The Roberts Mountains Formation, a regional stratigraphic study with emphasis on rugose coral distribution

GEOLOGICAL SURVEY PROFESSIONAL PAPER 973

The Roberts Mountains Formation, a regional stratigraphic study with emphasis on rugose coral distribution

By CHARLES W. MERRIAM *and* EDWIN H. MCKEE
With a section on Conodonts, *by* JOHN W. HUDDLE

GEOLOGICAL SURVEY PROFESSIONAL PAPER 973

A study of stratigraphy, facies, and coral distribution in the middle Paleozoic (Silurian and Devonian) limestone belt of the central and southwestern Great Basin

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

THOMAS S. KLEPPE, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, ***Director***

Library of Congress Cataloging in Publication Data

Merriam, Charles Warren, 1905–
The Roberts Mountains Formation.

(Geological Survey Professional Paper 973)
Bibliography: p. 43–45.
Includes index.
Supt. of Docs. no.: I 19.16:973
1. Geology, Stratigraphic–Silurian. 2. Geology, Stratigraphic–Devonian. 3. Rugosa. 4. Geology–Nevada. 5. Geology–California. I. McKee, Edwin H., joint author. II. Huddle, John Warfield, 1907– joint author. III. Title. IV. Series: United States Geological Survey Professional Paper 973.
QE661.M45 551.7'3'0979 76-608307

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 024-001-02893-0

CONTENTS

ILLUSTRATIONS

[Plates follow index]

TABLES

THE ROBERTS MOUNTAINS FORMATION, A REGIONAL STRATIGRAPHIC STUDY WITH EMPHASIS ON RUGOSE CORAL DISTRIBUTION

By CHARLES W. MERRIAM and EDWIN H. MCKEE

ABSTRACT

A large part of the Silurian and the base of the Devonian Systems are represented in the central and southwestern Great Basin by limestones of the Roberts Mountains and the Vaughn Gulch Formations. In Silurian time the Great Basin region was inundated by northward-trending shelf seaways of three wide facies belts: the eastern regional dolomite belt which bordered the ancient land mass on the east, the intermediate limestone belt here dealt with, and on the west, a chert-shale-graywacke belt with some volcanic rocks that extends into the Pacific Border province, best represented in southeastern Alaska. Studies of rugose corals show that each of the three belts has distinctive corals and associated fossils not yet found in the other belts; biofacies differences greatly complicate geologic correlation across the facies boundaries.

The Roberts Mountains Formation, mainly limestone, calcareous shale, and some dolomitic limestone, is widely distributed in the central Great Basin, where it has been mapped from the Tuscarora Mountains on the north to the Toquima and Toiyabe Ranges on the south and west. It is known to be present as far north as south-central Idaho but has been little studied in this region. The Vaughn Gulch Limestone and its lateral shaly graptolitic facies, the Sunday Canyon Formation, occur to the southwest in the Inyo Mountains. Thick eastern regional dolomite facies rocks such as the Lone Mountain Dolomite and the Laketown Dolomite come into close proximity to, or intertongue with, limestone of the middle belt in a few areas such as the Roberts Mountains, Bare Mountain near Beatty, Nev., and the Inyo Mountains. In a number of places such as in the Tuscarora Mountains, the Simpson Park Mountains, the Roberts Mountains, the Monitor Range, and the Toquima Range, the Roberts Mountains limestone has been subdivided into additional lithologic units given new formational names. These include the Windmill Limestone of Johnson, the McMonnigal Limestone, and the Wenban Limestone. The names Masket Shale and Gatecliff Formation were used by Kay for rocks in the Toquima and Toiyabe Ranges that closely resemble parts of the Roberts Mountains Formation elsewhere. In most areas the basal part of the formation is a black cherty limestone or dolomite followed upward by calcareous shaly laminated and platy limestone that bears graptolites. The upper part consists of thin-bedded laminated limestone and slabby thicker bedded allogenic limestone and dolomitic limestone yielding corals, brachiopods, and calcareous algae as well as graptolites.

The Silurian-Devonian boundary lies within this upper interval. This boundary, defined on the basis of graptolites in the standard time scale, is more than 100 m lower than that based on rugose corals and calcareous algae that uses as reference the well-known section in Gotland, Sweden.

INTRODUCTION

The name Roberts Mountains Formation applies to limestones, mostly argillaceous, and some dolomitic marine strata occupying a northerly oriented linear belt within the central and west-central Great Basin. Diverse fossil assemblages from many localities indicate that in the time-stratigraphic sense this formation probably makes up much of the Silurian and the bottom of the Devonian Systems as represented in the Great Basin of the western United States. The Silurian-Devonian boundary lies within the upper or even upper middle part of the formation. A reexamination of field relations of the fossil-bearing strata and a review of fossil comparisons with those of standard columns for the Silurian and Devonian Systems indicates that the standard time scale based on graptolites includes rocks in the Great Basin that are somewhat older than rugose corals would suggest.

The Roberts Mountains Formation is bordered on the east by dolomite that prevails throughout the east-central and eastern Great Basin. On the west, where the boundary is theoretical, the limestones are inferred to grade into shale, graywacke, coarse argillaceous rocks, volcanic rocks, and subordinate limestone of the Pacific border province (Merriam, 1973a). Paleogeographically, three subparallel northward-trending depositional facies belts are definable where the southwest Cordilleran geosynclinal seaways of middle Paleozoic (Silurian and Devonian) time crossed what is today the Great Basin. From east to west these belts are: the eastern dolomite belt, the intermediate limestone belt, and the western or Pacific Border graywacke belt. The transition from the dolomite to limestone belt passes through the classical facies of platform margin carbonate deposition. Limestones of the intermediate limestone belt persist to the southwest margin of the Great Basin, where they are represented by the Vaughn Gulch Limestone in the northern Inyo Mountains, Calif.

As rugose corals are among the diagnostic fossils of the Roberts Mountains Formation, this study was inspired by the need for dependable stratigraphic sequences in deformed Great Basin Paleozoic rocks to be used in conjunction with Rugosa and their stratigraphic ranges. Studies of Great Basin rugose corals and associated fossils have demonstrated marked biofacies differences between the three facies belts that make difficult interbelt paleontologic correlation.

PURPOSE AND SCOPE OF INVESTIGATION

In Silurian and Devonian limestone areas of the central and southwest Great Basin, geologic mapping within the past 10 years necessitates restudy and redefinition of the Roberts Mountains Formation and correlative units, including those of contiguous dolomite areas. Among primary objectives, this effort entails search for realistic vertical and lateral formation boundaries which reflect depositional facies relations. The physical stratigraphy depends upon refinement of geologic mapping and paleontologic correlation as background, and the biostratigraphy presented here leans heavily upon zonation of the Great Basin Silurian and Devonian by means of corals and associated megafossils (Merriam, 1973a, b, c; 1974). In this coral work, the Gotland, Sweden, Silurian yardstick is the primary standard of comparison and geologic correlation. In some sections a wide gap exists between the accepted Silurian-Devonian boundary as determined by the graptolite and conodont specialists and the placement of the boundary by the coral specialist. For example, the *Monograptus uniformis* Zone at the base of the Devonian falls as low as the middle part of the Silurian delimited by means of corals. Explanations are sought for these discrepancies.

The systematic and descriptive paleontology of many rugose corals listed in this report is treated in recent works (Merriam, 1973a, b). A paleontologic appendix covers stratigraphically relevant but undescribed megafossils and evaluates certain little-known rugose coral groups, calcareous algae, and conodonts for age determination, correlation, and biostratigraphy. As no megafossils were found by the geologists who mapped many exposures of the Roberts Mountains Formation, age designations of these structurally and stratigraphically isolated beds are based on conodont studies. Twelve plates illustrate some of the distinctive megafossils of this formation.

A detailed report by T. E. Mullens (unpub. data, 1975) covers comparative lithology, sedimentology, and petrology of the Roberts Mountains Formation and its economic potential as a gold-bearing formation.

Briefly touched upon herein are the complex environmental and geochemical aspects of the multifaceted dolomite problem bearing upon the complete change from marine limestone to pervasive diagenetic dolomite passing into the eastern dolomite belt.

In recent years the Roberts Mountains Formation has assumed economic importance as host rock for the Cortez and Carlin gold ores of central Nevada. As a result, the known extent of the formation has been intensively explored and prospected. Some economic aspects of ore search, geochemistry, and geophysical prospecting are treated in other reports (T. E. Mullens, unpub. data, 1975).

ACKNOWLEDGMENTS

Geologic mapping used in this report includes results of D. C. Ross in the northern Inyo Mountains, Calif., Harold Masursky and Jonathan C. Matti in the northern Simpson Park Mountains, and J. H. Stewart in the central Toiyabe Range and Shoshone Mountains, Nev. Efforts by these geologists toward clarifying geologic structure and stratigraphy have been most helpful. Detailed geologic mapping in the southern Tuscarora Mountains, Nev., by J. G. Evans, sheds new light on the source beds of earlier fossil collections made in the Bootstrap mine area before large-scale topographic maps made accurate field location possible. These especially well preserved silicified fossils collected by R. J. Roberts and associates near the Bootstrap mine in the years 1954 to 1958 first demonstrated the northward continuation of the Roberts Mountains Formation beyond the Humboldt River Valley. Rugose corals in Coal Canyon, Simpson Park Mountains, were first collected by R. J. Roberts; at a later time, Silurian and Devonian coral collections by J. G. Johnson and A. J. Boucot were contributed for use in this study. Collections of corals by Leland Cress at Maggie Creek, Tuscarora Mountains, revealed the presence of Silurian and Early Devonian corals in this area. A well-preserved colonial rugose coral from the Sunday Canyon Formation in Mazourka Canyon collected by C. H. Stevens of San Jose State University is acknowledged with thanks. Jonathan C. Matti made many helpful suggestions on the manuscript and reviewed the conodont section.

Graptolite identifications accompanying this report are the work of W. B. N. Berry.

Many detailed stratigraphic sections have been measured across the Roberts Mountains Formation throughout its known extent by T. E. Mullens. Lithologic data from these sections have been employed in the present report, especially at Bootstrap Hill in the Tuscarora Mountains.

J. W. Miller ably assisted Merriam in detailed geologic mapping of the Coal Canyon area and other parts of the northern Simpson Park Mountains. In the Toquima Range all the detailed geologic mapping providing the basis for stratigraphic conclusions in that area is the work of E. H. McKee. Earlier geologic mapping

of parts of that range was done by Kay and Crawford (1964).

All fossil photographs are the work of Kenji Sakamoto.

HISTORY OF INVESTIGATION

Silurian limestones were first studied in the Roberts Mountains by Merriam while he searched for the base of the Devonian System in that area (Merriam, 1940, p. 11). On the northwest side of Roberts Creek Mountain, the lowest beds in the Nevada Formation identified in 1940 contain the *Acrospirifer kobehana* fauna of Early Devonian age and appeared at that time to conformably overlie massive dolomites identified as the Lone Mountain Dolomite of supposedly, but as yet unestablished, Silurian or perhaps Early Devonian age. Comparison with the Lone Mountain type section 18 miles (29 km) to the south revealed significant lithologic differences. Whereas no limestone is present in the Upper Ordovician or Silurian at Lone Mountain, beneath the Lone Mountain Dolomite at Roberts Creek Mountain is a thick fossiliferous Silurian sequence of limestones and some dolomite named at that time the Roberts Mountains Formation by Merriam (1940). This unit occupied the stratigraphic interval between the underlying limestone and dolomite of the Hanson Creek Formation and the blocky light-gray dolomite interpreted by Merriam (1940) as the higher part of the Lone Mountain Dolomite. Comparison of the sections at Lone Mountain and Roberts Creek Mountain led to extension by Merriam (1940) of the name Roberts Mountains Formation to the dark dolomite beneath the type Lone Mountain Dolomite in accord with the view that this was a dolomite facies of the Roberts Mountains Formation. Later mapping in the Roberts Mountains by Winterer and Murphy (1960) clearly demonstrated the lateral equivalence by the intertonguing of the Roberts Mountains Formation and the Lone Mountain Dolomite. In a recent study of the stratigraphy and paleontology of the Lone Mountain Dolomite at Lone Mountain (Merriam, 1973b), the dark dolomite previously referred to as dolomitic Roberts Mountains Formation has been redesignated as part of the Lone Mountain Dolomite because it was considered desirable to retain the formational term Roberts Mountains for a predominantly limestone unit only.

Above the type section of the Roberts Mountains Formation, at Roberts Creek Mountain, the saccharoidal Lone Mountain dolomites have yielded no fossils; the possibility remains that the uppermost part of this thick dolomite sequence may correlate with the finer textured Beacon Peak Dolomite Member of the Nevada Formation.

Reconnaissance geology of the northern Monitor Range by Merriam and Anderson (1942) made known a southerly extension of the Roberts Mountains Formation. In Copenhagen Canyon, for example, the Silurian and Lower Devonian were found to be represented by thinly laminated calcareous shaly rocks carrying graptolite faunas and thicker graded beds of bioclastic limestone. Kay and Crawford (1964) recognized the occurrence of the Roberts Mountains Formation (called by them the Masket Shale) farther southwest in the Toquima Range, where various limestone and argillaceous limestones occupy parts of several separately mappable thrust plates. More recent detailed mapping in that area by McKee (1976) sheds additional light upon the facies, paleontology, and correlation of the Roberts Mountains Formation in the Toquima Range.

Northwest of the type area, the Roberts Mountains Formation was extended into the northern Simpson Park Mountains by R. J. Roberts and associates during reconnaissance geologic mapping of northern Eureka County in 1954–58. Knowledge of these rocks was further advanced by Winterer and Murphy (1960) and Johnson (1965). R. J. Roberts and associates extended the distribution of the Roberts Mountains Formation northward into the Tuscarora Mountains and Elko County during the Eureka County mapping program. Since 1967, parts of the southern Tuscarora Mountains near Carlin, Nev., have been mapped in detail by the U.S. Geological Survey. Where the formation is locally gold bearing, much has been learned of the complex structure and stratigraphy; geochemical and geophysical investigations have been carried out by economic geologists in connection with drilling exploration beyond the currently productive belt.

Geologic mapping of the Cortez quadrangle by Gilluly and Masursky (1965) and the Mount Lewis area by Gilluly and Gates (1965) extended the known occurrence of the Roberts Mountains Formation into the Cortez Mountains and northern Shoshone Range. The formation has subsequently become economically important as a gold ore host in that vicinity.

In 1968 the economic potential of the Roberts Mountains Formation as a source of gold in north-central Nevada became sufficiently evident to justify a special study by the U.S. Geological Survey. The lithologic and stratigraphic aspects of this study were undertaken by T. E. Mullens, who worked with quadrangle mapping parties and geochemists in economically promising areas. Mullens has carried out detailed section measurement and studies of sedimentary petrology in many areas, including those where mapping was in progress (Mullens, unpub. data, 1975).

Mapping of the Horse Creek Valley quadrangle in the northern Simpson Park Mountains by Harold

Masursky, begun about 1960, carried eastward the geology begun by Gilluly and Masursky in the adjoining Cortez quadrangle (1965). A progress map was transmitted by Masursky in 1971 for the use of the writers in conjunction with the Paleozoic stratigraphy. As the Horse Creek Valley quadrangle includes the Coal Canyon section, first fully described by Johnson (1965) and probably the best reference section for the Roberts Mountains Formation, parts of it have been remapped in more detail by Merriam and Miller, a work still in progress.

Interest in southwestern Great Basin Silurian limestones as correlatives of the Roberts Mountains Formation developed in 1946 with geologic mapping of the Cerro Gordo mining district, Inyo Mountains, Calif. (Merriam, 1963). At that time it became evident that westward and northward, the Hidden Valley Dolomite (McAllister, 1952) changed to limestone. Section measurement, reconnaissance geologic mapping, and fossil collecting were begun in 1947 at Mazourka Canyon, where the coral genera and calcareous algae of these Inyo Silurian beds were found to be closely allied to those of the central Great Basin. Subsequently, Ross (1963, 1966) carried out the refinements of detailed geologic mapping of the northern Inyo areas. A northward change of Silurian limestone into shale facies is demonstrated by the Ross mapping.

The underlying paleontologic motivation for this study of Silurian limestone dates from the discovery by Merriam of well-preserved Rugosa in the Roberts Mountains in 1933, and in the northern Inyo Mountains about 1946. As general worldwide knowledge of Silurian Rugosa progressed rapidly, coral studies leading to a provisional Great Basin Silurian coral zonation were initiated by Merriam (1963), providing, together with brachiopod studies, much of the paleontologic support for this contribution. Further incentive came with the brachiopod investigations of J. G. Johnson and A. J. Boucot, who introduced European comparisons, and with investigations by W. B. N. Berry of graptolites of Great Basin Silurian and Devonian rocks. Conodont studies by Gilbert Klapper coordinated with field studies of M. A. Murphy added a wealth of information about the Silurian and Devonian of central Nevada. The most modern discussion of the formation is the study by Matti, Murphy, and Finney (1975).

PALEONTOLOGIC ZONING OF THE GREAT BASIN SILURIAN AND LOWER DEVONIAN

Rugose corals provide a useful means of stratigraphic zonation in the Great Basin Silurian and Devonian limestone facies. These fossils, common in nearly all the bioclastic limestones, are generally well preserved and represent several genera known in the Silurian of Gotland, Sweden; England; eastern Europe; and Australia. Graptolites, the primary basis for subdividing the world Silurian System, are abundant in rocks of the lower part of the Great Basin Silurian and occur at many places well into the Devonian. Great Basin Silurian and Devonian brachiopods are well represented, and much has been done to tie their occurrences and stratigraphic ranges to mapped areas and measured sections. The large dasycladacean algae of the genus *Verticillopora* are especially useful in Great Basin Silurian strata. *Verticillopora* ranges upward from Great Basin Silurian coral zone B through zone E, apparently reaching a peak of development in coral zone D (see below).

Conodonts are found through much of the Silurian and Devonian limestone of this province and are currently being coordinated with age determinations based on associated megafossils.

Study of the stratigraphic distribution of Silurian Rugosa in correlative and overlapping reference sections throughout the Great Basin makes possible a hypothetical fivefold zonation based on the ranges of species and genera. Provisional zones are designated by capital letters A through E in ascending stratigraphic order. Gaps in the coral record within a single reference section are filled in correlative sections to complete the overlapping composite zonal scheme. No more than three coral zones have been recognized within any one reference column; further collecting is expected to eliminate some of these local gaps.

The five coral zones ranging in age from Early to Late Silurian are:

Age	*Coral zone*
Late Silurian[1]	E
	D
Middle Silurian	C
	B
Early Silurian	A

SCARCITY OF REEFS OR BIOHERMS IN THE ROBERTS MOUNTAINS FORMATION

Reef and biohermal structures occur in Silurian marine limestone and dolomite rich in calcareous algae, stromatoporoids, crinoids, and corals in many areas throughout the world (Lowenstam, 1949). These structures are parts of the Niagaran Series of the Great Lakes and the Gotland of Sweden (Manten,

[1]Age designation based on comparison with the Gotland, Sweden, Rugosa. Coral zone E contains rocks of Lower Devonian age based on the occurrence of *Monograptus uniformis*, the accepted index for lowermost Devonian in the Great Basin.

TABLE 1.—*Characteristic fossils of Great Basin Silurian coral zones*

Geologic age	Coral zone	Rugose corals	Tabulate corals	Brachiopods	Dasycladacean algae
Late Silurian[1]	E	*Stylopleura nevadensis* Merriam		*Orthostrophia* sp.	*Verticillopora annulata* Rezak
		Stylopleura berthiaumi Merriam		*Schellwienella*? sp.	
		Mucophyllum oliveri Merriam		*Barrandella*? sp.	*Verticillopora* cf. *V. annulata* Rezak
		Kodonophyllum mulleri Merriam		*Sicorhyncha*? sp.	
		Rhizophyllum cf. *R. enorme* (Oliver)		*Rhynchospirina* sp.	
				Plectatrypa? sp.	
		Rhizophyllum sp. D Oliver		*Atrypa* sp.	
		Chonophyllum simpsoni Merriam		*Meristella* sp.	
		Australophyllum (Toquima-phyllum) johnsoni Merriam		*Kozlowskiellina* sp. f	
		Carlinastraea tuscaroraensis Merriam			
		Kyphophyllum nevadensis Merriam			
		Kyphophyllum sp. c			
		Salairophyllum? sp.[2]			
	D	*Brachyelasma* sp.		*Dicoelosia* sp. r	*Verticillopora annulata* Rezak
		Stylopleura berthiaumi Merriam		*Gypidula* sp. r	*Verticillopora* cf. *V. annulata* Rezak
		Tonkinaria simpsoni Merriam		*Homoeospira* sp. r	
		Tryplasma duncanae Merriam		*Atrypa* sp.	
		Carlinastraea tuscaroraensis Merriam		*Kozlowskiellina* sp. f	
Middle Silurian	C	*Tryplasma newfarmeri* Merriam			
		Denayphyllum denayensis Merriam			
		Entelophylloides (Prohexagonaria) occidentalis Merriam			
	B	Streptelasmid corals (small)	*Halysites (Cystihalysites) magnitubus* Buehler		*Verticillopora* sp.
		Brachyelasma sp. B			
		Ryderophyllum ubehebensis Merriam			
		Pycnactis sp. K			
		Petrozium mcallisteri Merriam			
Early Silurian	A	*Rhegmaphyllum* sp. h	*Cladopora* sp.		
		Dalmanophyllum sp. A	*Heliolites* sp.		
		Palaeocyclus porpita subsp. *mcallisteri* Merriam	*Halysites* sp.		
		Rhabdocyclus sp. d		*Dicoelosia* sp.	
		Cyathophylloides fergusoni Merriam		*Dalmanella* sp.	
		Arachnophyllum kayi Merriam		*Atrypa* sp.	
		Neomphyma crawfordi Merriam			

[1]Age designation based on comparison with the Gotland, Sweden Rugosa. Coral zone E contains rocks of Lower Devonian age based on the occurrence of *Monograptus uniformis*, the accepted index for lowermost Devonian in the Great Basin.
[2]*Salairophyllum*? from uncertain stratigraphic horizon at Coal Canyon, Simpson Park Mountains, Nev. Probably from coral zone E.

1971). The Roberts Mountains Formation, however, shows little evidence of reefal structure, or even of minor bioherms having initial bottom relief. In most places, the lower part of the formation is thin and consists of evenly laminated fine-grained argillaceous limestone with no reeflike characteristics. The upper part of the formation contains thin- to medium-bedded bioclastic limestone as well as fine-grained thin laminated beds. These rock types represent a facies that must have formed at a moderate depth of water. Corals, calcareous algae, and brachiopods, mostly fragmental, are fairly abundant in parts of the formation, but they have not developed into reeflike structures; indeed, in most places the fossils have been transported with other calcareous debris as debris flows.

At Coal Canyon, Simpson Park Mountains, depositional breccias may mark the vicinity of small patch reefs or bioherms, but no inclined reef-marginal beds or reef core rock was found. Some limestone strata of the upper Roberts Mountains Formation in the Roberts Mountains rich in corals and other benthonic organisms appear to represent beds and banks of very low bottom relief, but many are thick allodapic beds deposited in basins or on a gentle slope at greater depths than reef formation and below wave base.

Stromatoporoids contributed much of the material toward the building of reefs in the Niagaran of Illinois (Lowenstam, 1949) and in the Silurian of Gotland, Sweden (Manten, 1971). In the coral-rich Roberts Mountains Formation limestones, stromatoporoids, though present, apparently were not important as reef builders.

DISTRIBUTION OF GREAT BASIN SILURIAN LIMESTONE AND DOLOMITE BELTS AND THE REGIONAL DOLOMITE PROBLEM

Areal distribution of Great Basin Silurian carbonate rocks in contrasting lithologic belts such as the intermediate limestone and eastern dolomite belts leads to paleogeographic speculation and review of the multifaceted unsolved problems of the origin of marine dolomite. It is not a purpose of this report to enter into the complexities of geochemical and metasomatic change. Dolomites of the eastern belt certainly fall in the category of regional dolomite of diagenetic origin as contrasted with localized hydrothermal or metamorphic dolomites. In several mining districts of this province, the hydrothermal type locally forms very large bodies that may easily be confused with the diagenetic type (Hewett, 1931, p. 57–58). Nonetheless, some interpretation is appropriate in explaining the discrete lithologic and paleogeographic boundary zone separating the eastern dolomite from the intermediate limestone belt within which the Roberts Mountains Formation is found.

In relation to regional dolomites of vast extent like the eastern dolomite belt, we may seek explanation of its lateral boundaries from various fields of study including paleogeography, paleobiology, geochemistry, marine environment and the sources of magnesium introduced to produce the double carbonate mineral dolomite. We may ask: how or why does proximity to the subdued Silurian land mass on the east favor diagenetic dolomitization while offshore limestones remain normal marine limestone?

The dolomite question has been reviewed by many workers, including Van Tuyl (1916a, b), Steidtmann (1911, 1917), Skeats (1918), Fairbridge (1957), and, more recently many authors represented in Pray and Murray (eds. 1965), Bathurst (1971), and Hsü and Schneider (1973). Beyond doubt, the Laketown and Lone Mountain Dolomites, like the Niagaran of the continental interior—nearly continuous dolomites that cover thousands of square miles and are locally more than a thousand feet thick—fall into a regional category.

It has long been known that the amount of regional dolomite increases downward through the geologic systems from Holocene to Precambrian (Fairbridge, 1957) and (Daly, 1907, 1909). The Silurian is one of the systems containing much continuous regional dolomite in North America, as in the Great Basin and the continental interior.

Ulrich and Schuchert (1902) were perhaps the first to note that certain extensive regional dolomites border upon ancient shorelines. In the Great Basin Silurian, the regional dolomite belt lies between the old subdued landmass on the east and the intermediate limestone on the west. Farther west the Pacific border graywacke belt, through its extent from northern California to Alaska, is not known to include dolomite of the diagenetic type. Fossil and lithologic evidence indicates that the Silurian eastern dolomite and the intermediate limestone both represent shallow marine environments, possibly with some deepening where limestones appear, especially the allogenic graded types, and further deepening into graptolitic fine-grained and laminated beds. The western limit of dolomite, here the Lone Mountain Dolomite, was the western limit of reef development that migrated westward by normal landward carbonate accumulation typical of all large carbonate-producing regions. The generally regressive series of carbonate rocks that were deposited in the Great Basin during the lower and middle Paleozoic are strong evidence for the landward accumulation of carbonate sediment (and hence retreat of the sea) produced in the shallow shelf seas. Very extensive tidal flats and mud shoals behind or east of the Lone Mountain reef are the present site of the regional dolomites we see today.

Studies of rugose corals suggest that the Lone Mountain and Laketown Dolomites contain marine faunas differing in biofacies from those of limestones in the Roberts Mountains Formation (Merriam, 1973a). This does not, however, imply that the dolomite facies was initially deposited as dolomite sediment by direct chemical precipitation. Other ecological factors must be sought: for example, differences of water temperature, depth, salinity, and food supply. Fossils are locally abundant in the dolomites, but unless silicified early, that is, prior to dolomitization, they are destroyed by dolomitic recrystallization. Among the factors to be considered is the proximity to the shoreline, where extensive mudflats were doubtless very broadly exposed at low tide to bring about diurnal evaporative concentration to produce brines. Percolation of the magnesium-rich brine into the carbonate sediments may have taken place by reflux action seaward from the mudflats as suggested by Adams and Rhodes (1960) or by capillary transfer through the sediments as suggested by Friedman and Sanders (1967). Another theory suggests that drainage from the landmass on the east introduced additional magnesium as well as calcium to become available for the additive process of dolomitization. Movement of the carbonate-bearing ground water upward through the nearshore mudbanks probably was facilitated by evaporation across the banks and the subsequent pumping action created by this system (Hsü and Siegenthaler, 1969, and Hsü and Schneider, 1973). Westward toward the boundary zone between the eastern dolomite belt and the intermediate limestone belt, the magnesium calcium ratio became too low for dolomitization because of the absence of shallow water evaporative sites and less extensive tidal mudflats.

It is possible that the organic community that populated the nearshore flats (now the dolomitic belt) produced proportionally more high-magnesium calcite or even some dolomite by their biochemical processes, thereby fixing a large amount of magnesium into the system. In slightly deeper water with greater circulation, a different assemblage of organisms produced mainly calcite, and limestone was the carbonate deposited. Sediments in this region were not dolomitized because magnesium was not available.

Concentration of brine magnesium carbonate by evaporation at low tide on mudflats as a major factor in the dolomitization process has been studied by a number of investigators under a theory involving supratidal mudflats to which marine waters are added only occasionally during exceptionally high springtides and heavy storms. Greater concentration of magnesium in the brines comes about by evaporation and by the solutions percolating downward and seaward (reflux) to bring about metasomatic dolomitization of underlying carbonate muds and sands already containing magnesium in organically secreted calcite matrices. In such evaporative environments, gypsum and other salines should also be represented. Within the past 10 years, penecontemporaneous dolomites attributed to supratidal environments have been found in the Persian Gulf (Illing and others, 1965, Hsü and Schneider, 1973, DeGroot, 1973), in the Netherlands Antilles (Deffeyes and others, 1965). These discoveries illustrate the local hydraulics and geochemistry of contemporary dolomite formation on a fairly large scale, but they do not appear to provide the entire key to resolving the problem of vast regional dolomites like those of the Great Basin Silurian.

In reality, dolomitization on a regional scale as in the eastern Great Basin is probably the product of all the mechanisms suggested. Addition of magnesium concentrated by evaporative processes on the inshore tidal flats, magnesium-rich solute introduced from the land drainage as well as crystalline dolomite clastic debris introduced from exposed and eroding dolomite formations (for example, the Ordovician Bighorn Dolomite), and redistribution of magnesium taken from sea water by organisms and deposited as high magnesium calcite must all be significant factors.

GEOGRAPHIC DISTRIBUTION OF SILURIAN LIMESTONES

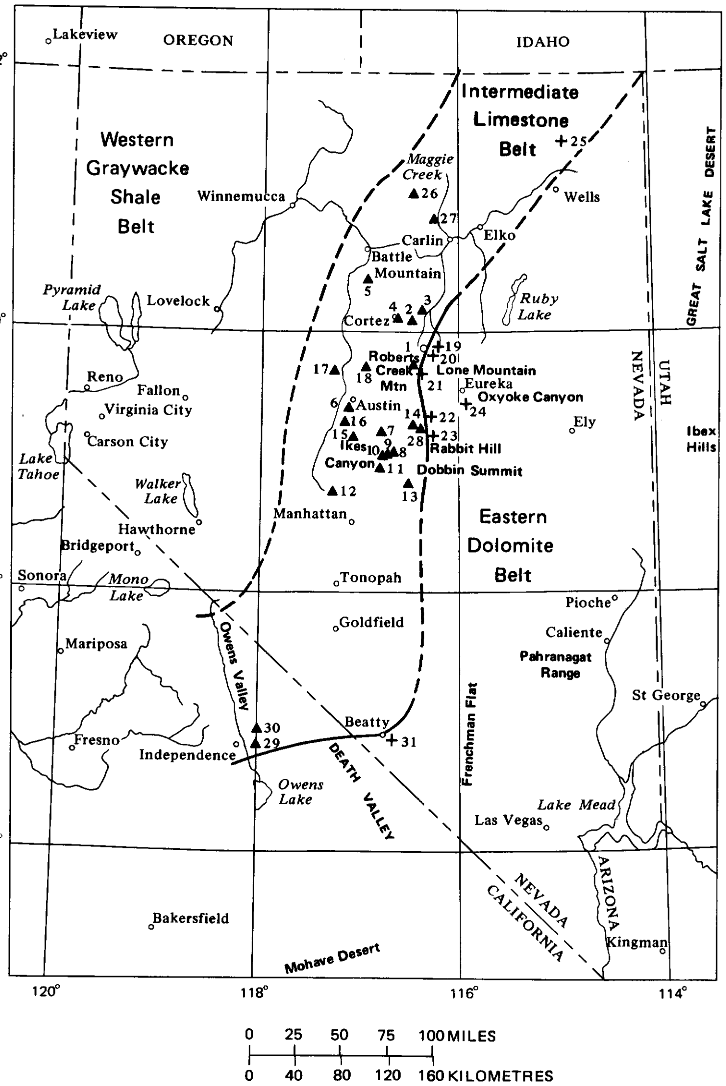
Strata of the Silurian intermediate limestone belt are known over a distance of about 325 miles (525 km) in a south-southwesterly direction from the Tuscarora Mountains of Elko County, northern Nevada, to the northern Inyo Mountains, southeastern California (fig. 1). The width of the slightly sinuous limestone band can only be estimated, but in most places, it is more than 50 miles (80 km) wide and may exceed 90 miles (145 km) before passing entirely into the western, predominantly shale-graywacke facies. Whereas the west boundary is inferred at this time because of lack of exposures and subsurface geologic data, the east boundary can be delimited within much narrower limits of error in many places, as, for example, at Roberts Creek Mountain, Bare Mountain near Beatty, Nev., and the Inyo Mountains, Calif., where the limestones and dolomites either intertongue, are interbedded, or crop out within a few miles of each other.

The intermediate limestone belt has been mapped and studied in detail in the Roberts Creek Mountains, the northern Simpson Park Mountains and Cortez Mountains, the Copenhagen Canyon area of the Monitor Range, the northern Toquima Range, and the northern Inyo Range. Outcrop areas where the geologic mapping is of a reconnaissance nature, or where the stratigraphic work has been confined to section measurement, are the Bootstrap mine area of the Tuscarora Mountains, Swales Mountain in the Independence Range, the Carlin Mine and Maggie Creek area in the Tuscarora Mountains, parts of the northern Monitor Range, and the Wall and Pablo Canyon area of the Toiyabe Range. A number of widely separated outcrop areas of these limestones have been identified and sections measured, but additional mapping or stratigraphic paleontology is needed. These areas include the Mount Callaghan area of the Toiyabe Range; the Ravenswood area of the Shoshone Range; areas near Reeds and Dry Canyons, Toiyabe Range; Dobbin Summit, Monitor Range; the Northumberland area of the Toquima Range; Bare Mountain area near Beatty; and occurrences north of Wells near Antelope Peak. A comprehensive documented stratigraphic summary of these localities and others is presented in T. E. Mullens (unpub. data, 1975).

ROBERTS MOUNTAINS FORMATION OF THE ROBERTS MOUNTAINS, NEV.

In the Roberts Mountains, the Roberts Mountains Formation is exposed over a large area on the west and northwest side of Roberts Creek Mountain, the type area of the formation. Other outcrops occur near the north edge of the range between Willow aand Birch Creeks.

The Roberts Mountains Formation in its type area includes a variety of dark-gray to bluish-gray lime-



EXPLANATION

▲ Roberts Mountains Formation and correlative formations

\+ Fossil localities of stratigraphic importance with regard to the Roberts Mountains Formation

1. Roberts Mountains Formation, type section. Roberts Creek Mountain, Roberts Mountains.
2. Roberts Mountains Formation, reference section. Coal Canyon, northern Simpson Park Range.
3. Roberts Mountains Formation. North pediment slopes of northern Simpson Park Range.
4. Roberts Mountains Formation. Cortez Mountains.
5. Roberts Mountains Formation. Goat Peak, Shoshone Mountains.
6. Roberts Mountains Formation. Dry Creek area, Toiyabe Range.
7. Roberts Mountains Formation. Petes Canyon window, Toquima Range.
8. Roberts Mountains Formation and Tor Limestone. June Canyon sequence. Ikes Canyon window, Toquima Range.
9. Roberts Mountains Formation and McMonnigal Limestone. Mill Canyon sequence. Ikes Canyon window, Toquima Range.
10. August Canyon sequence. Gatecliff Formation of Kay and Crawford (1964). Ikes Canyon window, Toquima Range.
11. Roberts Mountains Formation. Northumberland window, Toquima Range.
12. Roberts Mountains Formation. Pablo Canyon area, Toiyabe Range.
13. Roberts Mountains Formation. Clear Creek and Dobbin Summit area, Monitor Range.
14. Roberts Mountains Formation. Brock Canyon area, Monitor Range.
15. Roberts Mountains Formation. Bowman Creek area, Toiyabe Range.
16. Roberts Mountains Formation. Point of Rocks and Straight Canyons area, Toiyabe Range.
17. Roberts Mountains Formation. Ravenswood area, Shoshone Mountains.
18. Roberts Mountains Formation. Callaghan window, Toiyabe Range.

19–20. Beacon Peak Dolomite Member of Nevada Formation. Southern part of Sulphur Spring Range.

21. Lone Mountain Dolomite, type section. Lone Mountain.
22. Lone Mountain Dolomite. Mahogany Hills.
23. Lone Mountain Dolomite. Southern part of Fish Creek Range.
24. Beacon Peak Dolomite Member of Nevada Formation. Oxyoke Canyon, Mahogany Hills.
25. Late Silurian rugose corals in limestone. Antelope Peak, Snake Mountains.
26. Roberts Mountains Formation, reference section. Bootstrap Hill, southern part of Tuscarora Mountains.
27. Roberts Mountains Formation. Maggie Creek area, southern part of Tuscarora Mountains.
28. Rabbit Hill Limestone, type section; Roberts Mountains Formation. Copenhagen Canyon area, Monitor Range.
29. Vaughn Gulch Limestone, type area. Northern part of Inyo Mountains.
30. Sunday Canyon Formation. Barrel Spring area, northern Inyo Mountains.
31. Lone Mountain Dolomite above dark-gray limestone and dolomite probably correlative with Roberts Mountains Formation. Bare Mountain area.

FIGURE 1.—Part of Great Basin showing distribution of the Roberts Mountains Formation and correlative formations in the intermediate limestone belt and fossil localities of stratigraphic importance with regard to the Roberts Mountains Formation. Approximate limits of the Late Silurian-Early Devonian depositional facies belts are shown by heavy lines.

stones that are mostly thin bedded and weather in a platy to flaggy fashion. The basal part of the formation is thin-bedded blue-gray limestone with black chert interbeds and tabular chert nodules. Above this in the lower part of the formation is fine-textured thinly laminated limestone and calcareous shale with a few thin interbeds of coarse limestone. In the middle and upper parts of the formation, there is a change to predominantly coarser slabby-weathering blocky beds, a few centimetres to about 1 m thick, with partings of shale or laminated limestone. Crinoidal debris is abundant in these coarser beds, some of which are crinoidal bioclastic lenses containing abundant corals and brachiopods. As noted by Winterer and Murphy (1960, p. 123–129), some of the thicker beds are fossil-rich calcarenite locally revealing graded bedding. In places, the platy and laminated fine-grained beds contain abundant silt-size quartz granules. Coarse depositional limestone breccias or flat-cobble mud breccias with limestone matrix are present as lenses in the upper thicker bedded sequences.

Coarse-grained light-gray dolomitic limestone and dolomite occur as tongues and interbeds in the upper part of the formation; these dolomitic rocks can be traced laterally into a continuous dolomite, called Lone Mountain Dolomite. Silicified fossils are characteristic throughout the formation, especially in dolomitic limestones.

At the type area, the Roberts Mountains Formation is overlain by the Lone Mountain Dolomite. At some other places, it grades into sequences of laminated limestone interbedded with thicker bedded clastic limestones that have been named the McMonnigal Limestone (Kay, 1960, Kay and Crawford, 1964, and McKee and others, 1972), the Windmill Limestone (Johnson, 1965, Matti and others, 1975), and the Wenban Limestone of Gilluly and Masursky (1965).

TYPE SECTION

The type section of the Roberts Mountains Formation is on the northwest side of Roberts Creek Mountain between the south and middle forks of upper Pete Hanson Creek. The formation is about 2,000 feet (600 m) thick in the type section, where it occupies the stratigraphic interval between the Hanson Creek Formation and overlying dolomites classified here as the Lone Mountain Dolomite. It is here about 70 percent limestone, with a prominent cherty member at the base and dolomitic limestone and dolomite interbeds or tongues in the upper 200 m.

The Roberts Mountains Formation consists of well-bedded laminated dark-gray to slightly bluish-gray, platy, flaggy, and slabby limestone, dark-gray graded bioclastic limestone, calcareous shale, and subordinate black chert in the basal part of the formation. Most of the chert, shale, and laminated to shaly limestones occur in the lower part of the formation; the beds become on the whole thicker, coarser textured, and more bioclastic upward, with fewer of the laminated intercalations. Fossils are abundant in many horizons above the cherty interval, those in the laminated or shaly rocks are mainly graptolites.

In the type section, differences in lithology and paleontology make feasible a three-unit subdivision of the Roberts Mountains Formation as unit 1, 100 m; unit 2, 300 m; and unit 3, 200 m, in ascending stratigraphic order.

Unit 1.—Unit 1, a fine-textured cherty unit, is made up of a basal chert and dolomite 1–3 m thick overlain by fine-grained thin-bedded laminated dark-gray limestone weathering platy and flaggy with shaly partings. The limestones weather light gray. The laminae usually reveal an alternation of calcareous and argillaceous or silty layers; in places, millimetre-thick limy layers alternate with layers containing much dark-colored matter probably composed of iron oxides with organic substances (Winterer and Murphy, 1960, p. 123). The laminated strata include dark chert layers and nodules elongate parallel to bedding. The distinctive bluish-black chert-bearing interval of varying thickness less than 3 m at the bottom of the formation, is about 75 percent chert that contains subordinate unchertified and undolomitized limestone lenses. Upward the chert decreases in amount, occurring in discontinuous 1–5 cm layers separated by laminated limestone. Fossils are scarce in the laminated limestone, but shaly partings yield graptolites. The basal chert, resting upon the Hanson Creek Formation, which also is cherty in many places, is a widely recognized unit of the Great Basin Silurian. In some other areas it has yielded large pentameroid brachiopods.

Unit 2.—Unit 2, thickest of the three units in the type section of the Roberts Mountains Formation, is made up of platy to flaggy dark bluish-gray fine to fairly coarse textured impure limestones with interbeds of bioclastic limestone as much as 1 m thick. Calcareous shaly partings and thin laminated layers separate the thicker beds, many of which are highly fossiliferous (bioclastic); much of this debris is crinoidal. The introduction of the thicker, rather coarsely clastic crinoidal beds distinguishes unit 2 from unit 1. Scattered black chert lenses and nodules are present as high as about the middle of unit 2. In the upper part of the unit are a few light-gray recrystallized layers that are slightly dolomitic. Tabulate corals, pentameroids, and other brachiopods are abundant in the many bioclastic beds; the rugose corals are subordinate.

Unit 3.—Unit 3 is gradational with unit 2 through an interval wherein coarser textured crinoidal layers containing abundant *Conchidium* grade upward into a more uniformly thicker bedded sequence of light and dark-gray, somewhat blocky-weathering limestones that include coralline beds. About 75 m above its base, unit 3 becomes prevailingly lighter gray and less well bedded as it passes upward into the interbedded limestone and dolomite of the upper half. The lower coralline beds contain large heads of colonial Rugosa of Great Basin Silurian coral zone C. Light-gray-weathering limestones in the upper middle part of unit 3 contain abundant silicified corals of Great Basin Silurian coral zone D. Through the upper 122 m, bedding is poorly defined, the weathering more blocky, and fossils become fewer as the mixed carbonate rocks pass upward into the coarser saccharoidal dolomite of the overlying Lone Mountain Dolomite.

STRATIGRAPHIC RELATIONS TO UNDERLYING AND OVERLYING FORMATIONS

Careful examination of the contact separating the basal chert of unit 1 from the underlying Hanson Creek Formation has disclosed equivocal evidence of disconformity or angular discordance in the type section. Fossil evidence elsewhere, as in the Tuscarora Mountains (Berry and Roen, 1963), also suggests that some of the earliest Silurian may not be represented at or near the contact and hence a paraconformity exists in this part of the section.

The upper limit of the Roberts Mountains Formation in its type section is gradational with the Lone Mountain Dolomite (Lone Mountain unit 2 at Lone Mountain as redefined by Merriam in 1973). About 500 m of blocky dolomite between Roberts Mountains Formation unit 3 and richly fossiliferous lower beds of the Devonian Nevada Formation (or the McColley Canyon Formation of Murphy and Gronberg, 1970) yielded no fossils. Future study of the Lone Mountain Dolomite at Roberts Creek Mountain may show that the part of it correlates with part of the finer textured Beacon Peak Dolomite Member of the Nevada Formation of the Eureka district.

FACIES CHANGES FROM LIMESTONE TO DOLOMITE

A planimetric map of the upper Pete Hanson Creek area by Winterer and Murphy (1960, p. 120, fig. 2) that includes the type section of the Roberts Mountains Formation illustrates the intertonguing relation of unit 3 limestone to dolomitic beds of the Lone Mountain Dolomite. Dolomitic limestones of these unit-3 tongues contain a fauna more closely related to that of the Roberts Mountains limestone facies than to that of the Lone Mountain dolomite facies as known in the Eureka area (Merriam, 1973a, b). It is in Roberts Mountains unit 3 of the type area that we find the most clearly defined marginal interfingering of the intermediate limestone belt to the eastern dolomite belt in the Great Basin province.

STRATIGRAPHIC PALEONTOLOGY OF THE TYPE SECTION

The reference section for two of the five proposed Great Basin Silurian coral zones (Merriam, 1973a) occurs in the type section of the Roberts Mountains Formation, Silurian coral zones C and D in lithologic unit 3 of the formation. The other Great Basin Silurian coral zones have not been recognized in this section.

FOSSILS OF UNITS 1 AND 2

Poorly preserved *Monograptus* sp. with plain tubular thecae occur in unit 1 and the lowermost part of unit 2 (W. B. N. Berry, written commun., 1964). Fossils present in these lower beds are:

Massive favositids	Small *Conchidium*-like pentameroids
Cladopora sp.	*Dicoelosia* sp.
Heliolites sp.	*Eatonia?* sp.
Halysites sp.	*Merista?* sp.
Orthophyllum sp.	*Atrypa* sp.
Pycnostylid Rugosa	*Monograptus* sp.

The characteristic Lower Silurian rugose corals of Great Basin Silurian coral zone A which would be expected in these lower beds have not been found here; those absent include the genera *Palaeocyclus, Dalmanophyllum, Arachnophyllum,* and *Cyathophylloides.*

Fossils of early Middle Silurian (Great Basin Silurian coral zone B) were expected in the middle to upper beds of unit 2 but have not been found here. Rugose coral genera present are *Tryplasma, Palaeophyllum, Diplophyllum,* and *Microplasma.* Tabulate coral genera in these beds are *Aulopora, Cladopora, Heliolites,* and *Halysites.* In the uppermost beds of unit 2, brachiopods are abundant, especially medium-sized *Conchidium*-like pentameroids, some of which have fine radial costae, others radial costae of medium strength. Of the latter, one species (pl. 12, figs. 24–26) resembles the Norwegian *Conchidium münsteri* Kiaer as described and figured by St. Joseph (1938). This species, reported in southern Norway Silurian zone 5b, St. Joseph considered to be Early Silurian (Llandoverian). Other brachiopods abundant in higher beds of Roberts Mountains unit 2 are the small *Coelospira* sp. and *Ptychopleurella* sp.

FOSSILS OF UNIT 3

Unit 3 of the Roberts Mountains Formation includes two Great Basin Silurian coral zones, C and D, and is the reference section for both. Coral zone C lies about 10 m above the base of unit 3 and has yielded only corals, of which the following Rugosa are diagnostic:

Entelophylloides (*Prohexagonaria*) *occidentalis* Merriam
Tryplasma newfarmeri Merriam
Denayphyllum denayensis Merriam

Coral zone D lies about 90 m above the base and contains the following diagnostic Rugosa:

Stylopleura berthiaumi Merriam
Tonkinaria simpsoni Merriam
Tryplasma duncanae Merriam

Tabulate corals, dasycladacean algae, and brachiopods were abundant here in a diverse biota. The following are among the common associated fossils of coral zone D:

Verticillopora cf. *V. annulata* Rezak
Dicoelosia sp. r
Gypidula sp. r
Homoeospira sp. r
Kozlowskiellina sp. f
Atrypa sp.

AGE OF THE ROBERTS MOUNTAINS FORMATION OF THE TYPE SECTION

In the time-stratigraphic sense, the greater part, but not all, of the Silurian System as well as the lower part of the Devonian System, is believed to be recorded in the 600 m of Roberts Mountains Formation of its type section. Fossil evidence indicating the early part of Early Silurian (Llandoverian) is lacking; the rest of the system is present and is represented by graptolites, conodonts, and shelly fossils of Silurian age. The upper part of the formation is Lower Devonian in age (Klapper and Murphy, 1974; Berry and Murphy, 1975).

The basal chert of the Roberts Mountains Formation (bottom of unit 1), present in the type section and most other Great Basin Silurian carbonate sections of both limestone and dolomite, seems to be a dependable marker unit. That it does transgress hypothetical time planes from place to place has been suggested by F. G. Poole (written commun., 1971), and his geologic evidence is convincing. It has also been suggested that there may be two or more chert sequences of different ages at this place in the stratigraphic column of the Great Basin (Jonathan C. Matti, written commun., 1974). This possibility remains to be demonstrated. The Silurian age of the basal chert has been established in several widely separated localities. In the northern Monitor Range at Copenhagen Canyon, the basal chert contains fairly large pentameroid brachiopods of Silurian character. At Mill Canyon, Toquima Range, a coral assemblage beneath the chert contains *Cladopora*? sp., three species of *Favosites, Halysites* (or *Cystihalysites*), "*Cystiphyllum*" sp., and *Brachyelasma* sp., a fauna suggesting a Silurian age. Graptolites from the chert in the central Toquima Range were identified by W. B. N. Berry as *Climacograptus scalaris* and *Climacograptus* cf. *C. medius*; these species suggest an Early Silurian (Early Llandovery) age. As shown by Berry and Roen (1963), the beds in the southern Tuscarora Mountains that are a few feet above the basal chert marker contain graptolites of the *Monograptus riccartonensis* Zone of early Wenlockian age.

Roberts Mountains unit 2 and the lower part of unit 3 up to and including Great Basin Silurian coral zone C are provisionally classified as Middle Silurian (Wenlock). The lower and middle beds of unit 3, including coral zone D, are considered to be Late Silurian (Ludlovian); the higher Ludlovian faunas of coral zone E have not been found at the type section. The graptolite succession on which the currently accepted Silurian-Devonian boundary is based indicates that the upper part of unit 3 is Lower Devonian.

ROBERTS MOUNTAINS FORMATION OF THE NORTHERN SIMPSON PARK MOUNTAINS

GEOLOGIC SETTING

Silurian and Devonian strata are exposed along the lower north slopes of the Simpson Park Mountains (Horse Creek Valley quadrangle, Nevada), most of which are blanketed by andesite and basalt flows. In some parts of the foothill area, coarse gravel and fanglomerate obscure the Paleozoic strata. Only that part of the lower north slope of the range between Grouse Creek and Red Hill at the northeast tip is covered in this report.

Between Grouse Creek and Red Hill, a distance of about 11 km, the Paleozoic rocks are exposed in two areas: the Coal Canyon area (fig. 2) on the west and the Red Hill area on the east. Between these areas is a wide band of volcanic rock and gravel cover. Overthrust chert and shale of the Ordovician Vinini Formation crop out extensively in the Fye Canyon area on the southwest; Pennsylvanian or Permian conglomerate and limestone is found within the area and disconformably overlies the older Paleozoic strata.

Between Grouse Creek and Red Hill, the Paleozoic beds dip 20° to about 60° E.; the steeper dips are in the vicinity of faults. Most faults have a northerly strike; in some places, faulting has caused an apparent thickening of the stratigraphic section. In general, the beds become progressively younger eastward; the oldest exposed rocks are the uppermost beds of the Hanson Creek Formation on the west in a minor canyon half a mile east of the mouth of Grouse Creek Canyon. Nearly all the Silurian and Lower Devonian section is exposed at Pine Hill and Pyramid Hill on the west.

COAL CANYON AREA

Pine Hill on the west side of Coal Canyon is underlain by a nearly continuous east-dipping section of Roberts Mountains Formation truncated on the east by the Coal Canyon fault (fig. 2). On the opposite or east side of Coal Canyon, Pyramid Hill is largely Rabbit Hill Limestone of Early Devonian age underlain along the lower east slopes of Coal Canyon by the uppermost beds of the Roberts Mountains Formation. The upper part of the Roberts Mountains Formation here was named the Windmill Limestone by Johnson (1965). This unit of finely laminated fine-grained limestone and thin- to medium-bedded clastic limestones is a recognizable formation at a number of places elsewhere in the region.

At places along the west slope of Coal Canyon, the Coal Canyon fault is marked by a north-south zone of shearing and brecciation about 76 m wide. Within and adjacent to the fault zone, the east bedding dips are steep and locally reversed to the west. The fault strikes about N. 5° W.; although its overall dip was not determined by field observation, it is inferred to be a high-angle normal fault with a possible steep east dip. To the south, the Coal Canyon fault passes beneath volcanic cover.

COAL CANYON FAULT ZONE

Continuous measurement of the stratigraphic section across Coal Canyon from Pine Hill through Pyramid Hill must take into consideration a north-

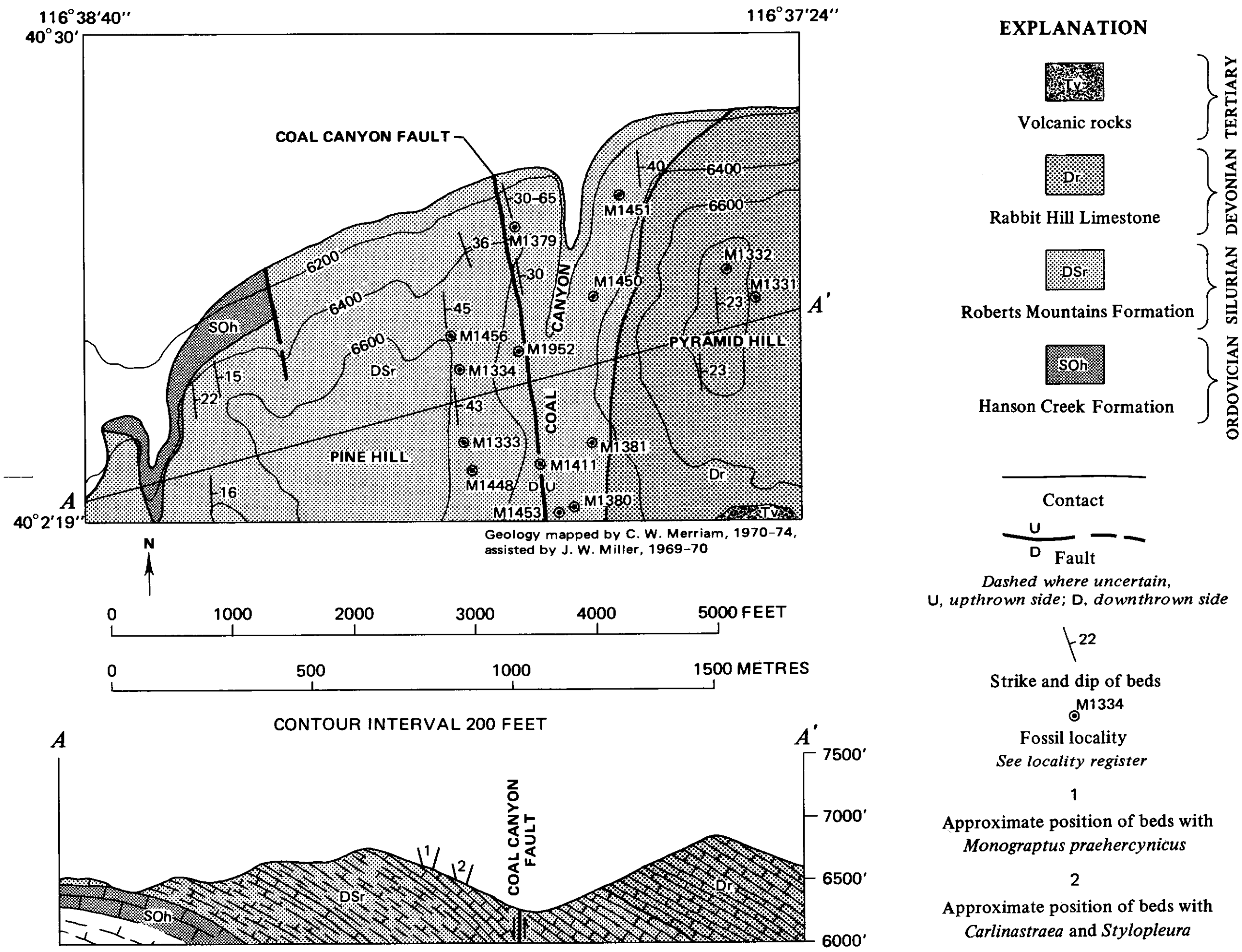


FIGURE 2.—The Coal Canyon area, northern Simpson Park Mountains, showing relations of the Roberts Mountains Formation in the vicinity of the Coal Canyon fault.

south fault break of undetermined magnitude. The Coal Canyon fault zone follows the steep west wall of the canyon for a distance of 800 m. It is best shown on the main northeast spur of Pine Hill, where its north-south trace is marked by a coarse calcite-impregnated limestone cataclastic breccia some 76 m wide. Minor surfaces disclosing dip and direction of displacement were not found at the margins of this coarse breccia. The general trend of the breccia mass suggests that it continues southward, mostly beneath talus, and passes beneath a volcanic inlier in upper Coal Canyon basin without observed displacement of the volcanic body. The fault appears to have had a steep dip, but the direction of inclination has not been determined. It is probably a high-angle normal fault, although it might conceivably be a thrust fault subsidiary to a fault in upper Coal Canyon herein named the Rocky Hills thrust. Mapping in the Pine Hill block reveals a steepening of bedding dip as the Coal Canyon fault zone is approached from the west. The steepened dips are fault drag features suggesting either downward movement of the east or Pyramid Hill block or west-to-east displacement of strata in the west or Pine Hill block on a low-angle thrust fault. The stratigraphic sections on the two sides of the canyon, the Pine Hill block on the west, the Pyramid Hill block on the east, are dealt with separately.

PHYSICAL STRATIGRAPHY OF THE PINE HILL SECTION

A nearly continuous section of Roberts Mountains Formation is exposed in Pine Hill west of the Coal Canyon fault. Only the uppermost beds of this section have been disturbed within the Coal Canyon fault zone. The Roberts Mountains Formation in the Pine Hill block is about 450 m thick and is here considered as having two lithologic units.

The lower Roberts Mountains unit of Pine Hill is about 330 m thick; the base is black chert, 1–2 m thick, resting with sharp contact upon thick-bedded light-gray-weathering Hanson Creek dolomite and limestone. The succeeding Roberts Mountains consists of laminated thin-bedded platy and flaggy-weathering dark-gray impure limestone with intercalations of calcareous shale or calcareous siltstone. There are a few bioclastic limestone interbeds 5 or 6 cm thick containing brachiopods and other fossils. Graptolites are fairly common in the laminated limestone and shaly units. In the lower 30 m above the basal chert, there are a few thin black chert bands and chert nodules. Lamination is a characteristic feature of some of the thin limy beds as in other areas of Roberts Mountains outcrop.

In the lower part of the lower 330-m interval, bioclastic limestone beds are few. A 1-inch, slightly bluish-gray fine-grained limestone is crowded with small silicified corals and brachiopods; another thin bed with unsilicified fossils yielded a smooth medium-sized *Pentamerus*-like brachiopod.

About 140 m above the formation base is a limonite brown or reddish-stained silty sandstone bed containing abundant graptolites.

The upper 120-m unit of the Roberts Mountains Formation in the Pine Hill block is an alternating thick and thinly bedded fairly coarse-grained dark-bluish-gray limestone with calcareous shaly and silty intercalations. The lithologic change from the lower unit to the upper unit is distinct, but not abrupt. Most of the thicker limestone beds are bioclastic and contain well-preserved corals and other fossils; the most abundant are massive *Favosites* colonies. About 15 m of this limestone in the upper half of the interval, which carries a varied fauna of rugose corals and brachiopods, is referred to as the *Carlinastraea* beds. Thick beds of depositional breccia occur in the upper part of the Roberts Mountains Formation on the east side of Coal Canyon in the *Toquimaphyllum* beds of the Pyramid Hill section.

The upper 120-m unit of the formation in the Pine Hill block is terminated on the east by the Coal Canyon fault. It is possible that the total thickness of this unit in unfaulted sections is much greater than 120 m.

STRATIGRAPHIC PALEONTOLOGY AND AGE OF ROBERTS MOUNTAINS FORMATION AT PINE HILL

Fossils collected through the 450 m of Roberts Mountains Formation in the Pine Hill block show the age to range from Early Silurian (late Llandoverian) for the lower beds to the Lower Devonian (Gedinnian) for the upper 100 m or so of the formation. This range in age is assigned on the basis of graptolites identified by W. B. N. Berry (written commun., Nov. 8, 1968). The upper 120-m unit contains abundant corals in the more massive beds; *Carlinastraea,* which is especially abundant, is considered representative of the Great Basin Silurian coral zone E.

Coiled graptolites in beds a few feet above the basal chert are reported as late Early Silurian (late Llandoverian). Graptolite assemblages near the top of the lower 330-m unit include *Monograptus praehercynicus* Jaeger.

Some limonitic silty limestone and siltstone beds about 140 m stratigraphically above the base of the Roberts Mountains Formation contain a graptolite assemblage reported upon by W. B. N. Berry (written commun., Oct. 16, 1972) as:

Lobograptus "scanicus"
Monograptus bohemicus?
Monograptus colonus
Monograptus sp. (of the *M. dubius* type)

The age of this horizon is considered by Berry to be early Ludlovian. Such a low position for early Ludlovian, some 310 m below the top of this section, suggests that the Wenlockian part of the formation is relatively thin compared with the Ludlovian.

The upper 120-m lithologic unit of the Roberts Mountains Formation at Pine Hill (the type Windmill Limestone of Johnson, 1965) is primarily thick-bedded dark-bluish-gray medium- to fairly coarse grained bioclastic limestone with thin-bedded limestone and calcareous shaly intercalations. The coarse-grained beds are made up of clastic debris, and most are graded. This unit forms prominent outcrops and the change from the platy and laminated limestones of the lower division is gradual. As described by Berry and Mullens (written communs., 1968), the *Monograptus praehercynicus* beds must lie near the base of this upper unit. Corals and brachiopods, especially corals, are abundant in the upper unit; the most abundant coral is the large, massive *Favosites*. A zone about 20 m thick above the middle of this unit has yielded the following fossils:

Favosites sp. (massive)
Cladopora sp.
Alveolites sp.
Syringopora sp.
Striatopora? sp.
Rhegmaphyllum? sp.
Brachyelasma sp. c
Tryplasma sp., cf. *T. duncanae* (fragmentary)
Tonkinaria simpsoni Merriam
Stylopleura sp. c, cf. *S. berthiaumi* Merriam
Carlinastraea tuscaroraensis Merriam
Gypidula sp.
Isorthis sp. (ventral valve)
Small dalmanellid brachiopod (dorsal valve)

This assemblage containing *Tryplasma, Tonkinaria,* and *Stylopleura* suggests that of Great Basin Silurian coral zone D at the Roberts Mountains Formation type section, although its most distinctive coral, *Carlina-*

straea, was not found at the type section. The species of *Carlinastraea* found at Pine Hill occurs in the uppermost fossil bed at Bootstrap Hill in the Tuscarora Mountains and at locality M1446 on the pediment slope north of Red Hill in the Simpson Park Mountains where it is associated with *Australophyllum (Toquimaphyllum) johnsoni* Merriam and *Stylopleura.* Such an association, in particular with *Toquimaphyllum,* suggests that there is no profound stratigraphic separation between the *Carlinastraea* beds at Pine Hill and those of Great Basin Silurian coral zone E on the east side of Coal Canyon (Pyramid Hill block), in which *Australophyllum (Toquimaphyllum) johnsoni* is the most distinctive rugose coral. Little is known of the stratigraphic range of any of these seemingly distinctive Rugosa.

FOSSILS COLLECTED WITHIN THE COAL CANYON FAULT ZONE

Several important fossil occurrences are within disturbed rocks of the Coal Canyon fault zone, and because of this, their true stratigraphic position remains uncertain. Among the fossils are the compact aseptate pycnostylid *Stylopleura*? sp. c (pl. 2, figs. 1 and 2) from locality M1379, *Australophyllum* sp. c (pl. 8, figs. 3–7), from locality M1318 and *Verticillopora annulata* (pl. 10, figs. 1–3) from locality M1411. From their positions in the fault zone, it appears probable that all these fossils came from horizons stratigraphically higher than the *Carlinastraea* beds.

PHYSICAL STRATIGRAPHY OF THE PYRAMID HILL SECTION

In Pyramid Hill, east of the Coal Canyon fault zone, about 400 m of east-dipping limestone and thinly bedded calcareous shaly and silty deposits include the uppermost part of the Roberts Mountains Formation (the Windmill Limestone of Johnson, 1965) and the overlying Rabbit Hill Limestone. About 150 m of the Roberts Mountains Formation is present here. The Rabbit Hill underlying most of Pyramid Hill continues eastward. As the depositional contact between the two formations is gradational, placement is arbitrary as understood at this time. The paleontologic change in corals, however, is profound with complete disappearance upward of all Rugosa of Silurian affinities and Rugosa classified previously as Silurian types (Merriam, 1973a). Only the small solitary variety *Syringaxon* is present in the Rabbit Hill Devonian of this section.

Within the Roberts Mountains Formation along the steep lower east slopes of Coal Canyon are bold massive outcrops of the more thickly bedded lenticular and locally fossil-rich limestones. Much of this lower slope is covered by talus mantle that is the source of weathered fossil material collected here. Some of the float fossils, like many large Rugosa, however, are traceable to their source beds.

The uppermost Roberts Mountains Formation of the Pyramid Hill is made up of fine-textured dark- to medium-dark-gray laminated platy to flaggy limestone, and thick-bedded (2 cm–2 m) coarse slightly bluish-gray bioclastic limestones, most of which are graded. Some of the more massive beds are lenticular, and locally they form prominent cliff exposures. The bioclastic beds, which are composed in considerable part of crinoidal debris, also contain abundant corals, brachiopods, and other fossils. In some places all fossils are silicified and weather out a limonite brown color. The thicker bedded limestones above the middle of the unit include numerous lenticular bodies of coarse-textured depositional limestone breccia in which some clasts are more than a foot in greatest diameter and range in shape from subangular to rounded. In some of the beds the corals present are surrounded by a coarse-grained and fine-grained limestone matrix; some beds are graded and of uniform thickness. Above the interval of thicker bedded coral-rich limestone and depositional breccia, the Roberts Mountains Formation becomes thinner bedded in about its uppermost 23 m, approaching the transition interval into overlying Rabbit Hill Limestone. In general, the lower part of the Rabbit Hill is much like the platy thin-bedded Roberts Mountains beds, but coarser textured bioclastic beds of the Rabbit Hill lack the bluish cast of such fossil-rich limestone beds in the Roberts Mountains. *Tentaculites* is common in the lower part of the Rabbit Hill Limestone. The characteristic *Leptocoelia* of the Rabbit Hill Limestone becomes abundant in *Leptocoelia* beds about 100 m stratigraphically above the base of the Rabbit Hill as mapped. The dark-gray platy limestones and calcareous shale and silty beds of the Rabbit Hill commonly weather very light gray.

In the upper part of the Roberts Mountains Formation of the Pyramid Hill section, the coral-rich more massive beds with depositional limestone breccia are referred to as the "upper coral zone with *Toquimaphyllum.*" On the west side of Coal Canyon in the Pine Hill block, the coral-rich beds are distinguished as the "lower coral zone with *Carlinastraea.*" The upper coral zone with *Toquimaphyllum* is the primary reference section for Great Basin Silurian coral zone E of Merriam (1973a). These rocks are Lower Devonian in age based on graptolites.

All Pyramid Hill fossils dealt with in this report came from a stratigraphic interval of about 50 m in the middle and upper parts of the Roberts Mountains Formation on the east side of Coal Canyon. This interval includes the thicker bedded coral-rich limestone and allogenic depositional limestone breccia. Some of the fossil material came directly from the bold outcrops in place, but much of it was collected on the talus below the bold exposures. The common fossils of this 50 m interval are:

Stromatoporoids
Favosites sp. (massive)
Cladopora sp.
Alveolites sp.
Stylopleura nevadensis Merriam
Stylopleura berthiaumi Merriam
Mucophyllum oliveri Merriam
Kodonophyllum mulleri Merriam
Rhizophyllum cf. *R. enorme* (Oliver)
Chonophyllum simpsoni Merriam
Kyphophyllum sp. c
Australophyllum (*Toquimaphyllum*) *johnsoni* Merriam
Orthostrophia sp.
Schellwienella? sp.
Barrandella? sp.
Sicorhyncha? sp.
Rhynchospirina sp.
Plectatrypa? sp.
Atrypa sp.
Meristella sp.
Kozlowskiellina sp. f
Verticillopora cf. *V. annulata* Rezak

The rugose coral assemblages in the coral-rich limestone interval of the Pyramid Hill exposures are of Silurian character as compared with assemblages of the Gotland, Sweden, Silurian standard and with those of Silurian strata of the Klamath Mountains, Calif., and Australia.

Mucophyllum oliveri, the most distinctive fossil in this fauna, bears a fairly close resemblance to *Mucophyllum* of the Silurian Gazelle Formation of the Klamath Mountains, Calif., and to Silurian *Mucophyllum crateroides* (Etheridge) of Australia. Similar corals from Gotland, Sweden, have previously been referred to *Schlotheimophyllum* or erroneously to *Chonophyllum. Kodonophyllum* is represented in the Gotland section, as is the slipper coral *Rhizophyllum,* which does, however, pass upward into the Early Devonian of eastern Europe. *Kyphophyllum* is a Silurian genus in Gotland but may range into earliest Devonian in the Klamath Mountains. *Toquimaphyllum,* proposed by Merriam (1973a) as a subgenus of the long-ranging *Australophyllum* in Silurian and Devonian rocks, is itself known in the Great Basin in later Silurian beds. The little-known pycnostylid Rugosa, which include *Pycnostylus* and *Stylopleura,* are characteristic of the Silurian System.

A float specimen from Coal Canyon assigned to the genus *Salairophyllum,* first reported from the Ural Mountains of the U.S.S.R., was probably derived from the higher Roberts Mountains limestone. In southeastern Alaska, *Salairophyllum* occurs in the Late Silurian limestones (Merriam, 1972) associated with *Conchidium alaskensis,* an index fossil of the Ludlovian Stage in Alaska.

Verticillopora, the large dasycladacean alga, is mostly confined to Silurian rocks of the Great Basin. In the Vaughn Gulch Limestone of the Inyo Mountains, it crosses the line into earliest Devonian at the base of the uppermost Vaughn Gulch limestone unit.

PROBLEM OF THE SILURIAN-DEVONIAN BOUNDARY AT PYRAMID HILL

A systematic study has been made (Merriam, 1973a) of the rugose corals from thick-bedded Roberts Mountains limestone of the upper coral zone with *Toquimaphyllum,* the reference section of Great Basin Silurian coral zone E as defined by Merriam (1973a). This coral zone contains distinctive genera and subgenera represented in the Silurian of Gotland, Sweden, in the Klamath Mountains Silurian of northern California (Merriam, 1972), and in the Silurian of Australia. None of these genera range into the overlying Rabbit Hill Limestone.

It is significant that no fossils have been collected through a stratigraphic interval of about 100 m from the top of the uppermost Roberts Mountains thick-bedded coralline limestone to the lowest fossils of the Rabbit Hill Limestone. The contact between the two formations as mapped is arbitrary, and from the coral evidence, with reference to Gotland, Sweden, the Silurian-Devonian boundary is discretionary and assumed to lie somewhere within the 100 m interval.

The rugose coral evidence bearing upon the Silurian-Devonian boundary clearly does not agree with that derived from study of the graptolites and from conodont research. The base of the *Monograptus uniformis* Zone, which is accepted as defining the base of the Devonian, places the boundary about 250 m lower in the section in the Pine Hill block on the west side of Coal Canyon. To clearly resolve this type of boundary problem will require the cooperative effort of specialists dealing with all the fossil groups represented in these rocks, emphasizing graptolites, conodonts, brachiopods, and rugose corals.

ROBERTS MOUNTAINS FORMATION, TUSCARORA MOUNTAINS

As a host rock of gold, the Roberts Mountains Formation has been traced widely in the Tuscarora Mountains and nearby areas of Elko and northern Eureka Counties, Nev. Structural complexity is everywhere characteristic of the formation, where, as part of the autochthonous group of rocks, it is overridden by graptolitic shales, argillites, and cherts of the Vinini Formation (Roberts and others, 1958). Complete stratigraphic sections of the Roberts Mountains Formation are rare here, but the basal chert is exposed 4 miles (6.4 km) southwest of the Big Six Mine (Berry and Roen, 1963) and at the gorge on Maggie Creek 8 miles (12.8 km) northwest of Carlin. Rocks of the unnamed Devonian limestone unit of Mullens (Evans and Mullens, 1976; T. E. Mullens, unpub. data, 1975) are above the Roberts Mountains Formation at Bootstrap Mine and at Maggie Creek. The section at the Carlin mine, though much faulted, seems to be nearly complete.

An excellent partial section occurs at the Bootstrap mine on Boulder Creek 22 miles (35.2 km) north-northeast of Dunphy, a short distance north of the Eureka-Elko County line. Although the basal chert is not exposed here, about 470 m of strata with several coral-bearing fossil zones has been measured by T. E. Mullens (unpub. data, 1975) at this locality. Evans and Mullens (1976) divide this section of rocks into two units, the lower 180 m called Roberts Mountains Formation and the upper 275 m termed unnamed Devonian limestone. We favor including the lower part of the unnamed Devonian limestone unit in the Roberts Mountains Formation because it is similar to the upper part of that formation at many places in central Nevada, in particular, the reference section at Coal Canyon in the Simpson Park Mountains. The upper part of the unnamed Devonian limestone unit of Evans and Mullens (1976) looks like the Rabbit Hill Limestone and is probably correlative with that formation. An alternative nomenclature, in line with other studies of the Silurian and Lower Devonian in central Nevada, would term the lower part of the unnamed unit of Evans and Mullens (the top of our Roberts Mountains Formation) the Windmill Limestone (Johnson, 1965) and the upper part the Rabbit Hill Limestone. The lumping of rocks into a general unnamed unit obscures basic lithologic similarities and correlations and is a step backward in our understanding of the paleotectonics of the region. Collections of unusually well-preserved silicified fossils made in this vicinity by R. J. Roberts during reconnaissance mapping of northern Eureka County convincingly demonstrated the Silurian age of some of the limestones. Fossil collections along the Mullens section traversed by Mullens and Merriam make possible a significant correlation with the Coal Canyon reference section and indirectly with the Roberts Mountains Formation type section.

PHYSICAL STRATIGRAPHY OF THE BOOTSTRAP HILL SECTION

Measurement of the Roberts Mountains Formation at Bootstrap Hill by T. E. Mullens (unpub. data, 1975) shows two major lithologic divisions totaling about 470 m. This section does not include the base of the formation, which presumably is the black chert unit. The lower division, 180 m of which is exposed, is made up of platy splitting laminated limestone with thicker interbeds of bioclastic and pelletal limestone. Of these strata, the fine-textured laminated limestones predominate. The upper 275 m unit consists of thicker bedded coarser bioclastic and pelletal limestone with a few intercalcalations of laminated limestone, especially the lower 50 m. Corals and brachiopods are abundant in some beds of the upper unit. The bioclastic and pelletal beds commonly exhibit graded bedding; many of these beds include breccia fragments and scour surfaces at the base.

The Bootstrap Hill section is possibly truncated at the top by a thrust fault (T. E. Mullens, written commun., 1972). The coral-bearing bed, that of *Carlinastraea tuscaroraensis,* lies about 400 m stratigraphically above the bottom of the section.

STRATIGRAPHIC PALEONTOLOGY OF THE BOOTSTRAP HILL SECTION

Three faunal zones are recognizable at Bootstrap Hill on the basis of corals and brachiopods. These range in ascending age from possible Great Basin Silurian coral zone A to coral zone D or E. The uppermost beds have yielded no coral fauna, but conodonts are varieties found in the Rabbit Hill Limestone.

Lowest coral-brachiopod zone.—Two fossil collections were made by R. J. Roberts, one from the southwest base of Bootstrap Hill (M1120) and the other from the west base of the next hill to the south (M1412). Both collections were taken from talus masking the lowest exposed strata.

The collection from locality M1412 is diverse and distinctive; it includes, among other fossils, the following forms:

Cyathophylloides sp. f
Cladopora sp.
Alveolitid tabulate coral
Conchidium sp. b
Fardenia sp. b
Ptychopleurella sp.
Coelospira sp. b
Kozlowskiellina sp. b
Merista sp.

The fossils from locality M1120 at the southwest base of Bootstrap Hill are *Cyathophylloides* sp. f, *Brachyelasma* sp. b, *Heliolites* sp., and *Favosites* sp.

The fossils at both localities are silicified and associated with chertified sedimentary material that is characteristic of lower beds of the formation near the basal chert marker. The marker bed presumably is lower in the section but is not exposed. The primitive colonial rugose coral *Cyathophylloides* in each of these assemblages resembles *C. fergusoni* of the Great Basin Silurian coral zone A described in collections from the Toquima Range.

Middle coral-brachiopod zone.—A 60-m stratigraphic interval starting 180 m from the base of the section and at the bottom of the more massive bioclastic sequence contains fossil assemblages that include the following forms.:

Cladopora sp.
Coenites sp.
Favosites (massive)
Stylopleura sp. b
Calostylis? sp.
Kodonophyllum sp. b
Kyphophyllum sp. b
Resserella sp.
Leptaena sp.
Salopina? sp.
Gypidula sp.
Coelospira sp.
Trematospira? sp.
Atrypa sp.
Howellella sp.
Glassia or *Cryptatrypa* sp.

Upper fossil zone with Carlinastraea.—Collections from what is here called the *Carlinastraea* bed, 70 m stratigraphically below the top of the Bootstrap Hill section, were made by R. J. Roberts in 1958 and were supplemented by additional collections by Mullens and Merriam in 1969. The complex rugose coral *Carlinastraea* occurs in very large colonies 1 m or more in diameter, as it does at Coal Canyon in the Simpson Park Mountains. Fossils found in the *Carlinastraea* bed at Bootstrap Hill are:

Cladopora sp.
Alveolites sp.
Favosites (massive)
Rhegmaphyllum sp.
Syringaxon? sp.
Tryplasma sp. cf. *T. duncanae* Merriam
Kyphophyllum? sp., cf. *K.* sp. b
Carlinastraea tuscaroraensis n. gen., n. sp.
Salopina? sp. (dorsal valve)
Large dalmanellid brachiopod (ventral valve)
Abundant crinoidal debris

AGE OF THE ROBERTS MOUNTAINS FORMATION AT BOOTSTRAP HILL

Coral and brachiopod evidence points to a Silurian age for part of the Bootstrap Hill section with an age range from Early Silurian (Great Basin Silurian coral zone A) for the lower beds containing *Cyathophylloides* to Late Silurian (Great Basin Silurian coral zone D or E) for the higher beds containing *Carlinastraea*. Like the the type and reference sections of the Roberts Mountains Formation, the upper part is Lower Devonian. This age, as elsewhere, is based on the graptolite standard which in central Nevada places the Silurian-Devonian boundary at a lower stratigraphic position than the corals would suggest.

Except for *Coelospira* sp. b, the brachiopod assemblage from the lowest faunal zone shows little similarity to known assemblages from other areas; the brachiopods of Great Basin Silurian coral zone A are in general poorly known.

The faunas of the middle coral-brachiopod zone generally fall in line with a Silurian age, in particular the Rugosa *Stylopleura, Calostylis?, Kodonophyllum,* and *Kyphophyllum*. Several of the brachiopods range upward into the Devonian; those provisionally assigned to *Salopina?, Coelospira,* and *Glassia* or *Cryptatrypa* are possibly more in harmony with a Silurian age.

The remarkable colonial rugose coral *Carlinastraea,* though resembling Devonian forms conventionally assigned to *Spongophyllum,* is generically quite distinct. *Carlinastraea tuscaroraensis,* which is specifically identical to that from Bootstrap Hill, occurs in the Simpson Park Mountains at Coal Canyon in beds with a coral fauna quite similar to that of Silurian coral zone D in the Roberts Mountains type section. *Carlinastraea* of a similar kind occurs in association with *Australophyllum* (*Toquimaphyllum*) *johnsoni* and *Stylopleura* cf. *S. nevadensis* in beds assigned to Great Basin Silurian coral zone E at locality M1446 in the northern foothills of the Simpson Park Mountains. *Carlinastraea* at Bootstrap Hill is therefore suggestive of either Great Basin Silurian coral zone D or E.

Studies of graptolites from the lower 180 m of the Mullens section (unpub. data, T. E. Mullens, 1975) (by W. B. N. Berry) give evidence for a higher position in the Silurian System than do the corals. *Monograptus* in beds from about 45 m above the base to about 90 m include:

Monograptus sp. (plain thecae)
Monograptus sp. (appears to have thecae with spines similar to those in *M. chimaera*)
Monograptus sp. (of the *M. dubius* type?)
Monograptus sp. (thecae appear to be similar to those of *M. uncinatus*)

Berry's conclusion (written commun., Nov. 8, 1968) is that these graptolites are possibly of Ludlovian Late Silurian age. Other graptolites from horizons about 175 m and 185 m above the base of the section are:

Monograptus angustidens Pribyl
Monograptus uniformis Pribyl

Their age is given as Earliest Devonian (*Monograptus uniformis* Zone).

ROBERTS MOUNTAINS FORMATION OF THE NORTHERN MONITOR RANGE

At Copenhagen Canyon near Rabbit Hill in the northern Monitor Range, the Roberts Mountains Formation is represented by thin-bedded laminated graptolite-bearing silty limestone and thin- to medium-bedded clastic limestones. It is overlain by Rabbit Hill Limestone. These Silurian and Lower Devonian strata were studied by Merriam and Anderson (1942, p. 1687) and later described in more detail after reconnaissance geologic mapping and stratigraphic measurement by Merriam (1963). A recent study by Matti, Murphy, and Finney (1975) focuses on the stratigraphy and environment of deposition of the Silurian and Lower Devonian rocks of this area and revises the reconnaissance map.

The most complete and measurable sequence of Roberts Mountains Formation in Copenhagen Canyon underlies an unnamed hill whose summit is about 1.6 km north-northeast of the top of Rabbit Hill in the SW¼ sec. 36, T. 16 N., R. 49 E. The formation to the top of the unnamed hill measured about 180 m (Merriam, 1963, p. 38); beds of several hundred metres more are present west of the hill but poorly exposed. A thickness of 480 m was measured by Matti, Murphy, and Finney (1975) on this traverse. The section is made up of platy to shaly weathering argillaceous limestone and calcareous shale grading upward into thin- to medium-bedded clastic limestones with fine-grained laminated limestone interbeds. On fresh surfaces these argillaceous beds are dark gray and fine textured; on weathering they become light gray or buff colored. Bioclastic and graded beds occur as sporadic interbeds in the middle part of the section and as the main lithologic type in the upper part; they are about 12 cm thick and are composed largely of fine sandy material with crinoidal debris. The platy silty limestones contain an abundance of graptolites best seen on weathered surfaces. No thick coarse bioclastic limestone lenses containing a diverse colonial coral fauna were found in this section, but brachiopods, which were collected from high in the section, are reported by Johnson, Boucot, and Murphy (1967).

The lower 30–40 m of the Roberts Mountains Formation at the unnamed hill is a very cherty limestone that is assumed to be correlative with, or to include, the basal Roberts Mountains chert marker of other Great Basin sections. It is, however, classified as the top of the underlying Hanson Creek Formation by Matti, Murphy, and Finney (1975). This conspicuously banded member consists of interbedded dark-gray or slightly bluish-gray fine-grained limestone and dark-gray chert that weathers limonite brown. Uneven lenses and pinch-and-swell beds of chert, 2–12 cm thick, make up one-third to one-half of this cherty unit.

Above the cherty member, for at least 140 m to the top of the hill, are thin-bedded fine-grained argillaceous limestones that are dark gray on fresh breaks but weather light gray with buff- and brownish-colored patches. A few dark-gray chert nodules occur at places in this interval.

PHYSICAL STRATIGRAPHY

The contact at the bottom of the lowest chert bed reveals no convincing physical evidence of erosion and disconformity with the underlying Hanson Creek Formation, of Late Ordovician and Early Silurian age. Of possible significance regarding the system boundary is a persistent calcareous sandstone bed that lies about 12 m stratigraphically below the chert. This fine sandstone contains abundant chert granules. According to F. G. Poole (oral commun., 1968), a sand of this kind occurs widely in the central Great Basin in about the same stratigraphic position. This bed provides a useful datum with reference to base of the Silurian System; it is especially valuable in sections lacking the chert marker.

The apparent thinning of the Roberts Mountains Formation at Copenhagen Canyon from the relative thick sections to the north is part of the gradual thinning of the unit to the west and south. In the Toquima Range to the west, two thrust plates containing rocks that were originally deposited farther west (presumably in the vicinity of the Toiyabe Range) contain complete sections of Roberts Mountains Formation that are 106 m thick and less than 3 m thick, respectively. Similarly, in the northern Inyo Mountains, Calif., a northward change of the Vaughn Gulch Limestone to graptolite-bearing shaly deposits was accompanied by a thinning of strata representing the Vaughn Gulch interval (Ross, 1966, p. 32).

STRATIGRAPHIC PALEONTOLOGY AND AGE OF THE ROBERTS MOUNTAINS FORMATION AT COPENHAGEN CANYON

Studies of graptolites and conodonts provide most of the paleontologic evidence of age of this formation in the Monitor Range; they indicate the age of the formation as Silurian and Lower Devonian. Generically undetermined pentameroid brachiopods about 3 cm long observed in the field near the top of the cherty unit suggest that this unit is best assigned to the Silurian System, in agreement with the graptolites and conodonts. The sporadic crinoidal limestone beds may eventually yield other shell megafossils of diagnostic age significance.

Graptolites identified by Ruedemann (Merriam and Anderson, 1942, p. 1687) came from surface rubble a few feet above the chert. These were identified as *Monograptus acus* Lapworth and *Monograptus pandus* Lapworth, suggesting to Ruedemann the approximate age of the lower and middle Gala beds of England, or of the Clinton Group (Middle Silurian) and younger Silurian beds in New York State.

Several graptolite collections made by Mullens and Merriam from higher in the section and identified by Berry include the following forms:

(float near top of basal chert, 33 m above base of formation)
- *Cyrtograptus* sp.
- *Monograptus priodon* (Bronn)
- Age: In the span of late Llandovery to early Wenlock.

(float 33–84 m above base of formation)
- *Cyrtograptus* sp.
- *Monograptus flemingii* (Salter)
- Age: Probably Wenlock.

(100 m above base of formation)
- *Monograptus dubius* (Suess)
- *Monograptus uncinatus* Tullberg
- *Gothograptus spinosus* Wood
- Age: Early Ludlow; *Monograptus nilssoni–M. scanicus* Zone.

(approximately 106 m above base of formation)
- *Monograptus* sp. cf. *M. nudus* type?
- *Monograptus* sp. cf. *M. jaculum* type?
- Age: In the span of middle Llandovery to Ludlow.

(90–150 m above base of formation)
- *Monograptus flemingii* (Salter)?
- *Monograptus* sp. (of the *M. dubius* type)
- Age: Probably late Wenlock.

Graptolites reported by Matti, Murphy and Finney (1975) include *Monograptus spiralis* and *Retiolites geinitzianus angustidens* 1 m above the top of the chert (33 m above the base of the formation as used here) these forms are late Llandoverian. Collections from high in the formation (in the Windmill Limestone as mapped by Matti and others, 1975) include *Monograptus birchensis*, *M. praehercynicus*, and *M. hercynicus;* those species indicate an Early Devonian age.

ROBERTS MOUNTAINS FORMATION AT BROCK CANYON, MONITOR RANGE

At Brock Canyon on the west side of the range, the Roberts Mountains Formation is exposed as parts of two separate thrust plates. One plate contains all the Middle and Upper Ordovician formations (Antelope Valley Limestone, Copenhagen Formation, Eureka Quartzite, and Hanson Creek Formation) recognized to the east around Antelope Valley as well as the Roberts Mountains Formation; the second plate contains Roberts Mountains Formation directly on the Antelope Valley Limestone. The Roberts Mountains Formation in both plates is finely laminated thin-bedded graptolitic silty limestone, but the basal chert is present in only one of the two sequences—the plate containing the complete series of Ordovician formations. The formation is at least 180 m thick, but the total thickness of the formation in either plate is unknown as it is the youngest unit in the respective sequences.

ROBERTS MOUNTAINS FORMATION AT DOBBIN SUMMIT, MONITOR RANGE

In the middle part of the Monitor Range at Dobbin Summit and Clear Creek, the Roberts Mountains Formation has been mapped by F. J. Kleinhampl (Kleinhampl and Ziony, 1967). In that area the formation is underlain by the Hanson Creek Formation and overlain by Rabbit Hill Limestone. This occurrence of the Roberts Mountains is of special significance as it is partly dolomitic, suggesting proximity to the border zone between the eastern dolomite belt and the intermediate limestone belt as at Roberts Creek Mountain and at Bare Mountain near Beatty, Nev. Rocks from the August Canyon thrust sequence in the Toquima Range that are in part correlative with the Roberts Mountains Formation are also dolomitic. The basal chert member was not found. Kleinhampl states:

> The Roberts Mountains Formation consists of two main units. The lower contains alternating pale brown-weathering slope-forming platy limestone and thinner but conspicuous medium-dark-gray ledgy limestone and dolomite containing abundant macerated fossils (crinoid columnals and corals). This unit closely resembles the Masket Shale of Kay and Crawford (1964, p. 439) in the Ikes Canyon area of the Toquima Range. An overlying gray massive cliffy dolomite and limestone unit is commonly present in the Monitor Range and is tentatively considered to be the upper part of the Roberts Mountains. It could be correlative with part of the Lone Mountain Dolomite. Because of the questionable age and name assignment and thinness of units, the Late Ordovician through Silurian strata are shown as undifferentiated dolomite on the northern Nye County geologic map. In the Dobbin Summit area, the Roberts Mountains is no more than about 60–120 m thick and consists mainly of the lower unit. In contrast, near Clear Creek, the lower member is 90 m thick and the upper gray massive dolomite member is 100 m thick (Greene, 1953, p. 27). Here the top is faulted out according to Greene.

The Rabbit Hill Limestone overlies the Roberts Mountains Formation in the Dobbin Summit area. The Rabbit Hill consists of very fossiliferous somewhat platy slope-forming limestone that is poorly exposed and weathers to chips and plates of pale yellowish- and pale reddish-gray and yellowish-brown colors. The formation may form an incomplete section as little as less than 100 to about 245 m thick and truncated at its top by a low-angle fault. The fault zone is marked by a discontinuous very dark gray chert.

ROBERTS MOUNTAINS FORMATION AT BARE MOUNTAIN

Of special interest are those localities where the Great Basin Silurian gives evidence of a position near a lateral transition from dolomite of the eastern dolomite belt to limestone of the intermediate limestone belt, such as Bare Mountain near Beatty, Nev., and the Roberts Mountains type section of central Nevada.

At Chuckwalla Canyon, near Bare Mountain, Cornwall and Kleinhampl (1960) mapped 300 m of Silurian rock as two formations. The upper unit, being entirely dolomite about 114 m thick, was assigned to the Lone Mountain Dolomite; the lower unit, about 190 m thick, was referred to the Roberts Mountains Formation; this lower unit is made up of alternating members of dark-gray limestone, dolomitic limestone, and dolomite; one-third to one-half of this sequence is dolomite. A Silurian age assignment is reasonable, for at Bare Mountain these beds occupy a stratigraphic interval between the Late Ordovician Ely Springs Dolomite and superjacent dolomite assigned to the Devonian.

The Bare Mountain sequence can be compared with the Lone Mountain Dolomite at its type section. As presently interpreted by Merriam (1973b), the type Lone Mountain includes a lower dark-gray dolomite called Lone Mountain Dolomite unit 1 and an upper light-gray dolomite termed Lone Mountain unit 2. Lone Mountain unit 1 is lithologically comparable in many respects to the Roberts Mountains Formation of Cornwall and Kleinhampl at Bare Mountain but differs by containing no limestone.

No fossils of stratigraphic significance were identified by Merriam (1973b) during the course of his work in the Lone Mountain Dolomite of the type section. The middle part of Lone Mountain unit 1 contains partly silicified brachiopods and corals, locally in abundance. None of the fossils prepared by acid etching were generically determinable; they include small pentameroids, small rhynchonellid brachiopods, and tabulate corals. Lone Mountain unit 2, the upper light-gray unit, has yielded a poorly preserved cerioid rugose coral and in dark-gray lenses of this upper division, colonial forms probably of the genus *Entelophyllum*. There are unconfirmed reports that larger pentamerids were collected from an unknown part of the Lone Mountain in its type section. In the Mahogany Hills and Fish Creek Range, Eureka County, Nev., identifiable fossils are present in Lone Mountain unit 2 (Merriam, 1973b). At Bare Mountain, the upper formation, or Lone Mountain Dolomite of Cornwall and Kleinhampl, has yielded no fossils. The underlying dark unit (Roberts Mountains Formation) contains abundant silicified fossils in its middle part, in both the limestone and the dolomite interbeds.

Correlation of the Bare Mountain strata with those of central Nevada is based somewhat more on general lithologic resemblance and stratigraphic sequence than on fossil evidence. The silicified fossil assemblages from the middle part of the lower dark-gray unit (Roberts Mountains Formation of Cornwall and Kleinhampl), which come mainly from dolomite interbeds, are not closely related to known faunas of the type Roberts Mountains Formation. Most abundant are pentameroid brachiopods which include a large, smooth *Pentamerus*-like genus, *Conchidium* of medium to large size, and *Virgiana*? sp. A similar *Pentamerus*-like genus occurs in the lower part of the Roberts Mountains Formation at Coal Canyon, Simpson Park Mountains, Nev. In the type section, Roberts Mountains pentameroids, especially *Conchidium*, are present in great abundance near the top of unit 2, that is, near the middle of the formation. The corals at Bare Mountain are *Heliolites* sp., large *Streptelasma*-like solitary forms, large solitary *Rhabdocyclus* sp. B, and *Stylopleura* sp. resembling *S. berthiaumi* of the Great Basin Silurian coral zone D. Near the base of the Bare Mountain section, the colonial *Palaeophyllum* sp. b occurs (Merriam, 1973a).

It is significant that a very cherty dolomite member lies at the base of the Roberts Mountains Formation at Bare Mountain. This member occupies the position of the basal chert marker of many Great Basin sections of the Roberts Mountains Formation.

ROBERTS MOUNTAINS FORMATION OF THE NORTHERN TOQUIMA RANGE

Good exposures of the Roberts Mountains Formation are found north of Petes Canyon, in the area between Ikes and Mill Canyons, and in the area around East and West Northumberland Canyons in the northern part of the Toquima Range. The formation in these localities occurs in different tectonic plates that have presumably been thrust from sites of deposition west of the Toquimas. A simplified geologic map, figure 3, outlines these structural relations. A total of five sequences of lower and middle Paleozoic rocks are present in the thrust slices; when unraveled palinspastically, they represent rocks from a large region in central Nevada.

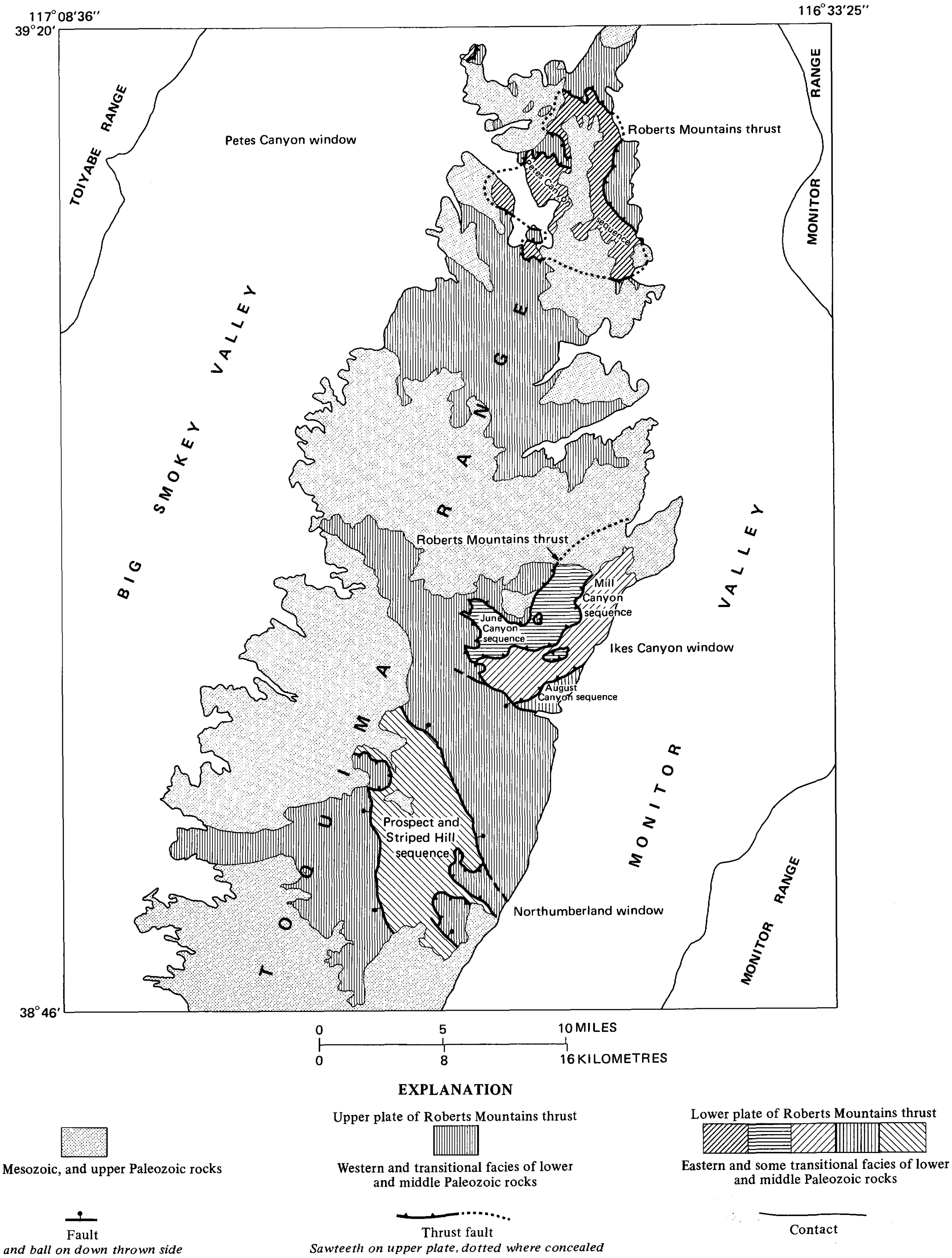


FIGURE 3.—The northern Toquima Range showing Paleozoic sequences that contain Silurian rock in separate thrust sheets. Based on geologic mapping by E. H. McKee in 1968–70.

PETES CANYON WINDOW

The Roberts Mountains Formation in the vicinity of Petes Canyon (fig. 1, loc. 7; fig. 3) is exposed in the Petes Canyon window in the Roberts Mountains thrust (McKee and Ross, 1969). An incomplete section of the formation is present here as the uppermost unit in the autochthon. A number of partial sections including the basal black chert unit are found; the thickest of these, in the central part of sec. 10, T. 16 N., R. 46 E., southeast corner of Lander County, contains more than 100 m of strata. The thickness of the order of 300 m estimated by McKee and Ross (1969) should probably be revised to about 200–250 m.

The basal contact with rocks mapped as the Hanson Creek Formation seems conformable, though obscured by small faults or alluvium in most places. No angular discordance was found between the Roberts Mountains and Hanson Creek, but fossil evidence suggests a hiatus between these formations.

The Roberts Mountains above the basal black chert is mostly thin-bedded platy-splitting graptolite-bearing argillaceous limestone. A few medium-bedded limestones contain a rich coral fauna, but the stratigraphic relation of these beds is not known because of structural complications. Graptolites, which provide the evidence for the age of lower parts of the formation, include monograptids ranging from upper Lower Silurian (Llandovery) into the upper part of the Middle Silurian (Wenlock and possibly lower Ludlow). The coral-bearing limestone beds contain forms typical of the Rabbit Hill Limestone of Early Devonian age.

IKES CANYON WINDOW

JUNE CANYON SEQUENCE

In the area between Ikes and Mill Canyons, carbonate strata of lower and middle Paleozoic age are exposed in a window in the Roberts Mountains thrust called the Ikes Canyon window (fig. 1, loc. 8; fig. 3). The Roberts Mountains Formation (or its correlatives) occurs in three somewhat different sequences of rocks that have been thrust together and are now exposed in this window. The upper thrust plate, named the June Canyon sequence by Kay and Crawford (1964), contains a metre or so of thin-bedded, platy-splitting graptolitic limestone between massive beds of Ordovician limestone and the Tor Limestone of Late Silurian and Early Devonian age. The upper contact with the Tor is conformable; the lower contact with Ordovician limestone appears conformable but may be a fault. In all places but one (approximately 1,500 m west of Ikes cabin site), the massive limestone units (Ordovician limestone and Tor) are in fault contact, the relatively incompetent Roberts Mountains limestone having been sheared out between them.

The total thickness of Roberts Mountains Formation, here made up entirely of the thin-bedded graptolitic limestone, is about 3 m. Fragments of the graptolite *Monograptus* aff. *M. praehercynicus* indicate that the few feet of strata that make up the formation in this thrust plate correlate with the upper part of the formation elsewhere in central Nevada and are of Lower Devonian age. Corals from the bottom part of the Tor above the graptolite horizon are typical of the Great Basin Silurian coral zone E (McKee and others, 1972), which is included in the Lower Devonian because of the underlying *Monograptus praehercynicus*.

MILL CANYON SEQUENCE

The middle thrust plate, named the Mill Canyon sequence by Kay and Crawford (1964) (fig. 1, loc. 9; fig. 3), contains a complete section of the Roberts Mountains Formation with both graptolites and corals. These strata are well exposed on the ridges above the lower reaches of Ikes Canyon.

The formation here is about 110 m thick and consists mostly of thin-bedded platy argillaceous limestone with increasing amounts of medium (5–30 cm) graded beds of clastic limestone toward the top. There is no chert at its base, and it rests with no obvious disconformity on massive limestone that contains Upper Ordovician fossils. The lowest fossils (graptolites) in the Roberts Mountains of the Mill Canyon sequence occur within a foot of its base and are Middle Silurian forms (McKee, 1975). The fossil evidence indicates a hiatus representing a time period of considerable duration at the base of the formation. The upper contact with the McMonnigal Limestone, gradational across an interval of about 25 m, was arbitrarily drawn where medium-bedded gray clastic limestone typical of the McMonnigal becomes the dominant lithology.

Graptolites that occur throughout the formation include late Middle Silurian (late Wenlock) forms at the base, Upper Silurian Ludlow) types somewhat higher, and *Monograptus praehercynicus*, which is Lower Devonian, in the upper part of the formation and in the bottom of the McMonnigal Limestone.

The Roberts Mountains–McMonnigal sequence has yielded coral faunas in normal order representing three, A, D, and E, of the five Great Basin Silurian coral zones. Coral zone A is represented by *Arachnophyllum kayi* with which *Cyathophylloides fergusoni* and *Neomphyma crawfordi* are associated. Above this horizon, coral zone D contains *Stylopleura nevadensis, Tonkinaria* sp., and large *Verticillopora annulata.* Coral zones A and D are in the Roberts Mountains Formation; coral zone E lies in the McMonnigal Limestone and includes *Australophyllum*

(Toquimaphyllum) johnsoni and a species of *Kyphophyllum.*

AUGUST CANYON SEQUENCE

Rocks in the lowest thrust plate in the Ikes Canyon window (fig. 1, loc. 10, fig. 3) were named the August Canyon sequence by Kay and Crawford (1964). It was assumed by these geologists that this sequence of strata is in situ, but it is possible that these rocks, along with the overlying two plates (Mill Canyon and June Canyon sequences), have moved from another region. As its base has not been found, there is no structural evidence bearing on the problem; stratigraphic considerations such as regional facies patterns shed little light on the site of deposition of the rocks. These strata contrast so markedly with the strata of equivalent age in the overlying thrust plates that new formational names proposed by Kay (1960) and Kay and Crawford (1964) seem appropriate. Rocks correlative with the Roberts Mountains Formation include all or most of the Gatecliff Formation of Kay (1960), the Bastille Limestone Member of the Masket Shale of Kay and Crawford (1964), and probably the lower part of the upper member of the Masket Shale of Kay and Crawford (1964). The name Masket Shale was used by these workers (1964) for strata in the Mill Canyon and June Canyon sequences; in this report and in others (McKee and others 1972; McKee, 1976), those strata are called the Roberts Mountains Formation.

The Gatecliff Formation of Kay and Crawford is comprised of three distinctive units, all dolomitic. It overlies with no apparent discordance dark-colored limestone containing a distinctive fauna considered to be Upper Ordovician (McKee, 1976). This Upper Ordovician limestone was named the Caesar Canyon Limestone by Kay and Crawford (1964). Corals indicative of the Silurian have been collected from the basal unit of the Gatecliff (McKee, 1976), which is a light-gray lithographic dolomite. The middle unit of the Gatecliff is dolomite distinctive by the presence of rounded quartz sand grains; no fossils have been found in this rock. The upper unit of the Gatecliff is dolomite and chert similar to the basal chert unit of the Roberts Mountains Formation in most of central Nevada. No fossils have been collected from this chert in the August Canyon sequence, but a few miles south, s similar chert unit in what is called the Prospect sequence by Kay and Crawford (1964) has yielded graptolites that indicate an Early Silurian age. The Bastille Limestone Member of the Masket Shale of Kay and Crawford is mostly unfossiliferous gray dolomite with medium-bedded bioclastic limestones at the top. These limestones contain a rich coral fauna equated with the Great Basin Silurian coral zone E. Part or possibly most of Silurian time is represented by the underlying dolomite or at the basal contact with the underlying Caesar Canyon Limestone of Kay and Crawford. The upper part of the Masket Shale of Kay and Crawford is thin-bedded laminated silty limestone, part of which may correlate with the upper part of the Roberts Mountains Formation and with the Rabbit Hill Limestone. It is of Lower Devonian age on the basis of a variety of Lower Devonian conodont forms (McKee, 1976).

NORTHUMBERLAND WINDOW

About 8 km south of the Ikes Canyon window, eastern to transitional facies (mostly carbonate) rocks are exposed in the Northumberland window in the Roberts Mountains thrust (fig. 1, loc. 11; fig. 3). The rocks in this window constitute the Prospect and Striped Hill sequences of Kay and Crawford (1964), presumed to have been thrust from the southwest to their present location in the north-central part of the Toquima Range (Kay and Crawford, 1964, fig. 8).

Both the Prospect and Striped Hill sequences contain Roberts Mountains Formation (called Masket Shale and Gatecliff Formation by Kay and Crawford, 1964) as their uppermost unit. The formation is typically thin-bedded platy-splitting argillaceous tan-weathering limestone similar to rocks mapped as Roberts Mountains Formation in most other places in central Nevada. Black cherty limestone occurs at the base of the formation. Monograptids from the chert zone at Water Canyon north of East Northumberland Canyon are indicative of the Lower Silurian (lower Llandovery). An Early and Middle Silurian age is assigned to the overlying platy unit of the Striped Hill sequence by Kay and Crawford (1964, fig. 5).

ROBERTS MOUNTAINS FORMATION IN THE TOIYABE RANGE

The Roberts Mountains Formation crops out in widely separated localities along most of the extent of the Toiyabe Range. Many of these occurrences mark the westernmost exposures of the formation at a given latitude; these outcrops lie approximately along long 117°15′. It is assumed that these outcrops have not been tectonically transported (thrust) from the west as have many thrust plates in the Toquima Range. Localities where partial or complete sections of Roberts Mountains Formation are exposed include: Callaghan window (fig. 1, loc. 18), about 24 km northeast of Austin; Dry Creek area (fig. 1, loc. 6), 11 km south-southwest of Austin; Point of Rocks and Straight Canyon area (fig. 1, loc. 16), about 27 km southwest of Austin; and Pablo Canyon (fig. 1, loc. 12), about 16 km west of Round Mountain. The formation crops out at a few other localities in the Toiyabe Range where it has not been studied in detail.

CALLAGHAN WINDOW

Lower Paleozoic carbonate strata are exposed in the Callaghan window (fig. 1, loc. 18) in the Roberts Mountains thrust about 24 km north of Austin (Stewart and Palmer, 1967; Stewart and McKee, 1968). The Roberts Mountains Formation is the top unit in the autochthonous sequence and occurs in scattered outcrops in the southern and northwestern parts of the window. Since it is the top unit, its thickness is not known. About 60 m can be measured in partial sections, but the formation is probably three to four times thicker in this part of the Toiyabe Range. The more than 1,000 m reported by T. E. Mullens (unpub. data, 1975) seems excessive on the basis of other measured sections in the region. The Roberts Mountains Formation lies on different rock units at localities only a few miles apart. In the Boone Creek area in the northern part of the window, it lies on Antelope Valley Limestone. There is no obvious angular discordance between these formations, but a hiatus spanning the Upper Ordovician and possibly part of the Lower Silurian must be represented at the contact. In the southern part of the window, it rests on rocks originally considered to be equivalent to the Hanson Creek Formation (Stewart and Palmer, 1967) but now considered likelier to be correlative with the Copenhagen Formation (Stewart and McKee, 1975). About 40 m of strata lithologically different from the underlying Antelope Valley Limestone and overlying Roberts Mountains separates these formations. At all places in the Callaghan window, the Roberts Mountains consists of a basal black chert about 10 m thick overlain by light-gray platy-splitting silty limestone that contains monograptids. No coralline limestone has been found in the incomplete sections of the formation in this area.

DRY CREEK AREA

On the west side of the Toiyabe Range about 11 km southwest of Austin, in the Dry Creek area, the Roberts Mountains Formation (fig. 1, loc. 6) is the uppermost unit of a section that includes Ordovician, Cambrian, and Precambrian strata below. About 120 m of tan- or gray-weathering platy argillaceous limestone makes up the formation in this area. There is no basal chert unit, and the formation lies with apparent conformity on medium-bedded Antelope Valley Limestone. A few fragments of *Monograptus* have been found in these platy rocks, and a collection of poorly preserved corals comes from a thicker bed of limestone near the top of the section. The corals, which include *Favosites* and *Zelophyllum* sp., suggest a Silurian age, probably in the upper part of the system. In overall aspect, this section resembles the Mill Canyon sequence of the Toquima Range, a sequence of strata in a thrust plate assumed to have originated in the general area of the Dry Creek section.

POINT OF ROCKS AND STRAIGHT CANYON

A faulted sequence of lower Paleozoic strata is exposed in the western and central part of the Toiyabe range in an area that includes Straight Canyon and an area of about 10 km^2 south of Reeds Canyon, including Point of Rocks Canyon about 27 km south of Austin (fig. 1, loc. 16). Here the rocks dip generally to the north, forming a homoclinal sequence. This seemingly simple structure is complicated by at least one thrust parallel to the strike of bedding and other faults that cut out, or repeat, parts of the section. Stratigraphic thicknesses are estimates based on a number of traverses across the section. The best exposure of the lower part of the Roberts Mountains Formation and underlying units is in Straight Canyon (sec. 18, T. 16 N., R. 43 E.) about 1.6 km west of the Kingston ranger station. Here about 3 m of dark chert and limestone that make up the basal part of the Roberts Mountains lies on a composite unit about 15 m thick of cherty limestone and dark shale containing cryptolithoid trilobites. These rocks are probably best correlated with units in the Toquima Range named Hanson Creek Formation (in Petes Canyon window) or Caesar Canyon Limestone in the August Canyon sequence of the Ikes Canyon window. There is no angular discordance between the unit and the Roberts Mountains chert, but they are probably separated by a hiatus as elsewhere in central Nevada. Above the chert is about 100 m or more of gray-weathering platy argillaceous limestone typical of the graptolite facies. A few monograptids were found a short distance above the basal chert in Straight Canyon and higher in the section on the west side of Point of Rocks Canyon. The section from Point of Rocks Canyon to the north side of the adjacent unnamed canyon to the north (unsurveyed sec. 36, T. 17 N., R. 42 E.) reveals about 300 m of thin-bedded Roberts Mountains Formation. This thickness, however, is subject to speculation and is probably excessive, for at least half the section is poorly exposed on the dip slope, and numerous faults mapped at other places in the region are probably present here. Scattered graptolites collected in these rocks indicate that they are forms considered to range from late Early Silurian (late Llandovery) to Devonian in age (Stewart and McKee, 1976). Further evidence for unresolved structural complications is that the succession of graptolite zones does not correspond to a simple traverse across the section. It is suggested here that the actual thickness of the formation in this part of the Toiyabe Range is of the order of 150 m. Thin- to medium-bedded bioclastic limestones become more numerous toward the top of the formation. Graptolites in this transition zone are of the *Monograptus hercynicus* group. Higher in the section, a massive limestone (about 4 m thick) contains the corals *Billingsastraea*? sp. T, a new species, and a new species of a *Hexagonaria*-like genus.

PABLO CANYON AREA

A faulted slice of Roberts Mountains Formation occurs in Pablo Canyon in the Toiyabe Range about 16 km west of the town of Round Mountain (fig. 1, loc. 12). The top of the formation here is everywhere faulted, and it is faulted at the base in most places. In the few places where the basal chert unit is exposed, it lies on 3–6 m of shaly and cherty rock that contains Ordovician graptolites. Most of the formation is gray- to tan-weathering thin-bedded platy-splitting silty limestone typical of the graptolitic facies seen elsewhere in central Nevada. The locality in Pablo Canyon is the westernmost occurrence of recognizable Roberts Mountains Formation at this latitude.

ROBERTS MOUNTAINS FORMATION IN THE SHOSHONE MOUNTAINS

A partial section of Roberts Mountains Formation crops out in the Shoshone Mountains in the Ravenswood area about 24 km northwest of Austin (fig. 1, loc. 17); the westernmost outcrops of the formation at this latitude are almost directly north of the Point of Rocks and Pablo Canyons sections along long 117°15′W. The formation here, as at the other places at this general latitude, is mostly graptolite-bearing thin-bedded platy-splitting silty limestone. About 250 m of rocks of this lithologic type occurs above a thin black chert-bearing unit that in turn lies on either Middle Ordovician Antelope Valley Limestone or shale, chert, and limestone of an unnamed unit tentatively correlated with the Copenhagen Formation (Stewart and McKee, 1976).

SILURIAN AND LOWER DEVONIAN LIMESTONES OF THE NORTHERN INYO MOUNTAINS, CALIF.

MAZOURKA CANYON

VAUGHN GULCH LIMESTONE

Within the intermediate limestone belt, the southernmost Silurian and Lower Devonian rocks of the Great Basin crop out at Mazourka Canyon, northern Inyo Mountains, Calif. (fig. 1, loc. 29). No exposures of these limestones have been found between the Inyo Mountains and the Toquima or Toiyabe Ranges, a distance of about 200 km. Named the Vaughn Gulch Limestone by Ross (1963, p. B81), these beds were for many years after their first geologic examination in 1912 believed to be entirely Devonian (Kirk, 1918; Stauffer, 1930). Geologic mapping of the Cerro Gordo mining district by the U.S. Geological Survey in 1946 stimulated renewed interest in these limestones when it was suspected that the Silurian and Lower Devonian Hidden Valley Dolomite (McAllister, 1952) of the southern Inyo and Panamint Mountains changes northward and westward to limestone as represented at Mazourka Canyon. Systematic collecting and study of the Vaughn Gulch and Hidden Valley Rugosa and dasycladacean algae began in 1947 with the Cerro Gordo work, during which the Vaughn Gulch section was measured and mapped. A study of these rocks by Waite (1953) pointed to the Silurian age of most of the formation and demonstrated northward facies changes into more argillaceous graptolite-bearing beds in the Mazourka Canyon area. Detailed geologic mapping of the Independence quadrangle by Ross (1963, 1965, 1966) further clarified the stratigraphic and structural relations, and work by Stevens and Ridley (1974) brought forth additional field evidence of northwestward change to graptolitic facies within the Vaughn Gulch. Correlation of the Vaughn Gulch with the Roberts Mountains Formation was made possible by comparative studies of its rugose corals and dasycladacean algae in the 60's. Stratigraphic details and fossil zonation as here presented came mainly from Merriam's field investigation during the years 1946–48 when most of the fossil collecting was done by the U.S. Geological Survey.

PHYSICAL STRATIGRAPHY

The Vaughn Gulch Limestone, in its type section, the ridge northwest of Vaughn Gulch near the mouth of Mazourka Canyon 4 km northeast of Kearsarge (Ross, 1963, 1966), is an unbroken sequence about 460 m thick resting conformably upon the Late Ordovician Ely Springs Dolomite and overlain unconformably by Mississippian conglomerate and quartzite of the Perdido Formation (McAllister, 1952, p. 22). The formation consists of well-bedded medium- to dark-gray impure carbonaceous limestone, argillaceous limestone, and calcareous siltstone including many fossil-rich beds. Some of the more argillaceous and silty interbeds weather in subdued fashion, becoming light gray, stained pink, or orange in places. Black chert zones are stratigraphically significant, occurring at the base and top of the formation; elsewhere minor chert is present as scattered nodules or thin lenses. Platy and flaggy exposures predominate, with limestone ranging from 2.5 to 15 cm separated by calcareous shaly or siltstone partings. Thicker limestone beds, some exceeding 1 m, are fairly common; many of them are coarsely bioclastic. These thicker beds weather out prominently and are most numerous in the middle part of the formation.

As noted by Ross (1966, p. 31), readily mappable lithologic subdivisions were not found within the Vaughn Gulch Limestone of the type section. Its faunal distribution, however, is conveniently subdivided into a lower part 107 m thick, a middle part 220 m thick, and an upper part 140 m thick.

Lower division of the Vaughn Gulch Limestone.—This part of the formation, about 107 m thick, consists largely of platy to flaggy partly laminated dark-gray to bluish-gray argillaceous limestone weathering light gray in places. It is more uniformly bedded with fewer bioclastic and fossil beds than higher parts of this formation. A persistent dark-gray chert member at the bottom, about 5 m thick, corresponds to that occurring near the base of the Silurian System elsewhere in the Great Basin. Weak partial dolomitization and nodular chert decrease upward to the lowest fossil bed of Great Basin Silurian coral zone A, which lies 40 m above the basal cherty beds. The few fossil beds in this division contain abundant *Heliolites* and favositids; more distinctive zone indicators like *Dalmanophyllum* are uncommon.

Middle division of the Vaughn Gulch Limestone.—The 220 m of limestone constituting the middle part of the Vaughn Gulch Limestone includes prominent medium- to dark-gray richly fossiliferous coralline and bioclastic beds in its upper half, of which the uppermost 100 m falls within Great Basin Silurian coral zone E. The dark-gray bioclastic beds range from 25 cm to more than 1 m and are commonly sculptured into prominent ribs separated by subdued intervals of thin-bedded silty or argillaceous limestone weathering a lighter gray. Much of the bioclastic material of these thick fossil beds is crinoidal debris. Some of the fossils that weather in relief are complete and partially silicified and impregnated with limonite. Below the middle of this 220 m division, the limestones are, in general, thin bedded and show fewer bioclastic members. No fossil accumulations with true biohermal relief were found. Chert is a minor constituent. Some 100 m of beds in the middle of this 220-m division contain an abundance of the large dasycladacean alga *Verticillopora annulata.* Though long ranging, these calcareous algae appear to be most numerous in the Great Basin Silurian coral zone D.

Upper division of the Vaughn Gulch Limestone.—A 140-m upper interval of the Vaughn Gulch Limestone includes those beds between the top of Great Basin Silurian coral zone E and the Mississippian disconformity. Bioclastic beds within the topmost 25 m contain an abundance of poorly preserved fossils. Contorted layers of dark-gray chert in the upper 10 m are associated with massive dark-bluish-gray crinoidal limestone with silicified partly macerated limonite-stained brachiopods, favositids, and both solitary and colonial large rugose corals. Below the upper beds, the limestone is partly laminated and platy down to the lower strata adjoining coral zone E where thicker bioclastic and coralline beds become more numerous. Graptolite and conodont evidence reported by Stevens and Ridley (1974) indicate that the upper part of the formation is Lower Devonian and probably as young as Middle Devonian.

STRATIGRAPHIC PALEONTOLOGY

Large collections of fossils made by Stauffer (1930) from limestone in what is now the type section of the Vaughn Gulch Limestone are the basis for his comparison and correlation with the Kennett Formation of northern California and assignment at that time of the limestone to the Devonian System. The fossils were meticulously zoned by Stauffer within a 500-m measured section comprising 14 numbered stratal units. In general, these units can be alined fairly well with those of the present measurement. As the Silurian and Devonian Rugosa of western North America were unknown at the time of Stauffer's work, the listed identifications of these forms in the Vaughn Gulch have little definitive significance by present standards. Nonetheless, the bed-by-bed tabulations by Stauffer clearly reflect the overall coralline nature of much of the formation and reveal the diversity of these coral assemblages. The lists show a relative abundance of tabulate corals including massive *Favosites,* the slender digitate *Cladopora,* and the less common *Heliolites.* Stromatoporoids are listed throughout but do not appear to have been especially important as limestone builders here. The spherical sponge *Hindia* is reported in several beds. Brachiopod and trilobite identifications are largely of questionable value, no doubt partly because the preservation is poor, and these fossil groups are comparatively scarce in the coral-rich beds. The abundant dasycladacean alga *Verticillopora* was at that time unrecognized in these deposits.

The biostratigraphy of the Vaughn Gulch Limestone as here presented is dependent upon study of the rugose corals and dasycladacean algae. Great Basin Silurian rugose coral zonation of Merriam (1973a), treated elsewhere herein, is based upon combined range and distribution data for these fossils in the Roberts Mountains Formation, the Hidden Valley Dolomite, and the Vaughn Gulch Limestone. The dasycladacean alga *Verticillopora,* which ranges upwards from Great Basin Silurian coral zone B to E and above this horizon, is abundant and probably peaks in coral zone D. Of the five Great Basin Silurian coral zones A through E, only zones A and E have been identified with certainty in the Vaughn Gulch Limestone.

The Vaughn Gulch Limestone, judged by comparable thicknesses and fauna, occupies most or all of the stratigraphic interval of the Hidden Valley Dolomite to the south and east. Great Basin Silurian coral zones A and B are typified by distinctive rugose coral assemblages in the Hidden Valley, whereas zones C, D, and E have their reference occurrences in the Roberts Mountains Formation.

Coral zone A.—Great Basin Silurian coral zone A is represented in the lower 107 m unit of the Vaughn Gulch by beds containing the columellate solitary rugose coral *Dalmanophyllum* sp. A, about 40 m above the top of the basal chert marker units; also occurring with the genus is a small tryplasmid, a pycnostylid coral, favositids, *Heliolites,* and *Camerotoechia.* Other zone A indicators like *Palaeocyclus, Arachnophyllum,* and *Cyathophylloides* have not been found in the Vaughn Gulch Limestone.

Verticillopora *beds.*—Strata in the middle part of the 220-m middle unit of the Vaughn Gulch contain an abundance of the large *Verticillopora annulata.* This algal genus ranges in decreasing numbers on up through the overlying Great Basin Silurian coral zone E into the lowermost beds of the upper 140-m unit of the Vaughn Gulch, above which it has not been found. Although the rugose coral fauna of Great Basin Silurian coral zone D has not been found in the Vaughn Gulch, it is not improbable that the beds in which *Verticillopora annulata* is most abundant occupy that interval in which Silurian *Verticillopora* appears to have peaked.

Coral zone E.—Great Basin Silurian coral zone E occupies the uppermost 100-m interval of the middle unit of the Vaughn Gulch Limestone. These upper beds include units 12, 13, and 14 of Stauffer (1930, p. 86–89). The large and diverse coral fauna contains an abundance of tabulates including *Favosites, Cladopora, Syringopora,* and *Heliolites,* together with the distinctive Silurian rugose corals *Australophyllum* (*Toquimaphyllum*) sp. similar to *A. johnsoni, Kyphophyllum* sp., and *Chonophyllum*-like species. *Rhizophyllum* sp. D Oliver is represented by float material, doubtless from coral zone E, and probably by "*Calceola sandalina* Lamarck" of the Stauffer list from his unit 12. *Verticillopora* ranges upward into coral zone E. With this assemblage is the brachiopod *Plectatrypa* sp. Crinoidal debris is abundant; the stromatoporoids, though present, appear to be subordinate.

Stauffer's rather lengthy faunal lists from the interval of coral zone E include brachiopods, among them *Camarotoechia, Atrypa, Gypidula, Athyris, Trematospira, Schizophoria,* and *Eatonia.*

Fossils of the upper Vaughn Gulch Limestone.—Except for the lowermost 8 m, the upper part of the Vaughn Gulch Limestone has yielded few well-preserved fossils. The lowermost beds contain the highest known *Verticillopora, Australophyllum* sp. v, and *Cladopora* and other favositids. Near the top of the formation at locality M1090 are poorly preserved rugose and tabulate corals, large *Atrypa,* and indeterminate spiriferoid brachiopods. Among the Rugosa are a large possible member of the Halliidae that resembles *Aulacophyllum* and a colonial genus that has features of *Acinophyllum* or *Diplophyllum.* Other fossils present are cystiphylloids, digitate and massive favositids, and stromatoporoids. *Australophyllum* sp. v resembles *A. landerensis* of the central Nevada Rabbit Hill Limestone of Early Devonian age. The diverse and highly distinctive Rabbit Hill fauna has not been found in this unit where it would be expected.

AGE

The age of the Vaughn Gulch Limestone, based on its coral fauna, ranges from Early Silurian (Llandoverian) to possible Early Devonian. *Dalmanophyllum* sp. A in the lower unit is an indicator of Great Basin Silurian coral zone A. Beds with abundant *Verticillopora annulata* in the middle of the middle lithologic unit of the Vaughn Gulch probably bracket Great Basin Silurian coral zone D although the rugose coral fauna of zone D was not found in these strata, and it is probable that *Verticillopora* reached its greatest development in coral zone D. Great Basin Silurian coral zone E, at the top of the middle unit, when compared with the Gotland, Sweden, standard, is Late Silurian (late Ludlovian).

In the absence of conclusive evidence from the coral faunas, the upper lithologic unit of the Vaughn Gulch is viewed as Late Silurian or Early Devonian. *Australophyllum* sp. v at its base resembles, but is not conspecific with, *A. landerensis* from the Lower Devonian Limestone Rabbit Hill. Near the top is a large *Aulacophyllum*-like coral, possibly of Early Devonian age; the cystiphylloids and the *Acinophyllum*-like coral might also be Devonian.

Graptolite and conodont evidence and correlation with the Sunday Canyon Formation noted by Stevens and Ridley (1974, p. 28) suggests that the formation extends upward to the Middle Devonian.

Comparable thicknesses of the Vaughn Gulch Limestone and the more easterly Hidden Valley Dolomite, as well as stratigraphic relations with bracketing units strongly suggest that both occupy about the same stratigraphic interval. Because of facies differences, only Great Basin Silurian coral zone A has been recognized. As shown by McAllister (1952), the Hidden Valley is largely of Silurian age and includes the reference occurrences of Great Basin Silurian coral zones A and B. The uppermost beds of this dolomite are of Early Devonian age in the Siegenian-Emsian range. It is probable that the highest Vaughn Gulch strata may be correlative with the fossil-bearing part of the Hidden Valley Dolomite. This correlation is made by Stevens and Ridley (1974, fig. 2).

SUNDAY CANYON FORMATION

The Silurian and Lower Devonian limestones of the intermediate limestone belt change facies to shale laterally within a relatively short distance in the Mazourka Canyon area of the northern Inyo Range, Calif. Detailed geologic mapping of the Vaughn Gulch Limestone northward for 19 km toward Badger Flat by Ross (1966) shows a progressive thinning of the formation and the change to calcareous shale, siltstone, and argillaceous limestone. Tongues of Vaughn Gulch bioclastic limestone reappear north of the type section, but within 8 km, near Barrel Spring, the general character of the deposits has become such as to justify the use of another name, Sunday Canyon Formation, for rocks correlative with the Vaughn Gulch Limestone. The more shaly facies continues northward another 10 km to Badger Flat and becomes progressively thinner. How much of the thinning is due to depositional processes such as initial deepening with less sedimentation of open marine waters toward the north and how much to erosional thinning at the unconformity with the overlying Mississippian is not known. The calcareous shales yield mainly graptolites, but occasional small Vaughn Gulch-type bioclastic lenses as far north as Al Rose Canyon contain rugose corals. In general, however, the proportion of carbonate material decreases toward the north (Ross, 1966, p. 32).

AGE

The age of the Sunday Canyon Formation has been determined mainly by means of abundant monograptids, nearly all collected near the base of the formation. Among the species present are (identified by W. B. N. Berry and R. J. Ross, Jr.):

- *Monograptus* cf. *M. dubius* (Suess)
- *Monograptus dubius* (Suess)
- *Monograptus* sp. (the *M. tumescens* type)
- *Monograptus* sp. (slender rhabdosomes, plain thecae)
- *Monograptus* sp. (the *M. vulgaris* type)
- *Monograptus* cf. *M. scanius* Tullberg

These forms suggest an age range in the Silurian from Wenlock to Ludlow. A locality 45 m above the base of the formation (USGS–D179–SD) yielded *Monograptus* cf. *M. uniformis* Pribyl, which is considered to be Early Devonian.

The problem of dating the Sunday Canyon is the same as that relating to the Roberts Mountains Formation in that the standard time scale based on graptolites is different than that based on corals and other benthonic organisms and usually suggests relatively younger ages for particular horizons. In the Mazourka Canyon exposures, it is not unlikely that most of the graptolitic deposits are relatively low in the Silurian column.

The rugose coral *Australophyllum stevensi* Merriam, from the upper 12 m of the Sunday Canyon, is of possible Early Devonian age.

Stevens and Ridley (1974), on the basis of graptolites and conodonts, indicate that the formation extends to the Middle Devonian.

THE SILURIAN-DEVONIAN BOUNDARY IN CENTRAL NEVADA

We do not attempt here to delve into the philosophical aspects of stratigraphy with respect to time boundaries, lithofacies, biofacies, and systemic definitions. Placement of the Silurian-Devonian boundary within the carbonate sequence of the central Great Basin is a problem when attempts are made to compare rugose coral zonation based on similarities with the Gotland, Sweden, sequence with graptolite zonation which is the accepted guide for time boundaries in this part of the geologic column. Any study of the Roberts Mountains Formation should, however, point out the conflict, where and how it arises, and what the current geologic thinking is on this matter. This problem is a classic one in stratigraphy involving lateral change of facies, time-transgressive rock units, and definition of time boundaries by faunas from different reference sections at different places in the world. Specifically, the Silurian-Devonian boundary is a troublesome boundary that has been the subject of much discussion and a number of international symposia beginning in 1958 and continuing to this time. The Silurian-Devonian Boundary Committee of the International Stratigraphic Commission has established a generally accepted boundary which proves to be viable in the Great Basin and in most parts of the world. This boundary is based on graptolites.

Placement of the boundary in many sections of lower Paleozoic rock in central Nevada is difficult because geologic structure is extremely complex and easily interpreted sequences of strata are rare. We point for examples to the section at Coal Canyon in the Simpson Park

Mountains (see p. 11), which appears superficially to be simple but contains at least one fault with uncertain offset in a critical part of the section. Detailed mapping is almost always a necessity before attempting stratigraphic studies in this region, and frequently even with careful mapping and repeated visits to the field, the relation of rock units remains clouded. When the geologic difficulties are added to the subtleties of faunal interpretation in a narrow belt of rocks deposited at the transition between shallow and deeper water, one realizes why placement of the Silurian-Devonian boundary has been disputed in this part of the world. Part of the problem rests on what fossils are available and what forms are used to define the boundary—what yardstick we are measuring with. When only one form is present, for example corals or graptolites, the section can be matched with similar standards elsewhere in the world. But, where more than one form is present, as in central Nevada, and the rocks have been correlated on the basis of lithology, the faunal yardsticks do not agree. Several basic explanations can account for this difference: various forms have different time ranges at different places in the world, or the standard sections such as that at Gotland, Sweden, or the Dinant Basin, Belgium, do not contain rocks wholly correlative. In central Nevada, the graptolite *Monograptus praehercynicus* is used by Berry (1970) to indicate the base of the *Monograptus uniformis* Zone. This zone is considered by most members of the Silurian-Devonian Boundary Committee of the International Stratigraphic Commission to be the lowest Devonian zone, and hence is accepted here as basal Devonian although no agreement exists on precisely what graptolite species or subspecies should be used to denote the base of the zone. *Monograptus praehercynicus* is found in the Roberts Mountains Formation at a number of places, and in a few places it occurs in a stratigraphic interval that also contains the coralline fauna diagnostic of the Great Basin Silurian coral zone E as defined by Merriam (1973a). In the central Nevada limestone belt represented by the Roberts Mountains Formation, the Silurian-Devonian boundary based on graptolites and on conodonts is a hundred metres or more lower in the same sequence of strata than the boundary based on rugose corals and calcareous algae.

AN APPRAISAL OF STRATIGRAPHIC AND AGE VALUES OF RUGOSE CORALS AND ASSOCIATED FOSSILS, WITH DESCRIPTION OF PREVIOUSLY UNKNOWN KEY RUGOSA

Most of the Cordilleran Rugosa listed and referred to in this report as related to the age and correlation of Great Basin Silurian rocks of the intermediate limestone belt are described in papers by Merriam (1972; 1973a) and a paper by Oliver, Merriam, and Churkin, (1975).

With continued geologic mapping, new Silurian rugose corals have since been discovered in the central Great Basin, and other Rugosa previously unknown in certain assemblages have been found in association at new localities. The stratigraphic ranges of some genera and species have been extended by further collecting and stratigraphic investigation.

Recent researches upon little-known taxonomic groups of Rugosa have resulted in a greatly improved understanding of their internal structure, their value as indicators of the Silurian and Devonian Systems, and their geologic ranges. The two principal groups of corals are those lacking dissepiments (nondissepimented corals) and those having dissipiments (dissepimented corals). The nondissepimented Rugosa with which we are concerned are the Family Kodonophyllidae, the Family Pycnostylidae, and the Family Tryplasmatidae. The dissepimented Rugosa of special interest here are the Family Spongophyllidae, including the new colonial genus *Carlinastraea.* Others of interest are assigned to the Family Endophyllidae, like the subgenus *Australophyllum (Toquimaphyllum)* and other forms of *Australophyllum.* Among the Family Kyphophyllidae, there are new and undescribed species of *Kyphophyllum.*

The dasycladacean algal group including *Verticillopora* is discussed briefly; insofar as known, this large and complex alga commonly associated with Silurian Rugosa ranges upward only into the lower part of the Devonian System.

RUGOSE CORALS OF SPECIAL STRATIGRAPHIC VALUE

SILURIAN NONDISSEPIMENTED RUGOSA

Family KODONOPHYLLIDAE

The Family Kodonophyllidae, which so far as known is confined to the Silurian of the Great Basin, comprises solitary and colonial nondissepimented Rugosa having long lamellar septa, a very wide stereozone, and flat tabulae or distally arched tabellae that may combine with septal tips to form an axial structure and calicular boss.

Two subfamilies of Kodonophyllidae are recognized: Kodonophyllinae and Mycophyllinae. These subfamilies and their taxonomy have been discussed in some detail by Merriam (1973a).

The genus *Kodonophyllum* Wedekind is present in the Late Silurian (Great Basin Silurian coral zone E) on the east side of the Coal Canyon fault, where it is represented by the large *Kodonophyllum mulleri* Merriam (pl. 4, figs. 5, 6). *Kodonophyllum* sp. b (pl. 5, figs. 22–24), described below, occurs in the middle coral-brachiopod zone at Bootstrap Hill, Tuscarora Mountains.

Subfamily KODONOPHYLLINAE Merriam

Members of the subfamily Kodonophyllinae Merriam are very thick walled fasciculate colonial and platelike solitary Rugosa having the characteristics of the family Kodonophyllidae. The tabulae and tabellae arch distally, combining with septal ends to form an axial structure and a calicular boss.

Kodonophyllum mulleri Merriam (1973a), of the upper part of the Roberts Mountains Formation, is a medium to large solitary coral with deep calice and large calicular boss (pl. 4, figs. 5, 6). The major septal count is about 48; septa, somewhat thickened throughout, are excessively thickened in the wide peripheral stereozone and in the axial structure, where they are obscured by merging with stereoplasm and septal terminations.

Kodonophyllum mulleri Merriam occurs in the northern Simpson Park Mountains in the upper part of the Roberts Mountains Formation; locality M1107, Great Basin Silurian coral zone E.

Kodonophyllum sp. b

Plate 5, figures 22–24

Figured material.—USNM 166481. Roberts Mountains Formation; Bootstrap Hill, Tuscarora Mountains, Nev., locality M1314.

Diagnosis.—Slender, subcylindrical *Kodonophyllum* with axial arching of wide tabulae, moderate to low for the genus.

Transverse thin sections.—Thick major septa number about 24, most of which extend to the axial structure. Minor septa buried in stereozone, which is one-fourth of corallite diameter. Septal grooves are broad and shallow. No discrete epitheca.

Longitudinal thin sections.—Tabulae are rather closely spaced, very uneven; many are complete, periaxially depressed, and rise nonuniformly toward axis. Axial rise is moderate to low for this genus. Trabeculae in wide stereozone is steeply inclined outward.

Comparison with related forms.—*Kodonophyllum mulleri* of the Roberts Mountains Formation is a larger, more robust species with more numerous septa than *Kodonophyllum* sp. b. It also has a more pronounced axial rise of tabulae. *K. truncatum* (Linnaeus) of the Gotland Silurian, a colonial form having ceratoid corallites, has a somewhat wider stereozone than the subcylindrical *K.* sp. b; otherwise features in detailed thin-section resemble those of the Nevada species.

Occurrence.—Roberts Mountains Formation; southern Tuscarora Mountains, Nev. Bootstrap Hill, locality M1314. In middle coral-brachiopod zone near bottom of upper 275 m lithologic division.

The range of *Kodonophyllum* in the classic Gotland Silurian column is Wenlockian to Ludlovian; occurrences in Great Britain are reported as Wenlockian. In the Great Basin, the occurrence in coral zone E is late Ludlovian, in the Tuscarora Mountains at Bootstrap Hill in the middle coral-brachiopod zone, perhaps as old as high Wenlock, but more likely Ludlovian.

Certain early Middle Devonian (Great Basin Devonian coral zone D) occurrences of *Kodonophyllum*-like corals of the Nevada Formation (Grays Canyon Limestone Member of the Eureka area) have the very wide peripheral stereozone of *Kodonophyllum*; the longitudinal features are unknown. These forms are probably aberrant developments from the *Siphonophrentis* (*Breviphrentis*) group that is characteristic of Great Basin Devonian coral zone D (Merriam, 1973c).

Subfamily MYCOPHYLLINAE Hill

Genus Mucophyllum Etheridge

Members of the subfamily Mycophyllinae, characterized by large discoid to turbinate corallites with a broad calicular platform and a flat-bottomed central pit, are especially characteristic of the Silurian. Septa are numerous and thick and in contact laterally forming a wide, thick stereozone. Tabulae are complete and straight to undulant. Longitudinal sections show the fine incremental layering of a very thick stereoone transected by nearly vertical trabecular pillars.

Schlotheimophyllum of the Gotland Silurian has a similar growth habit but differs by having a more complex axial structure, more like that of *Kodonophyllum*. *Mucophyllum* is known from Australia and from the Klamath Mountains, Calif. All occurrences are in Silurian deposits of late Wenlockian to Ludlovian age. *Mucophyllum oliveri* (pl. 4, figs. 1–4) has near-horizontal and undulant tabulae that are thickened where merging with the longer septa. *M. oliveri* comes from the east block of the Coal Canyon fault at Coal Canyon, northern Simpson Park Mountains, in the upper part of the Roberts Mountains Formation; locality 1108; Great Basin Silurian coral zone E.

Family STREPTELASMATIDAE Nicholson

Genus Brachyelasma Lang, Smith, and Thomas

Simple, solitary, nondissepimented Rugosa with partly complete tabulae ranges from Late Ordovician into the Silurian of the Great Basin. The tabulae bend downward as they approach the wall. Major septa do not reach the axis, though they commonly extend more than half that distance. Some species have a fossula.

Brachyelasma resembles the Devonian *Breviphrentis,* which has a wider stereozone and undergoes repeated rejuvenescence to form long segmented coralla not found in *Brachyelasma*.

Two species of *Brachyelasma* occur in the Roberts Mountains Formation. *Brachyelasma* sp. c (pl. 5, figs. 25, 26) comes from locality M1383 in the lower coral beds of the west fault block at Coal Canyon, Simpson Park Mountains; *Brachyelasma* sp. b (pl. 12, figs. 29–33) is from locality M1120 at Bootstrap Hill, Tuscarora Mountains, in the lower coral-brachiopod zone with *Cyathophylloides*.

Family STAURIIDAE Edwards and Haime

Genus Cyathophylloides Dybowski

Cyathophylloides, a primitive colonial nondissepimented rugose coral, is related to *Favistella* (or *Favistina* Flower) and to the phaceloid *Palaeophyllum*. These corals are common in the Upper Ordovician, but *Cyathophylloides* and *Palaeophyllum* range upward into the Lower Silurian.

Cyathophylloides forms massive cerioid colonies with narrow corallites having 12–14 smooth, simple lamellar major septa that meet axially where they may be twisted but do not form a discrete axial structure. Tabulae are complete; minor septa are short to fairly long. *Cyathophylloides* is represented in the Roberts Mountains Formation by *C. fergusoni* Merriam of Great Basin Silurian coral zone A in the Mill Canyon sequence at Ikes Canyon, Toquima Range. A similar species *C.* sp. f (pl. 12, figs. 27, 28) comes from the lowermost coral-brachiopod zone at Bootstrap Hill (locs. M1120, M1412).

Family TRYPLASMATIDAE Etheridge

The family Tryplasmatidae, characterized by spinose or acanthine septa, is especially common in rocks of the Silurian System. Tryplasmids have been reported in strata of the Devonian (Hill, 1956, p. F312; Oliver, 1960, p. 15) and are known in Late Ordovician rocks of Sweden. Reviews of the classification have been published by Hill (1936) and by Merriam (1973a). They are readily distinguished from the other nondissepimented Rugosa that have wide complete tabulae by their acanthine septa, and they do not have the wide stereozone of the Kodonophyllidae or the multiple interior calice offsets of the pycnostylids. The Stauriidae-like *Palaeophyllum* of the Late Ordovician and Silurian has medium to long lamellar septa.

The general characteristics of the tryplasmids are well shown by the undescribed Gotland species *Tryplasma* sp. g of the Hemse Group (Ludlovian) (pl. 3, figs. 16–19), *T. newfarmeri* Merriam (pl. 3, figs. 10–15) of Great Basin Silurian coral zone C, and *T. duncanae* Merriam (pl. 3, figs. 8, 9) of Great Basin Silurian coral zone D.

Family PYCNOSTYLIDAE Stumm

Pycnostylid rugose corals are among the most abundant and distinctive nondissepimented genera in certain facies of the Silurian System. It is possible these corals have Devonian descendants like *Cyathopaedium* and *Fletcherina*. None are known in rocks of Late Ordovician age.

The pycnostylids are colonial fasciculate Rugosa having subcylindrical corallites. The septa are very short and vertically continuous, or lacking. The stereozone is narrow. Most tabulae are complete and unarched medially. There are no dissepiments. Reproduction is by multiple offsets peripherally from the calice interior.

The Silurian genera are *Pycnostylus* Whiteaves, *Stylopleura* Merriam, and *Fletcheria* Edwards and Haime. Cerioid colonial genera like *Maikottia* Lavrusevitch and similar large undescribed genera from the Roberts Mountains Formation are provisionally assigned to this family.

The taxonomy of the Pycnostylidae has been treated in some detail by Merriam (1973a).

Genus Pycnostylus Whiteaves

With the type species *Pycnostylus guelphensis* Whiteaves of the Guelph Dolomite, Guelph, Ontario, (pl. 1, figs. 16–19), *Pycnostylus* is characterized by only four internal calice offsets or peripheral offsets. *Pycnostylus elegans* Whiteaves probably has a greater number of offsets (pl. 1, fig. 20). *Pycnostylus* is not known to possess the lateral connecting elements of *Stylopleura*.

Several poorly known Asiatic and Australian corals referred to by Hill (1940) as "ampleximorphs" are doubtfully related to *Pycnostylus*. These corals are reported to have amplexoid lamellar septa. Several little-known Silurian corals of similar character have been classified as *Pycnostylus* by Hill (1940) as *Amplexus* by Grabau (1930) and by Shimizu, Ozaki, and Obata (1934), and as *Amplexoides* by Wang (1947).

Pycnostylus Whiteaves is probably not a junior synonym of *Fletcheria* Edwards and Haime as interpreted by several workers. *Fletcheria tubifera* Edwards and Haime from Gotland has no septa but it does have a distinctive wall structure, and some of the tabulae (or large tabellae) are distally convex (pl. 3, figs. 1–7). Forms assigned by Norford (1962, pl. 15) to *Fletcheria* are probably best placed in *Pycnostylus*. A similar *Pycnostylus*, *Pycnostylus* sp. 1 (pl. 2, fig. 10), occurs in the Lone Mountain Dolomite but has not been found in the Roberts Mountains Formation.

Genus Stylopleura Merriam

The genus *Stylopleura* with type species *S. berthiaumi* Merriam (1973a), which was first found in the upper part of the Roberts Mountains Formation unit 3, is a phaceloid to cerioid coral. It differs from *Pycnostylus* by having a large number of subequal peripheral offsets of internal calice offsets and long tubular-connecting elements between corallites. Open bushy forms have trumpet-shaped flaring calices.

Of the described species of *Stylopleura, Stylopleura berthiaumi* of Great Basin Silurian coral zones D and E (pl. 1, figs. 1–9; pl. 2, figs. 8, 9) has a more open phaceloid construction with flaring calices than the other species. *S. nevadensis* of Great Basin Silurian coral zone E (pl. 2, figs. 3–6) tends to be of more crowded phaceloid to subcerioid compact construction with fewer lateral elements. Also found is *Stylopleura* cf. *S. nevadensis*, n. gen., n. sp. (pl. 2, fig. 7.)

Stylopleura sp. b

Plate 1, figures 10–12

Stylopleura sp. b, known from isolated fragmentary corallites at Bootstrap Hill, Tuscarora Mountains, resembles *S. berthiaumi,* but the specimens in the collection do not include those with reproductive calices. The long tubular connecting processes are well shown.

Stylopleura sp. b occurs at localities M1314 and M1315 in the middle coral-brachiopod zone of the Roberts Mountains Formation at Bootstrap Hill, where it is associated with *Kodonophyllum* sp. b, *Kyphophyllum* sp. b, and *Calostylis*? sp.

Stylopleura sp. c, cf. S. berthiaumi Merriam

Plate 1, figures 13–15

Stylopleura sp. c, cf. *S. berthiaumi* is a fairly compact phaceloid *Stylopleura* from the lower coral zone of the west block of the Coal Canyon fault at Coal Canyon, northern Simpson Park Mountains. It has the multiple calice offsets but none of the lateral connecting elements of *S. berthiaumi.* This form occurs here in the same beds with *Carlinastraea tuscaroraensis* and *Tonkinaria simpsoni* Merriam and is accordingly regarded as an occupant of the approximate interval of Great Basin Silurian coral zone D.

COMPACT CERIOID PYCNOSTYLIDAE OF SILURIAN LIMESTONE FACIES

Unusually large phaceloid to cerioid Rugosa lacking multiple peripheral offsets and resembling *Stylopleura nevadensis* Merriam are known from Late Silurian limestones of the Cordilleran belt. Being compact or appressed, these specimens do not show lateral connecting elements. Some, like *Stylopleura*? sp. T (Merriam, 1973a), have very wide corallites, a very thick wall, and closely spaced tabulae; others, like the large aseptate pycnostylid *Stylopleura*? sp. c from Coal Canyon in the Simpson Park Mountains, have a very thin wall without septa. The septate forms have short longitudinally continuous septa.

Corals provisionally assigned to this informal group are *Maikottia* sp., cf. *M. turkestanica* Lavrusevich of the Porcupine River, Alaska (Merriam, 1973a), *Stylopleura*? sp. T of the Ikes Canyon area, Toquima Range, Nev., and the compact thin-walled aseptate pycnostylid species *Stylopleura*? sp. c from Coal Canyon, Simpson Park Mountains, here described.

Stylopleura? sp. c

Plate 2, figures 1, 2

Stylopleura? sp. c is a large compact species. Corallites are as much as 24 mm wide and have a very thin straight wall. Septa are absent. Tabulae are closely spaced, uneven, and have a pronounced sag axially. Most tabulae are entire, but some near the periphery are short and terminate against a complete tabula. The similarity of this form to the Australian Silurian *Yassia* Jones in longitudinal section is deceiving, as it lacks the dissepiments of *Yassia* in the strict sense.

Occurrence.—A single incomplete corallum from Coal Canyon, Simpson Park Mountains, Nev., locality M1379, in sheared Roberts Mountains limestone at the west edge of the Coal Canyon fault zone.

DISSEPIMENTED RUGOSA OF THE GREAT BASIN SILURIAN LIMESTONE FACIES

Rugose corals with dissepiments, uncommon in the Cordilleran Late Ordovician, had become abundant by mid-Silurian time with the appearance of the lykophyllids, *Entelophylloides, Petrozium,* and other genera. Several Late Silurian colonial dissepimented groups disappeared by the end of the Silurian or the earliest Devonian, and new ones appeared in early Middle Devonian time. Families of special importance in the Late Silurian of the Great Basin intermediate limestone belt are the Spongophyllidae and the Endophyllidae.

Family SPONGOPHYLLIDAE Dybowski

Genus Carlinastraea, n. gen.

Type species.—*Carlinastraea tuscaroraensis* n. gen., n. sp., here designated; Late Silurian, upper beds of the Roberts Mountains Formation, Nev.

Diagnosis.—Cerioid spongophyllid having slender, fairly thick walled corallites, a strong marginarium of large to very large, steeply inclined lonsdaleioid dissepiments, and a nonuniform pattern of partially aborted septa in the tabularium of some corallites.

Remarks.—Direct comparison of *Carlinastraea* with the most nearly related genus, *Spongophyllum* Edwards and Haime, is not possible as the Edwards and Haime (1853) type material of *S. sedgwicki* (the type species) has been lost and only the original published illustrations (pl. 6, figs. 1–4) remain as a basis for reappraisal. These illustrations (Edwards and Haime, 1853, pl. 56, figs. 2, 2a–2e) with little doubt figure two different corals: (1) group 1 (pl. 56, figs. 2d, e), a thin-walled genus having many small peripheral lonsdaleioid dissepiments, (2) group 2 (pl. 56, figs. 2, 2a–2c), a genus having narrower, moderately thick-walled corallites, lacking or nearly lacking conspicuous lonsdaleioid dissepiments. It is not likely that the two forms fall within the range of variation of a single genus and species; so far this possibility is unknown. The usually accepted characterization of *Spongophyllum* is that of lonsdaleioid group 1, and it is with this group that *Carlinastraea* is compared. Comparison of *Spongophyllum sedgwicki* to *Lonsdaleia* by Edwards and Haime (1851, p. 425; 1853, p. 242) is further evidence that the original diagnosis is that of a cerioid rugose coral with well-developed lonsdaleioid dissepiments.

It is unfortunate that Jones (1929, p. 89) selected as the "neotype" of *Spongophyllum sedgwicki* a float specimen in "a dark coloured pebble" from "South Devonshire." Although not figured by Jones in 1929, thin sections of this "neotype" were illustrated by black and white drawings by Birenheide (1962, p. 68–74, pl. 9, fig. 8, pl. 10, fig. 10). The Birenheide figures show a coral without conspicuous lonsdaleioid dissepiments, agreeing reasonably well with non-lonsdaleioid group 2 of the Edwards and Haime type illustrations.

Comparing *Carlinastraea* with group 1 lonsdaleioid *Spongophyllum* of Edwards and Haime, the new genus *Carlinastraea* differs by having a much thicker wall with strong wall crests and all corallites have much larger lonsdaleioid dissepiments. The septa of *Carlinastraea,* being less continuous radially than those of *Spongophyllum sedgwicki,* are marked peripherally by septal crests. Aborting of septa, a feature of *Carlinastraea,* is unknown in *S. sedgwicki.* Mature corallites without lonsdaleioid dissepiments, as in group 2 of the Edwards and Haime *S. sedgwicki,* were not observed.

Carlinastraea tuscaroraensis n. gen., n. sp., occurs in the upper part of the Roberts Mountains Formation. As recorded by Edwards and Haime, the *Spongophyllum* types came from Devonian strata of Torquay, Devonshire, England. The Jones-selected neotype, being a float cobble, fails to confirm this occurrence. Recent studies of southern England Devonian Rugosa by Taylor (1950), Middleton (1959), and Webby (1964) make no reference to *Spongophyllum.* Two species of *Spongophyllum* (sp. A and sp. B) have been reported from the McCann Hill Chert of Alaska by Oliver (in Oliver and others, 1975); he considered it to be Early(?) to Late Devonian (Emsian? to Frasnian). Elsewhere in the Cordilleran belt of western North America, there are no records of strongly lonsdaleioid cerioid Devonian corals that closely resemble group 1 of *S. sedgwicki* or the new genus *Carlinastraea*.

Species from the Ural Mountains, USSR, assigned to *Spongophyllum* by Shurygina (1968) are herein assigned to the new genus *Carlinastraea.* Shurygina (1968, p. 121–135, pl. 59, figs. 1–3) reported these questionable species as Lower Devonian. The coral fauna that is included with *Spongophyllum* [*Carlinastraea*] by Shurygina in these Ural beds is more suggestive of the forms in the Late Silurian of Gotland. Among the genera from the Urals so listed are *Spongophylloides, Tryplasma, Neomphyma,* and *Rhizophyllum.* Also included is *Salairophyllum,* which in southeastern Alaska occurs with the large Late Silurian *Conchidium alaskense* and, at Coal Canyon, Simpson Park Mountains, Nev., occurs as float, doubtless from high beds of the Roberts Mountains Formation.

Carlinastraea tuscaroraensis n. gen., n. sp.

Plate 6, figures 5–7; plate 7, figures 1–4

Type and figured specimens.—Holotype USNM 166482, upper beds of the Roberts Mountains Formation, locality M1313, Bootstrap Hill, Nev. Figured specimens USNM 166483, locality M1384, Coal Canyon, Nev.; USNM 166484, locality M1409, Cortez, Nev.

Diagnosis.—Large massive *Carlinastraea.* The coralla have several hundreds of very narrow corallites whose septa are marked peripherally by strong wall crests; septa are mostly thin, nonuniform, and irregularly wavy; the largest lonsdaleioid dissepiments subtend one-fifth of a corallite circumference.

Transverse thin sections.—Wall is stereoplasmically thickened, has about 26 prominent, mostly obtuse wall crests uniformly spaced. Major septa are thin, smooth, unevenly wavy, nonuniform, and number 12–14—the longest reach the axis; septal crests are developed, peripherally in some corallites. Lonsdaleioid dissepiments number 6 to about 10 in a peripheral cycle and vary greatly in size; the largest subtend one-fifth of the corallite circumference. Minor septa, weakly developed, show as wall crests and sporadic outer septal crests.

Longitudinal thin sections.—Tabularium is less than one-fourth to more than one-third of corallite width; delicate tabulae are only in part complete, sag irregularly proximally, and for the greater part are rather closely spaced. Lonsdaleioid dissepiments, predominantly large with very steep axial inclination, are arranged in one to three columns on each side.

Fine structure.—Stereoplasmic wall is without discrete trabeculae and shows very fine calcitic fibers transversely oriented; faint lamellar texture in some places is developed toward inner wall surface.

Comparison with related forms.—*Carlinastraea giganteum* (Shurygina) of the Ural Mountains, USSR (Shurygina, 1968, p. 135, pl. 59, figs. 1, 2), differs from the new species by having less developed wall crests, straighter septa, and less steeply inclined lonsdaleioid dissepiments. *Carlinastraea originalis* (Zhmaev), also of the Urals (Shurygina, 1968, p. 134, pl. 59, figs. 3a–b), has less developed wall crests and more aborted septa than *C. tuscaroraensis.*

Occurrence.—Upper part of the Roberts Mountains Formation, northern Simpson Park Mountains, Nev.: locality M1384, Coal Canyon, west side in beds with a fauna believed to represent Great Basin Silurian coral zone D. Tuscarora Mountains, Nev., locality M1313, Bootstrap Hill. *Carlinastraea* cf. *C. tuscaroraensis,* Cortez Mountains, Nev., locality M1409, pl. 8, figs. 1, 2.

Family ENDOPHYLLIDAE Torley

Genus Ketophyllum Wedekind

The solitary genus *Ketophyllum* is common in the Silurian of Gotland, Sweden, and in eastern Europe. Only fragments of *Ketophyllum* sp. t (pl. 10, figs. 18, 19) have been collected by McKee in the Toquima Range, Nev. Some species of *Ketophyllum* are virtually indistinguishable from the Devonian *Tabulophyllum* except for the presence of a weak fossula in some forms of *Ketophyllum* (Wedekind, 1927); this structure is usually not visible in *Tabulophyllum.* Both have a very wide tabularium and closely spaced straight to somewhat undulant tabulae, many of which are complete. Both genera have a peripheral band of large lonsdaleioid dissepiments, and the thin septa break up peripherally as septal crests.

Ketophyllum sp. t occurs in the Toquima Range at locality M1393 in the Mill Canyon sequence on the south side of Ikes Canyon a mile northwest of the canyon mouth.

Genus Australophyllum Stumm

Large colonial heads of *Australophyllum* are common in Great Basin Silurian coral zone E, where it is represented by the subgenus *Australophyllum* (*Toquimaphyllum*). Other forms of *Australophyllum* sensu stricto occur in the same uppermost beds of the Silurian limestone facies and, though sparsely represented, range upward into the Lower Devonian Rabbit Hill Limestone. Some Middle Devonian species that were referred to *Australophyllum* in the past have but few sporadic lonsdaleioid dissepiments and are perhaps best assigned to other genera. The lonsdaleioid subgenus *Toquimaphyllum* has a worldwide geographic distribution. A similar form occurs to which the generic name *Klamathastraea* has been given (Merriam, 1972) in Late Silurian beds of the Gazelle Formation, Klamath Mountains, Calif. *Klamathastraea* differs from *Toquimaphyllum* by having a much wider tabularium, tabulae with a marginal depression, and a pronounced tendency to abort septa in mature growth stages.

Australophyllum (Australophyllum) sp. c

Plate 8, figures 3–7

Diagnosis.—Large *Australophyllum* with corallites of greatly varying width; lonsdaleioid dissepiments are in restricted peripheral patches only; tabulae closely spaced, in places crowded; septa are minutely wavy with spines and bumps in the periaxial band.

Transverse thin sections.—Corallites, highly variable in size, range in diameter from 9 to 28 mm at the same distal corallum surface. Septal count is about 62 in large corallites. Major septa reach the axis and are twisted near it; minor septa range from one-half to three-fourths length of major septa. Septa, locally thickened in dissepimentarium, may be slightly thickened in tabularium, wherein they become minutely wavy and ornamented laterally with spines and nodes. Narrower corallites show stereoplasmic wall thickening. Some larger lonsdaleioid patches quite irregular.

Longitudinal thin sections.—Tabularium width is one-fourth to one-third of corallite diameter. Dissepiments are medium to large in as many as nine columns on each side of wider corallites. Outer dissepiments are much less steeply inclined than inner ones. Tabulae are mostly close spaced or crowded; many are complete with a wavy proximal sag. Inner septal extensions have numerous lateral spines and bumps.

Comparison with other forms.—*Australophyllum* (*Toquimaphyllum*) *johnsoni* Merriam of Great Basin Silurian coral zone E has a much more continuous and uniform marginarium of lonsdaleioid dissepiments that are less steeply inclined; its tabularium is narrower than that of *Australophyllum* sp. c. *Australophyllum landerensis* Merriam has fewer septa, a more fully developed pattern of lonsdaleioid dissepiments, and fewer lateral spines and bumps on axial extensions of septa. *Australophyllum* sp. v of Late Silurian and Early Devonian beds in the Vaughn Gulch Limestone has a similarly restricted pattern of lonsdaleioid dissepiments but it differs by having narrower, thicker walled corallites and fewer septa; the septa are unthickened and lack the abundant lateral spines and nodes of *Australophyllum* sp. c. A similar coral from locality M1445 near the Big Six mine, Tuscarora Mountains, has the spiny septal extensions of *Australophyllum* sp. c but has very few small lonsdaleioid dissepiments and a thicker wall. The Tuscarora Mountains coral also differs by having localized crossbar carinae.

Occurrence.—Coal Canyon, Simpson Park Mountains; locality M1318 in Coal Canyon fault zone on west side of canyon. Although this coral head was not collected in place and the locality is in deformed strata within the fault zone, its field location suggests that it may have come from beds stratigraphically above the lower *Carlinastraea* coral beds of the west fault block.

Australophyllum (Australophyllum) sp. v

Plate 8, figures 8–11

Diagnosis.—*Australophyllum* has predominantly narrow, fairly thick-walled corallites and a restricted pattern of lonsdaleioid dissepiments; septa are mostly thin with very few nodes and spines in periaxial band.

Transverse thin sections.—Septal count is about 42 in average corallites. Some major septa reach axis; minor septa, mostly less than half the length of the major septa, commonly appear only as septal crests peripherally. Septa are slightly wavy. Lonsdaleioid dissepiments are medium and small and are restricted or absent in some corallites.

Longitudinal thin sections.—Tabularium is one-third to less than one-fourth of corallite diameter; tabulae are partly complete, closely spaced, and sagging. Dissepiments are steeply inclined, 4–7 columns on each side. Periaxial extensions of septa are nearly devoid of nodes and spines. Thickened wall shows no discrete trabecular structure.

Comparison to related forms.—*Australophyllum* sp. v is most closely related to *A. landerensis* Merriam from Lower Devonian beds of the northern Toquima Range, Nev. The Devonian form differs by having somewhat thickened and more wavy septa in the tabularium; the periaxial extensions of septa show more lateral nodes and bumps than in *A.* sp. v. *Australophyllum* sp. c has scattered, much wider corallites with a septal count of 62, and its periaxial septal extensions show abundant lateral spines and nodes.

Occurrence and age.—Mazourka Canyon, northern Inyo Mountains, Calif.; upper middle and upper beds of the Vaughn Gulch Limestone. Locality M1093, bottom of the upper unit of the Vaughn Gulch Limestone of Late Silurian and Early Devonian(?) age. Locality M1410 about 50 feet stratigraphically below M1093.

Subgenus Toquimaphyllum Merriam

(subgenus of Australophyllum Stumm)

Toquimaphyllum, a cerioid compact subgenus of *Australophyllum,* has a wide continuous marginarium of predominantly large lonsdaleioid dissepiments; the peripheral dissepiments are nearly flat or dip axially at low angles. The tabularium is narrow to moderately wide; the tabulae are closely spaced, sagging, and are without a marginal depression. The septa are thin, smooth, fairly straight, and discontinuous peripherally as septal crests. Some mature corallites have much shortened or obsolete septa.

Australophyllum (*Toquimaphyllum*) differs from *Australophyllum* sensu stricto by the greater development of large lonsdaleioid dissepiments forming a continuous marginarium, by the presence of septal crests peripherally, and by its tendency to lose septa in some mature corallites. The septa of *Toquimaphyllum* lack the carinae reported by Stumm (1949, p. 34) in *Australophyllum* sensu stricto. *Endophyllum* differs by having a much wider tabularium; the tabulae being nearly flat to slightly arched medially with a peripheral sag. The type species of *Endophyllum* shows a tendency to lose the outer wall, thus becoming partially aphroid. As known, *Endophyllum* does not, like *Toquimaphyllum*, have a tendency to shorten and lose septa.

Australophyllum (*Toquimaphyllum*) *johnsoni* Merriam (pl. 6, figs. 8–10) is the most abundant and distinctive rugose coral of Great Basin Silurian coral zone E (Late Silurian). The relations of this subgenus and its worldwide distribution are discussed in some detail by Merriam (1972a).

The type species *Australophyllum* (*Toquimaphyllum*) *johnsoni* Merriam comes from the Roberts Mountains Formation of the Mill Canyon sequence of the Ikes Canyon area, Toquima Range, Nev. Much of the study material was collected from the upper beds of the Roberts Mountains Formation at Coal Canyon, Simpson Park Mountains.

Australophyllum (Toquimaphyllum) johnsoni Merriam

Plate 6, figures 8–10

Collections from several localities in Silurian limestones between the northern Simpson Park Mountains and the northern Inyo Mountains of California contain many complete and fragmentary colonies of this species. *Australophyllum* (*Toquimaphyllum*) *johnsoni* has been found only in strata of Great Basin Silurian coral zone E. A detailed description of this species and a review of its taxonomy have recently been published by Merriam (1973a)

This species is characterized by wide corallites, the major septa normally reach the axis and break up peripherally as septal crests. Most mature corallites have a narrow tabularium and a correspondingly wide dissepimentarium in which the outer dissepiments are nearly flat. Partially aseptate corallites show only abbreviated tips of major septa.

Occurrence.—Upper beds of the Roberts Mountains Formation in the Mill Canyon sequence at Ikes Canyon, Toquima Range; locality M1114 (type locality). Upper beds of the Roberts Mountains Formation in east block of Coal Canyon fault zone, Coal Canyon, northern Simpson Park Mountains; several localities including M1106 and M1108. Foothill exposures 2.4 km north of Red Hill, SE¼NE¼ sec. 5, T. 25 N., R. 50 E., Simpson Park Mountains; locality M1446. Upper part of middle unit of Vaughn Gulch Limestone (these specimens differ slightly from typical *A. johnsoni*), Mazourka Canyon, northern Inyo Mountains; locality M1115. *Australophyllum,* possibly *A. johnsoni,* occurs in the Antelope Peak section 19 km north of wells, Elko County, Nev.

Family CHONOPHYLLIDAE Holmes

Genus Chonophyllum Edwards and Haime

Chonophyllum shares some characteristics of *Ketophyllum* and other members of the Endophyllidae, but it is solitary and usually has a narrower tabularium than most endophyllids. The lonsdaleioid pattern of *Chonophyllum* is much more irregular or less uniform and localized in peripheral patches.

Chonophyllum simpsoni Merriam (pl. 7, figs. 5, 6; pl. 9, figs. 9, 10) from the uppermost part of the Roberts Mountains Formation is a large trochoid to ceratoid species with major septa reaching the axis and a narrow tabularium. Its tabulae are closely spaced, undulant, and mostly incomplete with marginal tabellae. Inner dissepiments are commonly anguloconcentric in transverse section.

Chonophyllum simpsoni Merriam occurs at locality M1108 in the east block of the Coal Canyon fault, Coal Canyon, Simpson Park Mountains, Nev., the upper part of the Roberts Mountains Formation.

Family KYPHOPHYLLIDAE Wedekind

This large and somewhat heterogeneous provisional group of Silurian Rugosa as revised by Merriam (1973a) contains about eight genera as follows:

Kyphophyllum Wedekind
Strombodes Schweigger
Petrozium Smith
Entelophyllum Wedekind
Entelophylloides Rukhin (as a subgenus)
Entelophylloides (*Prohexagonaria*) Merriam
Neomphyma Soshkina
?*Tonkinaria* Merriam.

Of these genera, *Kyphophyllum* and *Tonkinaria* are of greatest importance to the stratigraphy of the intermediate limestone facies.

Genus Kyphophyllum Wedekind

Kyphophyllum builds large bushy phaceloid colonies; its subcylindrical corallites have a narrow stereozone and medium-narrow closely spaced tabulae. Restricted segments of the marginarium are occupied by large, irregular lonsdaleioid dissepiments. In the Roberts Mountains Formation and Vaughn Gulch Limestone, this genus is represented by *K. nevadensis* Merriam, *K.* sp. b, *K.* sp. c, *K.* sp. t, and other undescribed species. In the Great Basin, *Kyphophyllum* occurs in Great Basin Silurian coral zone E (Late Silurian).

Kyphophyllum nevadensis Merriam

Plate 9, figures 1–3

Kyphophyllum nevadensis has medium-wide to narrow corallites of variable diameter with a small number of major septa (about 22) and sporadic groups of relatively large lonsdaleioid dissepiments.

Occurrence.—Ikes Canyon (Mill Canyon sequence), Toquima Range, Nev. Great Basin Silurian coral zone E. Locality M1114, northwest side of Copper Mountain in lower part of the McMonnigal Limestone.

Kyphophyllum sp. b

Plate 5, figures 15–21

Kyphophyllum sp. b has very narrow corallites for the genus, a few wavy major septa (about 20), very few lonsdaleioid dissepiments, and lateral offsets that are attached at former calice rims. The dissepiments are all steeply inclined or vertical. Longitudinal exterior ribbing is strongly developed.

Occurrence.—Tuscarora Mountains, Nev. Locality M1314, middle part of the Roberts Mountains Formation.

Kyphophyllum sp. c

Plate 9, figures 4–8

Kyphophyllum sp. c has large corallites for the genus and a large number (about 60) of long, smooth, somewhat wavy septa, many of which are greatly lengthened minor septa. Longitudinal sections of *K.* sp. c are similar to those of *K. nevadensis* with a few large localized lonsdaleioid dissepiments. Some corallites are joined by lateral processes not observed in *K. nevadensis.*

Occurrence.—Coal Canyon, Simpson Park Mountains, Nev. Locality M1380, upper part of the Roberts Mountains Formation.

Kyphophyllum sp. t

Plate 10, figures 14–17

Kyphophyllum sp. t has narrow corallites of greatly varying diameter. The larger corallites have about 20 long, somewhat wavy major septa and very short minor septa. All dissepiments are steeply inclined. The stereozone is relatively wide for this genus.

Occurrence.—Toquima Range, Nev. Late Silurian and Devonian Tor Limestone of the June Canyon sequence; locality M1397.

Genus Tonkinaria Merriam

Tonkinaria, a solitary or loosely phaceloid genus, commonly has a flaring trumpet-shaped calice, ceratoid to turbinate corallites, and a narrow tabularium. The wall is a narrow stereozone, the septa are thin, and major septa reach or are slightly withdrawn from the axis. Dissepiments are mostly large, elongate, and steeply inclined. Multiplication is by peripheral calice offsets, of which there may be several on a single flaring calice rim.

Occurrence.—Tonkinaria simpsoni Merriam, the type species, comes from locality M1100 (pl. 5, figs. 1–9) in Roberts Mountains Formation unit 3 and Great Basin Silurian coral zone D of the reference section; locality M1103 in the Mill Canyon sequence at Ikes Canyon, Toquima Range, Nev., in Great Basin Silurian coral zone D; and locality M1383 (pl. 5, figs. 10–14) on the west side of Coal Canyon, Simpson Park Mountains, where it occurs in the west block of the Coal Canyon fault together with *Carlinastraea tuscaroraensis* and *Stylopleura.*

Family CALOSTYLIDAE Roemer

Genus Calostylis Lindström

Fragmentary and rather poorly preserved solitary rugose corals from Bootstrap Hill, Tuscarora Mountains, are referred provisionally to *Calostylis.* This Silurian genus occupies a peculiar relation to all other Rugosa (Smith, 1930, p. 294) by possessing perforate septa and a spongy axial structure.

Calostylis? sp. (pl. 7, figs. 7, 8) occurs at locality M1314, Bootstrap Hill, Tuscarora Mountains, Nev., in the middle part of the Roberts Mountains Formation.

Family LYKOPHYLLIDAE Wedekind

Solitary lykophyllid Rugosa have not been found to be among the more abundant corals of the Great Basin Silurian limestone. They may have been overlooked in collecting in limestone, however, as they are fairly numerous in the Hidden Valley Dolomite. This family is well represented in the Silurian of Gotland and elsewhere in Europe where the genera include *Phaulactis, Cyathactis, Pycnactis,* and *Ryderophyllum.*

The Lykophyllidae are medium and large solitary Rugosa with many columns of small to medium, rather steeply inclined dissepiments and a fairly wide tabularium made up of closely spaced, uneven, mostly incomplete tabulae and flat tabellae. Greatly thickened septa of early growth stages persist ontogenetically to at least early adult growth. A fossula is not generally present in mature transverse sections.

In the Great Basin Silurian, the Lykophyllidae are represented by abundant *Ryderophyllum* in Great Basin Silurian coral zone B of the Hidden Valley Dolomite (Merriam, 1973a) but are unknown in higher horizons of the dolomite facies and have not been identified from limestone facies of the better known sections. A lykophyllid resembling *Ryderophyllum* from an undetermined stratigraphic horizon in the Tuscarora Mountains is figured here (pl. 12, figs. 34–36).

FOSSILS ASSOCIATED WITH RUGOSE CORALS IN GREAT BASIN SILURIAN LIMESTONES

Tabulate corals, crinoids, brachiopods, and dasycladacean algae are common members as well as a *Hercynella*-like mollusk (pl. 10, fig. 20) of Great Basin Silurian coral communities. In general, the most abundant fossil remains of the limestone coralline facies are favositids, including entire massive heads of *Favosites* (pl. 10, figs. 9–13) and digitate forms (pl. 10, fig. 8). With these branching corals are the more slender ramose genera *Cladopora* (pl. 10, figs. 5–7) and *Coenites. Halysites* is rather uncommon and seems to be absent from the higher Silurian beds. Crinoids are represented by large volumes of crinoidal debris filling interstices and making crinoidal limestone, but no articulated or partial crinoid crowns were collected.

Limestone beds that contain silicified fossils yield abundant well-preserved brachiopods during extraction of the coral material by the acid technique. Among such occurrences are the Great Basin Silurian zone D coralline beds in unit 3 of the Roberts Mountains Formation type section, the upper coral-rich beds of Great Basin Silurian coral zone E at Coal Canyon, Simpson Park Mountains, and the lower beds of this formation at Bootstrap Hill, Tuscarora Mountains, Nev.

A few of the more distinctive brachiopods occurring with Silurian corals are illustrated herein. The following brachiopods occur in unit 3 of the type section Roberts Mountains Formation:

Dicoelosia sp. r (pl. 11, figs. 18–22)
Gypidula sp. r (pl. 11, figs. 25, 26)
Homoeospira sp. r (pl. 11, figs. 15–17)
Kozlowskiellina sp. f (pl. 11, figs. 9–12)

Silicified brachiopods from Great Basin Silurian coral zone E on the east side of Coal Canyon are:

Kozlowskiellina sp. f (pl. 11, figs. 13, 14)
Plectatrypa? sp. c (pl. 11, figs. 23, 24)

From the Roberts Mountains Formation of the Bootstrap Hill area, Tuscarora Mountains, unusually well preserved silicified brachiopods were collected by R. J. Roberts from a large talus slab at the base of the slope where the lowest beds of the formation are partly exposed. Other rocks in the same collection contained *Cyathophylloides* sp. f, an indicator of coral zone A. The following associated brachiopods are figured in this report:

Conchidium sp. b (pl. 12, figs. 18–22)
Fardenia sp. b (pl. 12, figs. 8–15)
Coelospira sp. b (pl. 12, figs. 1–7)
Kozlowskiellina sp. b (pl. 12, figs. 16, 17, 23)

Kozlowskiellina sp. f, which occurs in both Great Basin Silurian coral zones D and E, bears a rather close resemblance to *Plicocyrtina sinuplicata* Havlicek as figured by Lenz (1972, pl. 1, figs. 1–20). According to

Lenz, the Canadian species is of Early Devonian (late Siegenian) age.

In the type section of the Roberts Mountains Formation, the brachiopod *Conchidium* is most abundant and diverse near the top of lithologic unit 2 and below Great Basin Silurian coral zone C. These pentameroid brachiopod faunas have not been studied in detail. The form resembling *Conchidium münsteri* Kiaer is illustrated (pl. 12, figs. 24–26).

DASYCLADACEAN ALGAE AS INDICATORS OF THE SILURIAN

The family Dasycladaceae of green calcareous algae has a very long geologic range, through the Paleozoic to the present day. One of its subgroups, the Verticilloporaea (Rezak, 1959), throve in Great Basin Silurian seas, occupying environments favorable for the corals. In the Great Basin province, the family is well represented by the genus *Verticillopora* Rezak (pl. 10, figs. 1–4; pl. 11, figs. 1–8), some of whose individuals attained a relatively large size for the family. *Verticillopora* is a fairly reliable Great Basin Silurian indicator, as its remains have not yet been recognized in Ordovician strata and it is rarely found in rocks of early Devonian age. Its usefulness as a Silurian fossil was not recognized until recently; the cylindrical and conical thalli were generally ignored; collectors regarded them as fragmentary sponges or crinoid columnar segments, both of which they resemble in gross surficial features. Moreover, the dasycladaceans not uncommonly occur in crinoidal limestone.

The classification of living and fossil dasycladacean algae has been reviewed by Pia (1926, p. 105). In 1959, Rezak described Great Basin Silurian algal forms collected by U.S. Geological Survey mapping parties. Most of these specimens were assigned to the new genus *Verticillopora* Rezak. This genus is usually preserved by silicification. Its thallus commonly has the externally jointed appearance of a large crinoid stem with numerous rather uniformly perforated columnar segments. Internally the structure differs markedly from that of a crinoid column by having a wide, commonly five-sided or polygonal central chamber that housed the stipe (Rezak, 1959, p. 119), surrounded by cycles of small radiating tubes or canals that contained the lateral rays. Externally each segment reveals the small-ray canal pores (pl. 11, figs. 3, 6). Some individuals (pl. 10, figs. 1–3) have long, stout, tubular rootlike processes.

Verticillopora ranges upward from Great Basin Silurian coral zone B through coral zone E and into the Early Devonian. Unlike some rugose coral genera, *Verticillopora* is present in both limestone and dolomite facies of the Great Basin Silurian. This algal group seems to have attained its peak of development in limestone facies of Great Basin Silurian coral zone D. In the Vaughn Gulch Limestone of the Inyo Mountains, for example, the middle part of the formation below Great Basin Silurian coral zone E is heavily populated by *Verticillopora annulata* Rezak. The *Verticillopora* beds have yielded much of the best study material of this interesting calcareous algal family.

CONODONTS OF THE ROBERTS MOUNTAINS FORMATION

By John W. Huddle

Conodonts are abundant in much of the Roberts Mountains Formation. The presence of these microfossils where no megafossils occur makes their use especially important for stratigraphic studies and geologic mapping. Many conodont identifications were made for geologists mapping in the Carlin gold mine vicinity and other areas of the central Great Basin where the Silurian and Devonian strata are intensely deformed and would otherwise remain undated paleontologically. In order to correlate the isolated conodont occurrences with more continuous sections of the Roberts Mountains Formation, during this investigation conodont-bearing material was collected from beds yielding distinctive rugose corals and other megafossils of age significance. Conodont control sections have been measured in areas that have been mapped geologically in the Toquima, Monitor, and Simpson Park Ranges. Much more bed-by-bed conodont collecting remains to be done in these more continuous Silurian and Devonian control sections. An important conodont study of the type section of the Roberts Mountains Formation and nearby locations in the Roberts Mountains is that of Klapper and Murphy (1974); this study serves as a reference for comparison of other collected stratigraphic intervals in the central Great Basin.

A chart (table 2) of Roberts Mountains Formation conodont assemblages collected from the Toquima Range and localities between the Toquima Range and the Tuscarora Mountains lists conodont stratigraphic ranges. In addition, conodonts from the overlying Rabbit Hill Limestone are included.

The largest assemblages of conodonts listed here come from the upper part of the Roberts Mountains Formation at Coal Canyon, Simpson Park Mountains, on both the west and east sides of the Coal Canyon fault, and in the August Canyon sequence at Gatecliff in the Toquima Range. Here the name Bastille Limestone Member of the Masket shale of Kay and Crawford (1964) is used for strata correlative with part of the Roberts Mountains Formation.

Conodont form taxa are used in this report. Some multielement taxa are recognized, but until the multielement taxonomy is generally used, the form taxa will serve for stratigraphic studies.

Comments on some of the collections of specific stratigraphic interest are: Locality KV–70–19 (8827–SD) (table 2, No. 6), from the *Carlinastraea* beds, Coal Canyon in the Simpson Park Mountains.

The presence of *Spathognathodus remscheidensis* indicates that this collection is Early Devonian according to conodont zonation. The faunal list gives form taxa because it is simpler to use for stratigraphic purposes until the multielement taxonomy is more completely established. *Spathognathodus inclinatus* and several of the bar-type conodonts listed above (table 2) are part of a multielement taxon called '*Apparat*-H' by Walliser (1964), *Hindeodella excavata* by Jeppsson (1969), and *Ozarkodina inclinata* by Walliser (1972).

Locality KV–70–24 (8829–SD) (table 2, No. 7), *Carlinastraea* beds, Coal Canyon, Simpson Park Mountains.

Spathognathodus remscheidensis indicates an Early Devonian age for this collection and *Rotundacodina elegans* has been reported only from Early Devonian rocks. The new species of *Spathognathodus* is similar to *S. remscheidensis* but has aborted and small denticles anterior to the basal cavity.

Two conodont assemblages from the upper part of the Roberts Mountains Formation on the east side of the Coal Canyon fault in the Pyramid Hill block (table 2, Nos. 8 and 9) are from the interval of Great Basin Silurian coral zone E (collection 8216–SD, table 2, No. 8, made by T. E. Mullens):

The list includes only form taxa, and several of the bar elements belonged to multielement species. The age of the fauna is Early Devonian according to the known conodont ranges. This age is indicated by *Spathognathodus remscheidensis, Spathognathodus transitans,* and the form of *Spathognathodus inclinatus,* which is the one common in Lower Devonian rocks. The *Icriodus* is only a small fragment and is not specifically identifiable, but it also suggests a Devonian age. The *Scolopodus devonicus* is known only from Devonian collections. Many of the other conodonts range from Silurian to Devonian. Although there are few Late Silurian faunas described now (1973), all the evidence available indicates a Devonian age for this collection.

Collection 8828–SD (table 2, No. 9):

The two species of *Rotundacodina* were described by Carls and Gandl (1969) from the Lower Devonian of northeastern Spain. These species and *Spathognathodus remscheidensis* indicate an Early Devonian age for this collection. The new species of *Spathognathodus, S.* sp., differs from *S. remscheidensis* by having aborted anterior denticles instead of tall anterior denticles as in *S. remscheidensis*. *Spathognathodus* sp. occurs with *Spathognathodus boucoti* Klapper, an Early Devonian species, in a collection made by T. E. Mullens near Carlin, Nev. (USGS loc. 8447–SD). This occurrence supports my opinion that *S.* n. sp. cf. *Spathognathodus remscheidensis* is an Early Devonian species. Klapper reports (oral commun., March 1971) the occurrence of what is probably the same species with aborted anterior denticles in the Gedinnian Windmill Limestone of Johnson and Murphy (1969) at a stratigraphic horizon of 1,617 feet (493 m) in the west Coal Canyon section in the Simpson Park Mountains and on Pete Hanson Creek in the Roberts Mountains. It is unfortunate that species of *Icriodus* are not present in these collections of Silurian Coral Zone E to confirm the Early Devonian age of the Zone in terms of conodont chronology. Klapper and Murphy (1974), reported *I. woschmidti* from Birch Creek in the Roberts Mountains in the upper part of Roberts Mountains Formation.

Bed-by-bed collecting will be required to firmly establish conodont zonal distribution in these western Silurian and Devonian strata. Lowermost Devonian on the conodont scale conforms closely to that of the graptolite scale, placing the base of the Devonian System below or within Great Basin Silurian coral zone E. Although only a few conodonts have been identified from the Rabbit Hill Limestone, most of these are distinctive Early Devonian forms not recognized in the Roberts Mountains Formation.

LOCALITY REGISTER OF MAJOR FOSSIL LOCALITIES IN THE ROBERTS MOUNTAINS FORMATION AND CORRELATIVE STRATA

Roberts Mountains, Nev.

M1100.—Roberts Creek Mountain quadrangle, Nevada. Northwest side of Roberts Creek Mountain on measured section 550 m N. 79° W. of summit 9219 at altitude 8,680 feet. Upper part of Roberts Mountains Formation, unit 3.

M1102.—Roberts Creek Mountain quadrangle, Nevada. Northwest side of Roberts Creek Mountain. Lower beds of Roberts Mountains Formation unit 3 with *Prohexagonaria.* In measured reference section.

Northern Simpson Park Mountains, Nev.

M1032.—Horse Creek Valley quadrangle, Nevada. East side of Coal Canyon in NW¼ sec. 21, T. 25 N., R. 49 E. Rabbit Hill Limestone. Collected by R. J. Roberts, 1954.

M1075.—Horse Creek Valley quadrangle, Nevada. Near mouth of Coal Canyon, east side along top of ridge of summit 6909. Rabbit Hill Limestone, Lower Devonian.

M1076.—Horse Creek Valley quadrangle, Nevada. Near mouth of Coal Canyon, east side. Mostly float below top of ridge of summit 6909 and downslope to west. Rabbit Hill Limestone, Lower Devonian.

M1105.—Horse Creek Valley quadrangle, Nevada. Coal Canyon; float at canyon bottom 0.6 km south of mouth of Coal Canyon. Material probably from upper part of the section or upper coral-rich limestone breccia below Rabbit Hill Limestone.

M1105a.—Horse Creek Valley quadrangle, Nevada. Coal Canyon; float at canyon bottom 0.6 km south of mouth of Coal Canyon. Material probably from upper part of the section or upper coral-rich limestone breccia below Rabbit Hill Limestone.

M1106.—Horse Creek Valley quadrangle, Nevada. Coal Canyon near mouth in SE¼ sec. 17, T. 25 N., R. 49 E.; east side of canyon at altitude about 6,300 feet. Coral-rich limestone depositional breccia in upper part of the Roberts Mountains Formation and below Rabbit Hill Limestone.

M1107.—Horse Creek Valley quadrangle, Nevada. About 0.6 km south of mouth of Coal Canyon on east side of canyon and about 60 m above canyon bottom. Coral-rich limestone and depositional limestone breccia. Roberts Mountains Formation.

M1108.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, near mouth. Float collections below coral-bearing depositional breccia on east side of canyon below locality M1107. Roberts Mountains Formation.

M1110.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, near mouth. Coral-rich breccia limestone near top of Roberts Mountains section on east side of canyon. Collection made by A. J. Boucot, 1964.

M1310.—Horse Creek Valley quadrangle, Nevada. SE¼ sec. 17, T. 25 N., R. 49 E. West side of summit 6909 (Pyramid Hill) near top.

TABLE 2.—*Occurrence chart of conodont species collected from Silurian and Lower Devonian formations in central Nevada*

[Conodont species listed are form taxa. Identification by J. W. Huddle. Multielement apparatus reconstructions in the sense of Jeppson (1969) and Klapper and Philip (1971) have not been attempted]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acodina sp	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Belodella devonica (Stauffer)	--	--	--	--	--	--	--	×	--	--	--	×	×	--	--
Belodella resima (Philip)	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Belodella sp	--	×	--	--	--	×	--	×	×	--	×	--	--	--	--
Eantiognathus lipperti Bischoff	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hibbardella sp	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hindeodella sp	×	×	--	×	--	×	×	×	×	--	×	×	--	--	--
Icriodus latericrescens Branson and Mehl (subspecies not determined)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Icriodus latericrescens huddlei Klapper and Ziegler	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Icriodus latericrescens subspecies B Klapper[1]	Δ	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Icriodus latericrescens aff. *I. latericrescens* subspecies B Klapper	--	×	--	--	--	--	--	--	--	×	--	--	--	--	--
Icriodus sp	--	--	--	--	--	--	--	×	--	×	--	--	--	×	×
Ligonodina sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Lonchodina walliseri Ziegler	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Lonchodina sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Neoprioniodus excavatus (Branson and Mehl)	--	--	×	--	--	×	--	×	×	--	×	×	×	--	--
Neoprioniodus multiformis? Walliser	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Oneotodus? *beckmanni* Bischoff	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--
Ozarkodina denckmanni Ziegler	--	×	--	--	--	×	×	×	×	--	--	--	--	--	--
Ozarkodina gaertneri Walliser	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
Ozarkodina media Walliser	--	--	×	--	--	×	--	×	--	--	×	--	--	--	--
Ozarkodina aff. *O. media* Walliser	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--
Ozarkodina typica Branson and Mehl	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Ozarkodina ziegleri Walliser	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--
Ozarkodina aff. *O. ziegleri* Walliser	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Ozarkodina sp	×	--	--	--	--	--	--	--	--	--	--	--	--	×	--
Paltodus aff. *P. migratus* Rexroad	--	--	--	--	--	--	--	--	--	--	--	×	×	--	--
Paltodus sp	--	--	--	--	--	--	×	×	--	--	--	×	--	--	--
Panderodus sp	--	--	×	×	--	--	--	×	×	--	--	×	×	--	×
Pelekysgnathus furnishi Klapper	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Pelekysgnathus sp	--	--	--	--	--	--	--	--	--	--	--	--	×	×	--
Plectospathodus extensus Rhodes	--	--	×	--	--	--	--	×	--	--	×	×	--	--	--
Plectospathodus aff. *P. alternatus* Walliser	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Plectospathodus sp	×	--	--	--	--	×	--	--	×	--	--	--	--	--	--
Polygnathus foveolatus Philip and Jackson	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Prioniodina sp	×	--	--	--	--	×	--	--	--	--	--	--	--	×	--
Rotundacodina elegans Carls and Gandl	--	--	--	--	--	--	×	--	×	--	--	--	--	--	--
Rotundacodina noguerensis Carls and Gandl	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Scolopodus devonicus Bischoff and Sannemann	×	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Spathognathodus inclinatus inclinatus Rhodes	×	--	×	×	--	×	--	×	--	--	--	--	--	--	--
Spathognathodus primus (Branson and Mehl)[1]	--	--	--	--	--	--	--	--	--	--	--	×	--	Δ	--
Spathognathodus eosteinhornensis Walliser[1]	--	--	--	--	--	--	--	--	--	--	--	Δ	--	--	--
Spathognathodus remscheidensis Ziegler[1]	--	--	×	--	--	×	×	Δ	Δ	--	--	--	--	--	--
Spathognathodus n. sp., cf. *S. steinhornensis remscheidensis*	--	×	--	--	--	--	×	×	×	--	--	--	--	--	--
Ziegler	--	--	--	--	--	--	--	×	--	--	--	--	Δ	--	--
Spathognathodus transitans Bischoff and Sanneman[1]	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Spathognathodus cf. *S. transitans* Bischoff	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spathognathodus sp	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Synprioniodina sp	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Synprioniodina sp	--	--	--	--	--	--	×	×	×	--	--	--	--	--	--
Trichonodella blanda (Stauffer)	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Trichonodella blanda? (Stauffer)	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--
Trichonodella inconstans Walliser	×	--	--	--	--	--	--	--	--	--	--	--	--	×	--
Trichonodella sp	--	--	--	--	--	×	×	--	×	--	--	--	--	--	--

	Geographic locality:	Formation:	Approximate stratigraphic position of fossil collection:
1. 9165–SD	Toquima Range, Mill Canyon in August Canyon structural sequence.	Bastille Limestone Member of Masket Shale of Kay and Crawford (1964).	31 m above top of chert member of Gatecliff Fm. of Kay (1960).
2. 9166–SD	do	Upper member of Masket Shale of Kay and Crawford (1964).	91 m above top of chert member of Gatecliff Fm. of Kay (1960).
3. 8214–SD	Monitor Range, Copenhagen Canyon.	Roberts Mountains Formation	119 m above base of formation.
4. 8304–SD	do	do	187 m above base of formation.
5. 9167–SD	do	Rabbit Hill Limestone	Upper 31 m of formation at type section.
6. 8827–SD	Northern Simpson Park Mountains, Coal Canyon.	Thick-bedded upper part of Roberts Mountains Formation (mapped as Windmill Limestone by Johnson (1965) and Johnson and Murphy (1969).	*Carlinastraea* beds; unmeasured locality about 460 m above base of formation of west side of Coal Canyon.[2]

TABLE 2.—*Occurrence chart of conodont species collected from Silurian and Lower Devonian formations in central Nevada*—Continued

	Geographic locality:	Formation:	Approximate stratigraphic position of fossil collection:
7. 8829–SD	do	do	*Carlinastraea* beds; unmeasured locality near 8827–SD.
8. 8216–SD	do	do	Unmeasured locality; east side Coal Canyon about 520 m above base of formation.[2]
9. 8828–SD	do	do	Unmeasured locality; east side Coal Canyon about 550 m above base of formation.[2]
10. 9168–SD	do	Rabbit Hill Limestone	Unmeasured locality; east side Coal Canyon about 70 m above base of formation.[2]
11. 8228–SD	Tuscarora Mountains, Bootstrap Hill.	Roberts Mountains Formation	Lower 15 m of exposed section.
12. 8219–SD	do	do	37 m above base of exposed section.
13. 8219A–SD	do	do	119 m above base of exposed section.
14. 8215–SD	do	Roberts Mountains Formation (thick-bedded facies).	244 m above base of exposed section.
15. 8826–SD	Carlin area, Maggie Creek	Rabbit Hill Limestone	Unmeasured locality east side of Maggie Creek.

[1]Some occurrences of this taxon are anomalous with respect to its stratigraphic range as previously reported from central Nevada (Klapper, 1968; Klapper and others, 1971; Klapper and Murphy, 1975), the Canadian Yukon (Klapper, 1969; Fåhræus 1971), and Europe (Ziegler, 1971), and relative to monograptids of the *Monograptus uniformis* and *Monograptus hercynicus* groups. In order to accommodate this discrepancy, the anomalous stratigraphic occurrence of the taxon is shown as a Δ.
[2]The cited stratigraphic footage above base of the formation is estimated.

Upper 60 m of Rabbit Hill Limestone on this slope platy limestone with abundant trilobites.

M1317.—Horse Creek Valley quadrangle, Nevada. West side of Coal Canyon in sec. 20, T. 25 N., R. 49 E. near middle of north boundary, altitude about 6,600 feet. About 503 m stratigraphically above base of the Roberts Mountains Formation. Colonial rugose corals in place.

M1318.—Horse Creek Valley quadrangle, Nevada. West side of Coal Canyon, about 152 m west of canyon bottom at altitude 6,400 feet. Float material of large *Australophyllum*, probably from Coal Canyon fault zone in the Roberts Mountains Formation.

M1331.—Horse Creek Valley quadrangle, Nevada. Coal Canyon. SW¼SW¼ sec. 16, T. 25 N., R. 49 E.; east side of summit 6909 (Pyramid Hill), altitude 6,840 feet just east of section line, 150 m southeast of flag station 6909. Rabbit Hill Limestone.

M1332.—Horse Creek Valley quadrangle, Nevada. Coal Canyon area, top of Pyramid Hill (summit 6909), northwest of M1331, at flag station. Rabbit Hill Limestone.

M1333.—Horse Creek Valley quadrangle, Nevada. Coal Canyon area. West side of Coal Canyon, NE¼ sec. 20 near section line, 305 m northwest of hill 6400 at altitude 6,560 feet. About same zone as M1317. Dark-gray well-bedded limestone with abundant *Favosites* and other corals including a pycnostylid. Brachiopods present. Roberts Mountains Formation.

M1334.—Horse Creek Valley quadrangle, Nevada. Coal Canyon area. SE¼ sec. 17, T. 25 N., R. 49 E. on west side of Coal Canyon 460 m northwest of hill 6400 at altitude 6,560 feet and 200 m north of M1333, Roberts Mountains Formation. Dark-gray limestone with corals and brachiopods.

M1379.—Horse Creek Valley quadrangle, Nevada. West side of Coal Canyon near its mouth, SE¼ sec. 17, T. 25 N., R. 49 E.; 460 m N. 78° W. of summit of hill 6909, altitude 6,400 feet. East-dipping limestone of Roberts Mountains Formation, fault sliver in Coal Canyon shear zone. On crest of northeast-extending spur.

M1380.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, 850 m south of canyon mouth; NE¼ sec. 20, T. 25 N., R. 49 E.; 2,200 feet S. 33° W. of summit of hill 6909 on east side near top small knoll in canyon, altitude 6,400 feet. Upper beds of Roberts Mountains Formation, Great Basin Silurian coral zone E.

M1381.—Horse Creek Valley quadrangle, Nevada. Coal Canyon east side, 760 m south of canyon mouth, 520 m S. 40° W. of summit of hill 6909, altitude 6,320 feet. Upper beds of Roberts Mountains Formation.

M1383.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, west side sec. 17 near middle of south edge, T. 25 N., R. 49 E. At crest northeast spur 670 m S. 79° W. of summit of hill 6909, altitude 6,580 feet. Roberts Mountains Formation.

M1384.—Horse Creek Valley quadrangle, Nevada. Coal Canyon west side, NE¼ sec. 20, T. 25 N., R. 49 E.; 760 m S. 53° W. of summit 6909, altitude 6,520 feet. Roberts Mountains Formation. *Carlinastraea tuscaroraensis* locality.

M1411.—Horse Creek Valley quadrangle, Nevada. West side of Coal Canyon 0.8 km south of canyon mouth at altitude 6,360 feet on northwest side of small limestone knob, altitude 6,400 feet. Roberts Mountains Formation with *Verticillopora*.

M1446.—Horse Creek Valley quadrangle, Nevada. Foothills on north side of Simpson Park Mountains; 2.4 km north of Red Hill in SE¼NE¼ sec. 5, T. 25 N., R. 50 E. Low pediment exposures of Roberts Mountains Formation.

M1448.—Horse Creek Valley quadrangle, Nevada. East side of Pine Hill, 150 m south of middle of north edge of sec. 20, T. 25 N., R. 49 E., near north-south midline of section; altitude 6,500 feet. Roberts Mountains Formation. In coral beds with *Carlinastraea*.

M1449.—Horse Creek Valley quadrangle, Nevada. Top of main northeast spur of Pine Hill, 213 m north of south boundary of sec. 17, T. 25 N., R. 49 E., at north-south midline of section. Roberts Mountains Formation. In coral beds with *Carlinastraea*.

M1450.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, east side about 335 m south of canyon mouth at altitude 6,300 feet. Coral collection mostly float material. Great Basin Silurian coral zone E. Roberts Mountains Formation.

M1451.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, east side about 100 m south of canyon mouth at altitude 6,280 feet. Coral collections mostly loose float material. Great Basin Silurian coral zone E. Roberts Mountains Formation.

M1452.—Horse Creek Valley quadrangle, Nevada. Coal Canyon, west side about 460 m south of canyon mouth, altitude 6,300 feet. Within the Coal Canyon fault zone. Roberts Mountains Formation.

M1453.—Horse Creek Valley quadrangle, Nevada. Coal Canyon in NE¼ sec. 20, T. 25 N., R. 49 E., on top of small knoll 0.8 km south of canyon mouth, altitude 6,400 feet. Great Basin Silurian coral zone E. Roberts Mountains Formation.

M1454.—Horse Creek Valley quadrangle, Nevada. Coal Canyon about 975 m south of canyon mouth, altitude 6,400 feet on top of spur on which the Middle Devonian Woodpecker Limestone Member of the Nevada Formation is apparently overridden by an upper plate comprising parts of the Roberts Mountains Formation and overlying Rabbit Hill Limestone.

M1455.—Horse Creek Valley quadrangle, Nevada. Coal Canyon about 975 m south of canyon mouth, altitude 6,400 feet, on top of spur about 60 m east of M1454. Mixed Devonian assemblage apparently from both the Middle Devonian Woodpecker Limestone Member of the Nevada Formation and the Lower Devonian Rabbit Hill Limestone tectonically involved in the thrust.

M1456.—Horse Creek Valley quadrangle, Nevada. South middle part of sec. 17, T. 25 N., R. 49 E., at crest of main northeast spur, altitude 6,600 feet. In thick-bedded limestone with rugose corals. Roberts Mountains Formation.

Cortez Mountains, Nev.

M1409.—Cortez quadrangle, Nevada. West base of Cortez Mountains about 1.6 km southeast of the town of Cortez. NE¼ sec. 17, T. 26 N., R. 48 E., 2.6 km N. 76° E. of BM 5748, altitude 6,400 feet. Roberts Mountains Formation. *Carlinastraea*; probable float material.

Sulphur Spring Range, Nev.

M1148.—Garden Valley quadrangle, Nevada. Southern part of Sulphur Spring Range. East side of range in northeast corner sec. 35, T. 23 N., R. 52 E. Lone Mountain Dolomite with corals 0.8 km north-northwest of BM 5867 on east-west spur, altitude 6,100 feet.

Southern Tuscarora Mountains, Nev.

M1120.—Tuscarora Mountains near north end of Eureka County, Nev.; "Round Mountain," bottom of hill at southwest end. Collected by R. J. Roberts, June 1958. Roberts Mountains Formation limestone.

M1313.—Bootstrap mine area, Nevada. Bootstrap Hill section. Roberts Mountains Formation about 400 m stratigraphically above base of section on top of knob. *Carlinastraea* bed.

M1314.—Bootstrap mine area. Bootstrap Hill stratigraphic section 200–250 m stratigraphically above base. Roberts Mountains Formation.

M1315.—Bootstrap mine area. Bootstrap Hill stratigraphic section about 230 m stratigraphically above base. Roberts Mountains Formation.

M1412.—Tuscarora Mountains, Nev. Advance quadrangle sheet USGS Tuscarora 3SW (7–7–68); Elko County, Nev., near north edge of Eureka County. Bootstrap Hill area southwest of Bootstrap Hill. Just north of Eureka County-Elko County line at bottom of ridge about 300 m east of Dunphy-Tuscarora road and about 1,830 m S. 17° W. of top of Bootstrap Hill. Probably a large float boulder; contains silicified brachiopods in abundance.

M1413.—Tuscarora Mountains, Nev. Northeast Eureka County. Northeast of the Lynn window of R. J. Roberts. Collected by R. J. Roberts, 1958. Corals. Possibly in Jack's Creek drainage northeast of Big Six mine. Roberts Mountains Formation.

Toquima Range, Nev.

M1103.—Dianas Punch Bowl quadrangle, Nevada. Ikes Canyon. About 1.6 km up canyon from mouth on north side and about 100 m in altitude above creek bottom, altitude 7,900 feet. Southeast of Ikes cabin. Roberts Mountains Formation or Masket Shale of Kay and Crawford (1964). Coral-rich limestone with *Verticillopora.*

M1114.—Dianas Punch Bowl quadrangle, Nevada. Ikes Canyon area; 200 m northwest of summit 8474 (Copper Mountain), altitude 8,300 feet. In McMonnigal Limestone. Coral fauna with *Toquimaphyllum*. Great Basin Silurian coral zone E.

M1147.—Northeast corner of Wildcat Peak quadrangle. SW¼SW¼ sec. 16, T. 16 N., R. 46 E., on top of divide west of Henry Meyer Canyon, altitude 6,960 feet. Roberts Mountains Formation in beds with a fauna similar to that in the Rabbit Hill Limestone surrounded by graptolitic beds of Silurian age.

M1393.—Dianas Punch Bowl quadrangle, Nevada. South side of Ikes Canyon, a little less than 1.7 km northwest of canyon mouth. McMonnigal Limestone.

M1394.—Southeast corner of Wildcat Peak quadrangle. On north side of Mill Canyon 1,525 m west of east border of quadrangle on top of spur, altitude 8,560 feet and 730 m north of south boundary of quadrangle. Bastille Limestone Member of Masket Shale of Kay and Crawford (1964).

M1395.—Southeast corner of Wildcat Peak quadrangle. On north side of Mill canyon, altitude 8,000 feet and 2,400 m west of east border of quadrangle. Bastille Limestone Member of Masket Shale of Kay and Crawford (1964).

M1396.—Southeast corner of Wildcat Peak quadrangle, 1,220 m west of east border of quadrangle and 1,130 m north of south boundary of quadrangle; altitude 8,500 feet. Bastille Limestone Member of Masket Shale of Kay and Crawford (1964).

M1397.—Wildcat Peak quadrangle, Nevada. South side of Stoneberger Basin, 2.4 km southeast of top of Whiterock Mountain at altitude 9,100 feet, just east of letter "n" in word "Basin" of "Stoneberger Basin" (Wildcat Peak quadrangle). Tor Limestone.

Northern Inyo Mountains, Calif.

M1090.—Independence quadrangle, California. East of Kearsarge at mouth of Mazourka Canyon. In NE¼ sec. 8, T. 13 S., R. 36 E. Within 6 m of top Vaughn Gulch Limestone. Poorly preserved fossils of probable Early Devonian age.

M1091.—Independence quadrangle, California. At mouth of Mazourka Canyon. Near east line of sec. 8, T. 13 S., R. 36 E. at middle of NE¼, 366 m north of Vaughn Gulch creek bottom, altitude 4,840 feet. About 46 m stratigraphically above chert unit at base of Vaughn Gulch Limestone.

M1092.—Independence quadrangle, California. Same measured section as M1091, west of east section line of sec. 8 in NE¼, altitude 4,880 feet. Middle part of Vaughn Gulch Limestone about 305 m stratigraphically above the Eureka Quartzite equivalent.

M1093.—Independence quadrangle, California. East of Kearsarge at mouth of Mazourka Canyon. In NE¼ sec. 8, T. 13 S., R. 36 E. Base of upper unit of Vaughn Gulch Limestone about 412 m stratigraphically above Eureka Quartzite equivalent and 137 m below top of Vaughn Gulch Limestone.

M1115.—Independence quadrangle, California. East of Kearsarge at mouth of Mazourka Canyon. Measured section of Vaughn Gulch Limestone about 34 m stratigraphically below horizon of M1093. Rugose coral bed.

M1116.—Independence quadrangle, California. At mouth of Mazourka Canyon in measured section in which are localities M1092 and M1093. Coral bed about 9–15 m stratigraphically below M1093, near top middle unit of Vaughn Gulch Limestone.

M1128.—Independence quadrangle, California. East of Kearsarge at mouth of Mazourka Canyon. In measured section about 52 m stratigraphically below M1093 in higher middle part of the Vaughn Gulch Limestone. Beds with *Verticillopora.*

M1385.—Independence quadrangle, California. Sec. 8, T. 13 S., R. 36 E. Vaughn Gulch Limestone, Silurian. Probably same zone as locality M1128. *Verticillopora*. Collected by Craig D. Ross, 1961.

M1410.—Independence quadrangle, California. Mazourka Canyon east of Kearsarge in measured section. At top of middle unit of Vaughn Gulch Limestone and about 15 m stratigraphically below locality M1093.

Gotland, Sweden

M1382.—Gotland, Sweden. Hemse Group. Stop 40 of Internat. Geol. Cong. guidebook, 1960. Boardman collection, Sept. 10, 1960.

SELECTED REFERENCES

Adams, J. E., and Rhodes, M. L., 1960, Dolomitization by seepage refluxion: Am. Assoc. Petroleum Geologists Bull., v. 44, no. 12 p. 1912–1920.

Bathurst, R. G. C., 1971, Developments in Sedimentology 12—Carbonate sediments and their diagenesis: New York, Elsevier Publishing Co., 620 p.

Beales, F. W., 1953, Dolomitic mottling in Palliser (Devonian) Limestone, Banff and Jasper National Parks, Alberta: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 10, p. 2281–2293.

Berry, W. B. N., 1970, The base of the Devonian and an Early Devonian graptolite succession in central Nevada: Geol. Soc. America Bull., v. 81, p. 513–520.

Berry, W. B. N., and Roen, J. B., 1963, Early Wenlock graptolites from Roberts Mountains formation, Tuscarora Mountains, Nevada: Jour. Paleontology, v. 37, no. 5, p. 1123–1126.

Berry, W. B. N., and Murphy, M. A., 1975, Silurian and Devonian graptolites from central Nevada: California Univ. Pubs. Geol. Sci. V. 110, 109 p.

Birenheide, Rudolf, 1962, Revision der koloniebildenden Spongophyllidae und Stringophyllidae aus dem Devon: Senckenbergiana Lethaea, v. 43, no. 1, p. 41–99, 7 pls.

Blackwelder, Eliot, 1913, Origin of the Bighorn Dolomite of Wyoming: Geol. Soc. America Bull., v. 24, p. 607–624.

Carls, Peter, and Gandl, Josef, 1969, Stratigraphie and comodonten des Untes-Devons der Östlichen Iberischen Ketten (NE-Spanien): Neues Jahrb. Geologie u. Paläontologie Abh., v. 132, no. 2, p. 155–218.

Cornwall, H. R., and Kleinhampl, F. J., 1960, Preliminary geologic map of the Bare Mountain quadrangle, Nye County, Nevada: U.S. Geol. Survey Mineral Inv. Field Studies Map MF-239, scale 1:48,000.

Daly, R. A., 1907, The limeless ocean of Pre-Cambrian time: Am. Jour. Sci., ser. 4, v. 23, p. 93–115.

———1909, First calcareous fossils and the evolution of limestone: Geol. Soc. America Bull., v. 20, p. 153–170.

Deffeyes, K. S., Lucia, F. J., and Weyl, P. K., 1965, Dolomitization of Recent and Plio .Pleistocene sediments by marine evaporate waters on Bonaire, Netherlands Antilles, *in* Dolomitization and limestone diagenesis, a symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 13, p. 71–88.

DeGroot, K., 1973, Geochemistry of the tidal flat brines at Umm Said, SE Qatar, Persian Gulf, *in* Purser, B. H., ed., The Persian Gulf Holocene carbonate sedimentation and diagenesis in a shallow sea: New York, Heidelberg, Berlin, Springer-Verlag, p. 377–394.

Duncan, Helen, 1956, Ordovician and Silurian coral faunas of western United States: U.S. Geol. Survey Bull. 1021-F, p. 209–236, 7 pls.

———1957, *Bighornia,* a new Ordovician coral genus: Jour. Paleontology, v. 31, no. 3, p. 607–615, 1 pl.

Edwards, H. M., and Haime, Jules, 1850–1854, A monograph of the British fossil corals: London, Palaeontographical Soc., 322 p., 72 pls.

———1851, Monographie des polypiers fossiles des terrains palaeozoiques: Mus. Histoire Nat., Paris, Archives, v. 5, 502 p., 20 pls.

Evans, J. E., and Mullens, T. E., 1976, The Bootstrap window, Elko County, Nevada: U.S. Geol. Survey Jour. Research, v. 4, no. 1, pp. 119–125.

Fåhræus, Lars, E., 1971, Lower Devonian conodonts from the Michella and Prongs Creek Formations, Yukon Territory: Jour. Paleontology, v. 45, no. 4, p. 665–683.

Fairbridge, R. W., 1957, The dolomite question, *in* LeBlanc, R. J., and Breeding, J. G., eds., Regional aspects of carbonate deposition—a symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 5, p. 126–178.

Friedman, G. M., and Sanders, J. E., 1967, Origin and occurrence of dolostones, *in* Chilingar, G. V., ed., Carbonate rocks, Part A: New York, Elsevier Publishing Co., p. 267–348.

Gilluly, James, and Gates, Olcott, 1965, Tectonic and igneous geology of the northern Shoshone Range, Nevada: U.S. Geol. Survey Prof. Paper 465, 153 p.

Gilluly, James, and Masursky, Harold, 1965, Geology of the Cortez quadrangle, Nevada: U.S. Geol. Survey Bull. 1175, 117 p.

Grabau, A. W., 1930, Corals of the Upper Silurian Tingi Beds of Kweichow: Geol. Soc. China Bull., v. 9, no. 3, p. 223–240b, 3 pls.

Greene, J. M., 1953, Paleozoic stratigraphy of Clear Creek Canyon, Monitor Range, Nye County, Nevada: Columbia Univ., New York, M.S. thesis, 37 p.

Hewett, D. F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U.S. Geol. Survey Prof. Paper 162, 172 p.

Hill, Dorothy, 1935, British terminology for rugose corals: Geol. Mag. [Great Britain], v. 72, no. 857, p. 481–519, 21 figs.

———1936, The British Silurian rugose corals with acanthine septa: Royal Soc. London Philos. Trans., ser. B, no 534, v. 226, p. 189–217, 2 pls.

———1940, The Silurian Rugosa of the Yass-Bowning District, N.S.W.: Linnean Soc. New South Wales Proc., v. 65, pt. 3–4, p. 388–420, 3 pls.

———1956, Rugosa, *in* Moore, R. C., ed., Treatise on invertebrate paleontology, pt. F, Coelenterata: [Lawrence, Kans.] Kansas Univ. Press and Geol. Soc. America, p. F233–F234.

Hsü, K. J., and Siegenthaler, C., 1969, Preliminary experiments on hydrodynamic movement induced by evaporation and their bearing on the dolomite problem: Sedimentology, v. 12, p. 11–25.

Hsü, K. J., and Schneider, J., 1973, Progress report on dolomitization-hydrology of Abu Dabi Sabkhas, Arabian Gulf, *in* Purser, B. H., ed., The Persian Gulf Holocene carbonate sedimentation and diagenesis in a shallow sea: New York, Springer-Verlag, p. 409–422.

Illing, L. V., Wells, A. J., and Taylor, J. C. M., 1965, Penecontemporary dolomite in the Persian Gulf, *in* Dolomitization and limestone diagenesis—a symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 13, p. 89–111.

Jeppsson, L., 1969, Notes on some Upper Silurian multielement conodonts: Geol. Fören Stockholm Förh, v. 91, p. 12–24.

Johnson, J. G., 1965, Lower Devonian stratigraphy and correlation, northern Simpson Park Range, Nevada: Canadian Petroleum Geology Bull., v. 13, no. 3, p. 365–381.

Johnson, J. G., Boucot, A. J., and Murphy, M. A., 1967, Lower Devonian faunal succession in central Nevada, *in* Oswald, D. H., ed., International symposium on the Devonian System, Calgary 1967 [Proc.], Volume II: Calgary, Alberta, Alberta Soc. Petroleum Geologists, p. 679–691.

Johnson, J. G., and Murphy, M. A., 1969, Age and position of Lower Devonain graptolite zones relative to the Appalachian standard succession: Geol. Soc. America Bull. v. 80, no. 7, p. 1275–1282.

Jones, O. A., 1929, On the coral genera *Endophyllum* Edwards and Haime and *Spongophyllum* Edwards and Haime: Geol. Mag. [Great Britain], v. 66, no. 2, p. 84–91, 1 pl.

———1930, A revision of some Paleozoic coral genera and species [abs.]: Cambridge Univ., Abs. Dissert. Acad. Year 1928–29, p. 35–36.

Jones, O. T., 1933, Major divisions of the Paleozoic era—Lower Paleozoic; The lower Paleozoic rocks of Britain: Internat. Geol. Cong., 16th, Washington, D.C. 1933, Rept., v. 1, p. 463–484.

Kay, Marshall, 1960, Paleozoic continental margin in central Nevada, western United States: Internat. Geol. Cong., 21st, Copenhagen 1960, Rept., pt. 12, p. 93–103.

Kay, Marshall, and Crawford, J. P., 1964, Paleozoic facies from the miogeosynclinal to the eugeosynclinal belt in thrust slices, central Nevada: Geol. Soc. America Bull., v. 75, p. 425–454.

Kirk, Edwin, 1918, Stratigraphy of the Inyo Range (southern California): U.S. Geol. Survey Prof. Paper 110, p. 19–48.

Klapper, Gilbert, 1968, Lower Devonian conodont succession in central Nevada [abs.]: Geol. Soc. America, Cordilleran Sec., 64th Ann. Mtg., p. 72–73.

———1969, Lower Devonian conodont sequence, Royal Creek, Yukon Territory, and Devon Island, Canada, with a section on Devon Island stratigraphy by A. R. Ormiston: Jour. Paleontology, v. 43, p. 1–27, pls. 1–6.

Klapper, Gilbert, and Philip, G. M., 1971, Devonian conodont apparatuses and their vicarious skeletal elements: Lethaia, v. 4, p. 429–452.

Klapper, Gilbert, Sandberg, C. A., Collinson, Charles, and others, 1971, North American Devonian conodont biostratigraphy, *in* Sweet, W. C., and Bergström, S. M., eds., Symposium on conodont biostratigraphy: Geol. Soc. America Mem. 127, p. 285–316.

Klapper, Gilbert, and Murphy, M. A., 1974, Silurian-Lower Devonian conodont sequence in the Roberts Mountains Formation of central Nevada: California Univ. Pubs. Geol. Sci., V. 111, 62 p.

Kleinhampl, F. J., and Ziony, J. I., 1967, Preliminary geologic map of northern Nye County, Nevada: U.S. Geol. Survey open-file map, scale 1:200,000.

Lamb, G. F., 1901, A revision of the genera and species of Canadian Paleozoic corals; the Madreporaria Aporosa and the Madreporaroria Rugosa: Canada Geol. Survey, Canadian Paleozoic Contr. 4, p. 97–197.

Lang, W. D., Smith, Stanley, and Thomas, H. D., 1940, Index of Palaeozoic coral genera: British Mus. (Nat. History), 231 p.

Lenz, A. C., 1972, Plicocyrtina and Plicoplasia (Brachiopoda) from the Lower Devonian of the northern Canadian Cordillera: Jour. Paleontology, v. 46, no. 1, p. 99–103.

Lowenstam, H. A., 1949, Niagaran reefs in Illinois and their relation to oil accumulation: Illinois Geol. Survey Rept. Inv. 145, p. 7–36.

McAllister, J. F., 1952, Rocks and structure of the Quartz Spring area, northern Panamint Range, California: California Div. Mines Spec. Rept. 25, 38 p.

McKee, E. H., 1976, Geology of the northern part of the Toquima Range, Eureka, Lander, and Nye Counties, Nevada: U.S. Geol. Survey Prof. Paper. 931 (in press).

McKee, E. H., Merriam, C. W., and Berry, W. B. N., 1972, Biostratigraphy and correlation of McMonnigal and Tor Limestones, Toquima Range, Nevada: Am. Assoc. Petroleum Geologists Bull., v. 56, no. 8, p. 1563–1570.

McKee, E. H., and Ross, R. J., Jr., 1969, Stratigraphy of eastern assemblage rocks in a window in Roberts Mountains thrust, northern Toquima Range, central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 53, p. 421–429.

McLaren, D. J., 1970, Presidential address; time, life and boundaries: Jour. Paleontology, v. 44, no. 5, p. 801–815.

Manten, A. A., 1971, Silurian reefs of Gotland—Developments in Sedimentology 13: New York, Elsevier Pub. Co., 539 p.

Matti, J. C., Murphy, M. A., and Finney, S. C., 1975, Silurian and Lower Devonian basin and basin-slope limestones, Copenhagen Canyon, Nevada: Geol. Soc. America Spec. Paper 159, 48 p.

Merriam, C. W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada: Geol. Soc. America Spec. Paper 25, 114 p., 16 pls.

———1963, Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada: U.S. Geol. Survey Prof. Paper 423, 67 p.

———1972, Silurian rugose corals of the Klamath Mountains region, California: U.S. Geol. Survey Prof. Paper 738, 50 p., 8 pls.

———1973a, Silurian rugose corals of the central and southwest Great Basin: U.S. Geol. Survey Prof. Paper 777, 66 p., 16 pls.

———1973b, Paleontology and stratigraphy of the Rabbit Hill Limestone and Lone Mountain Dolomite of central Nevada: U.S. Geol. Survey Prof. Paper 808, 50 p., 12 pls.

———1973c, Middle Devonian rugose corals of the central Great Basin: U.S. Geol. Survey Prof. Paper 799, 53 p.

———1974, Lower and lower-Middle Devonian rugose corals of the central Great Basin: U.S. Geol. Survey Prof. Paper 805, 83 p., 25 pls.

Merriam, C. W., and Anderson, C. A., 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 1675–1728.

Middleton, G. V., 1959, Devonian tetracorals from south Devonshire, England: Jour. Paleontology, v. 33, no. 1, p. 138–160, 1 pl., 6 text figs.

Minato, Masao, 1961, Ontogenetic study of some Silurian corals of Gotland: Stockholm Contr. Geology, v. 8, no. 4, p. 37–100, 22 pls.

Mullens, T. E., and Poole, F. G., 1972, Quartz-sand-bearing zone and Early Silurian age of upper part of the Hanson Creek Formation in Eureka County, Nevada, *in* Geological Survey research 1972: U.S. Geol. Survey Prof. Paper 800–B, p. B21–B24.

Murphy, M. A., and Gronberg, E. C., 1970, Stratigraphy and correlation of the Lower Nevada Group (Devonian) north and west of Eureka, Nevada: Geol. Soc. America Bull., v. 81, p. 127–136.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geol. Survey Prof. Paper 276, 77 p.

Norford, B. S., 1962, The Silurian fauna of the Sandpile group of northern British Columbia: Canada Geol. Survey Bull. 78, 51 p., 16 pls.

Oliver, W. A., Jr., 1960, Devonian rugose corals from northern Maine: U.S. Geol. Survey Bull. 1111–A, p. 1–23, pls. 1–5.

Oliver, W. A., Jr., Merriam, C. W., and Churkin, Michael, 1975, Ordovician, Silurian, and Devonian corals of Alaska, *in* Paleozoic corals of Alaska: U.S. Geol. Survey Prof. Paper 823–B, p. B13–B44.

Osmond, J. C., 1954, Dolomites in Silurian and Devonian of east-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 38, no. 9, p. 1911–1956.

Pia, Julius, 1926, Pflanzen als Gesteinsbildner: Berlin, Germany, Gebrüder Borntraeger, 355 p., 166 text figures.

Pray, L. C., and Murray, R. C., eds., 1965, Dolomitization and limestone diagenesis—a symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 13, 180 p.

Rezak, Richard, 1959, New Silurian Dasycladaceae from the southwestern United States, Pt. 2 *of* Johnson, J. H., Konishi, Kenji, and Rezak, Richard, Studies of Silurian (Gotlandian) algae: Colorado School Mines Quart., v. 54, no. 1, p. 115–129.

Roberts, R. J., Hotz, P. E., Gilluly, James, and Ferguson, H. G., 1958, Paleozoic rocks of north-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, no. 12, p. 2813–2857.

Ross, D. C., 1963, New Cambrian, Ordovician and Silurian formations in the Independence quadrangle, Inyo County, California, *in* Geological Survey research 1963: U.S. Geol. Survey Prof. Paper 475–B, p. B74–B85.

———1965, Geology of the Independence quadrangle, Inyo County, California: U.S. Geol. Survey Bull. 1181–0, 64 p.

———1966, Stratigraphy of some Paleozoic formations in the Independence quadrangle, Inyo County, California: U.S. Geol. Survey Prof. Paper 396, 64 p.

St. Joseph, J. K. S., 1938, The Pentameracea of the Oslo region, being a description of the Kiaer collection of pentamerids: Norsk Geol. Tidsskr., v. 17, no. 4, p. 225–236, 8 pls., 23 text-figs.

Shimizu, Saburo, Ozaki, Kin-emon, and Obata, Tadahiro, 1934, Gotlandian deposits of northwest Korea: Shanghai Sci. Inst. Jour., sec. 2, v. 1, p. 59–88, pls. 9–18.

Shinn, E. A., Ginsburg, R. N., and Lloyd, R. M., 1965, Recent supratidal dolomite from Andros Island, Bahamas, *in* Dolomitization and limestone diagenesis—a symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 13, p. 112–123.

Shurygina, M. R., 1968, Poznesiluriyskiye rannedevonskiye rugozy vostochnogo sklona severnogo i srednogo Urala [Late Silurian and Early Devonian rugose corals from the eastern slope of the northern and central Urals], *in* Ivanovsky, A. B., Korally pogranichnykh sloeb Silura i Devona Altae-Saianskoi gornoi oblasti i Urala [Corals from the Silurian-Devonian boundary beds of the Altay-Sayan Mountains and the Urals]: Moscow, "Nauka" [Pub. House], p. 117–150, pls. 49–65. (Akad. Nauk SSSR Sibirsk. Otdeleniye Inst. Geologiya i Geofizika).

Skeats, E. W., 1918, The formation of dolomite and its bearing on the coral reef problem: Am. Jour. Sci., ser. 4, v. 45, art. 13, p. 185–200.

Smith, Stanley, 1930, Some Valentian corals from Shropshire and Montgomeryshire, with a note on a new stromatoporoid: Geol. Soc. London Quart. Jour., v. 86, p. 291–330, pls. 26–29.

———1933, On *Xylodes rugosus* sp. nov., a Niagaran coral: Am. Jour. Sci., ser. 5, v. 26, no. 155, p. 512–522, 1 pl.

———1945, Upper Devonian corals of the Mackenzie River region, Canada: Geol. Soc. America Spec. Paper 59, 126 p., 35 pls.

Stauffer, C. R., 1930, The Devonian of California: California Univ. Pubs., Dept. Geology, v. 19, no. 4, p. 81–118, 5 pls.

Steidtmann, Edward, 1911, The evolution of limestone and dolomite, pt. 1: Jour. Geology, v. 19, nos. 4–5, p. 323–428.

———1917, Origin of dolomite as disclosed by stains and other methods: Geol. Soc. America Bull., v. 28, p. 431–450, pls. 22–28.

Stevens, C. H., and Ridley, A. P., 1974, Middle Paleozoic off-shelf deposits in southeastern California: evidence for proximity of the Antler orogenic belt?: Geol. Soc. America Bull., v. 85 p. 27–32.

Stewart, J. H. and McKee, E. H., 1968, Geologic map of the Mount Callaghan quadrangle, Lander County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–730.

———1976, Geology and mineral deposits of Lander County, Nevada, with a section on Mineral deposits by Harold K. Stager: Nevada Bur. Mines Bull. (in press).

Stewart, J. H., and Palmer, A. R., 1967, Callaghan window—a newly discovered part of the Roberts thrust, Toiyabe Range, Lander County, Nevada, *in* Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575–D, p. D56–D63.

Stumm, E. C., 1949, Revision of the families and genera of the Devonian tetracorals: Geol. Soc. America Mem. 40, 92 p., 25 pls.

———1952, Species of the Silurian rugose coral genus *Tryplasma* from North America: Jour. Paleontology, v. 26, no. 5, p. 841–843, pl. 125.

———1964, Silurian and Devonian corals of the Falls of the Ohio: Geol. Soc. America Mem. 93, 184 p., 2 figs., 80 pls.

Taylor, P. W., 1950, The Plymouth Limestone, and the Devonian Tetracorals of the Plymouth Limestone: Royal Geol. Soc. Cornwall (England) Trasn., v. 18, pt. 2, p. 146–160, 161–214, 5 pls.

Ulrich, E. O., and Schuchert, Charles, 1902, Paleozoic seas and barriers in eastern North America: New York State Mus. Bull., v. 52, p. 633–663.

Van Tuyl, F. M., 1916a, The origin of dolomite: Iowa Geol. Survey Ann. Rept. 1914, v. 25, p. 251–422.

———1916b, New Points on the origin of dolomite: Am. Jour. Sci., ser. 4, v. 42, p. 249–260.

Waite, R. H., 1953, Age of the "Devonian" of the Kearsarge area, California [abs.]: Geol. Soc. America Bull., v. 64, no. 12, pt. 2, p. 1521.

———1956, Upper Silurian Brachiopoda from the Great Basin [Nevada, Utah]: Jour. Paleontology, v. 30, no. 1, p. 15–18, pl. 4.

Walcott, C. D., 1884, Paleontology of the Eureka district [Nevada]: U.S. Geol. Survey Mon. 8, 298 p., 24 pls.

Walliser, O. H., 1964, Conodonten des Silus: Abhandlungen des Hessischen Landesamtes für Bodenforschung, Heft 41, 106 p., 32 pls.

———1972, Conodont apparatuses in the Silurian, *in* Lindström, M., and Ziegler, W., eds., Symposium on conodont taxonomy: Geol. et Palaeontol., Sonderb. 1, p. 75–79.

Wang, H. C., 1947, New material of Silurian rugose corals from Yunnan: Geol. Soc. China Bull., v. 27, p. 171–192, 2 pls. [Nanking, China].

Webby, B. D., 1964, Devonian corals and brachiopods from the Brendon Hills, West Somerset (England): Palaeontology, v. 7, pt. 1, 22 p., 1 pl., 6 text figs.

Wedekind, Rudolf, 1927, Die Zoantharia von Gotland (bes. Nordgotland): Sveriges Geol. Undersökning, ser. Ca, no. 19, 94 p., 30 pls.

Whiteaves, J. F., 1884, On some new, imperfectly characterized or previously unrecorded species of fossils from the Guelph Formation of Ontario: Canada Geol. Survey, Palaeozoic Fossils, v. 3, no. 4, p. 1–43.

Winterer, E. L., and Murphy, M. A., 1960, Silurian reef complex and associated facies, central Nevada: Jour. Geology, v. 68, no. 2, p. 117–139, 7 pls.

Ziegler, Willi, 1971, Conodont stratigraphy of the European Devonian, *in* Sweet, W. C., and Bergström, S. M., eds., symposium on conodont biostratigraphy: Geol. Soc. Am. Mem. 127, p. 227–284.

INDEX

[Italic page numbers indicate major references]

PLATES 1–12

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

PLATE 1

FIGURES

1–9. *Stylopleura berthiaumi* Merriam

1–6. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3. Locality M1100, Roberts Creek Mountain, Nev.

1. View of broken calice interior showing three offsets. Paratype, USNM 159384a. ×2.
2. Lateral view of two corallites from a large colony (paratype USNM 165359) showing connecting elements. ×1.
3. Calice view showing multiple calice budding. Paratype USNM 159383. ×2.
4. Partial lateral view of holotype. USNM 159382. ×1½.
5. Partial lateral view of paratype showing lateral element attached to *Cladopora* branch. USNM 159384. ×1.
6. Longitudinal thin section. USNM 165358a. ×2.

7–9. Great Basin Silurian coral zone E. Roberts Mountains Formation. Locality M1106, Coal Canyon, Simpson Park Mountains, Nev. USNM 159385. ×1.

7. Lateral view.
8. Calice view.
9. Partial interior view showing calice offsets.

10–12. *Stylopleura* sp. b

10–11. Silurian Roberts Mountains Formation. Locality M1314, Bootstrap Hill, Tuscarora Mountains, Nev.

10. Lateral view of broken corallite. ×1½.
11. Lateral view of piece of corallite showing base of hollow lateral element. ×2.
12. Longitudinal thin section. ×2. Silurian. Roberts Mountains Formation. Locality M1315, Bootstrap Hill, Tuscarora Mountains, Nev.

13–15. *Stylopleura* sp. c, cf. *S. berthiaumi*

Great Basin Silurian coral zone D. Roberts Mountains Formation. Locality M1317, Coal Canyon, Simpson Park Mountains, Nev. ×2.

13. Longitudinal thin section.

14, 15. Transverse thin sections.

16, 17. *Pycnostylus guelphensis Whiteaves*?

Longitudinal and transverse sections. ×2. Unenlarged copies of plate X, figures 4, 4a in Lambe (1901). Silurian, Guelph Dolomite; Ontario, Canada.

18, 19. *Pycnostylus guelphensis* Whiteaves.

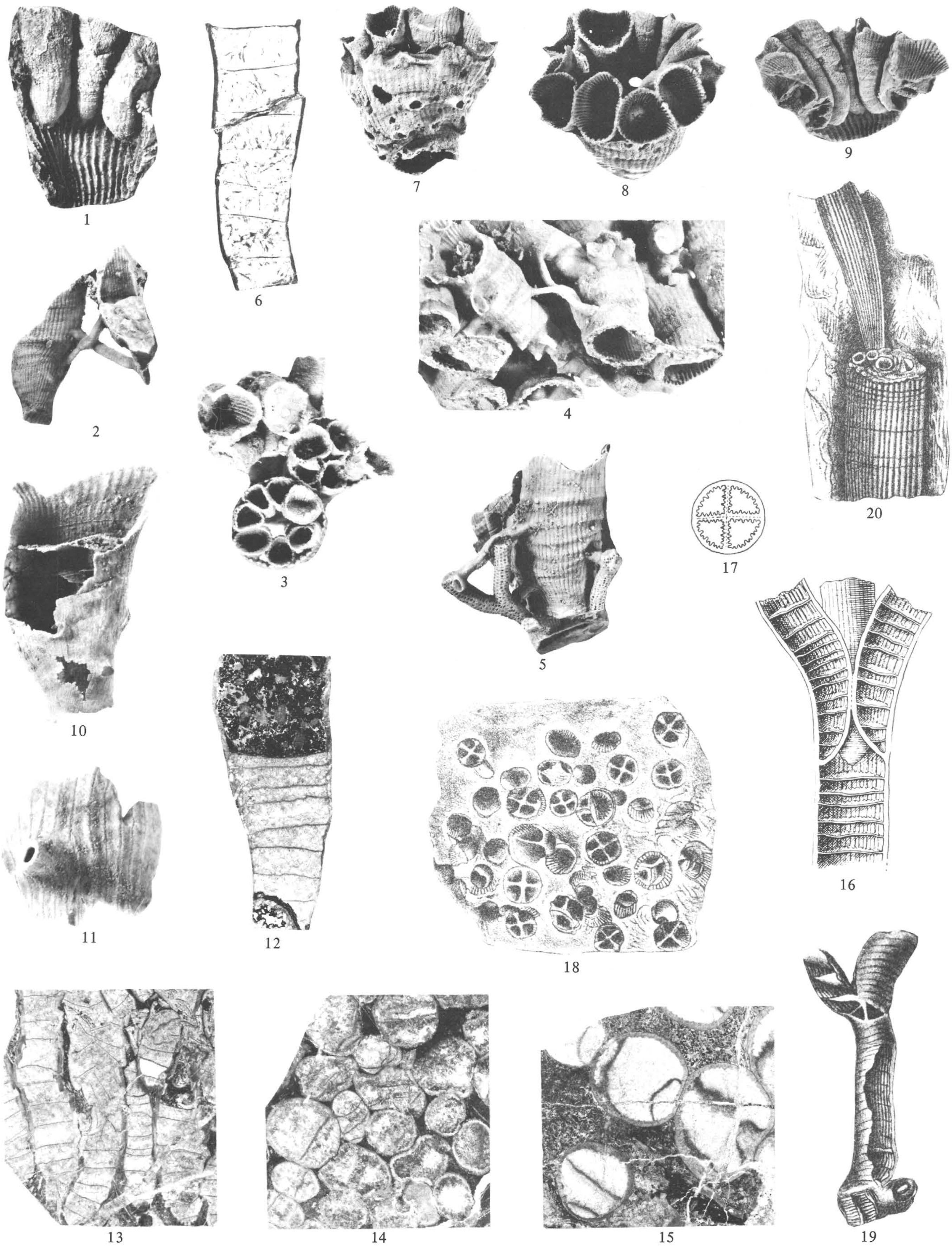
Unenlarged copies of two of Whiteaves' type illustrations (Whiteaves, 1884, pl. 1, figs. 1a, b). Silurian, Guelph Dolomite; Ontario, Canada. ×1.

18. Transverse section of corallum.
19. Lateral view of broken corallite with two remaining offsets; note lack of exterior longitudinal ribbing.

20. *Pycnostylus elegans* Whiteaves.

Anterior end of a mature corallite with several offsets. Note external ribbing. ×1. Unenlarged copy of one of Whiteaves' (1884) type illustrations.

Silurian, Guelph Dolomite; Ontario, Canada.



STYLOPLEURA AND *PYCNOSTYLUS*

PLATE 2

FIGURES

1, 2. *Stylopleura*? sp. c

Transverse and longitudinal thin sections. ×2. Silurian, Roberts Mountains Formation. Locality M1379, Coal Canyon, Simpson Park Mountains, Nev.

3–6. *Stylopleura nevadensis* Merriam

Great Basin Silurian coral zone E. Roberts Mountains Formation. Coal Canyon, Simpson Park Mountains, Nev.

3, 4. Longitudinal and transverse thin sections of same colony. Paratype, USNM 159431a. ×2. Locality M1380.

5. Upper surface of holotype, USNM 159431. ×½. Locality M1107.

6. Longitudinal thin section of holotype showing a lateral connecting element. USNM 159431. ×2. Locality M1107.

7. *Stylopleura* cf. *S. nevadensis* n. gen., n. sp.

Longitudinal thin section. ×2. Great Basin Silurian coral zone E. Roberts Mountains Formation. Locality M1381, Coal Canyon, Simpson Park Mountains, Nev.

8, 9. *Stylopleura berthiaumi* Merriam

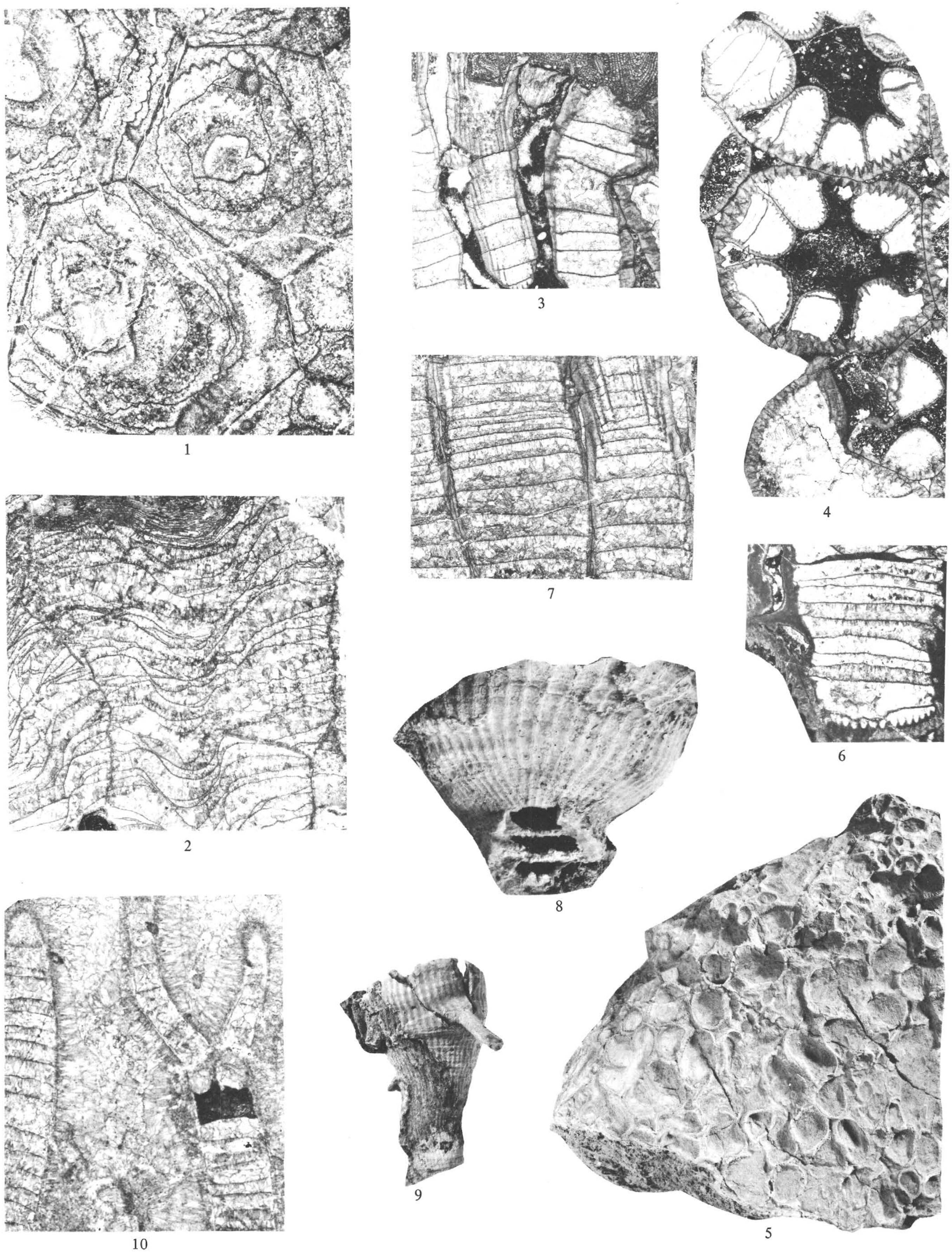
Great Basin Silurian coral zone D. Locality M1103, Ikes Canyon, Toquima Range, Nev.

8. Lateral view of flaring calice. ×1.

9. Lateral view of same individual showing connecting element. ×1.

10. *Pycnostylus* sp. 1

Longitudinal thin section. ×3. Silurian, Lone Mountain Dolomite. Locality M1148, southern Sulphur Spring Mountains, Nev.; 4.8 km south of Romano Ranch.



STYLOPLEURA AND *PYCNOSTYLUS*

PLATE 3

FIGURES

1–7. *Fletcheria tubifera* Edwards and Haime.

1. Lateral view of corallum. Copy of original type figure of Edwards and Haime (1851, pl. 16, fig. 5). Silurian, Gotland, Sweden. ×1½.

2–7. Silurian, Slite Group (Wenlockian); Slite, Lännaberget, Gotland, Sweden.

2. Lateral view of corallum showing corallite surface ornamentation. ×2.

3. Transverse thin section. ×2.

4, 5. Longitudinal thin sections. ×2.

6, 7. Transverse sections showing multiple calice offsets and wall structure. Note absence of septa. ×6.

8, 9. *Tryplasma duncanae* Merriam

Great Basin Silurian coral zone D. Roberts Mountains, Formation, unit 3. Locality M1100, Roberts Creek Mountain, Roberts Mountains, Nev.

8. Lateral view of holotype, USNM 159374. ×2.

9. Oblique calice view of paratype, USNM 159375. ×5.

10–15. *Tryplasma newfarmeri* Merriam

Great Basin Silurian coral zone C. Roberts Mountains Formation, unit 3. Locality M1102, Roberts Creek Mountain, Nev.

10, 11. Longitudinal thin sections of holotype, USNM 159377. ×3.

12, 13. Longitudinal thin sections of holotype, USNM 159377. ×8.

14, 15. Transverse thin sections of holotype, USNM 159377. ×8.

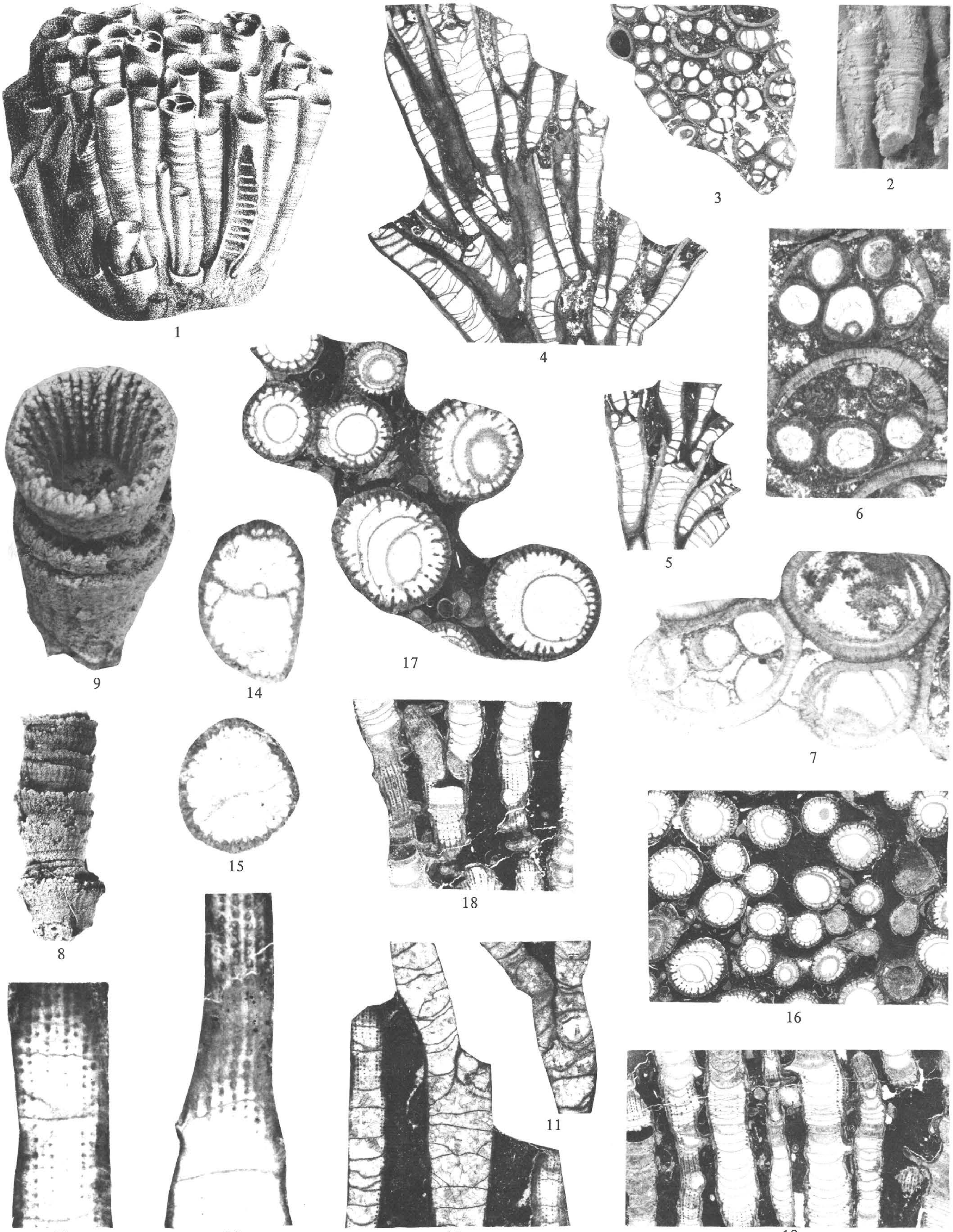
16–19. *Tryplasma* sp. g

These figures are all of the same corallum. Silurian, Hemse Group (Ludlovian); locality M1382, Gotland, Sweden.

16. Transverse thin section. ×2.

17. Transverse thin section. ×4. Enlargement of part of figure 16.

18, 19. Longitudinal thin sections. ×2.



FLETCHERIA AND *TRYPLASMA*

PLATE 4

FIGURES

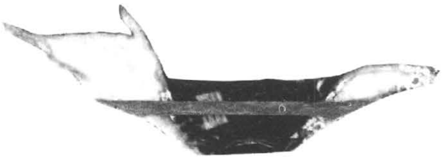
1–4. *Mucophyllum oliveri* Merriam

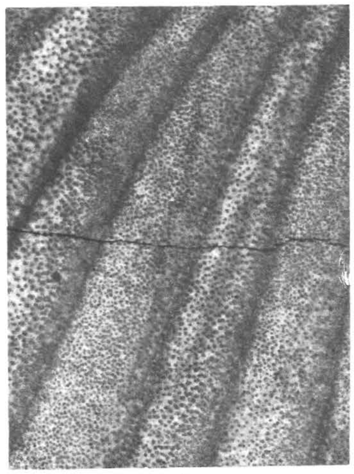
Great Basin Silurian coral zone E. Locality M1108, Coal Canyon, Simpson Park Mountains, Nev.

1. Longitudinal section of paratype, USNM 159391. Photographed in water. ×1.
2. Transverse section of holotype, USNM 159390. Smoothed surface photographed in water. ×1.
3. Longitudinal thin section of holotype, USNM 159390. ×4.
4. Part of transverse thin section of holotype, USNM 159390, showing pattern of trabeculae. ×2.

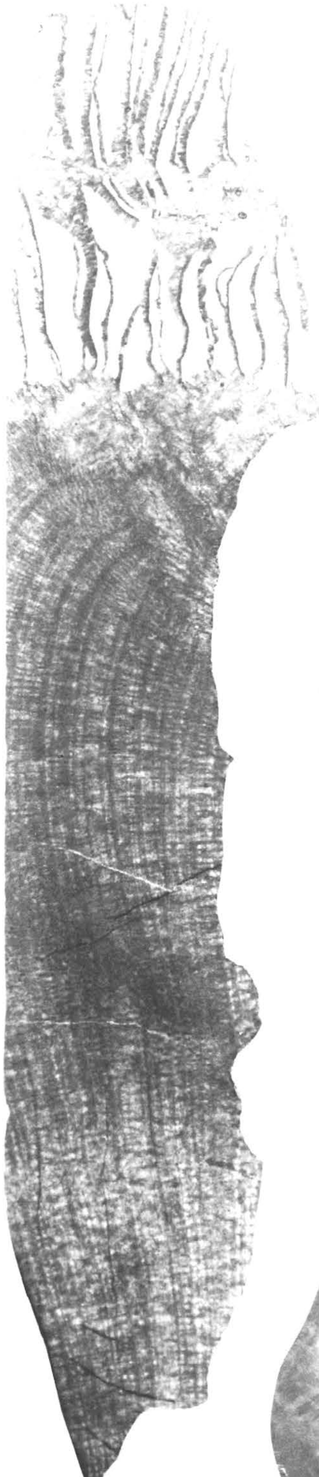
5, 6. *Kodonophyllum mulleri* Merriam

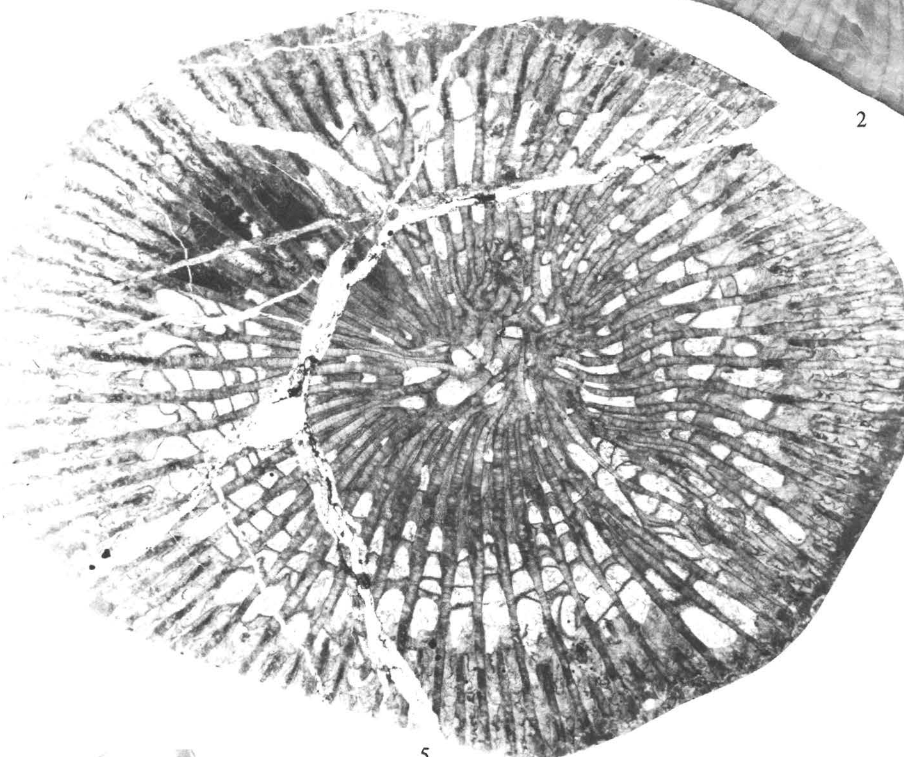
Transverse and longitudinal thin sections of holotype, USNM 159386. ×4. Great Basin Silurian coral zone E. Locality M1107, Coal Canyon, Simpson Park Mountains, Nev.

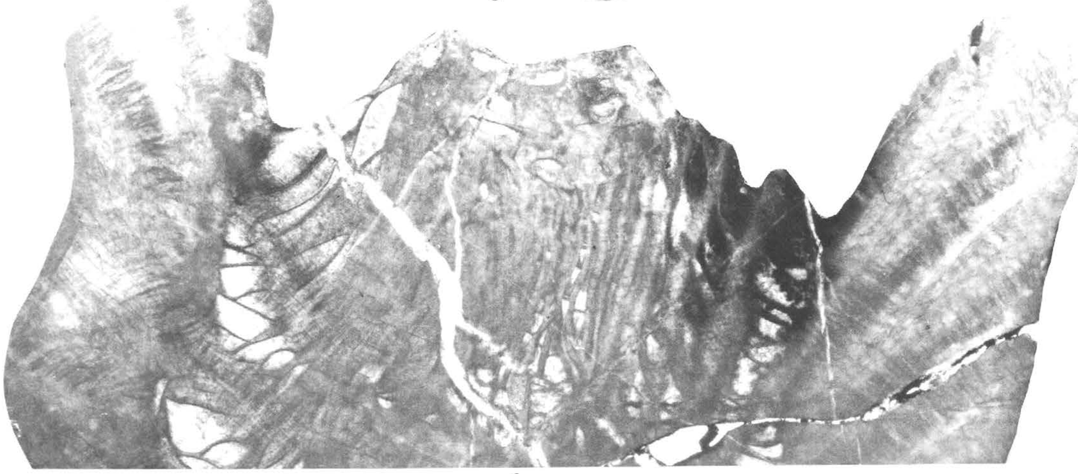

1


4


2


3


5


6

MUCOPHYLLUM AND *KODONOPHYLLUM*

PLATE 5

FIGURES

1–14. *Tonkinaria simpsoni* Merriam

1–9. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3. Locality M1100, Roberts Creek Mountain, Roberts Mountains, Nev.

1, 2. Lateral (×1½) and calice (×2) views of paratype, USNM 159402.

3, 4. Transverse (×4) and longitudinal (×3½) thin sections of paratype, USNM 159404.

5. Transverse thin section. USNM 159405. ×2.

6. Calice view. ×2.

7. Longitudinal thin section of same individual. ×3.

8, 9. Lateral exterior and calice views of holotype, USNM 159403. ×1½.

10–14. Great Basin Silurian coral zone D. Roberts Mountains Formation. Locality M1383; Coal Canyon, Simpson Park Mountains, Nev.

10. Oblique lateral view of corallum showing bases of three offsets at calice rim. ×2.

11–13. Calice rim of three coralla showing offsets. ×2.

14. Calice view. ×2.

15–21. *Kyphophyllum* sp. b

Silurian, Roberts Mountains Formation. Locality M1314; Bootstrap Hill, Tuscarora Mountains, Nev.

15. Lateral view of corallite showing a single offset. ×2.

16. Lateral view of partial corallum ×2.

17. Lateral view of calice interior. ×2.

18, 19. Transverse and longitudinal thin sections of corallite. ×3.

20, 21. Transverse and longitudinal thin sections of corallite. ×3.

22–24. *Kodonophyllum* sp. b.

Transverse and longitudinal thin sections of three corallites. ×3. Silurian, Roberts Mountains Formation. Locality M1314, Bootstrap Hill, Tuscarora Mountains, Nev.

25, 26. *Brachyelasma* sp. c.

Transverse and longitudinal thin sections of same individual. ×1½. Great Basin Silurian coral zone D. Roberts Mountains. Formation. Locality M1383; Coal Canyon, Simpson Park Mountains, Nev.

TONKINARIA, KYPHOPHYLLUM, KODONOPHYLLUM, AND *BRACHYELASMA*

PLATE 6

FIGURES

1–4. *Spongophyllum sedgwicki* Edwards and Haime.

Copies of original figures of the type material of Edwards and Haime (1850–54, pl. 56, figs. 2a, c, d, e). Torquay, England; according to Edwards and Haime from the Devonian strata.

1. Transverse section enlarged (Edwards and Haime, fig. 2d, ×1½).
2. Longitudinal section enlarged (Edwards and Haime, fig. 2e, ×1½). This section is conceivably from same corallum as figure 1.

3, 4. Transverse sections enlarged (Edwards and Haime, figs. 2c and 2a, ×1½). These figures probably do not represent the same species and are possibly not congeneric with corals illustrated by figures 1 and 2 of this plate.

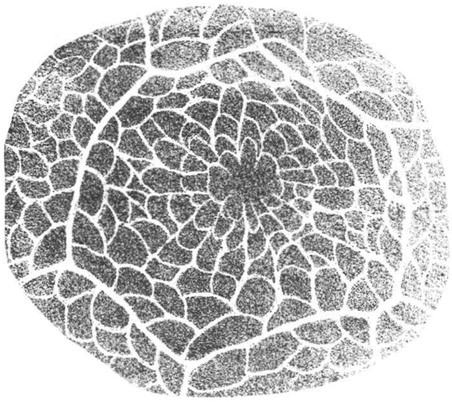
5–7. *Carlinastraea tuscaroraensis* n. gen., n. sp.

5. Transverse thin section. ×3. Great Basin Silurian coral zone D. Roberts Mountains Formation. Locality M1384, Coal Canyon, Simpson Park Mountains, Nev.

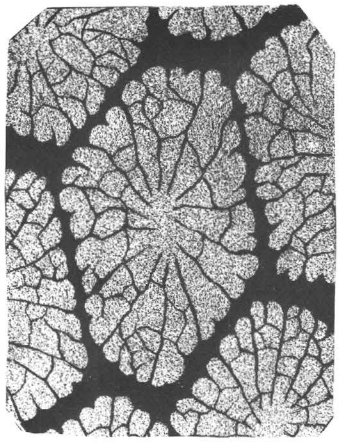
6, 7. Transverse and longitudinal thin sections of holotype, USNM 166482. ×2½. Roberts Mountains Formation. Locality M1313, Bootstrap Hill.

8–10. *Australophyllum (Toquimaphyllum) johnsoni* Merriam

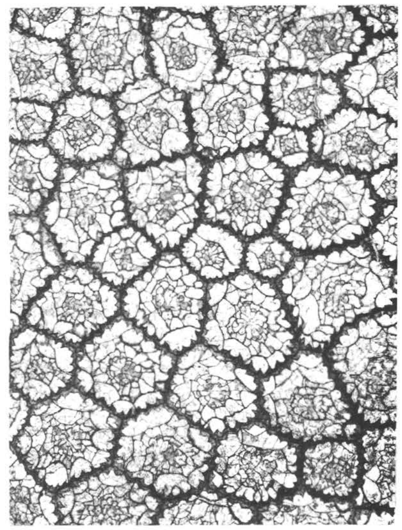
Transverse and longitudinal thin sections of holotype, USNM 150420. ×2. Great Basin Silurian coral zone E. Locality M1114, Ikes Canyon, Toquima Range, Nev.



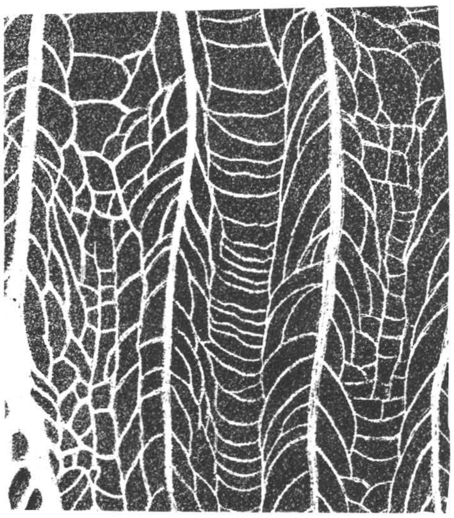
1



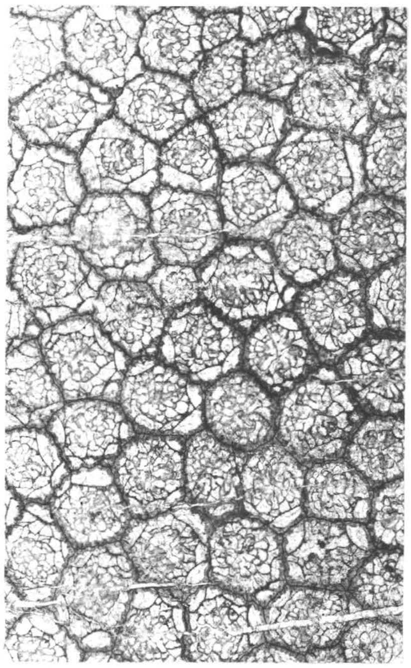
3



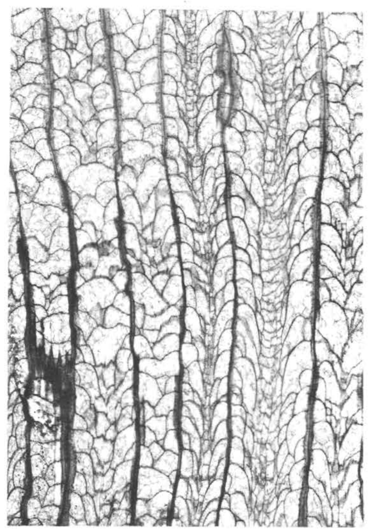
6



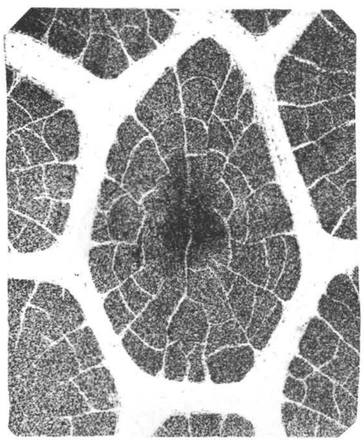
2



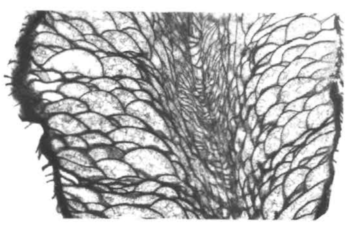
5



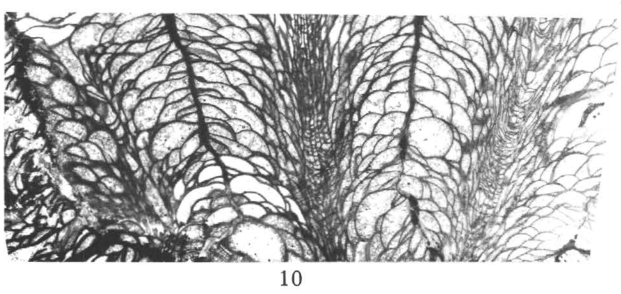
7



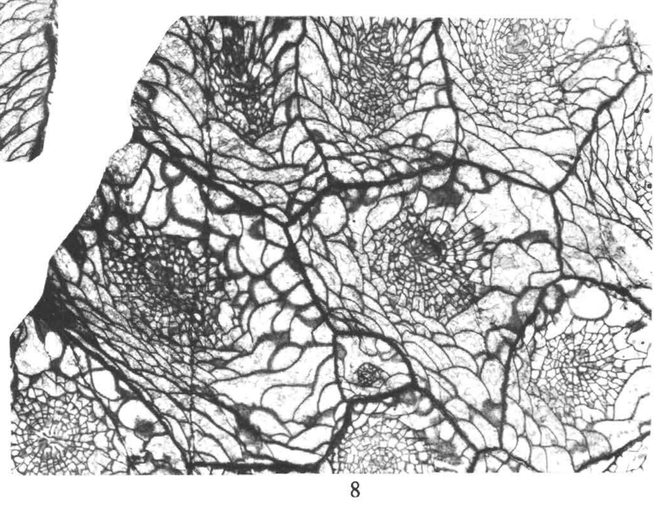
4



9



10



8

SPONGOPHYLLUM, CARLINASTRAEA, AND *AUSTRALOPHYLLUM*

PLATE 7

FIGURES

1–4. *Carlinastraea tuscaroraensis* n. gen., n. sp.

1–3. Transverse and longitudinal thin sections of holotype, USNM 166482. ×6. Roberts Mountains Formation. Locality M1313, Bootstrap Hill, Tuscarora Mountains, Nev.

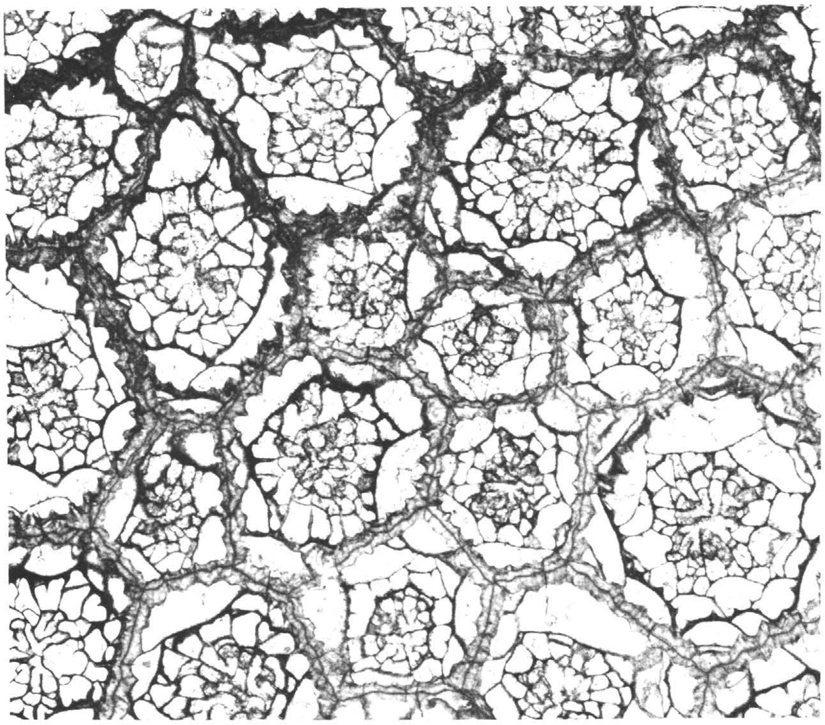
4. Longitudinal thin section. ×6. Great Basin Silurian coral zone D. Roberts Mountains Formation. Locality M1384, Coal Canyon, Simpson Park Mountains, Nev.

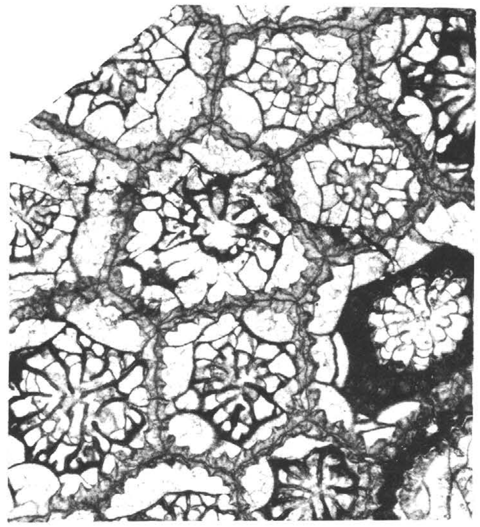
5, 6. *Chonophyllum simpsoni* Merriam

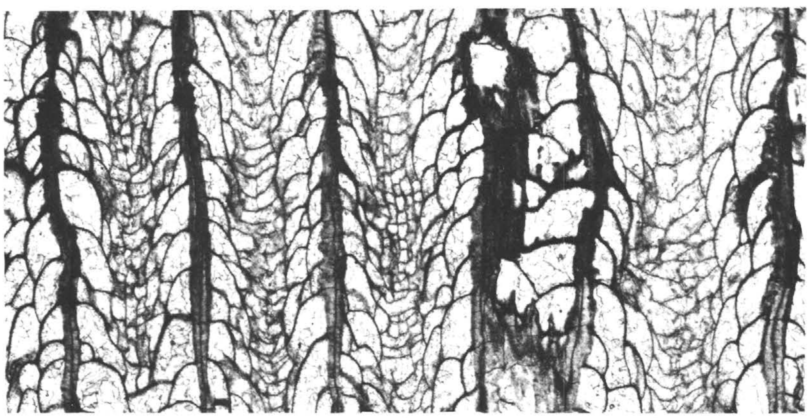
Transverse and longitudinal thin sections of holotype, USNM 159408. ×1½. Great Basin Silurian coral zone E. Roberts Mountains Formation. Locality M1108, Coal Canyon, Simpson Park Mountains, Nev.

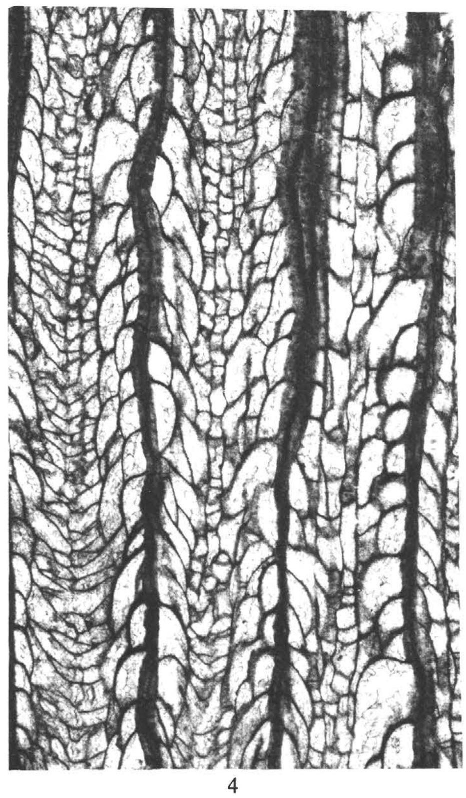
7, 8. *Calostylis*? sp.

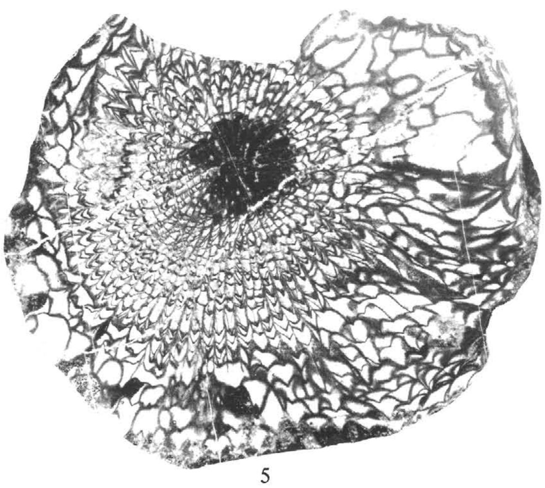
Transverse thin sections. ×3. Roberts Mountains Formation. Locality M1314, Bootstrap Hill, Tuscarora Mountains, Nev.

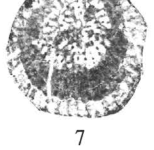

1

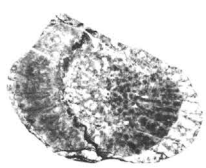

2

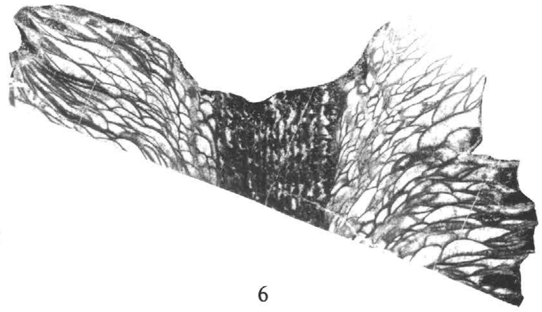

3


4


5


7


8


6

CARLINASTRAEA, CHONOPHYLLUM, AND *CALOSTYLIS*?

PLATE 8

FIGURES

1, 2. *Carlinastraea* sp., cf. *C. tuscaroraensis*, n. gen., n. sp.

Transverse and longitudinal thin sections of same corallum. ×2. Roberts Mountains Formation. Locality M1409, Cortez Mountains, Eureka County, Nev.

3–7. *Australophyllum* (*Australophyllum*) sp. c

Locality M1318, west side of Coal Canyon in fault zone, Northern Simpson Park Mountains, Nev. All the thin sections are from same corallum.

3–5. Transverse thin sections. ×2.

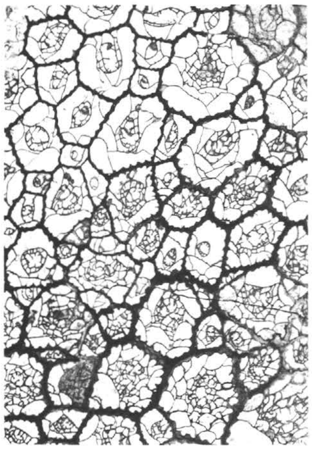
6, 7. Longitudinal thin sections. ×2.

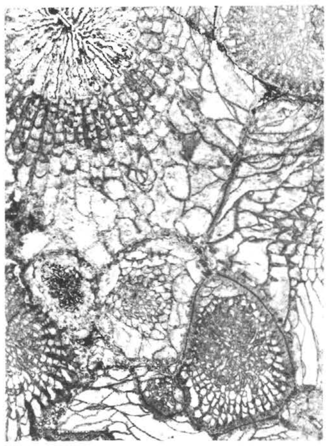
8–11. *Australophyllum* (*Australophyllum*) sp. v

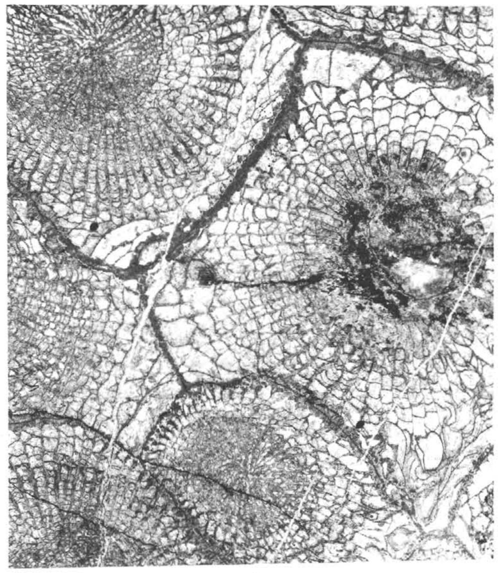
Vaughn Gulch Limestone. Mazourka Canyon, northern Inyo Mountains, Calif.

8, 9. Transverse and longitudinal thin sections of same corallum. ×2. Locality M1410.

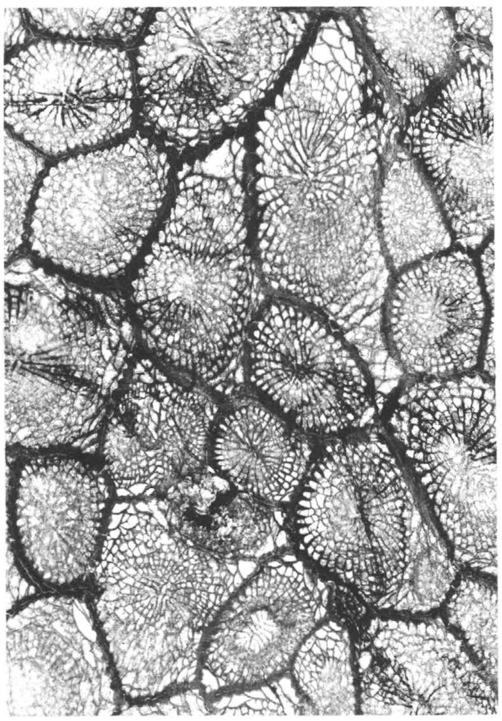
10, 11. Transverse and longitudinal thin sections of another corallum. ×2. Locality M1093.

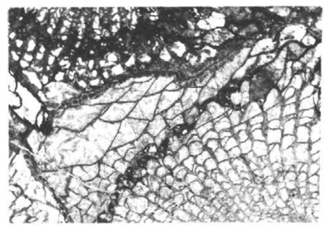

1

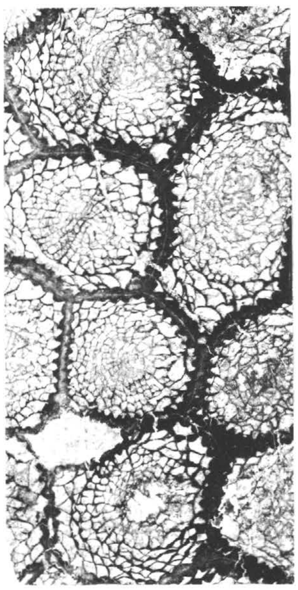

3

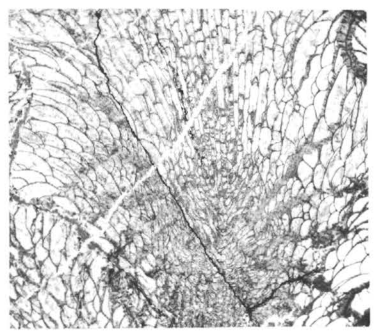

4

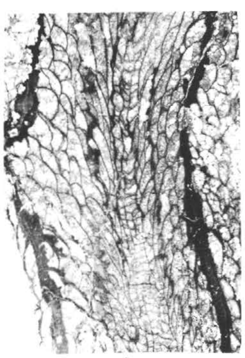

2

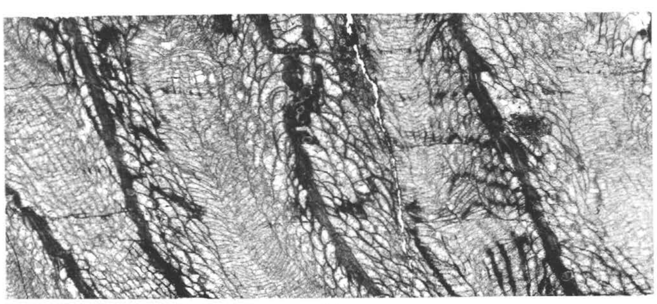

10

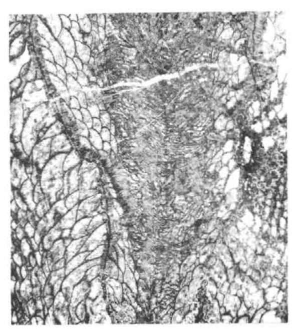

5


8


6


9


11


7

CARLINASTRAEA AND *AUSTRALOPHYLLUM*

PLATE 9

FIGURES

1–3. *Kyphophyllum nevadensis* Merriam

Great Basin Silurian coral zone E. Locality M1114, Ikes Canyon, Toquima Range, Nev. Holotype, USNM 159425.

1. Transverse thin section. ×4.
2. Transverse thin section. ×2.
3. Longitudinal thin section. ×2.

4–8. *Kyphophyllum* sp. c

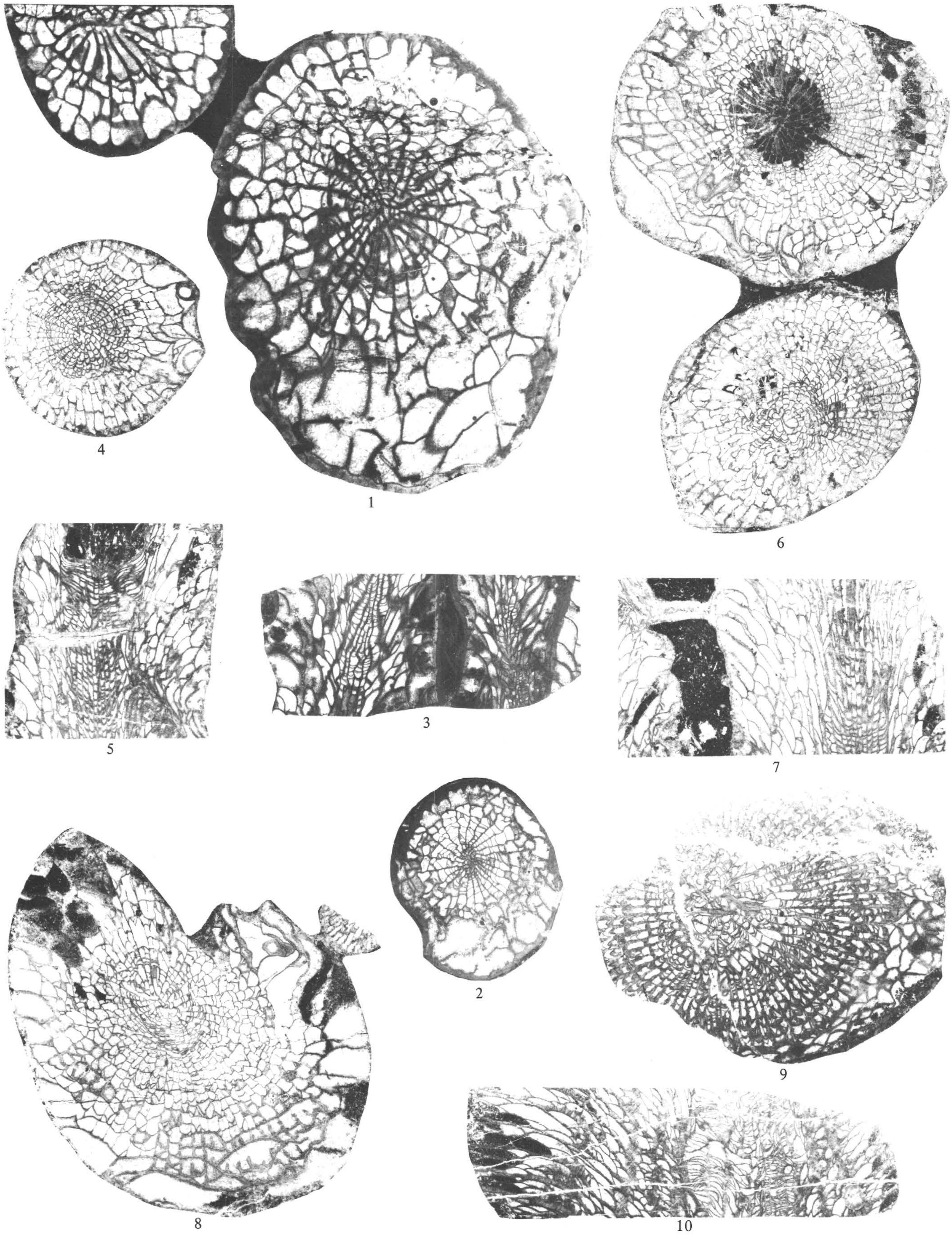
Transverse and longitudinal thin sections. Great Basin Silurian coral zone E. Locality M1380, Coal Canyon, Simpson Park Mountains, Nev.

4, 6, 8. Transverse thin sections. ×2.

5, 7. Longitudinal thin sections. ×2.

9, 10. *Chonophyllum simpsoni* Merriam

Transverse and longitudinal thin sections of paratype, USNM 159409. ×2. Great Basin Silurian coral zone E. Roberts Mountains Formation. Locality M1108, Coal Canyon, Simpson Park Mountains, Nev.



KYPHOPHYLLUM AND *CHONOPHYLLUM*

PLATE 10

FIGURES

1–3. *Verticillopora annulata* Rezak.

Roberts Mountains Formation. Locality M1411, west side of Coal Canyon, northern Simpson Park Mountains, Nev. All figures are of the same individual.

1. Latex impression of exterior. ×1.
2. Chert filling of internal cavity. ×1.
3. Latex impression of interior. ×1.

4. *Verticillopora* sp., cf. *V. annulata* Rezak.

End view showing central cavity and small radial canals to exterior. ×½. Roberts Mountains Formation, upper part. Great Basin Silurian coral zone E. Locality M1106, east side of Coal Canyon near mouth, northern Simpson Park Mountains, Nev.

5–7. *Cladopora* sp. v.

Lateral views of pieces of branching colonies. ×2.

8. Digitate favositid.

Lateral view of piece of branching colony. ×1½. Vaughn Gulch Limestone, basal beds of upper unit. Locality M1093, Mazourka Canyon, northern Inyo Mountains, Calif.

9–11. *Favosites* sp. c.

Transverse and two longitudinal thin sections. ×2. Roberts Mountains Formation. Locality M1411, west side of Coal Canyon, northern Simpson Park Mountains, Nev.

12, 13. *Favosites* sp. d.

Transverse and longitudinal thin sections of form with very narrow corallites. ×2. Roberts Mountains Formation, upper part. Great Basin Silurian coral zone E. Locality M1106, east side of Coal Canyon near mouth, northern Simpson Park Mountains, Nev.

14–17. *Kyphophyllum* sp. t.

Lower part of Tor Limestone. Locality M1397, Toquima Range, Nev. All figures are of the same corallum.

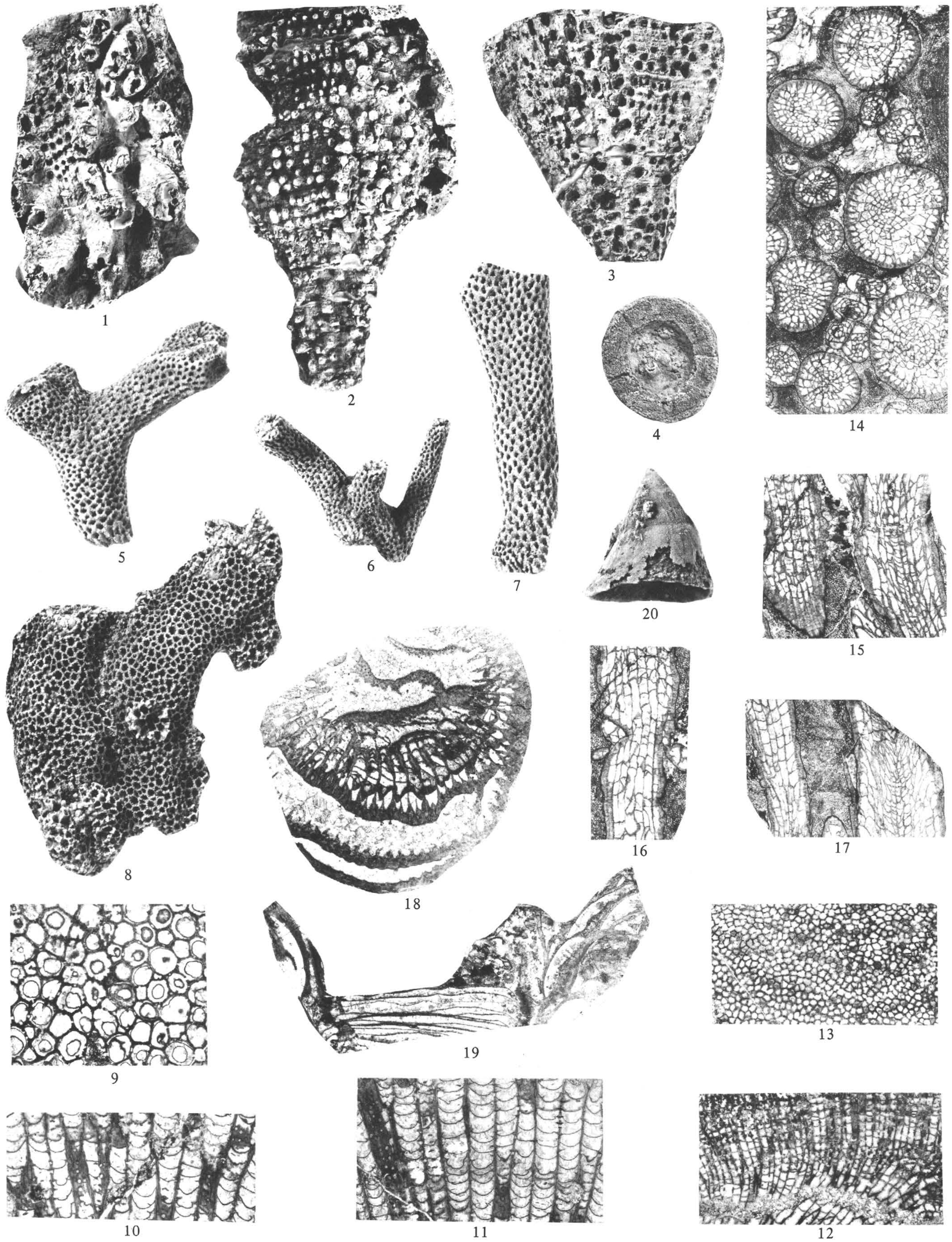
14. Transverse thin section. ×2.
15–17. Longitudinal thin sections. ×2.

18, 19. *Ketophyllum* sp. t.

Transverse and longitudinal thin sections of same corallum. ×2. McMonnigal Limestone. Locality M1393, Toquima Range, Nev.

20. *Hercynella*-like mollusk.

Lateral view. ×1½. Near locality M1106, Coal Canyon, east side near mouth. Northern Simpson Park Mountains, Nev.



VERTICILLOPORA, CLADOPORA, FAVOSITES, KYPHOPHYLLUM, KETOPHYLLUM, AND *HERCYNELLA*

PLATE 11

FIGURES 1–6. *Verticillopora annulata* Rezak.

1–4. Great Basin Silurian coral zones D–E. Upper middle part of Vaughn Gulch Limestone. Locality M1128, Mazourka Canyon, Inyo Mountains, Calif.

1. Transverse view. ×1½.

2, 3. Transverse and lateral views of same individual. ×1½.

4. Lateral view. ×1½.

5. Lateral view. ×1. Great Basin Silurian coral zones D–E. Locality M1385, Mazourka Canyon, Inyo Mountains, Calif.

6. Transverse view. ×1½. Great Basin Silurian coral zone D. Locality M1103, Ikes Canyon, Toquima Range, Nev. Roberts Mountains Formation.

7, 8. *Verticillopora* cf. *V. annulata* Rezak.

Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.

7. Weathered specimen showing wall of internal cavity. ×3.

8. Weathered interior showing radial canals. ×2½.

9–14. *Kozlowskiellina* sp. f

9–12. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.

9, 10. Exterior and interior of same ventral valve. ×2.

11, 12. Interior and exterior of same dorsal valve. ×3.

13, 14. Exterior and interior of same ventral valve. ×2. Great Basin silurian coral zone E. Upper part of Roberts Mountains Formation. Locality M1106, Coal Canyon, Simpson Park Mountains, Nev.

15–17. *Homoeospira* sp. r

Dorsal, ventral, and anterior views of same individual. ×2. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.

18, 21, 22. *Dicoelosia* sp. r

Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.

18. Interior of dorsal valve. ×4.

21, 22. Dorsal and ventral exterior views of same individual. ×4.

19, 20. *Dicoelosia* sp. r.

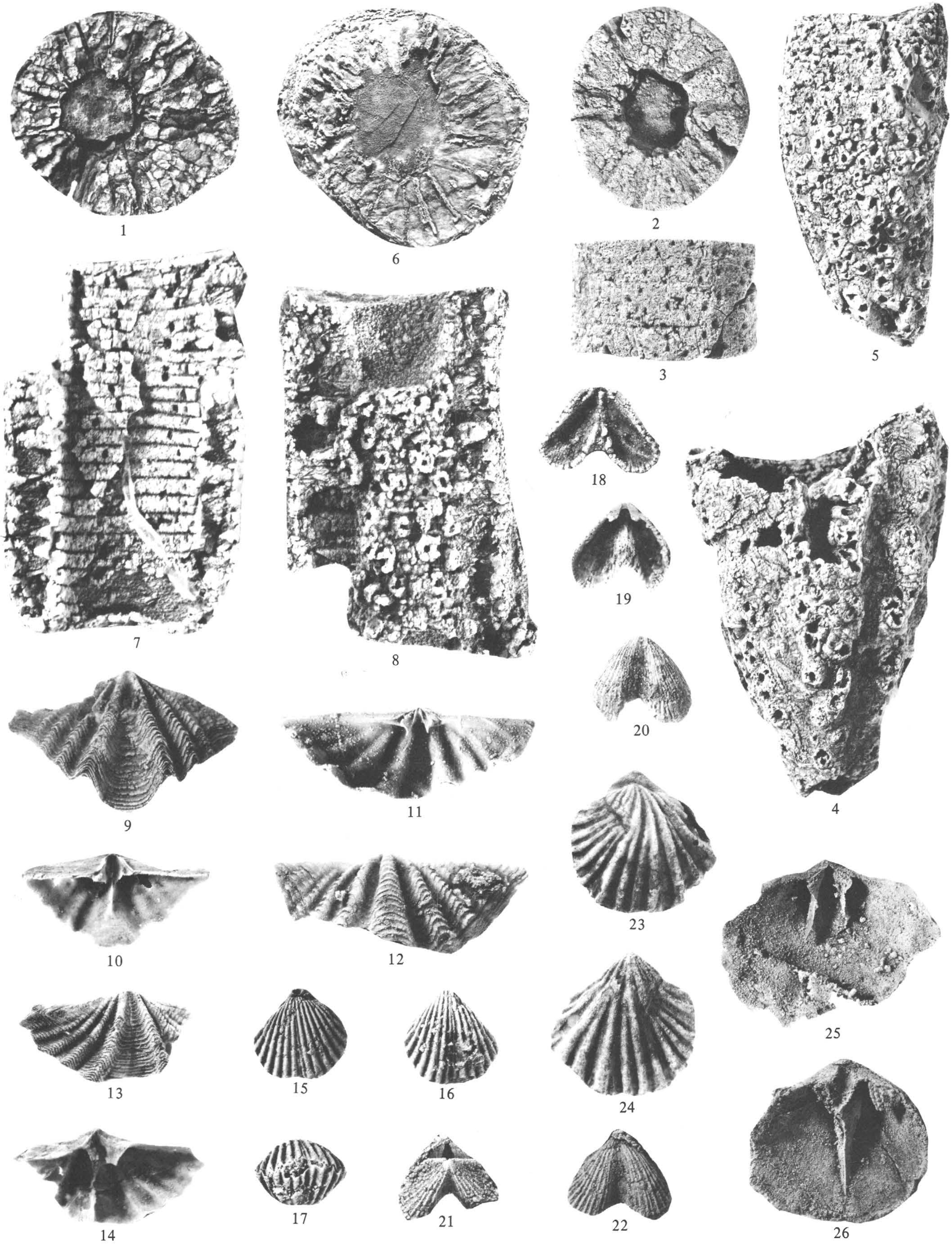
Interior and exterior views of same ventral valve. ×2½. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.

23, 24. *Plectatrypa*? sp. c

Dorsal and ventral exterior of same individual. ×2. Great Basin Silurian coral zone E. Locality M1106, Coal Canyon, Simpson Park Mountains, Nev.

25, 25. *Gypidula* sp. r.

Dorsal and ventral interior of same individuals. ×2. Great Basin Silurian coral zone D. Roberts Mountains Formation, unit 3 near top. Locality M1100, Roberts Creek Mountain, Nev.



VERTICILLOPORA, KOZLOWSKIELLINA, HOMEOSPIRA, DICOELOSIA, PLECTATRYPA?, AND *GYPIDULA*

PLATE 12

FIGURES 1–7. *Coelospira* sp. b

Roberts Mountains Formation. Locality M1412, Bootstrap Hill, southern Tuscarora Mountains.

1. Exterior view of ventral valve. ×4.

2, 3. Dorsal valve and ventral valve exterior views of same shell. ×4.

4. Exterior view of dorsal valve. ×4.

5. Interior view of dorsal valve. ×4.

6. Interior view of ventral valve. ×4.

7. Interior view of dorsal valve. ×4.

8–15. *Fardenia* sp. b

Roberts Mountains Formation. Locality M1412, Bootstrap Hill, southern Tuscarora Mountains.

8. Interior view of ventral valve. ×2.

9, 10. Exterior and interior views of same dorsal valve. ×2.

11, 12. Exterior and interior views of same dorsal valve. ×2.

13, 14. Exterior and interior views of same dorsal valve. ×2.

15. Interior view of ventral valve. ×2.

16, 17, 23. *Kozlowskiellina* sp. b

Roberts Mountains Formation. Locality M1412, Bootstrap Hill, southern Tuscarora Mountains.

16, 17. Exterior and interior views of same ventral valve. ×2.

23. Exterior view of dorsal valve. ×2.

18–22. *Conchidium* sp. b.

Roberts Mountains Formation. Locality M1412, Bootstrap Hill area, southern Tuscarora Mountains, Nev.

18, 19. Exterior and interior views of same ventral valve. ×1.

20. Exterior view of ventral valve. ×2.

21, 22. Exterior and interior views of same dorsal valve. ×2.

24–26. *Conchidium* sp., cf. *C. münsteri* Kiaer.

Type section of Roberts Mountains Formation on Pete Hanson Creek. Upper beds of unit 2. Roberts Creek Mountain, Nev.

24, 25. Exterior ventral and lateral views of same ventral valve. ×1.

26. Lateral view of same shell as in figures 24 and 25 split longitudinally to show medium septum and spondylium. ×1½.

27, 28. *Cyathophylloides* sp. f.

Transverse and longitudinal thin sections. ×4. Locality M1412, Bootstrap Hill area, southern Tuscarora Mountains, Nev.

29–33. *Brachyelasma* sp. b.

Locality M1120, Bootstrap Hill southwest side, southern Tuscarora Mountains, Nev.

29, 30. Transverse and longitudinal thin sections of same corallum. ×2.

31–32. Transverse thin sections of same corallite. ×2.

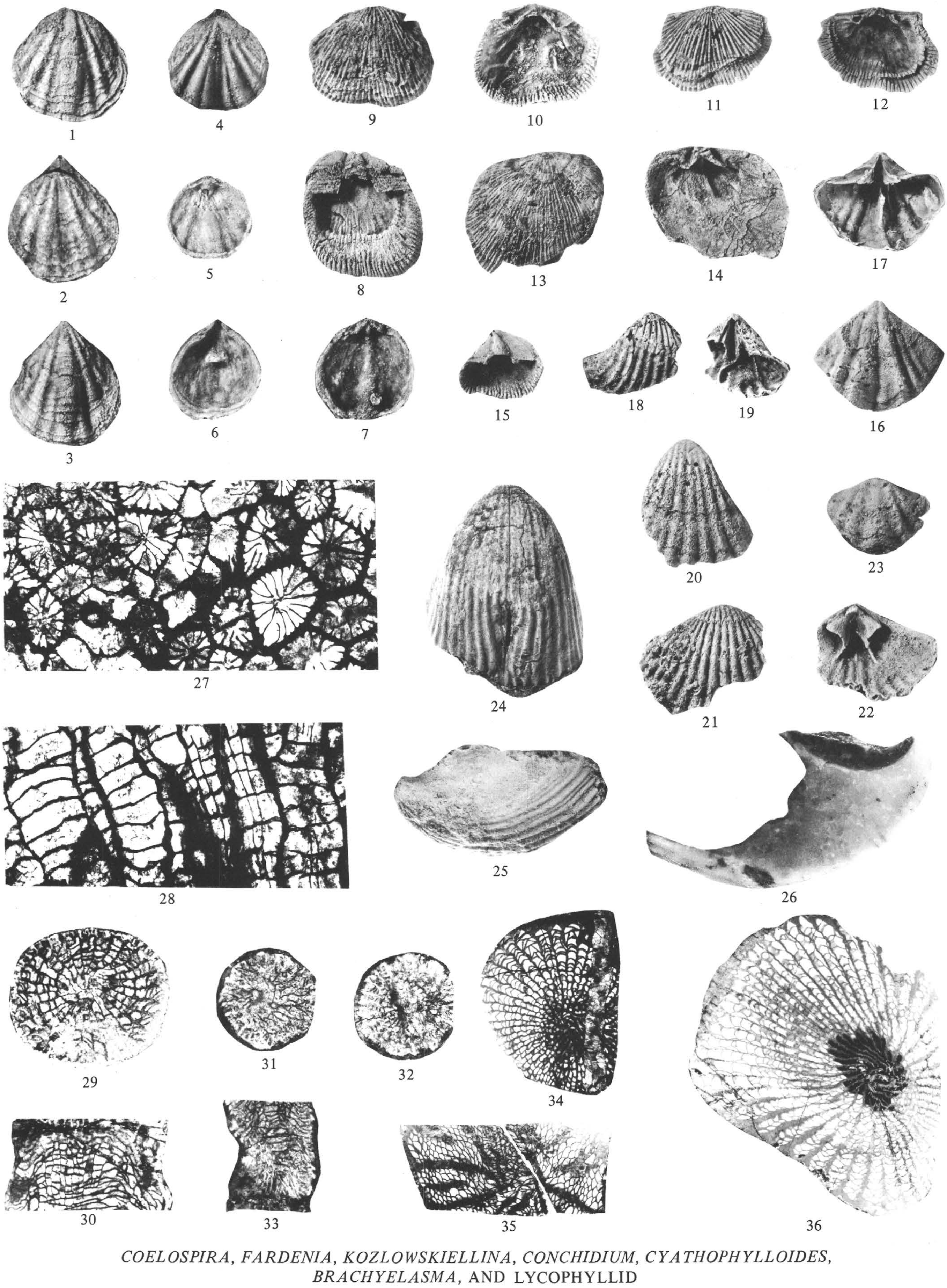
33. Longitudinal thin section of corallite in figures 31 and 32. ×2.

34–36. Lykophyllid rugose coral.

Locality M1413, northeast of Lynn window of R. J. Roberts, Tuscarora Mountains, northeast Eureka County.

34, 35. Transverse and longitudinal thin sections of same corallum. ×2.

36. Transverse thin section. ×2.



COELOSPIRA, FARDENIA, KOZLOWSKIELLINA, CONCHIDIUM, CYATHOPHYLLOIDES, BRACHYELASMA, AND LYCOPHYLLID