argillite, and conglomerate. Occurring with these are considerable amounts of gray bedded chert. Rock associations of this kind characterize the Pacific Border province from California to Alaska, where the Silurian record is one of recurrent volcanic activity and crustal unrest. Andesites and basalts appear to have been the sources from which much of the graywacke was derived. Moreover, it is not improbable that the bedded cherts are also related in origin to vulcanism.

The Pacific Border graywacke suite is limited on the east by a belt of coralline limestones unaccompanied by graywacke and volcanic rocks. This belt crosses the western Great Basin in a northeasterly direction between the graywacke and the very extensive Silurian dolomite belt occupying the central and eastern Great Basin. Thus the Silurian marine rocks in the southwestern part of the Cordilleran geosyncline are distributed in three contrasting lithologic belts as follows:

(1) western graywacke belt of the Pacific Border;
(2) intermediate limestone belt; and
(3) eastern dolomite belt.

In these belts or subprovinces, rugose coral faunas of about the same age show biofacies differences seemingly related in part to change of depositional environment, as well as to the vagaries of faunal dispersal and paleogeography.

Clastic sediments of the Gazelle Silurian seaway, which are on the whole poorly sorted and of prevailingly coarse texture, suggest rapid deposition and high-energy agencies of transport. In spite of somewhat inharmonious factors, the entombed limestone bodies are largely fine-textured, quite pure carbonate and are exclusively nondolomitic. These limestone bodies appear to have been deposited in relatively quiet water.

As noted elsewhere, the Silurian rocks of the Pacific Border province of southeastern Alaska are some 20,000 feet thick (G. D. Eberlein, written commun., 1963) and are on the whole similar lithologically and faunally to those of the northeastern Klamath subregion. Absence of diagenetic dolomite is likewise a feature of these Alaskan strata. It is premature to generalize, but present data support the conclusion that extensive dolomitization did not take place in the Silurian of the American Pacific Border.

Limestone bodies of the Gazelle Formation range from small lenses a foot thick within the siliceous clastics to heavy bedded masses over a hundred feet thick having lateral extent of several thousands of feet. The largest of these limestones, like unit 3, is situated near the top of the formation; smaller bodies appear to be distributed sporadically throughout this predominantly clastic formation.

Reef origin has long been suspected for the isolated craggy limestone bodies in the Gazelle. Thus far, however, a search for reefal bedding structures has remained unrewarded. Much of the coarser textured carbonate within this formation is obviously biogenic, like that of the Niagaran patch reefs and bioherms of the continental interior and the well-known Gotland reefs; as in many of the described Silurian reef complexes, a large percentage of the Gazelle calcareous detritus is crinoidal; lesser amounts of detritus were contributed by stromatoporoids, calcareous algae, corals, brachiopods, and mollusks and are listed in decreasing order of magnitude. Origin of the wholly fine-textured pure limestone facies, whether chemical or mechanical, is unexplained.

Virtual absence of fossils in the noncalcareous or sparingly calcareous graywacke suggests that the sea bottom where this kind of rapid sedimentation was in progress may have been inhospitable to benthonic species.

The Niagaran reefs (Lowenstam, 1948, 1949, 1950) and those of the Gotland Silurian (Hadding, 1941, 1950; Jux, 1957) reveal complex bedding characteristics unrecognized thus far in the Gazelle limestones and in those of southeastern Alaska. Among those features are massive unstratified core rock as distinguished from that of inclined flank beds and well-stratified interreef rock. Evidently the reefs exhibited bottom relief. Typical Gotland patch reefs or bioherms have cores of inverted cone shape; the massive core rock intertongues marginally with reef detritus and thence merges laterally with interreef marlstone. Bioherm and patch reef complexes of the Great Lakes Niagaran are shallow sea features distinguished by unstratified, somewhat altered cores surrounded by inclined flank beds suggesting initial relief. Lowenstam's detailed researches (1948, 1950) point up the major role of frame-building and sediment-binding organisms in their construction. Calcareous algae and stromatoporoids probably functioned in the strengthening processes, but the biologic affiliation of some of the cementing organisms which made rigid wave-resistant structures possible has not been ascertained.

Diversity of the Gazelle coral faunas and the great abundance of other lime-secreting organisms including algae suggest that the essential biota for reef building existed. As in tropical regions today, the warm, shallow sea evidently favored rapid proliferation and evolutionary differentiation of corals and other invertebrate groups. The Gazelle rugose corals appear to be more numerous and generically diverse than are those known in the southeastern Alaska Silurian; it is inferred these taxonomic differences may be of a latitude-zonal nature. Frame-building and cementing organisms like stromatoporoids and calcareous algae, which are abundant in the Gazelle, provided agents for sediment binding, essential to continued in situ upbuilding in a shallow marine zone of strong wave action.

Factors unfavorable to growth of reef or bioherm complexes in the Gazelle sequence are the widespread barren graywacke environment and the tectonic instability of the shallow sea bottoms and neighboring land areas. Sites for limestone deposition were less numerous and extensive than in shelf sea areas where clastic deposition was reduced. Scattered reefs are nonetheless to be expected in the tectonically active Pacific Border province, especially during quiescent intervals when vulcanism ceased.

The shelf seas of the Great Lakes Silurian (Lowenstam, 1948, 1950) provide an interesting contrast with their extensive reef-complex building. However, shelf sea conditions and tectonic stability do not provide the entire explanation, for the coexisting shelf sea dolomites of the central and eastern Great Basin were seemingly not amenable to the growth of patch reefs of the Great Lakes or Gotland types.

The significance of primary or diagenetic dolomitization in relation to Silurian reefs calls for detailed investigation. At one extreme we have the dolomite-free limestones of the tectonically active Pacific Border, at the other the eastern Great Basin shelf sea carbonates in which dolomitization is essentially complete. Intermediate in character are the dolomite-prone Great Lakes Niagaran reefs and the Gotland reef complex deposits with little or no dolomite.

In the Gotland region, where reef building conditions were optimum and dolomitization unimportant, the general environment was more like that of a stable shelf. There is, however, indirect evidence of rather active crustal unrest in the not distant hinterland, possibly to the north. As described by Hede (1921), Hadding (1941), and more recently by Jux (1957), lateral facies change is great in the Gotland reef complex intervals, thus complicating mapping and stratigraphic interpretation. In part this facies fluctuation is related to repeated influx of argillaceous debris in large amounts, a possible result of landward crustal disturbance.

CORAL-BEARING LIMESTONE CONGLOMERATE

The limestone breccia-conglomerate, which is described as Gazelle unit 2 (text fig. 5; pl. 4, fig. 13), has yielded more corals and other fossils than any other part of this formation. Conglomerates of underlying unit 1 are mainly of the siliceous variety, whereas those of unit 2 are composed of angular to subrounded gray limestone blocks and cobbles cemented by argillite matrix. Corals and other fossils are abundant in limestone cobbles as well as in the argillite matrix. The partly

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angular shape of some blocks makes it unlikely that the material was transported far from the site of initial deposition and partial lithification. In some places the limestone conglomerate passes gradationally into overlying thick-bedded pure limestone of Gazelle unit 3 and the admixed argillaceous matter disappears. The genetic relationship of the coral-rich limestone breccia-conglomerate is considered in connection with origin of the massive limestones.

ORIGIN OF CORALLINE LIMESTONES IN THE GAZELLE FORMATION

Explanation of the origin of the coral-bearing limestone bodies in the Gazelle Formation is at present highly speculative; these limestone bodies invite comparison with the classic coral-rich Niagaran carbonate rocks and with those of Gotland. For the present, however, field observations of even bedding in the Gazelle limestones largely rule out the existence here of features analogous to bioherms or patch reef complexes. These rather pure limestones are believed to have accumulated as mixtures of in situ bioclastic material and fine lime mud partly of mechanical origin but perhaps also partly of chemical origin. A good deal of this material was undergoing wave attack and redistribution after initial deposition, as evidenced by patches of limestone conglomerate within Gazelle unit 3. The limestone bodies are viewed as shallow sea banks accumulating in protected embayments where, in somewhat quieter waters, they were bypassed by currents transporting the coarse material which formed graywacke and siliceous conglomerate on neighboring sea bottoms. Later changes such as renewal of vulcanism and crustal disturbance, brought about burial of these limestone bodies to form lenses in the clastic graywacke sequence.

The coral-bearing limestone conglomerate of Gazelle unit 2 largely represents reworked material from more or less lithified coralline limestone. Several explanations are possible. For example, uplift of the sea bottom or marine withdrawal may have resulted in accelerated wave erosion and undermining of consolidated coralline lime mud banks, or this material may represent submarine talus debris torn from the margins of reefs. However, the field observations do not support a theory that these blocks occupy inclined reef flank beds dipping away from a reef core. Burial of the conglomerate blocks by laterally introduced argillaceous material is perhaps significant in this connection (pl. 4, fig. 13). At Parker Rock the basal part of the limestone cap rock corresponding to Gazelle unit 3 shows inclined tongues of limestone breccia-conglomerate. These tongues are the nearest thing to reef flank features recognized in the northeastern Klamath subregion.

At one locality the lowest beds of massive limestone of Gazelle unit 3 include abundant chert pebbles in a 30-foot-thick transitional zone from a siliceous conglomerate which at that point occupies the position of the limestone conglomerate of Gazelle unit 2. Here is shown the upward change from conditions of high-energy coarse debris transport to a presumably more tranquil environment of lime mud accumulation and coral proliferation.

Reefs and reef flank structures have not been observed in the Silurian beds of Alaska on the Pacific Border or in coral-rich beds of the eastern dolomite belt of the Great Basin. Coral-rich limestone breccia-conglomerate occurs in the uppermost Silurian of the intermediate limestone belt of the Great Basin. In the northern Simpson Park Mountains of west-central Nevada coarse limestone breccias have yielded a large Silurian rugose coral fauna; although no supporting structural evidence of reefs was found here, these limestone breccias suggest that marginal reef talus material was deposited here in a high-energy wave environment (Winterer and Murphy, 1960).

CLASSIFICATION OF KLAMATH MOUNTAINS SILURIAN RUGOSA

Taxonomic evaluation of certain rugose coral families and genera is encouraged by current research upon Silurian and Devonian corals of this coelenterate order throughout the Cordilleran Belt. The classification which has evolved as a result of these efforts differs in some details from existing arrangements. Family assignment of particular genera as well as family or subfamily status of some groups departs from the recent classification of Hill (1956), the most comprehensive and adequate thus far published. Availability in the literature of existing family designations eliminates the necessity far more than a very few new family names. Among the proposed additions and emendations are the elevation of subgenera to generic status or the reverse and the proposal of new genera and subgenera. The family Pycnostylidae is restored.

Gross morphologic characters (Hill 1935, 1956) are relied upon in these descriptive and taxonomic studies. Whereas attention was given to details of microstructure and fine structure use of these minute features as aids in rugose coral systematics is thus far attended by limited success (Wang, 1950; Kato, 1963) as compared, for example, with highly effective use of wall structure in fusulinid classification. It is nonetheless recognized that fine structure will eventually aid in recognition of some rugose coral families, such as Tryplasmatidae and Phillipasastraeidae. Because of poor preservation, techniques of this kind are futile in connection with study of many of the western Paleozoic corals, especially as applied to those from dolomitic rocks where complete fossil silicification is to expected.

Of 13 rugose coral families recognized in the Great Basin Silurian,[3] 10 occur in the northeastern Klamath subregion. Silurian rugose coral families not found thus far in this subregion are: Arachnophyllidae, Goniophyllidae, Chonophyllidae, and Acervulariidae.

Order RUGOSA Edwards and Haime, 1850

I. Family Laccophyllidae Grabau, 1928
  1. Genus *Syringaxon* Lindström, 1882
    Syringaxon sp. c
II. Family Streptelasmatidae Nicholson, 1889 [4] (as Streptelasmidae)
  a. Subfamily Streptelasmatinae Nicholson, 1889 [4]
    1. Genus *Dalmanophyllum* Lang and Smith, 1939
      Dalmanophyllum sp. h
III. Family Stauriidae Edwards and Haime, 1850
  1. Genus *Palaeophyllum* Billings, 1858
    Palaeophyllum? sp. G
  2. Genus *Wintunastraea* new genus
    Wintunastraea stanleyi n. gen., n. sp.
IV. Family Pycnostylidae Stumm, 1953
  1. pycnostylid sp. H
V. Family Tryplasmatidae Etheridge, 1907
  1. Genus *Zelophyllum* Wedekind, 1927
    Zelophyllum sp. G
VI. Family Kodonophyllidae Wedekind, 1927
  a. Subfamily Kodonophyllinae
    1. Genus *Kodonophyllum* Wedekind, 1927
      Kodonophyllum sp. g
  b. Subfamily Mycophyllinae
    1. Genus *Mucophyllum* Etheridge, 1894
      Mucophyllum mcintyrei n. sp.
VII. Family Lykophyllidae Wedekind, 1927
  1. Genus *Cyathactis* Soshkina, 1955
    Cyathactis gazellensis n. sp.
VIII. Family Cystiphyllidae Edwards and Haime, 1850
  1. Genus *Cystiphyllum* Lonsdale,[5] 1839
    Cystiphyllum sp. c
IX. Family Kyphophyllidae Wedekind, 1927
  1. Genus *Kyphophyllum* Wedekind, 1927
    Kyphophyllum greggi n. sp.
  2. Genus *Petrozium* Smith, 1930
    Petrozium staufferi n. sp.
  3. Genus *Shastaphyllum* new genus
    Shastaphyllum schucherti n. gen., n. sp.
    ?*Shastaphyllum* sp. c
X. Family Endophyllidae Torley, 1933
  1. Genus *Klamathastraea* new genus
    Klamathastraea dilleri n. gen., n. sp.

[3] Merriam, C. W., unpublished data.
[4] In Nicholson and Lydekker, 1889.
[5] Pages 675-699 and 5 plates in Murchison, 1839.

SYSTEMATIC AND DESCRIPTIVE PALEONTOLOGY

Family LACCOPHYLLIDAE Grabau, 1928

Reference form.—*Syringaxon siluriensis* (McCoy) 1850.

Diagnosis.—Small solitary turbinate to subcylindrical rugose corals with narrow peripheral stereozone. Septa smooth, lamellar, dilated periaxially within a tubular stereoplasmic aulos. No dissepiments. Tabulae uparched strongly, complete or nearly so; axial parts horizontal within aulos, lateral segments steeply inclined to outer wall.

Remarks.—Corals of this family characterize the higher Silurian and Lower Devonian rocks with the genera *Syringaxon* Lindström and *Barrandeophyllum* Počta. Late Paleozoic genera provisionally classified here include *Trochophyllum* Edwards and Haime, *Permia* Stuckenberg, and *Amplexocarinia* Soshkina.

Genus SYRINGAXON Lindström, 1882

1882. *Syringaxon* Lindström, p. 20.
1900. *Laccophyllum* Simpson, p. 201.
1902. *Nicholsonia* Počta, p. 184.
1928. *Laccophyllum* Simpson. Grabau, p. 82.
1928. *Alleynia* Počta (*Nicholsonia* Počta). Grabau, p. 82.
1935. *Syringaxon* Lindström. Butler, p. 117.
1938. *Syringaxon* Lindström (in part). Prantl, p. 21.
1949. *Syringaxon* Lindström. Stumm, p. 10.
1962. *Syringaxon* Lindström (in part). Flügel and Free, p. 224.

Type species.—*Cyathaxonia siluriensis* McCoy 1850 (Butler, 1935); by monotypy. Silurian; Upper Ludlow, England.

Diagnosis.—Laccophyllid corals with deep calice and strongly developed aulos (Flügel and Free, 1962). Uparched tabulae either continue wall to wall through aulos, terminate in aulos, or abut as tabellae on contiguous tabulae. Quadrants in neanic growth stages defined by narrow fossulae.

Remarks.—*Laccophyllum* Simpson 1900 is a synonym (Grabau, 1928). *Syringaxon* occurs in the western American Silurian but is most abundant in Early Devonian Rabbit Hill strata of the Great Basin, where it characterizes the *Syringaxon* coral facies. Although uncommon in the west above the Rabbit Hill Limestone, this genus ranges into the Middle Devonian. Late Paleozoic analogs may be homeomorphic.

Syringaxon sp. c
Plate 4, figure 10

Small trochoid to ceratoid solitary corals, 8 mm or less in length fairly common in the Gazelle Formation. Of these, a single individual herein figured reveals a septal pattern like that of *Syringaxon*, with 20 smooth even straight septa coalescing laterally short of the axis to produce a partial aulos. No minor septa. Inside the thin epitheca the septa thicken peripherally in a well-defined septal stereozone.

Another individual of the same size (pl. 4, fig. 9) has short septa of about the same number, but it lacks the aulos. Perhaps it is more appropriately assigned to ?*Orthophyllum* sp.

Syringaxon sp. c has fewer septa than the species characterizing the *Syringaxon* facies of the Great Basin Rabbit Hill Limestone (Helderbergian). The Rabbit Hill species has minor septa and a very deep calice.

Occurrence.—In tan-weathering shales of either unit 2 or the top beds of unit 1, Gazelle Formation at south end of Chastain Ridge, loc. M1135.

Family STREPTELASMATIDAE Nicholson, 1889[6]
(as STREPTELASMIDAE)

Reference form.—*Streptelasma corniculum* Hall 1847; Trenton Group, Middle Ordovican

Diagnosis.—Solitary rugose corals with wedge-tapering lamellar major septa, short to very short minor septa, and a well-developed septal stereozone. Septa thickened ontogenetically to later neanic growth stage and laterally in contact, thereafter thinning progressively from axis toward periphery. Tabulae and tabellae irregularly arched, obscured by stereoplasmic thickenings. No dissepiments. Fossula weak or lacking.

Remarks.—Streptelasmatidae with long septa tend to produce either loose or rodlike axial structures; these are twisted combinations of stereoplasmically swollen axial tips of septa involved with uparched median tabular segments.

In some western Late Ordovician stratigraphic sections, Streptelasmatidae are the earliest solitary Rugosa and have already evolved specialized genera like *Bighornia* (Duncan, 1957) with columella and externally angulate cross section. The western Silurian Streptelasmatidae are subdivided into two subfamilies: Streptelasmatinae and Siphonophrentinae.

[6] In Nicholson and Lydekker, 1889.

Subfamily STREPTELASMATINAE Nicholson, 1889[7]
Genus DALMANOPHYLLUM Lang and Smith, 1939

1933. *Tyria* Scheffen, p. 33, pl. V, figs. 2–3.
1939. *Dalmanophyllum* Lang and Smith, p. 153.
1940. *Dalmanophyllum*. Lang, Smith, and Thomas, p. 49.
1961. *Dalmanophyllum* Lang and Smith. Minato, p. 81–86, text figs. 20, 21, 22, 23; pl. XI, pl. XIX, figs. 2–5.

Type species.—*Cyathaxonia dalmani* Edwards and Haime 1851; by original designation (Lang and Smith, 1939, p. 153). Silurian (early Wenlockian); Högklint group, Gotland, Sweden.

Diagnosis.—Trochoid Streptelasmatinae with solid bladelike axial structure occupying center of inverted bell-shaped calice; transverse outline of calice rim broadly ovoid, nonangulate. Weak fossula in line with median plane of axial rod. Major septa dilated, extend to columella in early adult and younger growth stages; minor septa short. Septal stereozone narrow to moderately wide. Tabulae largely suppressed by stereoplasmic thickening.

Occurrence.—Late Llandovery and early Wenlock.

Dalmanophyllum sp. h
Plate 1, figures 11–14

Incomplete solitary ceratoid corals from Horseshoe Gulch have the axial structure and wide septal stereozone of *Dalmanophyllum*. Major septa number about 36; some are incorporated axially in the rodlike columellar structure. Minor septa mostly less than half the length of major septa; some do not extend far beyond the stereozone. Irregular tabulae distally arched; no dissepiments. In longitudinal thin section, the axial structure appears as a distinct rod, reinforced by stereoplasm, projects upward in a deep calice.

Remarks.—Similar *Dalmanophyllum* with narrow stereozone occurs in the Montgomery Limestone of the Taylorsville area, California. A larger streptelasmid in the Montgomery has a wider, more open axial structure and is more suggestive of the genus *Grewingkio*. Trochoid *Dalmanophyllum* occurs also in Great Basin coral zone A of Early Silurian age in the Vaughn Gulch Limestone and Hidden Valley Dolomite of the northern Inyo and Panamint Mountains.

Occurrence.—Horseshoe Gulch area, loc. M1131; associated with a fauna considered to be Early Silurian.

Family STAURIIDAE Edwards and Haime, 1850

Reference form.—*Stauria astreiformis* Edwards and Haime. Silurian; Gotland, Sweden.

As here interpreted the Stauriidae comprise primitive bushy and cerioid Rugosa with slender elongate corallites, narrow peripheral stereozone, complete tabulae, and thin lamellar septa. Major septa are very long or

[7] In Nicholson and Lydekker, 1889.

of medium length, never stubby as in Pycnostylidae or stubby-spiny as in the Tryplasmidae. In the more primitive species, dissepiments are absent. In other species, dissepiments develop sporadically in local groups of one to three columns; some corallites lack dissepiments.

Stauriidae comprise the more abundant compound Rugosa of Late Ordovician rocks; these seemingly have no morphologic or genetic connection with the contemporary members of the solitary *Streptelasma* group. Origin of the Stauriidae is perhaps to be sought among the Tabulata. Ordovician Stauriidae are *Favistella* Dana (or *Favistina* Flower), *Cyathophylloides* Dybowski, and *Palaeophyllum* Billings. These are succeeded in the Silurian by advanced species of *Palaeophyllum* and *Cyathophylloides* as well as by *Stauria* and *Wintunastraea*. The Silurian *Circophyllum* may also belong in this family.

In the Devonian System, Stauriidae continue on as *Dendrostella* Glinski, *Columnaria* Goldfuss, and possibly also *Synaptophyllum* Simpson (as revised by McLaren, 1959).

A stauriid known only from float material near the Ordovician-Silurian boundary in the Roberts Mountains, Nev., has the overall characterization of *Cyathophylloides* but possesses a single column of large peripheral dissepiments.

In the Gazelle Formation, Silurian corals referable to the Stauriidae are the species questionably placed in *Palaeophyllum* and the new stauriid genus *Wintunastraea*.

Genus **PALAEOPHYLLUM** Billings, 1858

1858. *Palaeophyllum* Billings, p. 168.
1956. *Palaeophyllum*. Duncan, pl. 25, figs. 1a–b.
1959. *Palaeophyllum* Billings. Hill, p. 4.
1961. *Palaeophyllum* Billings. Flower, p. 88.
1963. *Palaeophyllum* Billings. Oliver, p. 4.

Type species.—*Palaeophyllum rugosum* Billings. Ordovician; Black River or Trenton Group, Quebec, Canada.

Diagnosis.—Phaceloid Stauriidae with narrow peripheral stereozone; no dissepiments. Major lamellar septa long and simple, minor septa short; tabulae complete, commonly arched with axial depression. Forms large colonies by lateral increase.

Remarks.—This genus is probably related to the cerioid *Favistella* or *Favistina* and to *Cyathophylloides* common in the Late Ordovician. *Palaeophyllum* and *Cyathophylloides* are present in the Silurian strata of the Cordilleran Belt where they occur with nondissepimented corals of similar growth habit but have acanthine septa and are therefore assigned to the tryplasmids. The morphology and taxonomy of *Palaeophyllum* have recently been dealt with by Flower (1961) and by Oliver (1963).

Palaeophyllum? sp. G

Plate 2, figures 9, 10

These nondissepimented phaceloid Rugosa provisionally assigned to *Palaeophyllum* have complete straight tabulae, only slightly thickened lamellar septa, and little peripheral stereoplasm. In transverse thin section *Palaeophyllum?* sp. G shows about 44 mostly rather short but not stubby septa which alternate long and short in places, the longer extend to about half the corallite radius. In longitudinal thin section the straight tabulae are fairly closely spaced. Where peripheral stereoplasm is present the trabeculae are nearly horizontal.

Zelophyllum sp. G from the same beds differs from *Palaeophyllum?* sp. G. in possessing thick and very short undifferentiated septa in a fairly uniform septal stereozone. Unlike *Palaeophyllum?* sp. G. the *Zelophyllum* in question is not known to be colonial.

Occurrence.—Willow Creek area, Chastain Ridge locality M78. Weathered fossils along fault zone in Gazelle Formation, probably from topmost unit 1 or unexposed unit 2. Corals quite similar to *Palaeophyllum?* sp. G occur in the lower part of the Vaughn Gulch Limestone, northern Inyo Mountains, Calif.

Genus **WINTUNASTRAEA**, new genus

Type species.—*Wintunastraea stanleyi* n. gen., n. sp. (here designated); Silurian; Gazelle Formation, northeast Klamath Mountains, Siskiyou County, Calif.

Diagnosis.—Cerioid stauriid having sporadic groups of small and large lonsdaleioid dissepiments but lacking a continuous dissepimentarium. Tabulae closely spaced, nearly flat peripherally, very strongly arched axially. Septal stereozone with scattered nearly horizontal trabeculae.

Remarks.—Major septa of *Wintunastraea* are numerous, long, smooth or slightly wavy; minor septa are short. Some corallites reveal no dissepiments. *Stauria* may be either fasciculate or cerioid; the new genus *Wintunastraea* is known only with cerioid growth habit. *Wintunastraea* also differs from *Stauria* in having markedly arched tabulae and isolated groups of lonsdaleioid dissepiments in one to three columns. *Columnaria* has scattered smaller dissepiments which are less distinctly lonsdaleioid, has shorter septa, and lacks the arched tabulae of *Wintunastraea*. *Cyathophylloides* lacks the longsdaleioid dissepiments and has fewer septa and less arched tabulae.

Wintunastraea is monotypic, known thus far only in the Silurian Gazelle Formation.

Wintunastraea stanleyi, new genus, new species

Plate 3, figures 1–3; plate 4, figures 4–5.

Type.—Holotype, USNM 159464, Gazelle Formation; locality M1135, Willow Creek area. The holotype colony is the only specimen of this coral discovered so far.

Diagnosis.—*Wintunastraea* has 24 to 30 long major septa. Septal tips very slightly dilated or coalesce with those of adjacent septa. Strongly uparched tabulae with an axial depression.

Transverse thin sections.—Some major septa extend to the axis and range in number from 24 to 30; others merge at tips with contigous septa. Those septa with free axial tips may be slightly dilated. Minor septa short but not stubby; about one-fourth the length of major septa. Septa fairly smooth to slightly undulant, without major thickening beyond stereozone, which is of narrow to medium width. Lonsdaleioid dissepiments mostly rather large; groups of these most common at outer wall angulations. Stereozone usually on the inside of dissepiment groups. Outer wall sharply set off from stereozone by textural differences.

Longitudinal thin sections.—Dissepiments absent in parts of corallities. Tabulae close spaced, characterized by an outer and an axial series. Outer series nearly horizontal; axial series occupies about one-half the corallite diameter and rises abruptly in bulbous fashion with medium sag. Some individual tabulae traceable from the peripheral flat zone through the axial sag, but entire or complete tabulae uncommon; most of the flat peripheral parts terminate inward against bulbous tabellae of the axial arch. Some tabulae traceable peripherally through the stereozone to the outer wall. Nearly horizontal trabeculae visible between tabulae, locally these project spinosely beyond the stereozone.

Elongate lonsdaleioid dissepiments in localized groups, in single columns or as many as three columns commonly thickened by stereome on their axial surfaces.

Reproductive offsets.—Small interstitial offsets lacking dissepiments and stereozone probably developed from outermost edge of a parent calice.

Fine structure.—The thin outer wall or epitheca between corallites is minutely three layered and has a median clear lamina with outer and inner dark laminae of dusty carbonaceous calcite. The outer wall sharply contrasted with the lighter gray laminar stereozone.

Occurrence.—The excellently preserved material of this new genus was collected by Maitland Stanley at the south end of Chastain Ridge (loc. M1135), where it was associated with *Shastaphyllum schucherti*. These fossils were embedded in tan argillaceous matrix, evidently having weathered from deformed beds near the contact between massive limestones of Gazelle unit 3 and the graywacke-argillite sequence of unit 1. It is possible the beds yielding this coral fauna are the limestone breccia-conglomerate of Gazelle unit 2 which is not exposed at locality M1135, but is exposed at Bonnet Rock where it yields the latest Gazelle fauna in this area. Study material consists of the single corallum which is the holotype.

Family PYCNOSTYLIDAE Stumm, 1953

Reference form.—*Pycnostylus guelphensis* Whiteaves 1884. Silurian; Guelph Dolomite, Ontario, Canada.

Fasciculate rugose corals with subcylindrical mature corallites; septa low, continuous longitudinal ridges arising from narrow stereozone without acanthine spines. Tabulae complete, straight, unarched; no dissepiments. Reproduction by internal wall offsets from calice periphery. Trumpet-shaped flaring calices characteristic.

Genera included in the Pycnostylidae are:

Pycnostylus Whiteaves, 1884
Fletcheria Edwards and Haime, 1851
(?) *Fletcherina* Lang, Smith, and Thomas, 1955
(?) *Cyathopaedium* Schlüter, 1889

The Pycnostylidae are characteristic of the American Silurian. In the Great Basin they are represented by an undescribed genus with abundant lateral connecting processes, trumpet-shaped calice, and numerous offsets; *Pycnostylus* is reported to have but four such offsets, whereas the Great Basin genus has as many as eleven.

The Stauriidae differ in having long lamellar septa and uparched tabulae. Fasciculate Iryphasmatidae are externally similar but may be distinguished by their acanthine septa and lack of multiple calice offsets. The problematic *Zelophyllum* group of Tryplasmatidae is also homeomorphic but is not known to have multiple calice buds or markedly flaring calices; this group reveals discontinuous patches of acanthine septa (see pl. 1, figs. 3–5).

Fletcheria is poorly understood. This Gotland Silurian genus has some cystose tabulae and a rather thick wall, with structure like that of *Syringopora* (Duncan, 1956, pl. 25, figs. 6a–b). According to Duncan, *Fletcheria* lacks septa. On the basis of Duncan's evaluation and the original figure of Edwards and Haime (1851, pl. 14, fig. 5), it seems doubtful that the type species of *Fletcheria* is congeneric with *Pycnostylus* as implied by Lang, Smith, and Thomas (1940, p. 112).

The Klamath Mountains pycnostylids are too incomplete to characterize generically, but they can be distinguished from *Zelophyllum* by bushy growth habit and multiple calice offsets. It is possible that some straight-shaped *Zelophyllum* from Klamath and southeastern Alaska may be solitary corals.

Pycnostylid sp. H

Plate 1, figures 8–10

Loosely fasciculate species from the Silurian beds at Horseshoe Gulch with calice offsets numbering from three to five and a fairly wide stereozone which is about one-quarter of the radius. Undifferentiated septa number about 46, some with and some without short internal projections. Trabeculae nearly horizontal; do not project inward significantly as acanthine spines. Tabulae straight, thickened, and widely spaced.

Occurrence.—Horseshoe Gulch area, loc. M1130; collected by A. J. Boucot. This form was not found in association with the Early Silurian fauna of loc. M1131. Similar pycnostylids were collected by Boucot 1½ miles south of Mountain House, China Mountain quadrangle.

Comparable pycnostylids occur at Parker Rock, loc. M1030 (pl. 2, figs. 7, 8), but these have more closely spaced tabulae and narrower stereozone.

Family TRYPLASMATIDAE Etheridge, 1907

Reference form.—*Tryplasma aequabile* (Lonsdale)[8] 1845. Silurian; Ural Mountains, Russia.

Solitary and colonial rugose corals with acanthine septa (Hill, 1936) comprising columns of trabecular spines protruding from a peripheral stereozone. Tabulae complete or partial, unarched. No dissepiments.

In some Tryplasmatidae the trabecular spines are mostly buried in stereoplasm with only inner tips exposed; in others they project obliquely inward and upward as long free spines (Schouppé, 1950).

Genera of Tryplasmatidae in the Great Basin Silurian are: *Tryplasma* Lonsdale[8] 1845, *Palaeocyclus* Edwards and Haime 1849, *Rhabdocyclus* Lang and Smith 1939, and *Zelophyllum* Wedekind 1927. Of these, *Tryplasma* may be further subdivided on the basis of external form and growth habit (Stumm, 1952). Only *Zelophyllum* has been found in the northeastern Klamath Mountains.

Genus ZELOPHYLLUM Wedekind, 1927

1927. *Zelophyllum* Wedekind, p. 34–35, pl. 5, figs. 1–5, pl. 6, figs. 11–13.
1937. *Zelophyllum* Wedekind. Soshkina, p. 46–49, pl. vii, figs. 5–8, pl. viii, figs. 3–6.
1940. *Zelophyllum* Wedekind. Lang, Smith, and Thomas, p. 142.
1956. *Zelophyllum* Wedekind. Hill, p. F312, fig. 213:7.
1956. *Zelophyllum*. Duncan, pl. 23 (expl., figs. 2a–d).

Type species.—*Zelophyllum intermedium* Wedekind, 1927; by original designation. Silurian; Högklint, Gotland, Sweden.

Diagnosis.—Corallites of medium size, very elongate, subcylindrical, with medium to narrow septal stereozone, short, partly acanthine septa, and complete, rather closely spaced tabulae. No dissepiments.

Remarks.—*Zelophyllum* appears to have been correctly assigned to the Tryplasmatidae by Hill (1956, p. F310–F312). Alaskan specimens show especially well the discontinuous acanthine features (pl. 1, figs. 3–5) which cannot be observed in Wedekind's black and white illustrations of the type species. In transverse section the wide septal bases which comprise the stereozone are sutured laterally along a vague dark boundary (pl. 1, fig. 2). The axis of the septum is a more pronounced but shadowy dark line passing inward to the sharp blade (or spine) of the septal edge. In longitudinal section nearly horizontal trabeculae are visible within the stereozone; in places where the stereozone is thinnest, these project as long, fairly uniform spines like those of *Tryplasma*. Until Wedekind's Gotland type species is restudied in thin section, the true taxonomic status of *Zelophyllum* will remain uncertain.

Doubts exist regarding the colonial nature of *Zelophyllum*. Compact or fasciculate colonies are unknown among the Alaskan or Klamath species. Separate corallites as collected do not reveal lateral attachment processes or evidences of contact with adjacent corallites; hence these may have lived in solitary habit.

Pycnostylid Rugosa, which resemble *Zelophyllum* and are the most likely to be confused, have the fasciculate growth habit. Some Pycnostylidae develop numerous rodlike or tubular lateral connections. Members of this Silurian family lack acanthine septa and produce multiple internal calice offsets not known in *Zelophyllum*.

Phaceloid Stauriidae may be distinguished from *Zelophyllum* by their longer lamellar (not acanthine) septa. Some genera may have a few dissepiments.

Pseudamplexus differs in being, usually, a large and heavy coral with much wider septal stereozone and without true acanthine septal spines.

Occurrence.—*Zelophyllum* is known only in strata of Silurian age.

Zelophyllum sp. G

Plate 1, figures 6, 7

Incomplete subcylindrical *Zelophyllum* of medium size from the Gazelle Formation; probably of solitary growth habit. Resembles a species abundant in the *Atrypella-Conchidium* zone of southeastern Alaska (pl. 1, fig. 1–5).

The stereozone, approximately one-sixth of the radius, includes 56 short septa which are not well differentiated as major and minor. Inner septal blades may extend about one-half the stereozone width. Stereozone calcite is minutely laminar. The epitheca is very thin;

[8] Appendix A, p. 591–634 of Murchison, de Verneuil, and Von Keyserling, 1845.

longitudinal (septal) grooves are weakly defined. External rugae are few and widely spaced.

Tabulae are close-set, fairly straight, unarched, and mostly complete. Most stereozone trabeculae are nearly horizontal; no well-defined acanthine spines were recognized.

Occurrence.—Gazelle Formation, Chastain Ridge, loc. M78. The figured specimen was partly encrusted by a stromatoporoid and is coated by a brown argillite matrix with crinoidal debris.

A similar *Zelophyllum* occurs in the massive light-gray limestone of Gazelle unit 3 at Bonnet Rock.

Family KODONOPHYLLIDAE Wedekind, 1927

Reference form.—*Kodonophyllum milne-edwardsi* (Dybowski). Silurian; Gotland, Sweden.

Solitary and colonial rugose corals have long septa, a very wide stereozone, no dissepiments, and a tabularium of flat tabulae or arched tabellae; in one subfamily these tabellae combine with septal ends to produce an axial structure.

Two subfamilies are recognized: Kodonophyllinae and Mycophyllinae.

Subfamily KODONOPHYLLINAE Wedekind, 1927

Fasciculate colonial and platelike solitary Kodonophyllidae with arched tabellae and tabulae which combine with septal ends to produce an axial structure. Described genera are *Kodonophyllum* Wedekind and *Schlotheimophyllum* Smith. Only *Kodonophyllum* is known in the Klamath Mountains Silurian.

Kodonophyllum sp. g
Plate 4, figures 11, 12

Fragmentary specimens of *Kodonophyllum* have been found only in the massive limestone unit 3 in the Gazelle Formation at Bonnet Rock.

In transverse section, species g shows a wide stereozone with 30 major septa which meet axially to form a twisted vortex. Minor septa, somewhat less than one-half the radius, extend to the stereozone edge. Major septa thickened, with scattered small lateral bumps and swellings.

The longitudinal section reveals an axial boss in the center of a deep calice. Trabeculae are peripherally inclined at a low angle in the wide stereozone.

Kodonophyllum sp. g. resembles an undescribed species in Great Basin Silurian coral zone E at Coal Canyon, Simpson Park Mountains, Nev.[9] The Great Basin species has more septa and is less twisted axially than the Klamath Mountains form. *Kodonophyllum truncatum* (Linnaeus) of the Gotland Silurian (Smith and Tremberth, 1929, pl. VIII, figs. 5–7) has less twisted septal ends in the axial structure than the Klamath Mountains form. *K. truncatum* is a colonial form.

[9] Merriam, C. W., unpub. data.

Occurrence.—Willow Creek area, south side of Bonnet Rock east of locality M191 in massive limestone cap rock of unit 3, Gazelle Formation.

Subfamily MYCOPHYLLINAE Hill, 1940

Large solitary platelike and subcylindrical Kodonophyllidae with straight, usually unarched and complete tabulae. No axial structure. Genera included in this subfamily are. *Mucophyllum* Etheridge, 1894, *Clamydophyllum* Počta, 1902, *Pseudamplexus* Weissermel, 1897, and possibly *Briantia* Barrois, 1889. Only *Mucophyllum* is known in the Klamath Mountains Silurian.

Genus MUCOPHYLLUM Etheridge, 1894

1894. *Mucophyllum* Etheridge, p. 11–18, pls. iii, iv.
1926. *Mucophyllum*. Lang, p. 431, 433, pl. xxx figs. 7, 8.
1940. *Mycophyllum*. Lang, Smith, and Thomas, p. 87.
1940. *Mycophyllum crateroides* Etheridge. Hill, p. 399–400, pl. xii, figs. 1, 2.
1940. not *Mycophyllum liliiforme* (Etheridge). Hill, p. 401, pl. xi. figs. 18, 10, pl. xii, figs. 3–6.
1945. *Mucophyllum crateroides* Etheridge. Smith, p. 19.
1949. *Mucophyllum* Etheridge. Stumm, p. 49, pl. 23, figs. 9, 10.
1956. *Mucophyllum* Etheridge. Hill, p. F277, fig. 189: 3a.

Type species.—*Mucophyllum crateroides* Etheridge, 1894, by monotypy. Silurian; Hatton's Corner, Yass River, New South Wales, Australia.

Diagnosis.—Large discoid, or patellate to turbinate, usually solitary rugose corals with broad calice platform, reflexed margin, and flat-bottomed central pit. Septa numerous, thick, laterally in contact to form a wide stereozone; some longer septa reach the axis. Tabulae medium wide or narrow, complete, straight to undulant. No dissepiments. Longitudinal section shows fine, near-horizontal incremental layering of thick stereozone which is transected by near-vertical trabecular pillars. Radial grooves of calice platform overlie sutures between thickened septa.

Remarks.—A distinctive feature of *Mucophyllum* is the thick layered stereoplasmic disc occupying the position of a dissepimentarium but lacking dissepiment structure. *Schlotheimophyllum* has a less dense stereozone (Stumm, 1964) and a more complex axial structure like that of *Kodonophyllum*. *Naos Lang*, 1926 (possibly a synonym of *Craterophyllum* Foerste, 1909) has well-defined naotic dissepiments and zigzag septa which break up pheripherally in naotic fashion. *Chonophyllum* Edwards and Haime, 1850, as here interpreted, is a distinct genus unrelated to the above-mentioned genera with which it has been confused. The involved taxonomy of these genera has been treated in detail by Lang (1926,

p. 428–434), Smith (1945, p. 18–20), Stumm (1949, p. 48–49), and Hill (1956, p. F271, F276–277, F300).

Mushroom-shaped and trumpet-shaped calices are characteristic of several perhaps unrelated Silurian rugose coral genera. These rugose genera, like *Mucophyllum* and *Schlotheimophyllum*, have complete straight tabulae, but others have elongate, stemlike cylindrical corallites without a greatly thickened stereoplasmic disc. Among these genera is *Tryplasma liliiforme* Etheridge, which is evidently not a *Tryplasma*; Hill (1940, p. 401) placed it in *Mucophyllum*. Other elongate forms with flaring calice were assigned to *Pseudomphyma* by Wedekind (1927, pls. 6, 7, 8). In the Great Basin Silurian are generically unnamed corals resembling *Tryplasma liliiforme* with flaring calice. Some of these have sporadic acanthine septa and probably belong in *Zelophyllum;* others with very short septa are related to *Pycnostylus* Whiteaves.

Corals with generic features of *Mucophyllum* may have major septa extending to the axis as, for example, the specimens from the Silurian Roberts Mountains Formation in the Great Basin. These specimens, however, possess nearly horizontal tabulae, unlike the uparched tabulae of typical *Schlotheimophyllum*, and lack the complex axial structure of that genus. As noted by Hill (1940, p. 400), individuals of the type species of *Mucophyllum* (M. *crateroides* Etheridge) may have long major septa which are amplexoid—extended axially only on the upper surfaces of tabulae.

Geologic occurrence.—*Mucophyllum* is known only in rocks of Silurian age. All known occurrences seem to be Wenlock or Ludlow.

Mucophyllum mcintyrei, new species
Plate 6, figures 9, 10

Type.—Holotype USNM 159453.

Diagnosis.—Thick patellate *Mucophyllum;* markedly convex calice platform slopes abruptly inward to steep-sided calice pit, and slopes more gently outward toward reflexed rim. Tabulae straight, thick, and closely spaced beneath flat-bottomed pit. Longer septa terminate at edge of tabularium. Stereozone vertically thickest below convex inflection of calice platform, thins peripherally to sharp rim.

Transverse section.—No transverse thin section of a surface beneath the calice platform is available. The weathered undersurface (pl. 6, fig. 9) reveals about 66 stereoplasmically thickened septa laterally in contact, except at tabularium margin where all taper to abrupt free terminations. Join lines of septa make prominent radial features on the weathered surface, each lying in a radial depression. No clearly defined concentric features suggesting residual or stereoplasmically suppressed dissepiments were observed.

Longitudinal section.—Thick and rather close-set, somewhat undulant tabulae lack thickenings at septal intersection of other *Mucophyllum* species. Incremental stereoplasmic banding rather thick near the axis, thins appreciably toward the periphery (pl. 6, fig. 10). Halfway between the periphery and the calice platform inflection, the layers or bands number 22; light bands alternate with dark. Light, more transparent, bands thinner than dark. Abundant vertical trabecular rods clearly visible near periphery, become shadowy and vague toward axis.

Comparison with related forms.—The greatest depth (vertical thickness) of the stereozone of *Mucophyllum mcintyrei* is greater than that of *M. crateroides* Etheridge. An undescribed species from the Roberts Mountains Formation (Silurian) of Nevada has more numerous and more uniformly thin incremental layering of the stereozone and more irregular thickening and undulation of the tabulae due to septal intersections.

Occurrence.—Unit 1, Gazelle Formation. South side of Mallethead Ridge on main fork of Willow Creek, China Mountain quadrangle, loc. M87. Study material of this new species consists of the single corallum collected at loc. M87 by J. R. McIntyre, and fragmentary material, possibly representing the same form, collected at Parker Rock loc. M1030.

Family LYKOPHYLLIDAE Wedekind, 1927

Reference form.—*Phaulactis cyathophylloides* Ryder, 1926. Wenlock, Silurian, Slite Group, Gotland, Sweden.

Solitary rugose corals with multiple columns of small to medium dissepiments; tabularium fairly wide, usually not abruptly differentiated at margin from dissepimentarium. Septa thickened and laterally in contact into or beyond neanic growth stage. No well-defined fossula in mature calice.

These profusely dissepimented Rugosa are the earliest of this kind in the geologic record. Devonian Halliidae and Bethanyphyllidae, though similar, have a mature fossula but do not have the persistent septal thickening in the neanic stages as do typical lykophyllids.

Genera classified in the Lykophyllidae are: *Phaulactis* Ryder, 1926, *Pycnactis* Ryder, 1926, *Holophragma* Lindström, 1896, *Desmophyllum* Wedekind, 1927, *Cyathactis* Soshkina, 1955, and *Ryderophyllum* Tcherepnina, 1965. This family is represented in the northeastern Klamath Mountains by *Cyathactis*.

Genus CYATHACTIS Soshkina, 1955

1955. *Cyathactis* Soshkina, p. 122, pl. 11, figs. 1, 2.
1963. *Cyathactis* Soshkina. Ivanovsky, p. 75.
1965. *Micula? catilla* Sutherland, p. 28, pl. 17.

Type species.—*Cyathactis typus* Soshkina, by author designation. Silurian; Russia.

Diagnosis.—Small to medium-sized trochoid and ceratoid Lykophyllidae. Septa numerous, long, thin, smooth, fairly straight at maturity; a wide dissepimentarium of small and medium globose dissepiments. Tabularium medium wide with closely spaced, mostly incomplete, axially flattened tabulae and marginal tabellae. No septal stereozone. Crowded dissepiments with angulo-concentric chevron pattern in transverse section.

Remarks.—Corals here assigned to *Cyathactis* resemble *Phaulactis* Ryder in advanced growth stages; the more significant differences are developmental. In the neanic stage, *Phaulactis* has thickened septa laterally in contact, followed by mature septal thinning (Minato, 1961, p. 46–68). Material showing earliest development of *Cyathactis* is not available, but late neanic transverse sections of *C. gazellensis*, 8 mm in diameter, reveal thinned septa. Comparable transverse sections of *Phaulactis cyathophylloides* show all septa in lateral contact. *Phaulactis* is described as passing through an early *Pycnactis* phase (Ryder, 1926, p. 385–390; pl. IX). By definition, *Pycnactis* retains thickened septa throughout mature growth, whereas *Phaulactis* commonly loses the thickening more or less completely in advanced stages. Individuals of *Phaulactis* may retain some initial dilation in cardinal quadrants well into mature growth, as is well illustrated by Minato's researches.

Corals which probably belong either in *Cyathactis* or *Phaulactis* have previously been assigned to *Cyathophyllum*, *Entelophyllum*, and *Xylodes*. Of these, *Xylodes* Lang and Smith, 1927 is an homonym as well as a synonym of *Entelophyllum* Wedekind. *Entelophyllum* is usually colonial, having narrower tabulae and cylindrical corallites with numerous lateral connecting processes. Some species assigned in the past to *Entelophyllum* have abundant zigzag carinae, not features of *Cyathactis*.

The genus *Micula* Sytova (1952, p. 133) has thickened septa within the dissepimentarium of mature coralla. It possesses a wider tabularium than *Cyathactis* with its tabulae less flattened axially and also a narrow septal stereozone not present in *Cyathactis*.

Many described and well-illustrated corals may be compared generically in detail with *Cyathactis gazellensis* n. sp. It is probable that "*Micula? catilla*" Sutherland (1965, p. 28, pl. 17, figs. 1–2; pl. 18, fig. 5) is congeneric. *Cyathophyllum prosperum* Barrande (in Počta, 1902, p. 105, pl. 103, figs. 6–8; Prantl, 1940, p. 12–21, text figs. 1–3, pl. II, figs. 5–7) has similar features in longitudinal section. *Cyathophyllum pegramense* (Foerste) is perhaps the closest American form (Amsden, 1949, p. 110, pl. XXXIV, figs. 5–7, 11, 12), but if it has initial septal thickening, it would be classified as *Phaulactis*. Further comparisons are made below under the description of *Cyathactis gazellensis*. *Ryderophyllum* Tcherepnina, 1965 is possibly a synonym of *Cyathactis*.

Cyathactis gazellensis, new species

Plate 6, figures 1–8

Type.—Holotype USNM 159448; paratypes USNM 159451, 159452,

Diagnosis.—*Cyathactis* with numerous uniform, smooth, slightly wavy septa which are very thin in the tabularium and thin or very slightly thickened in the dissepimentarium. Some tabulae nearly complete with axial flattening and peripheral sag. Dissepiments in multiple columns, external ones flattened-elongate, inclined axially at low angle. Chevron pattern of close-set dissepiment traces shown in transverse section.

External features.—Small curved-trochoid individuals characteristic, larger ones become ceratoid distally. Some individuals with prominent rugae or rejuvenescence flanges.

Mature transverse sections.—Major septa about 34, some of which reach the axis; minor septa exceed one-half the length of major septa. Chevron dissepiment traces most numerous in middle of dissepimentarium, become wider spaced and less regular near wall. Wall thin; stereozone absent. Symmetry entirely radial, without trace of fossula.

Neanic transverse sections.—A neanic section 8 mm in diameter with uniformly thin septa numbering about 48, of which the longer major septa approach the axis. No stereoplasmic thickenings. No fossula.

Longitudinal sections.—Tabularium slightly more than one-half corallite diameter and not sharply set off from the dissepimentarium. Most tabulae incomplete, slightly arched, with axial flatness or slight sag; marginal tabellae border the peripheral sag. Tabulae closely spaced. Wide dissepimentarium comprising as many as 16 columns on each side. Many peripheral dissepiments fairly large, elongate, or flattened; near the wall are inclined axially at a low angle.

Reproductive offsets.—No offsets were found in this solitary species. An individual of *Cyathactis catilla* as figured by Sutherland (1965, pl. 17, fig. 3b) shows four offsets at the calice periphery.

Microstructure—Septa reveal no trace of trabecular structure.

Comparison with related forms.—*Cyathactis catilla* (Sutherland) of the Silurian Henryhouse Limestone possesses a similar longitudinal section; in transverse section the concentrated chevron pattern of dissepiment traces is not developed as in *gazellensis*. However, *catilla* appears more closely related morphologically to *Cyathactis* than to *Micula* or to *Phaulactis*. Sytova's *Micula antiqua* (Sytova, 1952, p. 134, pl. 1, figs. 1–11) has a more nearly cylindrical shape, a wider tabularium, thickened septa, and a thicker wall.

Cyathophyllum pegramense (Foerste) is similar in gross characteristics (Amsden, 1949, p. 110, pl. XXXIV, figs. 5–7, 11, 12), but it has a wider tabularium and the transverse chevron pattern is less developed. Illustrations of the neanic stage in transverse sections are not available, but Amsden's longitudinal section suggests that *pegramense* has thickened septa at this stage and, therefore, may belong in *Phaulactis*.

A lykophyllid species in Silurian coral zone B of the Great Basin Hidden Valley Dolomite has a less concentrated chevron pattern than *Cyathactis gazellensis* and a wider tabularium; the neanic development is unknown. This form is provisionally assigned to *Ryderophyllum*.

Among well-illustrated foreign species of true *Phaulactis*, there are rather close resemblances in mature transverse section to *P. irregularis* (Wedekind) and *P. cyathophylloides* Ryder (Minato, 1961, pl. V, figs. 14–15; pl. VII, figs. 10–20; pl. II, fig. 23). However, these Gotland species lack the concentrated chevron pattern of *Cyathactis gazellensis*.

Cyathophyllum prosperum Barrande of the Bohemian Late Silurian (Tachlowitz, e2) shows a similar tabularium, but many more of the dissepiments are nearly horizontal and the corallum is subcylindrical. In transverse section the Bohemian species reveals thickened septa and a more complex pattern of dissepiment traces (Prantl, 1940, text figs. 6, 7, pl. II, fig. 5). The genus name *Xylodes*, applied to this foreign species, is an homonym and also a possible synonym of *Entelophyllum* Wedekind; the latter term seems inappropriate for the Gazelle fossil on morphologic grounds.

Occurrence.—Unit 2, Gazelle Formation at Bonnet Rock, loc. M191. Parker Rock, loc. M1030. Study material from Bonnet Rock includes 16 coralla.

Family CYSTIPHYLLIDAE Edwards and Haime, 1850

Reference form.—*Cystiphyllum siluriense* Lonsdale,[10] 1839. Silurian, Wenlock Limestone, Dudley, England.

Silurian *Cystiphyllum*, one of several genera characterized by mature internal structure mainly of cystose dissepimental tissue, is distinguished by trabecular septal spines like those of the Tryplasmatidae. Weak radiating spiny septal ridges on the calice floor are the nearest approach to continuous septa (Edwards and Haime, 1850–54, p. 298, pl. 72, fig. 1a; Počta, 1902, pls. 36–40). There is a considerable difference among species in the size and number of septal spines; in fact, some of the western Silurian cystiphyllids reveal none and cannot, therefore, be placed in the genus with complete certainty.

Cystiphylloids of the Devonian include homeomorphic genera not known to be related genetically to Silurian *Cystiphyllum*. These do not have the trabecular septal spines and are classified in other families such as Cystiphylloididae and Digonophyllidae; the latter has strong septal crests and discrete, but usually discontinuous, septa.

Forms assigned to the family Cystiphyllidae are: *Cystiphyllum* Lonsdale,[10] 1839. *Hedströmophyllum* Wedekind, 1927, *Holmophyllum* Wedekind, 1927, and possibly *Microplasma* Dybowski, 1873. The group of *Cystiphyllum? henryhousense* Sutherland (1965), may constitute another potential genus or subgenus in this largely Silurian family.

Genus CYSTIPHYLLUM Lonsdale, 1839

1839. *Cystiphyllum siluriense* Lonsdale. In Murchison, 1839, p. 691, pl. xvi bis, fig. 1 (not fig. 2).
1850–54. *Cystiphyllum* Lonsdale. Edwards and Haime, p. lxxii. *Cystiphyllum siluriense* Lonsdale. Edwards and Haime, p. 298, pl. LXXII, figs. 1, 1a.
1927. (?) *Cystiphyllum siluriense* Lonsdale. Wedekind, p. 65, pl. 19, figs. 3–5.
1940. *Cystiphyllum* Lonsdale. Lang, Smith, and Thomas, p. 48.
1949. (?) *Cystiphyllum lineatum*? Davis. Amsden, p. 112, pl. XXIX, figs. 6–11.
1956. (?) *Cystiphyllum* Lonsdale. Hill, p. F312, fig. 214: 1a–b.
1965. *Cystiphyllum* Lonsdale. Sutherland, p. 23–24.

Type species.—*Cystiphyllum siluriense* Lonsdale, 1839; by subsequent designation Edwards and Haime (1850–54, pl. lxxii). Edwards and Haime cite Lonsdale (in Murchison, 1839, pl. xvi bis, fig. 1); they note that only fig. 1 represents the type species; thus they exclude fig. 2. Wenlock Silurian; Dudley, Worcestershire, England.

Diagnosis.—Trochoid, turbinate, and ceratoid rugose corals with shallow to moderately deep conical calice. Internal tissue predominantly dissepimental; septa, if present, represented by radially alined, slender, mostly short trabecular spines extending inward and upward from convex distal surfaces of dissepiments and tabulae. Tabularium commonly not sharply differentiated from dissepimentarium; wide near-horizontal tabulae absent in mature growth stages.

Remarks.—There is clearly much homoeomorphy among cystiphylloid corals. The Silurian *Cystiphyllum*-like corals are numerous and diverse but not sufficiently well understood at present to make possible a meaningful classification. Among them are possible new generic and subgeneric groupings based on such criteria as growth habit, width and discreteness of tabularium and size, abundance or absence of the trabecular septal

[10] Pages 675–699 and 5 plates in Murchison, 1839.

spines. In addition to the supposedly slender-spined type species *siluriense*, possibly new and distinct genera are embodied in such forms as *Cystiphyllum? henryhousense* Sutherland (1965, p. 24, pls. 13–16). Variation studies like that made by Sutherland are needed for all other cystiphylloid genera. A wide discrete tabularium and elongate subcylindrical growth habit distinguish the unit of *henryhousense*, which, as noted by Sutherland (1965, p. 23), should probably be viewed as generically distinct from *Cystiphyllum* proper.

New cystiphylloid genera with wide discrete tabularia have recently been described from the Siberian Platform by Ivanovsky (1963, p. 103–110, pls. XXIX–XXXIII). The variation range of these Siberian Rugosa requires elucidation in comparison with *henryhousense* and other species.

To judge from study of western North American Silurian cystiphylloids, trabecular septal spines are the exception rather than the rule. Alaskan Silurian forms from Kuiu Island reveal no spines; these have a well-differentiated tabularium and an outermost narrow zone of small compact dissepiments. The few specimens of cystiphylloids collected from the Gazelle Formation do not show trabecular septal spines.

Distinguishing Silurian cystiphylloids from some of those of the Devonian is difficult. Devonian species are generally considered to lack trabecular spines. Many of the larger Devonian forms are homoeomorphic and wholly distinct genetically. Some are classified with the Digonophyllidae; these have all degrees of septal development, from none whatever to sporadic septal crests to radially continuous lamellar septa. Theoretically the septal crests of Devonian cystiphylloids are distinguishable from the trabecular septal spines of Silurian true *Cystiphyllum*. Devonian species usually lack wide near-horizontal tabulae like *henryhousense*.

Cystiphyllum sp. c

Plate 1, figures 15, 16; plate 3, figures 5, 6

The Gazelle corals classified as *Cystiphyllum* sp. c are medium to large size for this genus, external configuration trochoid to ceratoid. Conical calice deep, above a poorly differentiated tabularium; wide dissepimentarium reveals as many as 11 columns of large, elongate dissepiments on each side. Nonuniform tabularium formed of one or two large semiglobose axial tabellae with flat bases, or less commonly, a single wide continuous sagging tabula which terminates like an axially inclined dissepiment. No trabecular spines on most individuals. In longitudinal thin section most dissepiments have steeply inclined bases. In transverse section the pattern is of fairly uniform large, peripherally concave or lonsdaleioid dissepiments with a few scattered smaller ones. Trabecular spines, although uncommon, in the peripheral zone and near the wall of this species.

Cystiphyllum sp. c has relatively larger axial tabellae than the form figured by Edwards and Haime (1850–54, pl. 72, figs. 1, 1a) as *C. siluriense* Lonsdale, the type species. Wedekind's figures (1927, pl. 19, figs. 3–5) of *siluriense* from Gotland show numerous trabecular spines not present in *Cystiphyllum* sp. c. *Cystiphyllum? henryhousense* Sutherland has an elongate subcylindrical growth habit, a well-differentiated and very wide tabularium, and scattered trabecular spines internally—all features which distinguish it from *Cystiphyllum* sp. c.

Occurrence.—Unit 2, Gazelle Formation, Willow Creek area. Chastain Ridge, loc. M1135; Bonnet Rock, loc. M191.

Family KYPHOPHYLLIDAE Wedekind, 1927

Named for the Gotland Silurian *Kyphophyllum lindströmi* Wedekind, this family, as presently interpreted, comprises cerioid and fasciculate species with elongate subcylindrical corallites having long lamellar septa and one to several dissepiment columns of which the outermost in some forms are lonsdaleioid. Tabulae in most are rather wide and uparched. An axial structure is developed in species of *Petrozium*.

Genera provisionally included in the Kyphophyllidae are: *Kyphophyllum* Wedekind 1927, *Strombodes* Schweigger, 1819, *Petrozium* Smith, 1930, *Entelophyllum* Wedekind, 1927, *Entelophylloides* Rukhin, 1938, *Neomphyma* Soshkina, 1937, and the new genus *Shastaphyllum*. Of these *Kyphophyllum*, *Petrozium*, and *Shastaphyllum* have been found in the beds of the northeastern Klamath subregion that are Silurian to possible Early Devonian.

Genus KYPHOPHYLLUM Wedekind, 1927

1927. *Kyphophyllum* Wedekind, p. 18–22, pl. 2, figs. 7–10; pl. 27, figs. 13–16.
1937. *Kyphophyllum* Wedekind, Soshkina, p. 90–91, pl. III, figs. 1–5.
1940. *Cyphophyllum* Lang, Smith, and Thomas, p. 47.
1952. *Kyphophyllum* Wedekind; Sytova, p. 144–150, text figs. 2, 15, 16, 17, 18, 19, 20; pl. V, figs. 1–7, pl. VI, figs. 1–6.

Type species.—*Kyphophyllum lindströmi* Wedekind, 1927 (by original designation). Silurian; Gotland, Sweden.

Diagnosis.—Solitary and compound phaceloid rugose corals with a narrow to moderately wide septal stereozone, a nonuniform peripheral zone partly of lonsdaleioid dissepiments, long thin septa (some of which extend to the axis), and a medium to wide tabularium with complete and incomplete tabulae.

Remarks.—Species assigned to this genus also resemble phaceloid *Pilophyllum* but differ by having a somewhat narrower septal stereozone and a decidely narrower tabularium. The tabulae of *Pilophyllum* are very wide, closely spaced, and largely incomplete. *Neomphyma* Soshkina 1937 differs from *Kyphophyllum* by having a very narrow tabularium with large and irregular lonsdaleioid dissepiments.

Kyphophyllum greggi, new species

Plate 8, figures 1–5, 8.

Type.—Holotype, USNM 159461; paratypes, USNM 159462, 159463.

Diagnosis.—*Kyphophyllum* with medium septal stereozone, medium-wide to wide, closely spaced, partly complete tabulae with axial sag. Peripheral zone with septal crests.

External appearance.—Bushy heads, medium-sized, with small corallites; fairly compact to loose with matrix-filled interstices. No lateral connections observed. Longitudinal (septal) grooves well defined.

Transverse sections.—Major septa number about 22, some extend to the axis; minor septa commonly more than one-half the length of major septa. Septa straight or slightly wavy; generally thin except for peripheral stereozone. Though some slightly thicken at axis, no axial structure is formed. Mature stages have groups of larger lonsdaleioid dissepiments in localized patches.

Longitudinal sections.—Dissepiments in two to four columns on each side, mostly elongate; outer as well as inner dissepiments commonly inclined steeply. Tabulae usually sag rather than uparch as in the type species.

Reproductive offsets.—Numerous small interstitial corallites represent offsets from mature calice rims.

Fine structure.—Septal stereozone with fine lamellar structure in stereoplasm, but no distinctive trabecular features observed.

Comparison with related forms.—*Kyphophyllum greggi* resembles a form in the Ural Mountains assigned by Sytova (1952, p. 145) to *K. lindströmi* Wedekind, a Gotland species. The new species, *greggi*, does not, however, have uparched tabulae, which seem to be a feature of the Ural species. Typical *lindströmi* (Wedekind, 1927, pl. 2, figs. 7–10) differs by having more widely spaced, uparched tabulae, fewer elongate dissepiments, and a larger septal count. Closely related forms occur in the Late Silurian (coral zone E) of the Toquima Range of central Nevada (p. 8, fig. 6).

Occurrence.—Coral-rich limestone of Silurian or Early Devonian age at Gregg Ranch, loc. M1133. Study material consists of parts of four large coralla, each with numerous corallites (pl. 7, figs. 11–14; pl. 8, fig. 7).

Genus PETROZIUM Smith, 1930

Type species.—*Petrozium dewari* Smith (by original designation). Silurian (Valentian); Buildwas, Shropshire, England.

Diagnosis.—Smith's original diagnosis is as follows:

Dendroid rugose corals with long cylindrical corallites, which are reproduced non-parricidally by marginal gemmation; thin carinate septa of which the major reach or nearly reach the axis; small, distally arched tabulae; and small well-developed dissepiments.

Remarks.—Smith's figures are not sufficiently enlarged to show the details of carinate septa. Of the three American species referred to this genus and here discussed, only one has suggestions of zigzag carinae; the other two have smooth septa. The axial structure may be well developed as a rod reinforced by stereome, as in the Alaskan *Petrozium* from Kuiu Island, or it may be incipient or undeveloped as in the other two species and in *Dewari*, the type species. The arching tabulae of the tabularium, well illustrated by Smith (1930, pl. xxvi, fig. 28), seem to be characteristic of the genus; globose or strongly arched axial tabulae (or tabellae) are bordered periaxially by smaller tabellae of a depressed zone. The axial tabellae may be combined with septal ends in an axial structure. The globose dissepiments are in two or three columns; the outer column is commonly almost horizontal.

The stratigraphic range of *Petrozium* is unknown, but the type species is Valentian or Lower Silurian; the Hidden Valley form occurs in Silurian coral zone B of the Great Basin, which is probably Wenlockian and possibly well down in that stage.

Petrozium differs from Devonian *Disphyllum* which lacks the uparched tabular features of *Petrozium* and does not have an incipient or well-developed axial structure.

Petrozium staufferi, new species

Plate 7, figures 1–6

1894. *Diphyphyllum fasciculum* Meek. Schuchert, p. 422 (in Diller and Schuchert).

1930. *Diphyphyllum fasciculum* Meek. Stauffer, p. 98.

Type.—Holotype, USNM 159458.

Diagnosis.—*Petrozium* with fairly compact phaceloid growth habit, forms heads more than one foot in diameter. Corallites slender. Septa non-carinate; longer septa extend to axis where some join but do not form a discrete axial structure. Wall thin, without continuous stereozone. Dissepimentarium narrow, commonly in two columns; peripheral dissepiments nearly horizontal. Some of the wide strongly uparched tabulae nearly complete.

External features.—Large colonies of this species fairly compact to more open phaceloid; always with considerable amounts of argillaceous matrix between the roughly parallel cylindrical corallites. Outer surfaces of corallities with epitheca which is covered by fine incremental transverse raised rings, but otherwise devoid of prominent rugae. No transverse connections observed between corallites.

Transverse sections.—Slender corallites with about 18 major septa. Major septa tend to become more irregular toward the axis; some merge laterally; others radially. Minor septa usually more than half the length of major septa. Septa smooth, slightly thickened. No uniform septal stereozone. Irregular patches of stereoplasmic infilling. In corallites where most major septa meet axially, no discrete rod or axial structure. Axial union of a pair of major septa in some corallites suggests a cardinal fossula.

Longitudinal sections.—Width of tabularium exceeds half the corallite diameter. Tabulae strongly uparched, with periaxial depression; some tabulae nearly complete. Dissepiments usually in two columns, less commonly three or even four; outer dissepiments nearly horizontal, inner dissepiments more nearly vertical.

Reproductive offsets.—None observed. Probably develop as several offsets from outer edge of calice.

Comparison with related forms.—*Petrozium staufferi* differs from the type species *P. dewari* Smith by lacking carinae, but it is otherwise quite similar. An undescribed species from the Silurian and Early Devonian Hidden Valley Dolomite of the Panamint Mountains, Calif., has thicker septa peripherally, with a few zigzag carinae; its dissepiments are relatively smaller and form more numerous vertical columns. The Alaskan *Petrozium* from the Silurian of Kuiu Island has an even wider dissepimentarium and an axial column reenforced by stereoplasm to form a discrete rod (pl. 7, figs. 7, 8).

Occurrence.—Unit 2, Gazelle Formation; Bonnet Rock, loc. M191. This species seems to be the more abundant colonial rugose coral in unit 2, where it is associated with *Cyathactis gazellensis*. Study material of this form consists of parts of at least four large coralla comprising several hundreds of corallites.

Genus SHASTAPHYLLUM, new genus

Type species.—*Shastaphyllum schucherti* n. sp., here designated. Silurian, Gazelle Formation; northeastern Klamath Mountains, Calif.

Diagnosis.—Cerioid rugose corals with elongate, slender, thin-walled corallites. Septa numerous, thin and noncarinate; some major septa extend to axis. Tabularium narrow; tabulae straight, complete, and closely spaced. Dissepiments relatively large, steeply inclined, some elongate or lonsdaleioid peripherally, and arranged in three or four columns.

Remarks.—Some corallites may lack lonsdaleioid features. *Shastaphyllum* differs from *Spongophyllum*, as represented by its type species, *S. sedgwicki* Edwards and Haime, by having a much thinner wall, more numerous septa, more dissepiment columns, and a narrower tabularium.

Unrelated cerioid and phaceloid Rugosa with nonuniform scattered lonsdaleioid dissepiments like *Shastaphyllum* have, from time to time, been placed by authors in *Spongophyllum*. (See Birenheide, 1962.) It is proposed that only those resembling *sedgwicki* (with thick-walled slender corallites, few dissepiment columns and sporadic lonsdaleioid features) be included. Those having a more uniform, wide and continuous lonsdaleioid band and lacking an axial structure are here classified as Endophyllidae including *Klamathastraea* n. gen. and *Australophyllum*. *Australophyllum*, as here employed, includes species previously assigned by authors to *Spongophyllum*.

Shastaphyllum differs from *Evenkiella* Soshkina, 1955, as represented by *E. helenae* Soshkina (Ivanovsky, 1963, p. 88; pl. XXIV, figs. 2a–b), by having a much wider tabularium. *Tenuiphyllum* Soshkina, 1937 differs by having wider uparched tabulae and a suggestion of an inner wall in some mature corrallites.

Shastaphyllum schucherti, new genus, new species

Plate 2, figures 1–6; plate 3, figure 4; plate 4, figure 8

1894. *Acervularia* sp. undet. Schuchert, p. 422 (in Diller and Schuchert).
1930. *Acervularia* sp. Stauffer, p. 98.

Type.—Holotype, USNM 159457 loc. M1132; paratype, USMN 159465, Loc. M1135; Chastain Ridge, Willow Creek area, northeastern Klamath Mountains, Calif. Ludlovian, Late Silurian.

Diagnosis.—*Shastaphyllum* with about 60 uniformly thin septa, slender corallites and delicate internal structure. Scattered irregular lonsdaleioid dissepiments in peripheral zone; very narrow tabularium in some corallites.

Transverse sections.—Major septa average about 29, thin, noncarinate, fairly straight, even, or minutely wavy; many septa reach the axis where the tips may be dilated. No continuous stereozone, but thin septa wedge out abruptly toward wall. Minor septa range from very short peripheral wedges to those more than one-third the length of major septa. Septa discontinuous peripherally in patches of lonsdaleioid dissepiments

Longitudinal sections.—Tabularium narrow, usually less than one-fourth the width of corallite, less commonly widening to one-third the width. Tabulae very thin, straight, unarched, complete, and closely spaced. Dissepiments retatively large, partly elongate, and steeply inclined, in three or four columns on each side. Tabulae vague or unrecognizable in some corallites.

Reproductive offsets.—Transverse sections show offsets from calice rim and probably also within calice. Some immature corallites with slight septal thickening toward axis; septal thickening produces an incipient aulos.

Comparison with other forms.—This coral differs greatly from *Spongophyllum sedgwicki*, the type species of *Spongophyllum*, which has a thick wall, fewer septa, and fewer dissepiment columns. *Spongophyllum inficetum* Počta (1902, pl. 102, fig. 1; Prantl, 1952, p. 13, pl. 1, fig. 2) of the Bohemian Late Silurian possesses more numerous and regular lonsdaleioid dissepiments. *Spongophyllum shearsbyi* Chapman of the Yass, Australia, Silurian (Hill, 1940, p. 408, pl. XII, figs. 1, 2) has a thicker wall, more fully developed lonsdaleioid dissepiments, and a wider tabularium.

Spongophyllum saumaensis Shurygina (1968, p. 134, pl. 59, figs. 4a–b) which is from the eastern slope of the Ural Mountains, appears to be congeneric with the Gazelle form, but it differs specifically by having a thicker wall, fewer septa, and more numerous lonsdaleioid dissepiments. Both species have the narrow tabularium of *Shastaphyllum* and are quite similar in longitudinal section. Although regarded by Shurygina (1968, p. 123) as Early Devonian, the associated rugose coral assemblage is quite suggestive of faunas from the Cordilleran belt of North America, here interpreted as Late Silurian (Ludlovian).

In transverse section *Shastaphyllum schucherti* resembles *Tenuiphyllum ornatum* Soshkina (1937) of the Ural Mountains Silurian; this Russian form differs in its wider arched tabulae and greater number of dissepiment columns. *Tenuiphyllum ornatum* has a suggestion of an inner wall in some mature corallites, a feature observed only in immature corallites of *Shastaphyllum*.

Occurrence.—Gazelle Formation, Willow Creek area; Chastain Ridge; at fault contact of unit 1 and unit 3, loc. M1135. Holotype from Diller collection, loc. M1132.

Similar corals occur in the upper middle part of the Silurian and Devonian(?) Vaughn Gulch Limestone of Owens Valley, Inyo County, Calif.

Study material of *Shastaphyllum schucherti* consists of five coralla and fragments of other coralla.

Shastaphyllum? sp. c
Plate 4, figures 6, 7

An unusually well preserved partial corallum from the Hayfork vicinity, Trinity County, Calif., is provisionally assigned to the new cerioid genus *Shastaphyllum*.

Shastaphyllum? sp. c has about 40 thin, fairly straight, noncarinate septa; some of the major septa reach the axis. Minor septa may exceed half the length of major septa. No stereozone; the fairly even septa do not wedge out approaching the thin wall. Lonsdaleioid dissepiments, if present, inconspicuous. Tabularium one-fourth to one-third the corallite width; some tabulae complete, fairly straight. Dissepiments, three or four columns, medium to large, axially inclined at low angles for this genus.

Shastaphyllum? sp. c differs from *S. schucherti* n. gen., n. sp., of the Silurian Gazelle by having larger corallites and a much lower septal count, by lacking well-defined lonsdaleioid features, and by the flatness of its dissepiments. *Shastaphyllum*? sp. c bears some resemblance to an undescribed *Entelophylloides* in the Silurian Roberts Mountains Formation (Great Basin Silurian coral zone C) of central Nevada. The Nevada coral has more numerous columns of small dissepiments, a higher septal count, and somewhat arched tabulae.

Occurrence.—Hayfork area, southern part of the Hayfork quadrangle, Trinity County, Calif., loc. M1281. Collected by W. P. Irwin of the U.S. Geological Survey, 1968. This coral was not found in place, and the strata from which it came are unknown. Other identified Paleozoic fossils from this general vicinity are of late Paleozoic age.

Family ENDOPHYLLIDAE Torley, 1933

Reference forms.—*Endophyllum bowerbanki* Edwards and Haime, and *E. abditum* Edwards and Haime, 1851. Devonian, Torquay, England.

Cerioid and aphroid rugose corals with wide to very wide corallites. A broad marginarium with some large lonsdaleioid dissepiments. Tabularium, narrow to very wide, with closely spaced tabulae. No axial structure.

Genera provisionally assigned to the Endophyllidae are as follows:

Endophyllum Edwards and Haime, 1851
Yassia Jones 1930
Australophyllum Stumm, 1949
An undescribed Great Basin Silurian subgenus of *Australophyllum*
Klamathastraea n. gen.

Pilophyllum Wedekind of the Gotland Silurian, a solitary or phaceloid genus, may likewise belong in this family, but it differs from the others by having a wider septal stereozone and a noncompact subcylindrical growth habit.

Some corals here assigned to the Endophyllidae have previously been placed by authors in *Spongophyllum*. True *Spongophyllum*, as typified by *S. sedgwicki* Edwards and Haime, is excluded from the Endophyllidae, as here redefined, by reason of its slender corallites, rather narrow tabularium, and narrower, simpler, and possibly only sparingly lonsdaleioid dissepimentarium.

It is proposed that the generic name *Spongophyllum* be reserved for species agreeing in general structure and proportions with the Devonian *S. sedgwicki*, as originally illustrated by Edwards and Haime (1853, pl. 56, figs. 2, 2a–c, and 2e). These figures reveal a thickened wall and little suggestion of lonsdaleioid features in four of the five transverse views; only figure 2d of Edwards and Haime's plate 56 shows a lonsdaleioid pattern. There is no assurance that the form so illustrated (fig. 2d) is conspecific. (See also Stumm, 1949, p. 31, pl. 14, figs. 10, 11; Birenheide, 1962, p. 68–74, pl. 9, fig. 8, pl. 10, fig. 10.)

Lonsdaleioid dissepiments recur in several rugose coral families and by themselves are not regarded as indicative of direct genetic relationship. Among the Silurian Rugosa, dissepiment patterns of this kind characterize the Endophyllidae as well as other families to which belong the following genera: *Ketophyllum*, *Spongophylloides*, *Strombodes*, *Kyphophyllum*, and *Pilophyllum*. Of the various Devonian rugose coral groups with lonsdaleioid features, several of cerioid habit have, from time to time, rather indiscriminately been classified as *Spongophyllum*. Some of these may more appropriately be assigned to *Australophyllum;* others are perhaps allied to *Hexagonaria*. Late Paleozoic columellate corals like *Lonsdaleia*, which has a marginarium of this pattern, are well known.

Abbreviation or loss of mature septa is a tendency manifested by the later Silurian Endophyllidae. Among these are *Yassia*, without mature septa; a subgenus of *Australophyllum* (see *Australophyllum* sp. E, pl. 4, figs. 1–3), with septa reduced or lost in some corallites; and the new genus *Klamathastraea*, with similarly reduced or obsolete septa.

Genus KLAMATHASTRAEA, new genus

Type species.—Klamathastraea dilleri n. sp.; here designated. Silurian Gazelle Formation, Siskiyou County, Calif.

Diagnosis.—Cerioid endophyllid corals with wide, straight, flat and mostly complete tabulae. Septa usually short, confined to outer part of tabularium. Lonsdaleioid dissepimentarium wide, outer dissepiments flat. Septal crests absent. Wall thin.

Remarks.—Tabulae commonly have a well-defined peripheral depression. *Endophyllum* is distinguished by its wider tabulae, more persistent peripheral depression, and much longer septa which may reach the axis and extend laterally to break up as septal crests. Moreover, the British Devonian *Endophyllum* includes aphroid forms lacking an outer wall as well as cerioid forms with a much thicker wall than *Klamathastraea*. (See Jones, 1929, p. 84–87, pl. X, figs. 1–4.)

Australophyllum differs from *Klamathastraea* by having a narrower tabularium with overall proximal sag and lacking a peripheral depression. Also its long septa may reach the axis and extend laterally as septal crests. *Yassia* Jones of the Australian Silurian has narrower tabulae and is without septa, but it otherwise resembles *Klamathastraea*.

Klamathastraea dilleri, new genus, new species

Plate 5, figures 1–5

1894. *Endophyllum* n. sp. Schuchert (in Diller and Schuchert), p. 420–422.

1930. *Endophyllum* sp. Stauffer, p. 98.

Type.—USNM 159456; Silurian; Gazelle formation, Siskiyou County, Calif. Loc. M1132.

Diagnosis.—Klamathastraea with short septa distinguishable as major and minor; no conspicuous overall tapering or waviness. Peripheral depression of tabulae well developed to absent in some corallites.

External features.—Holotype a large flattened lenticular head about 10 inches in greatest diameter. Weathered upper surface resembles that of *Lonsdaleia* or *Lithostrotionella* without axial structures. Corallites mostly large; small interstitial corallites and calice offsets unknown.

Transverse sections.—Septa about 38, short, simple, unthickened, without overall axial taper, commonly alternate short and very short. Dissepimentarium without septal crests; thin wall lacks wall crests. Some larger dissepiments unevenly concave outward.

Longitudinal sections.—Dissepimentarium sharply set off from tabularium. Lonsdaleioid dissepiments mostly large and elongate, in three to six columns in mature stages; flattened and horizontal near periphery, axially becoming near vertical. Wide tabulae closely spaced, with peripheral sag lacking in parts of some corallites.

Fine structure.—Recrystallization has destroyed trabecular structure in the very narrow stereozone. A median dark threadlike wall band paralleled by narrow, discontinuous hyaline strands on one or both sides.

Reproductive offsets.—Unknown.

Comparison with other forms.—Klamathastraea dilleri n. sp. resembles undescribed Silurian species of *Australophyllum*, especially a subgenus occurring in the higher Silurian limestone (Great Basin Silurian coral zone E) of the central Great Basin (pl. 4, figs. 1–3); however, these species lack the peripheral depression of the tabulae, which are narrower, and they normally have long septa with septal crests. *Australophyllum fritschi* (Novak) from beds of possible Late Silurian age in Czechoslovakia (p. 5, figs. 6–8) has a thicker wall with wall crests, less even tabulae with no peripheral sag, and corallites with long septa; other sporadic corallites have reduced septa like *K. dilleri*.

Remarks.—The holotype of *Klamathastraea dilleri*, here described, is believed to be the specimen referred to in Diller's field notes of October 20, 1884, as having come from the limestone at Bonnet Rock. Mistakenly identified as "*Lithostrotion*" (Walcott, 1886), this coral was probably the basis for an initial Carboniferous age assignment of the Gazelle Formation.

Occurrence.—Unit 2, Gazelle Formation, west side of Bonnet Rock, Willow Creek area. Greenish-gray shale attached to the base of this coral agrees lithologically with the argillaceous matrix of the rubbly conglomeratic limestone from which most of the well-preserved Gazelle fossils in that area have come.

LOCALITY REGISTER

(See figs. 1, 2, and 64)

Northeastern Klamath subregion

Willow Creek area

Locality M191.—Yreka quadrangle, Calif. (1954); Bonnet Rock, southwest side, SE¼ sec. 6, T. 42 N., R. 6 W., altitude 4,000 feet. Nodular argillaceous limestone of unit 2, Gazelle Formation.

Locality M1132.—Yreka quadrangle, Calif. (1954); Bonnet Rock, west side, sec. 6, T. 42 N., R. 6 W. Old USGS number 586. Heads of rugose corals from this locality are labeled as collected by "Storrs," Nov. 1, 1893. However, Diller's field notes of 1884 refer to similar corals collected at that time, probably from unit 2 of the Gazelle Formation.

Locality M78.—Yreka quadrangle, Calif. (1954); Chastain Ridge, south end, NW¼ sec. 7, T. 42 N., R. 6 W., about one-third of a mile northnortheast of old Chastain Ranch house (now Payton Ranch). Collections made at east edge of massive limestone outcrop and 700 feet east of a limestone quarry. Loose fossils weather from shale near a fault, probably having come from unexposed unit 2 or topmost beds of unit 1 in the Gazelle Formation. Original collections of 1933 made by R. A. Bramkamp, F. E. Turner, and C. W. Merriam.

Locality M190.—Yreka quadrangle, Calif. (1954); Chastain Ridge, south end, NW¼ sec. 7, T. 42 N., R. 6 W., 1,800 feet north of Lime Gulch road, on east side of ridge, altitude 3,600 feet. Lower part of thick-bedded limestone of unit 3, Gazelle Formation.

Locality M87.—China Mountain quadrangle, Calif. (1955); south side of Mallethead Ridge on main fork of Willow Creek, NW¼ sec. 19, T. 42 N., R. 6 W.; 1,000 feet north of creek, 500 feet east of section line; altitude 3,500 feet. Limestone lenses with rugose corals.

Locality M230.—Yreka quadrangle, Calif. (1954); Chastain Ridge, south end. Field loc. S26, Aug. 31, 1951; same general locality as M78.

Locality M1135.—Yreka quadrangle, Calif. (1954); Chastain Ridge, south end, east side, SW¼ sec. 6, T. 42 N., R. 6 W., 500 feet north of section line, altitude 3,600 feet. Near contact of unit 3 massive limestone and unit 1, Gazelle Formation.

Locality M1280.—Yreka quadrangle, Calif. (1954); upper part of Lime Gulch, 1 mile east of Payton Ranch house, NE¼NW¼SW¼ sec. 12, T. 42 N., R. 7 W. Gazelle Formation; *Monograptus* locality of Michael Churkin, Jr. (1965).

Parker Rock (Lovers Leap) area

Locality M81.—Etna quadrangle, Calif. (1934); at Rail Creek–Kangaroo Creek divide on Rail Creek side, SE¼ sec. 29, T. 41 N., R. 7 W. Small limestone outcrop.

Locality M83.—Etna quadrangle, Calif. (1934); northwest side of Parker Rock, altitude 4,700 feet; SW¼ sec. 29, T. 41 N., R. 7 W. Limestone cobbles with silicified fossils in conglomerate associated with *Halysites*-bearing limestone.

Locality M84.—Etna quadrangle, Calif. (1934); northwest side of Parker Rock, altitude 4,700 feet; SW¼ sec. 29, T. 41 N., R. 7 W. Other fossil-rich cobbles from same conglomerate as M83 but containing a different fauna.

Locality M85.—Etna quadrangle, Calif. (1934); southeast side of Parker Rock, altitude 4,600 feet; NW¼ sec. 32, T. 41 N., R. 7 W. Fossiliferous limestone cobbles in breccia-conglomerate.

Locality M86.—Etna quadrangle, Calif. (1934); south side of Lovers Leap at west end Parker Rock, altitude 4,800 feet; NE¼ sec. 31, T. 41 N., R. 7 W. Thinly bedded gray limestone beneath massive limestone caprock of Parker Rock.

Locality M90.—Etna quadrangle, Calif. (1934); on top of ridge at Parker Rock; SW¼ sec. 29, T. 41 N., R. 7 W., altitude 5,000 feet. Massive *Halysites*-bearing limestone on ridge line near boundary between sections 29 and 32.

Locality M1028.—China Mountain quadrangle, Calif. (1955); east side of Parker Rock near top; SE¼ sec. 29, T. 41 N., R. 7 W., altitude 5,000 feet. Fossil-bearing conglomeratic limestone below massive limestone caprock of Parker Rock, 1 mile south of Gregg Ranch house.

Locality M1029.—China Mountain quadrangle, Calif. (1955); south side of Parker Rock; NE¼ sec. 32, T. 41 N., R. 7 W., altitude 4,800 feet. Rubbly conglomeratic limestone beneath massive gray limestone caprock of Parker Rock.

Locality M1030.—China Mountain quadrangle, Calif. (1955); southeast side of Parker Rock, NE¼ sec. 32, T. 41 N., R. 7 W., altitude 4,700 feet near boundary of sections 32 and 33. Near base of massive limestone caprock of Parker Rock.

Gregg Ranch area

Locality M80.—China Mountain quadrangle, Calif. (1955); southwest of Gregg Ranch house on east fork Scott River ("Plowmans Valley"), south of Callahan road; SE¼NE¼ sec. 20, T. 41 N., R. 7 W. Fossiliferous limestone cobbles from conglomerate.

Locality M82.—China Mountain quadrangle, Calif. (1955); east fork of Scott River three-fourths of a mile northeast of Gregg Ranch house; SE¼ sec. 16, T. 41 N., R. 7 W., altitude 4,150 feet. Small limestone outcrop with corals on south side of stream.

Locality M89.—Etna quadrangle, Calif. (1934); three-fourths of a mile southeast of Gregg Ranch house; middle of line separating NE¼ from SW¼ sec. 21, T. 41 N., R. 7 W. Silicified fossils in limestone lenses.

Locality M1133.—China Mountain quadrangle, Calif. (1955); seven-tenths of a mile southeast of Gregg Ranch house, altitude 4,200 feet; SE¼ sec. 21, T. 41 N., R. 7 W.; coral-bearing limestone.

Grouse Creek area

Locality M1134.—China Mountain quadrangle, Calif. (1955); south fork of Grouse Creek on "Red Tag trail", altitude 4,600 feet; SE¼ sec. 21, T. 40 N., R. 7 W. Dark-gray silty limestone with well-preserved fossils.

Horseshoe Gulch area

Locality M1130.—Etna quadrangle, Calif. (1955); Horseshoe Gulch, an east branch of McConnahue or "McConaughy" Gulch; in sec. 3 or sec. 4, T. 41 N., R. 8 W. Float limestone cobbles with corals.

Locality M1131.—Etna quadrange, Calif. (1955); Horseshoe Gulch; near line between secs. 3 and 4, T. 41 N., R. 8 W. Limestone with silicified fossils near small earth dam, on north side of gulch.

Central belt of metamorphic rocks

Weaverville area

Locality M1378.—Weaverville quadrangle, Calif. (1950); northwest of Douglas City on Trinity River, near middle of sec. 2, T. 32 N., R. 10 W. Limestone cobbles from conglomerate. *Rhizophyllum.*

Western belt of Paleozoic and Triassic rocks

Hayfork area

Locality M1281.—Hayfork quadrangle, Calif. (1951); 4 miles southeast of Hayfork, 1,000 feet south of the Mueller mine, altitude 3,650 feet, middle branch of Kingsbury Gulch. Float coral material.

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PLATES 1–8

[Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colo. 80225]

PLATE 1

FIGURES 1–4. *Zeolphyllum* n. sp. (p. 31).

1. Transverse thin section (× 4).
2. Transverse thin section (× 8).
3. Longitudinal thin section (× 4).
4. Longitudinal thin section (× 8).

Locality M1001, Cone Bay; northern Heceta Island, southeastern Alaska. Late Silurian *Atrypella-Conchidium* beds.

5. *Zelophyllum* n. sp. (p. 31).
Longitudinal thin section (× 8). Northern Heceta Island, southeastern Alaska. Late Silurian *Atrypella-Conchidium* beds.

6, 7. *Zelophyllum* sp. G (p. 31).
Transverse and longitudinal thin sections (× 2); USNM 159454. Gazelle Formation, locality M78, Chastain Ridge.

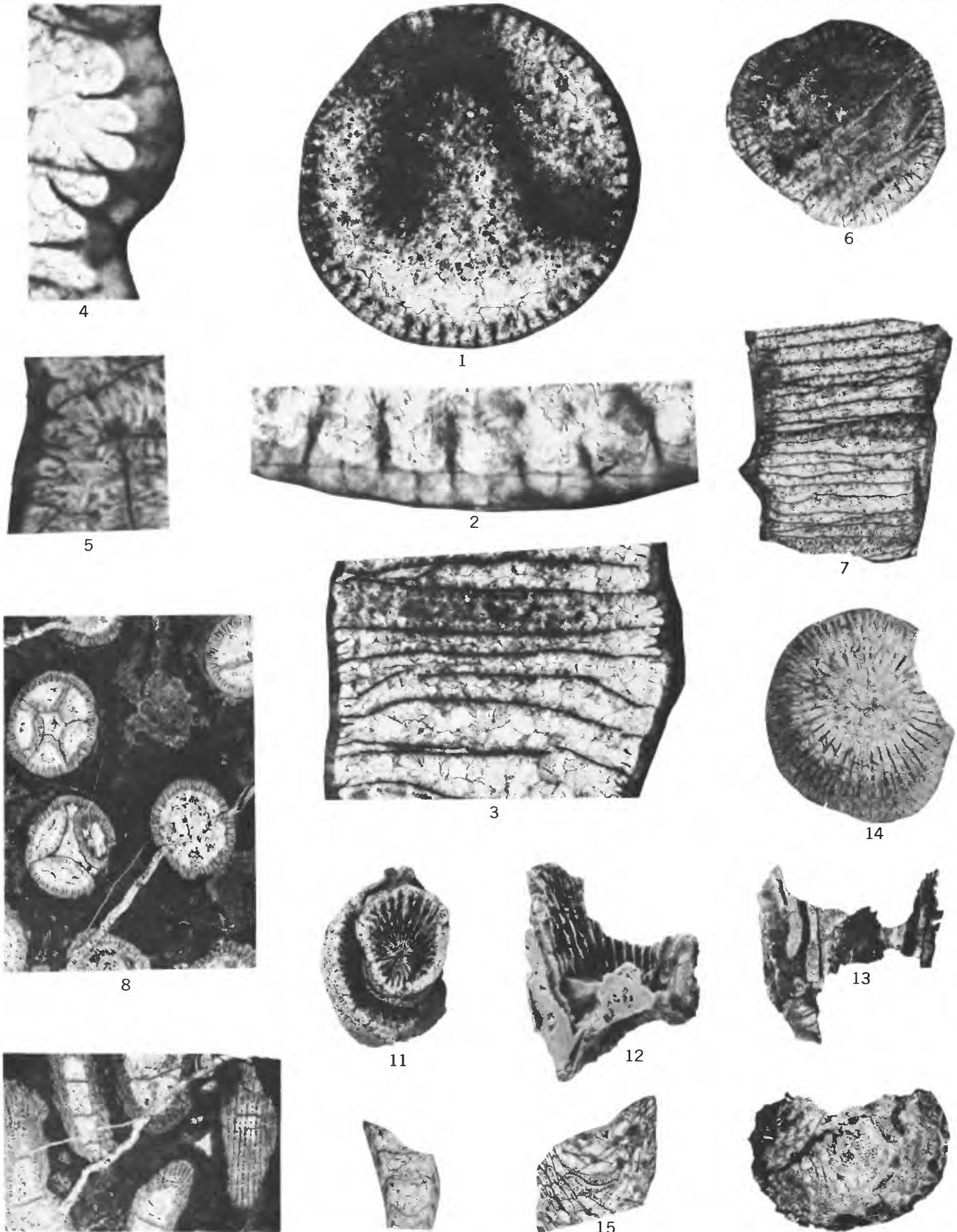
8–10. Pycnostylid sp. H (p. 31).
Transverse and longitudinal thin sections (× 2); USNM 159455. Silurian beds, locality M1130, Horseshoe Gulch.

11–14. *Dalmanophyllum* sp. h (p. 28).

11. Calice view (× 2).
12. Lateral calice view showing median boss (× 2).
13. Longitudinal thin section (× 2) showing axial structure.
14. Transverse thin section (× 3).

Early Silurian; locality M1131, Horseshoe Gulch.

15, 16. *Cystiphyllum* sp. c (p. 36).
Longitudinal thin section (× 1½); transverse thin section (× 2). Unit 2, Gazelle Formation; locality M191, Bonnet Rock.



ZELOPHYLLUM, PYCNOSTYLID, *DALMANOPHYLLUM*, AND *CYSTIPHYLLUM*

PLATE 2

FIGURES 1–6. *Shastaphyllum schucherti* n. gen., n. sp. (p. 38).

1, 2. Transverse thin sections (× 6) and (× 3) of holotype, USNM 159457.

3–6. Longitudinal thin sections of holotype, USNM 159457, (× 3), (× 6), (× 6), (× 6).

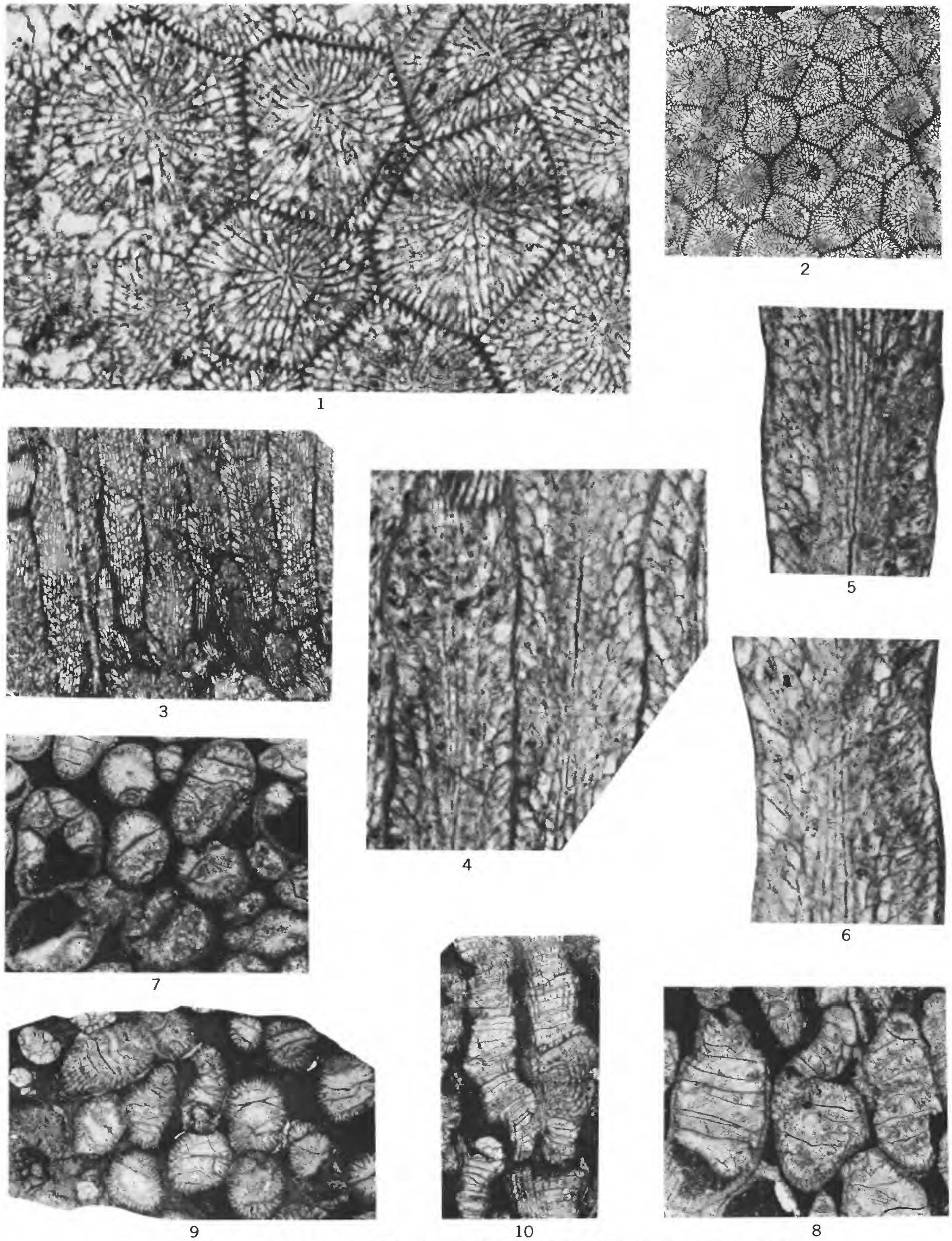
Silurian. Gazelle Formation; locality M1132. Bonnet Rock,

7, 8. Pycnostylid sp. (p. 31).

Transverse and longitudinal sections (× 2). Silurian, Gazelle Formation; locality M1030 Parker Rock.

9, 10. *Palaeophyllum*? sp. G. (p. 29).

Transverse and longitudinal sections (× 2). Silurian, Gazelle Formation; locality M78, Chastain Ridge.



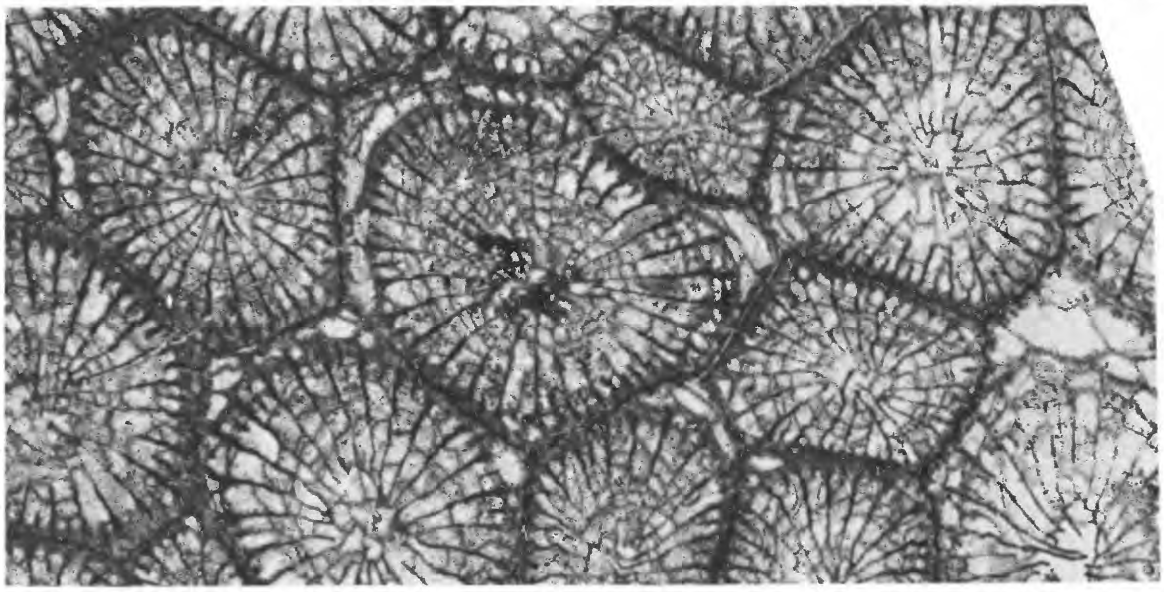
SHASTAPHYLLUM, PYCNOSTYLID, AND *PALAEOPHYLLUM*?

PLATE 3

FIGURES 1–3. *Wintunastraea stanleyi* n. gen., n. sp. (p. 30).
Transverse and longitudinal thin sections of holotype (× 5); USNM 159464.

4. *Shastaphyllum schucherti* n. gen., n. sp. (p. 38).
Longitudinal thin section of paratype (× 5); USNM 159465.

5, 6. *Cystiphyllum* sp. c (p. 36).
Longitudinal and transverse thin sections, slightly enlarged; USNM 159466. Silurian, Gazelle Formation; locality M1135, Chastain Ridge.



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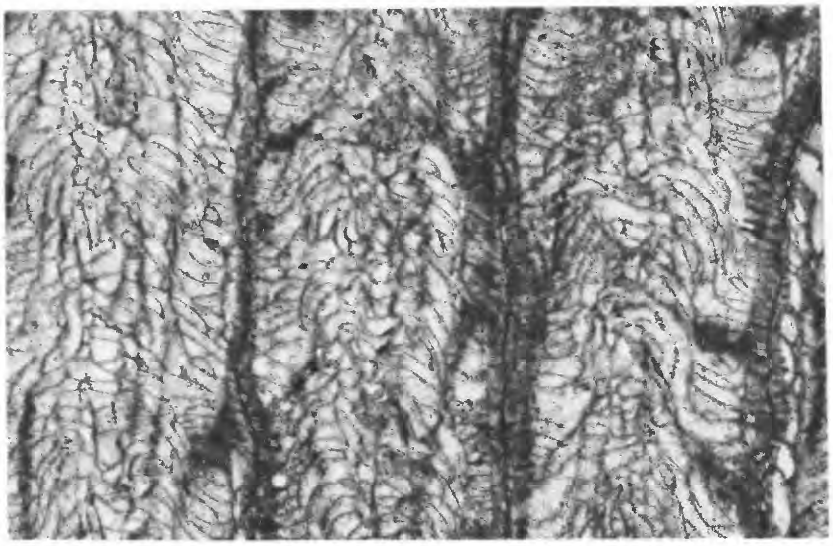

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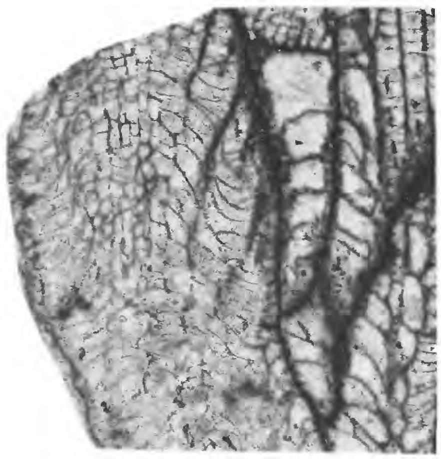

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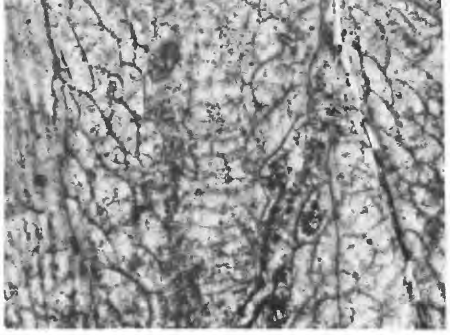

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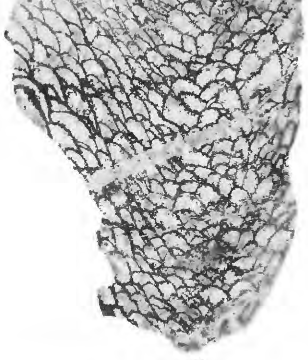

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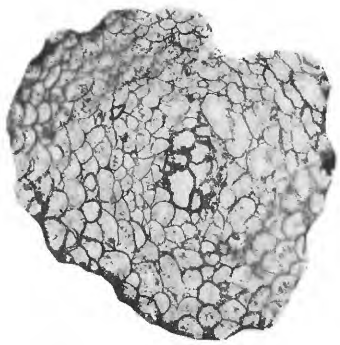

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WINTUNASTRAEA, SHASTAPHYLLUM, AND *CYSTIPHYLLUM*

PLATE 4

FIGURES 1–3. *Australophyllum* sp. E (p. 40).

1. Transverse thin section (×2), USNM 159420.
2. Longitudinal thin section (×2), USNM 159420.
3. Transverse thin section (×2), USNM 159420.

Late Silurian, coral zone E; locality M1114, Ikes Canyon, Toquima Range, Nev.

4, 5. *Wintunastraea stanleyi* n. gen., n. sp. (p. 30).
Transverse and longitudinal thin sections of holotype (× 1½), USNM 159464. Late Silurian, Gazelle Formation; locality M1135, Chastain Ridge, Willow Creek area.

6, 7. *Shastaphyllum*? sp. c (p. 39).
Transverse and longitudinal thin sections(× 1½). Locality M1281, southern part of Hayfork quadrangle, Trinity County, Calif.

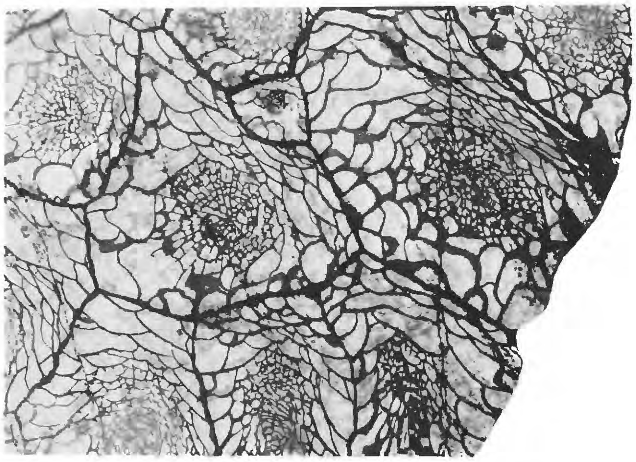
8. *Shastaphyllum schucherti* n. gen., n. sp. (p. 38).
Weathered surface of corallum (× 1). Late Silurian, Gazelle Formation; locality M1135, Chastain Ridge, Willow Creek area.

9. ?*Orthophyllum* sp. (p. 28).
Transverse thin section (× 7). Late Silurian, Gazelle Formation; locality M1135, Chastain Ridge, Willow Creek area.

10. *Syringaxon* sp. c (p. 28).
Transverse thin section (× 15). Late Silurian, Gazelle Formation; locality M1135, Chastain Ridge, Willow Creek area.

11, 12. *Kodonophyllum* sp. g (p. 32).
Transverse and longitudinal thin sections (× 2). Late Silurian, Gazelle Formation, unit 3; Bonnet Rock, Willow Creek area.

13. Spotted argillaceous rubbly limestone with corals (× 1½) of type common in unit 2 of the Gazelle Formation (p. 12). Locality M1029, Parker Rock, east fork of Scott River.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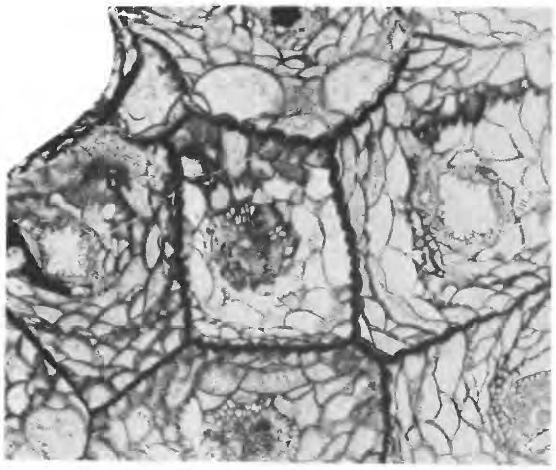
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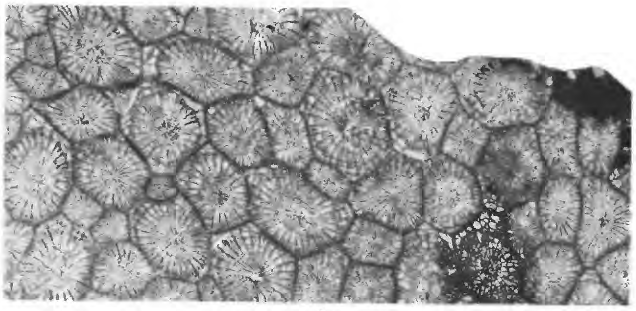
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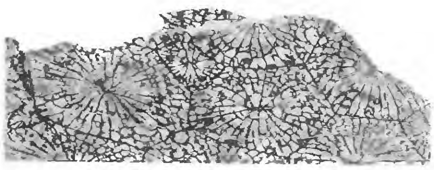
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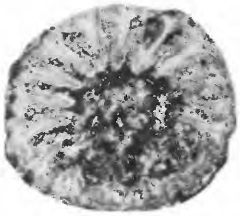
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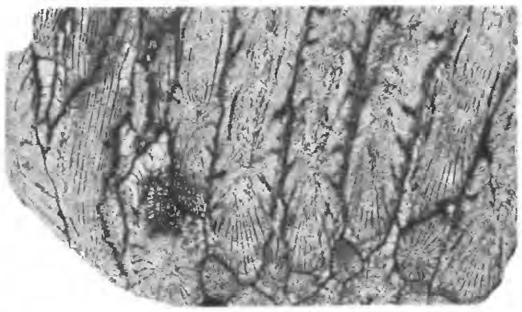
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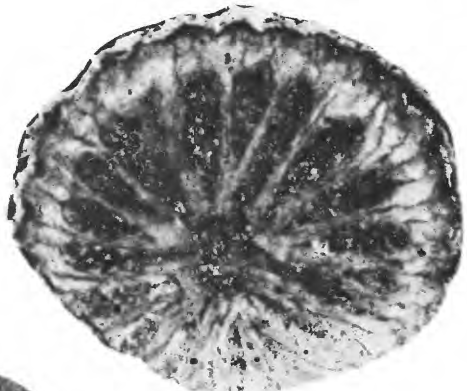
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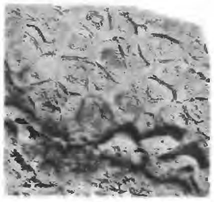
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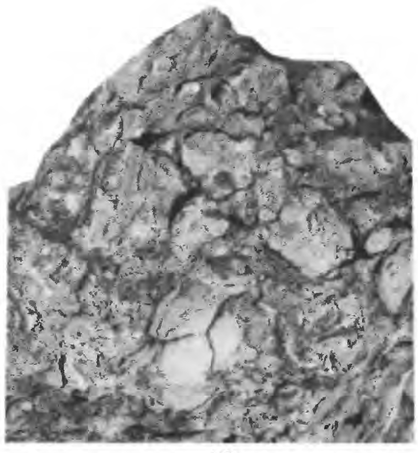
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AUSTRALOPHYLLUM, WINTUNASTRAEA, SHASTAPHYLLUM, ?ORTHOPHYLLUM, SYRINGAXON, KODONOPHYLLUM, AND CORALLINE RUBBLY LIMESTONE OF THE GAZELLE FORMATION

PLATE 5

FIGURES 1–5. *Klamathastraea dilleri* n. gen., n. sp. (p. 40).

1, 2. Transverse and longitudinal thin sections of holotype (× 2½); USNM 159456.

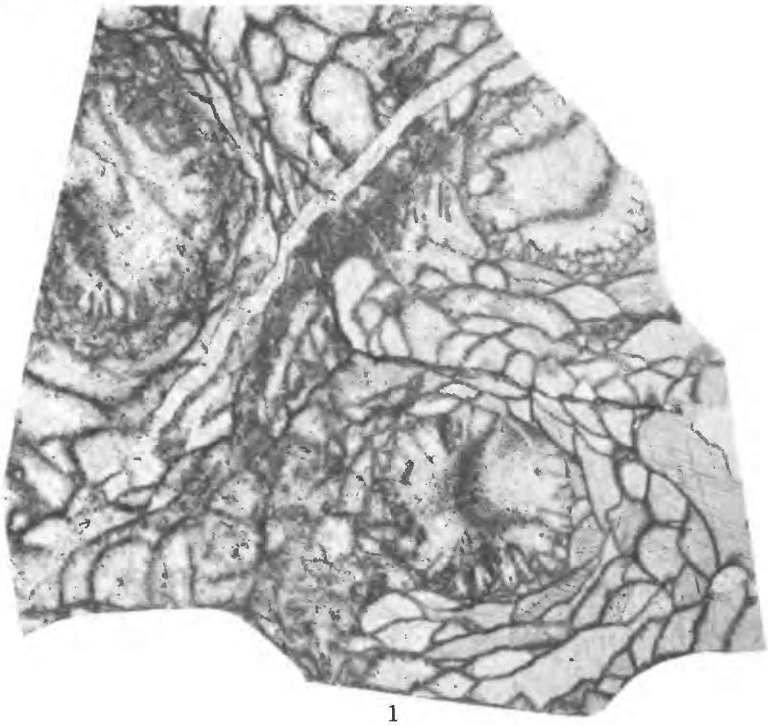
3, 4. Transverse and longitudinal thin sections of holotype (× 1½); USNM 159456.

5. Weathered under surface of holotype (× ⅔); USNM 159456.

Silurian, Gazelle Formation; locality M1132, Bonnet Rock.

6–8. *Australophyllum fritschi* (Novak). (p. 40).

Transverse and longitudinal thin sections (somewhat enlarged). Copies of figs. 6, 7, 8, pl. 102, Počta (1902). Upper Silurian (Kozel, e2), Czechoslovakia.



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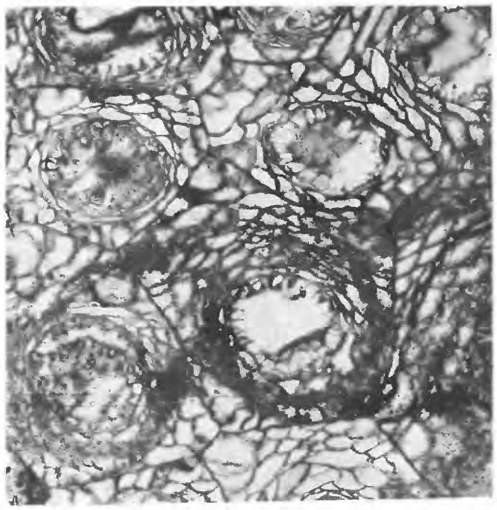

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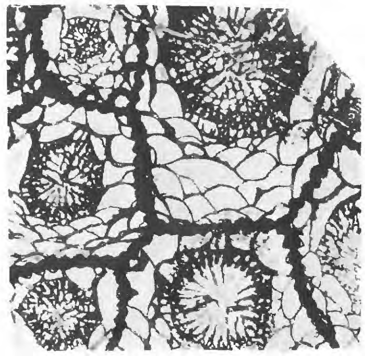

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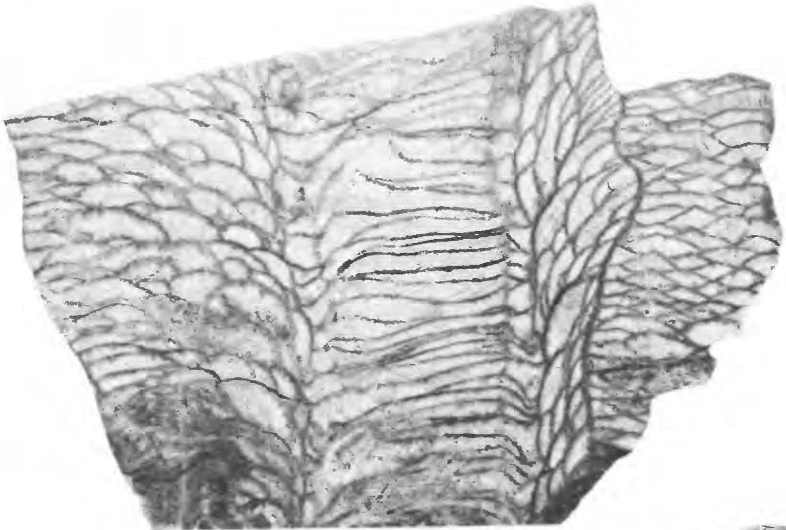

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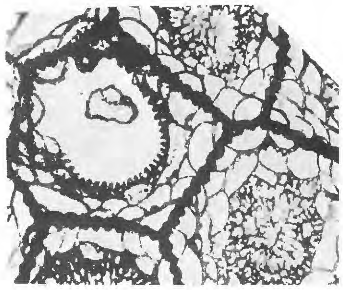

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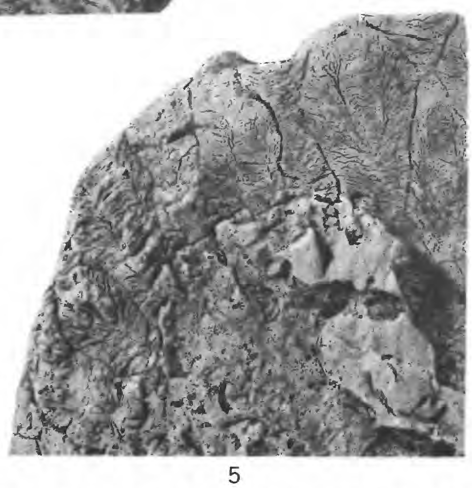

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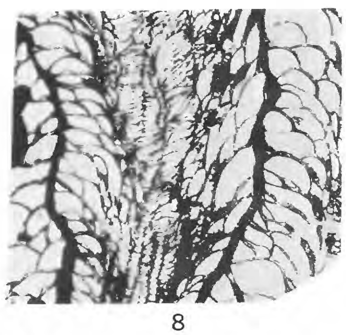

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KLAMATHASTRAEA AND *AUSTRALOPHYLLUM*

PLATE 6

FIGURES 1–5, 7–8. *Cyathactis gazellensis* n. sp. (p. 34).

1, 2. Lateral views of two small corallites (× 1); USNM 159446, 159447.

3, 4. Transverse thin section of holotype (× 2); USNM 159448 and enlargement of part of same (× 8).

5. Longitudinal thin section of paratype (× 6); USNM 159449.

7, 8. Longitudinal thin sections of two paratypes: USNM 159451 (× 2), USNM 159452 (× 4).

Silurian, Gazelle Formation, unit 2; locality M191, Bonnet Rock, Willow Creek area.

6. *Cyathactis gazellensis* n. sp. (p. 34).

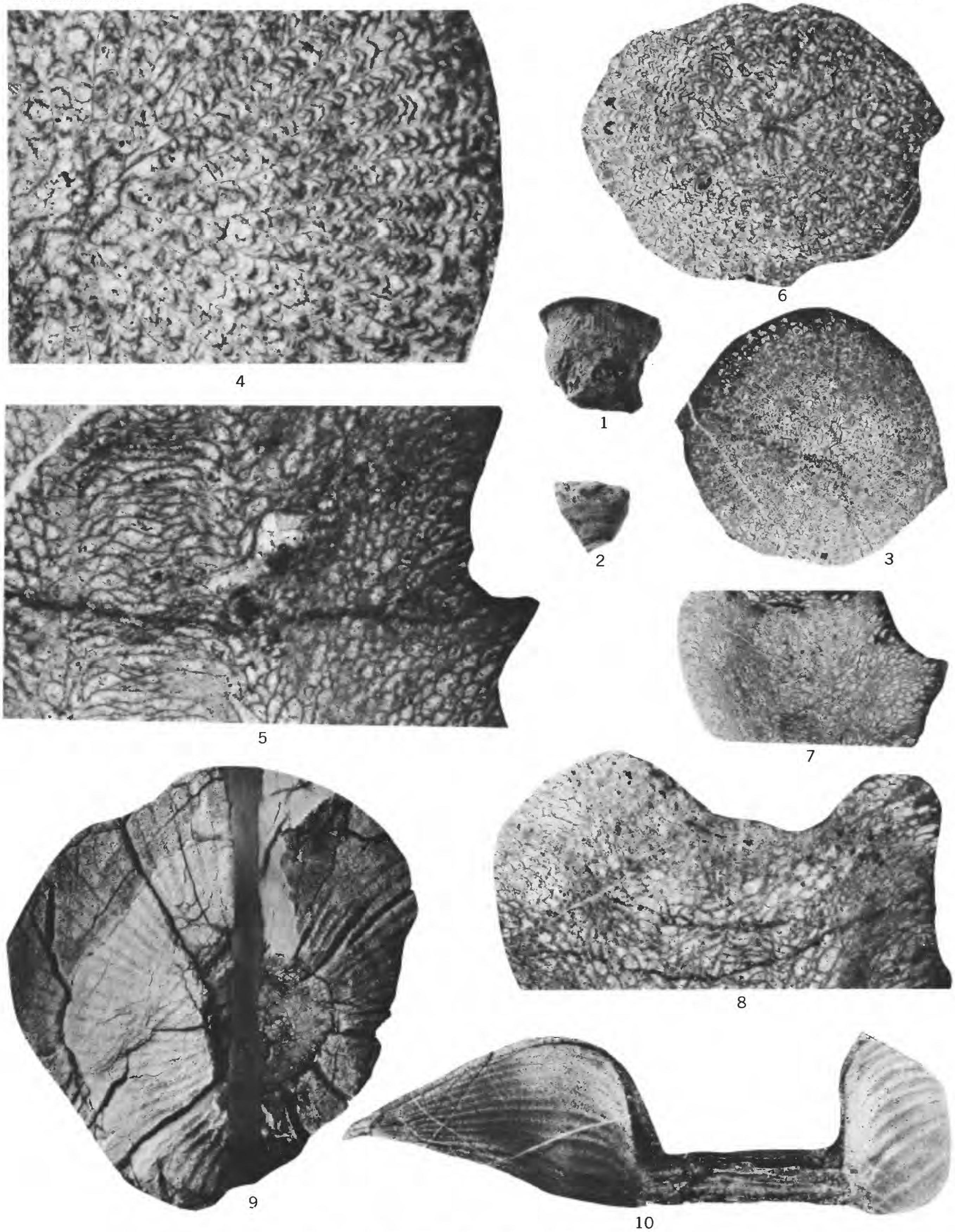
Transverse thin section (× 3); USNM 159450. Silurian, Gazelle Formation; locality M1030, Parker Rock.

9, 10. *Mucophyllum mcintyrei* n. sp. (p. 33).

9. Weathered undersurface of holotype USNM 159453 (× 1).

10. Longitudinal thin section of holotype USNM 159453 (× 1½).

Silurian, Gazelle Formation; locality M87, main fork of Willow Creek, China Mountain quadrangle, Calif.



CYATHACTIS AND *MUCOPHYLLUM*

PLATE 7

FIGURES 1, 3–6. *Petrozium staufferi* n. sp. (p. 37).
Holotype, USNM 159458.
1. Transverse thin section (× 4).
3. Longitudinal thin section of corallite (× 4).
4–6. Longitudinal thin sections of three corallites (× 8).
Silurian, Gazelle Formation unit 2; locality M191, Bonnet Rock, Willow Creek area.

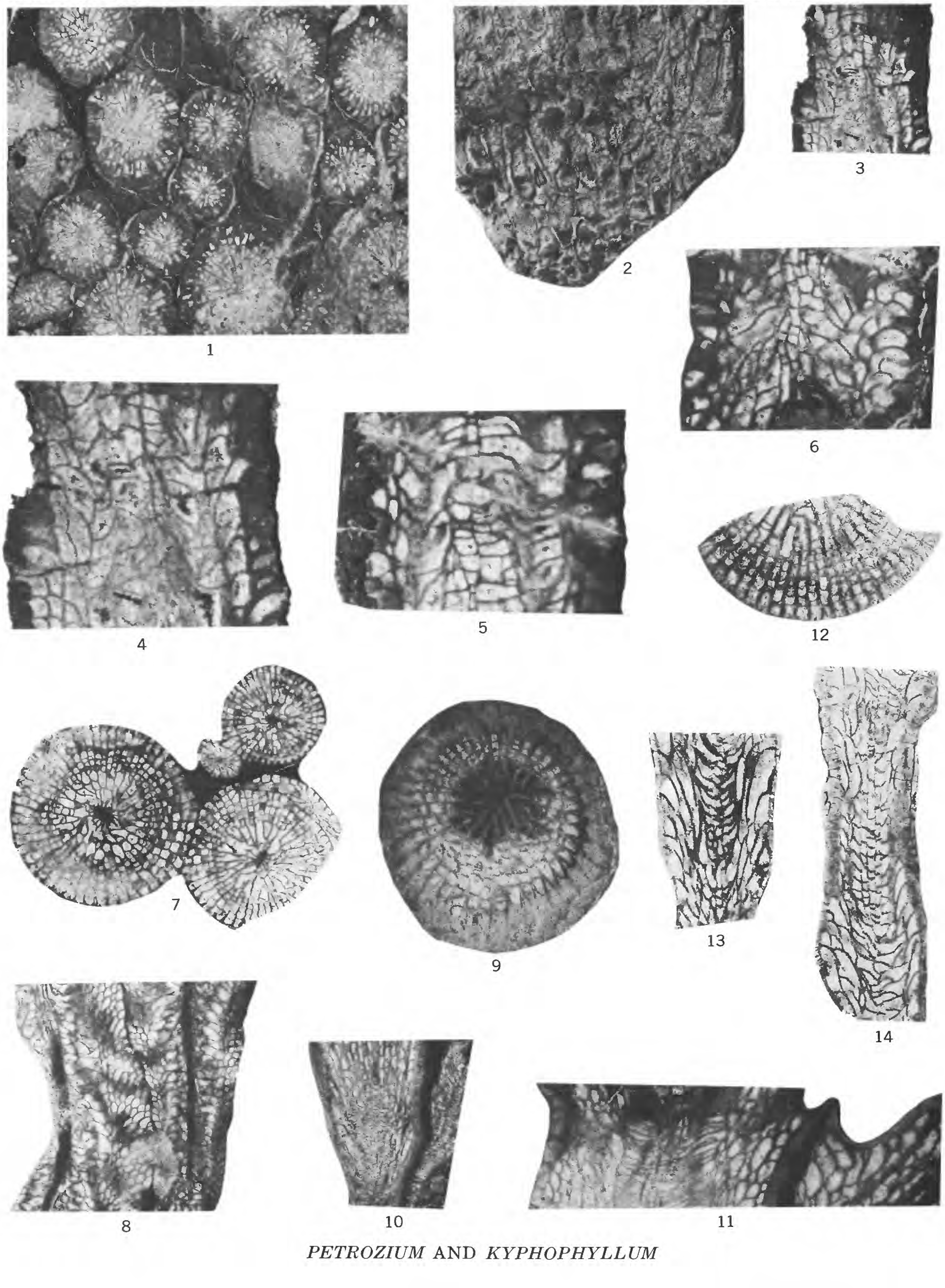
2. *Petrozium staufferi* n. sp. (p. 37).
Oblique external view of part of large colony (× 1).
Silurian, Gazelle Formation unit 2; locality M191, Bonnet Rock, Willow Creek area.

7, 8. *Petrozium* sp. (p. 38).
Transverse and longitudinal thin sections (× 4); shows discrete axial rod. Silurian; locality M1162 Kuiu Island, southeastern Alaska.

9, 10. *Kyphophyllum greggi* n. sp. (p. 37).
9. Transverse thin section (× 4); USNM 159459.
10. Longitudinal thin section (× 2); USNM 159460.
Gazelle Formation, locality M1133, Gregg Ranch.

11. *Kyphophyllum* cf. *K. greggi* n. sp. (p. 37).
Longitudinal thin section (× 4). Silurian or Early Devonian; locality M1134, Grouse Creek Etna quadrangle, Calif.

12–14. *Kyphopyhllum* cf. *K. greggi* n. sp. (p. 37).
Transverse and longitudinal thin section (× 4). Gazelle Formation, locality M82. Gregg Ranch.



PETROZIUM AND *KYPHOPHYLLUM*

PLATE 8

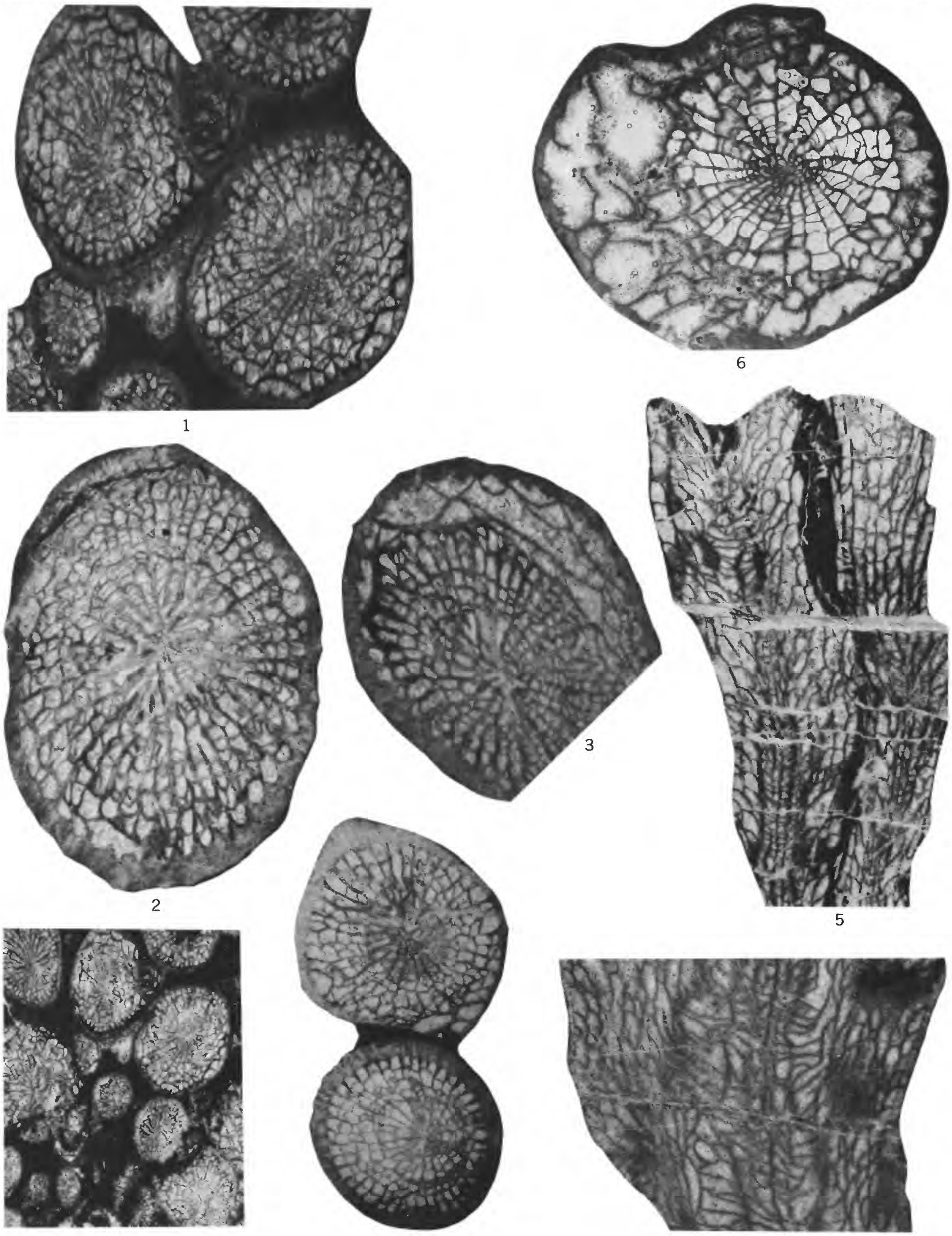
FIGURES 1–5, 8. *Kyphophyllum greggi* n. sp. (p. 37).

1. Transverse thin section of holotype (× 4); USNM 159461.
2, 3. Transverse thin sections (× 4).
4. Transverse thin section of holotype (× 4); USNM 159461.
5. Longitudinal thin section of paratype (× 4); USNM 159462.
8. Longitudinal thin section of paratype (× 4); USNM 159463.

Silurian or Early Devonian. Locality M1133, Gregg Ranch.

6. *Kyphophyllum* sp. (p. 37).
Transverse thin section (× 4). Late Silurian; locality M1114, Ikes Canyon, Toquima Range, Nev.

7. *Kyphophyllum* cf. *K. greggi* n. sp. (p. 37).
Transverse thin section (× 4). Silurian or Early Devonian; locality M1134, Grouse Creek, Etna quadrangle, Calif.



KYPHOPHYLLUM