Coralliferous Carbonate Shelves of Mississippian Age, West Side of Antler Orogen, Central Nevada

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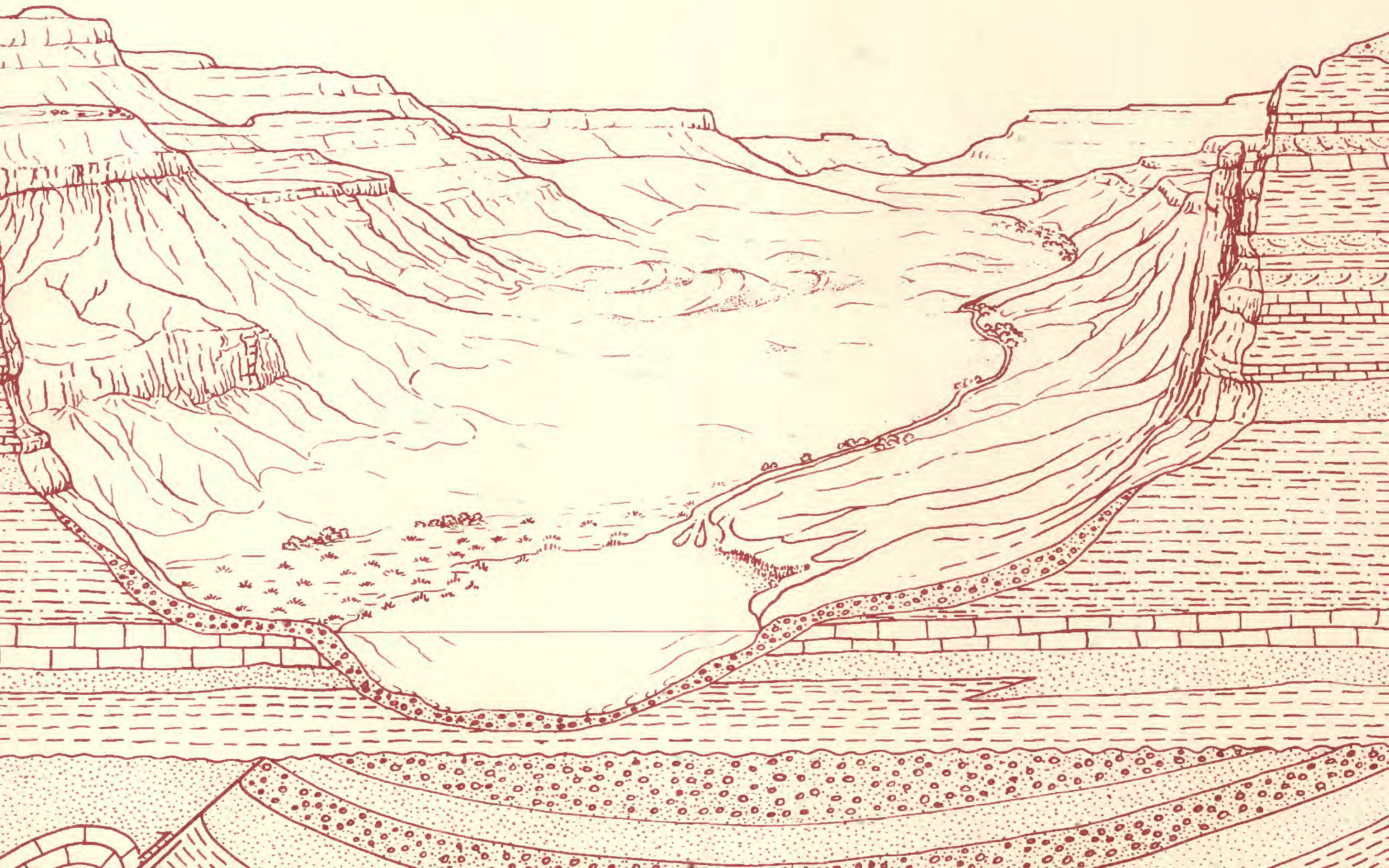

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Coralliferous Carbonate Shelves of Mississippian Age, West Side of Antler Orogen, Central Nevada

By WILLIAM J. SANDO

EVOLUTION OF SEDIMENTARY BASINS—EASTERN GREAT BASIN
HARRY E. COOK and CHRISTOPHER J. POTTER, Project Coordinators

U.S. GEOLOGICAL SURVEY BULLETIN 1988–F

A multidisciplinary approach to research studies of sedimentary rocks and their constituents and the evolution of sedimentary basins, both ancient and modern

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CORALLIFEROUS CARBONATE SHELVES OF MISSISSIPPIAN AGE, WEST SIDE OF ANTLER OROGEN, CENTRAL NEVADA

By William J. Sando

ABSTRACT

Mississippian coral faunas collected from eight areas along the west side of the Antler orogen in central Nevada contain elements of three Western Interior coral zones. The oldest fauna, which represents Coral Zone IIB (Osagean, late Tournaisian), is present in deep-water carbonate gravity-flow deposits in one area in south-central Nevada and in another area in north-central Nevada. A more diversified younger fauna, present in all eight areas, represents Coral Zone IIID (middle to late Meramecian, middle Viséan) and lived on nearshore and offshore shelves that were distributed along the entire west side of the orogen. A third fauna, present in three areas, represents Coral Zone IV (latest Meramecian, late Viséan) and lived on two small shelves on the west side of the orogen in the southern part of the study area.

Close similarities between the Antler coral faunas and endemic faunas of the Antler foreland basin and Cordilleran platform east of the orogen and the absence of similar coral faunas west of the orogen indicate that the Antler corals were derived by westward migrations from eastern sources through straits that separated islands in an island chain that extended across central Nevada from south to north. Probable locations for these straits are inferred from distributions of similar coral faunas on both sides of the Antler island chain, locations of areas on the orogen where Mississippian sediments were never deposited, locations of siliciclastic submarine fan systems in the Antler foreland basin, and postulated paleocurrent circulation patterns in the foreland basin.

The Mississippian coralliferous sequences in seven areas on the west side of the Antler orogen are parts of a western overlap sequence on the Roberts Mountains allochthon and are truncated either by pre-Permian erosion or by the Triassic Golconda thrust. In the eighth area, a similar coralliferous sequence is in the Golconda allochthon.

INTRODUCTION

The Antler orogen is a linear positive area in central Nevada produced by Late Devonian to Early Mississippian plate collision (Roberts, 1951; Roberts and others, 1958; Poole and others, 1967; Burchfiel and Davis, 1972; Poole, 1974; Poole and Sandberg, 1977, 1991) or plate convergence (Burchfiel and Royden, 1991). During Mississippian time, this positive area separated the Havallah oceanic inner arc basin in western Nevada from the Antler foreland basin, an area of flysch and molasse deposition in eastern Nevada (fig. 1). In the eastern part of the orogen, highly deformed sedimentary rocks of Cambrian through Devonian age are overlain unconformably by less deformed Pennsylvanian and younger sedimentary rocks, and there is no credible evidence that Mississippian sediments were ever deposited (area 7, fig. 1, is an exception resulting from thrust transport). The western part of the orogen contains scattered, small areas of carbonate, terrigenous, and volcanic rocks of Mississippian age that are overlain unconformably by Permian and younger sedimentary rocks or are truncated by sedimentary rocks of Mississippian to Permian age moved eastward on thrust faults. Although the western boundary of the eastern Antler area coincides with the 0.706-initial-strontium isopleth that marks the eastern limit of inferred Paleozoic oceanic crust, the restored western margin of the Paleozoic continent probably coincides with the western limit of the Antler orogen (Poole and Sandberg, 1991, p. 108, 109). Most Mississippian paleogeographic maps depict the Antler orogenic highland as a continuous land area (Poole, 1974, fig. 1; Poole and Sandberg, 1977, fig. 1, 1991, fig. 8; Little, 1987, fig. 5).

Although corals of Mississippian age have been known from carbonate rocks on the west side of the Antler orogen for about 70 years, their paleogeographic significance has never been thoroughly investigated. These corals were used for dating some of the western Antler rocks as Mississippian by H.M. Duncan (*in* Roberts and others,

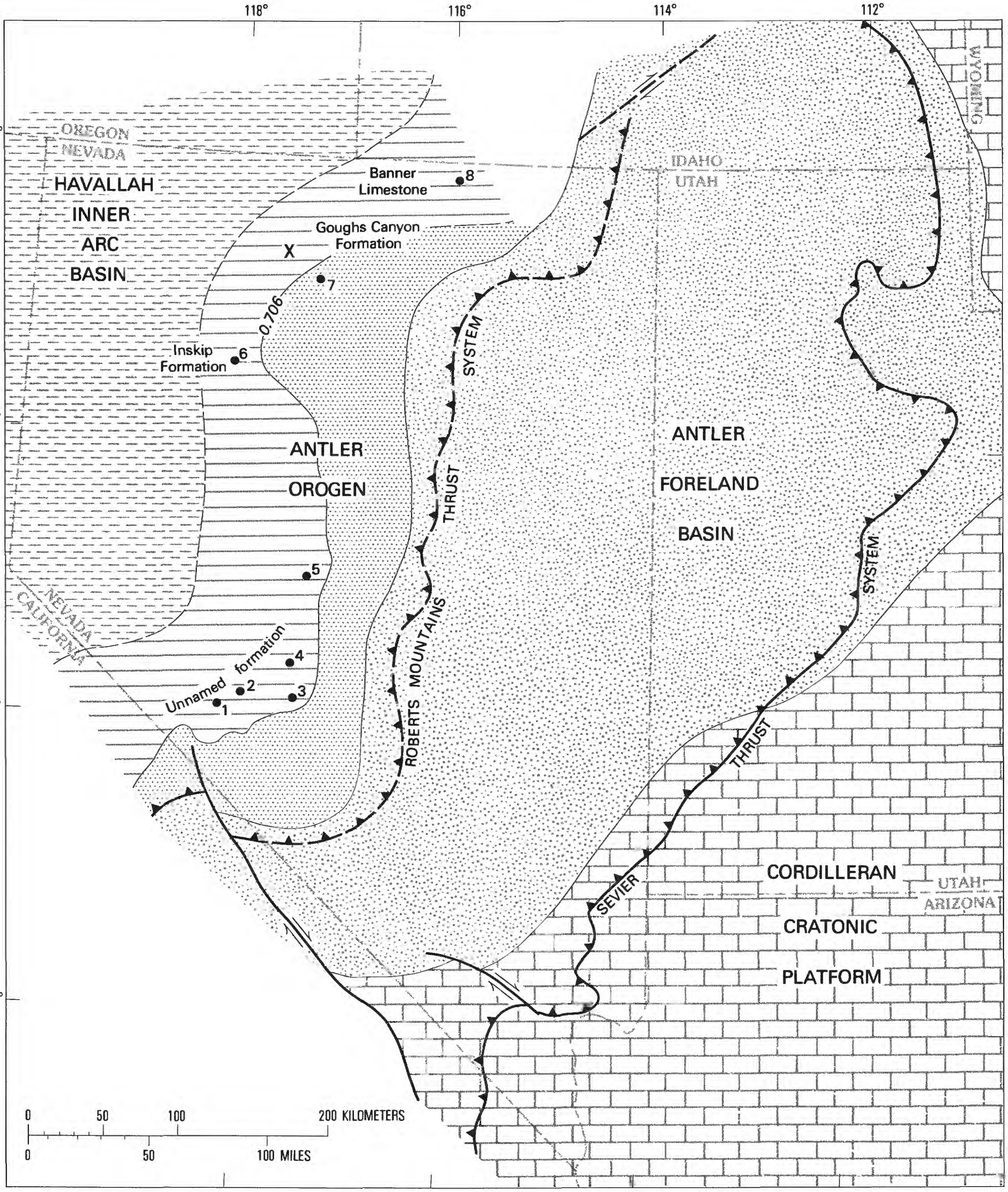
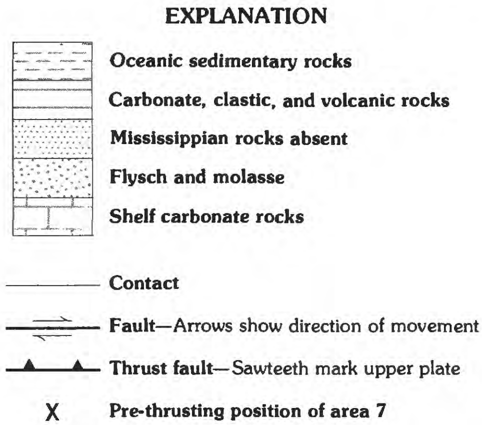


Figure 1 (above and facing column). Mississippian paleotectonic units and locations of coralliferous areas described in text (solid circles), Nevada and adjacent States. Areal extent of Mississippian rocks beneath Golconda allochthon and younger rocks on west side of Antler orogen restored from distribution of isolated outcrops. Modified from Poole and Sandberg (1977, 1991).



1958, p. 2847; *in* Hotz and Willden, 1964, p. 26–28) and by Sando (*in* Poole and Sandberg, 1977, p. 79, 1991, p. 131; *in* Little, 1987, p. 58, Appendix A). Some western Antler Mississippian coral localities were located and listed by Sando (*in* Sando and Bamber, 1985, p. 41, fig. 2), and these localities formed the basis for Sando's (1989, figs. 3C, F, G) paleogeographic interpretations of the Antler orogen during Mississippian time; however, none of these published works discusses the paleogeographic implications of the corals.

The purpose of this paper is to present evidence bearing on the origin of the western Antler corals and how these corals got to their present locations. A new hypothesis on the paleogeography of the Antler orogen is built on this evidence. An earlier version of these ideas is in an abstract by Sando (1992).

Acknowledgments.—I am particularly indebted to F.G. Poole for sharing with me much unpublished data on south-central Nevada and for several enlightening discussions on the geology of the Antler orogen (Poole does not agree with all of my interpretations). I am also grateful to K.B. Ketner and to M.B. and L.B. McCollum (Eastern Washington University) for unpublished information derived from their recent studies in north-central Nevada (my interpretations do not always coincide with the ideas of these colleagues). I thank L.B. McCollum for coral collections from the Goughs Canyon Formation and A.G. Harris for conodont data on collections made by E.L. Miller, A.E. Jones, and D.H. Whitebread in north-central Nevada. I also thank Poole, Ketner, M.B. McCollum, J.T. Dutro, Jr., N.J. Silberling, and M.E. Taylor for their helpful reviews of the manuscript. I am especially grateful to B.L. Mamet for his analysis of foraminifer and algal assemblages from the study area (see appendix).

GEOLOGY OF CORAL OCCURRENCES

In this part of the report, I present data on the geologic age, habitat, and preservation of the coral assemblages and on the petrography of the rocks in which the corals occur. These data, together with published and unpublished information on the coral occurrences, are then used to interpret the geologic history of the sedimentary sequences in which the corals are found. I have not made any field observations in the study area but have relied heavily on material and information given me by other geologists. Geologic ages and usages of formal stratigraphic units in discussions of the stratigraphy are those of the writers cited as references and do not necessarily coincide with ages and usages currently recognized by the U.S. Geological Survey (USGS).

Geologic ages for the coral assemblages are given in terms of the Western Interior coral zones of Sando and Bamber (1985) and correlative North American and western European series and stages (Sando, 1985)(see also time scale on fig. 2). Coral assemblages are listed for each of the coral zones recognized, along with USGS Upper Paleozoic locality numbers and geographic areas, for all collections studied (tables 1–3).

The shallow-water habitat index (SWHI) is a measure of the probability that the living habitat of a given coral genus was in shallow water (<100 m, <300 ft) versus deep water (>100m, >300 ft) based on distribution data from the Western Interior (Sando, 1980). Genera having SWHI=50–100 are more probably shallow-water forms than genera having SWHI=0–50. In this study, mean SWHI for each collection and grand mean SWHI for each zone in each area were calculated (table 4). SWHI values, together with petrographic data, are used to interpret the environments in which the corals lived.

The corals are in sedimentary sequences exposed in five areas in south-central Nevada and three areas in north-central Nevada (figs. 1, 2). A total of 51 collections

Table 1. Distribution of Zone IIB (Osagean, late Tournaisian) corals in collections from areas of central Nevada.
[See text for descriptions of areas. Collection numbers refer to USGS Upper Paleozoic locality file (–PC). Superscript T indicates collection from which thin sections were made; superscript plus (+) indicates species similar to Western Interior Province species]

Coral taxa	Area/collection 5	7
Nondissepimented solitary rugosans		
Amplexizaphrentis sp.$^{+}$	–	14026^{T}
Cyathaxonia sp.$^{+}$	25581	14026
Sychnoelasma cf. *S. ulrichanum* (Girty)$^{+}$	25579	–
	25581^{T}	–
Rotiphylloid corals, undet.$^{+}$	–	14026
Lophophyllum? sp.$^{+}$	25581	14026^{T}
Ufimia sp.	–	14026^{T}
Dissepimented solitary rugosan		
Vesiculophyllum sp.$^{+}$	25581	–
Tabulate		
Michelinia? sp.	–	14026^{T}
	–	19808

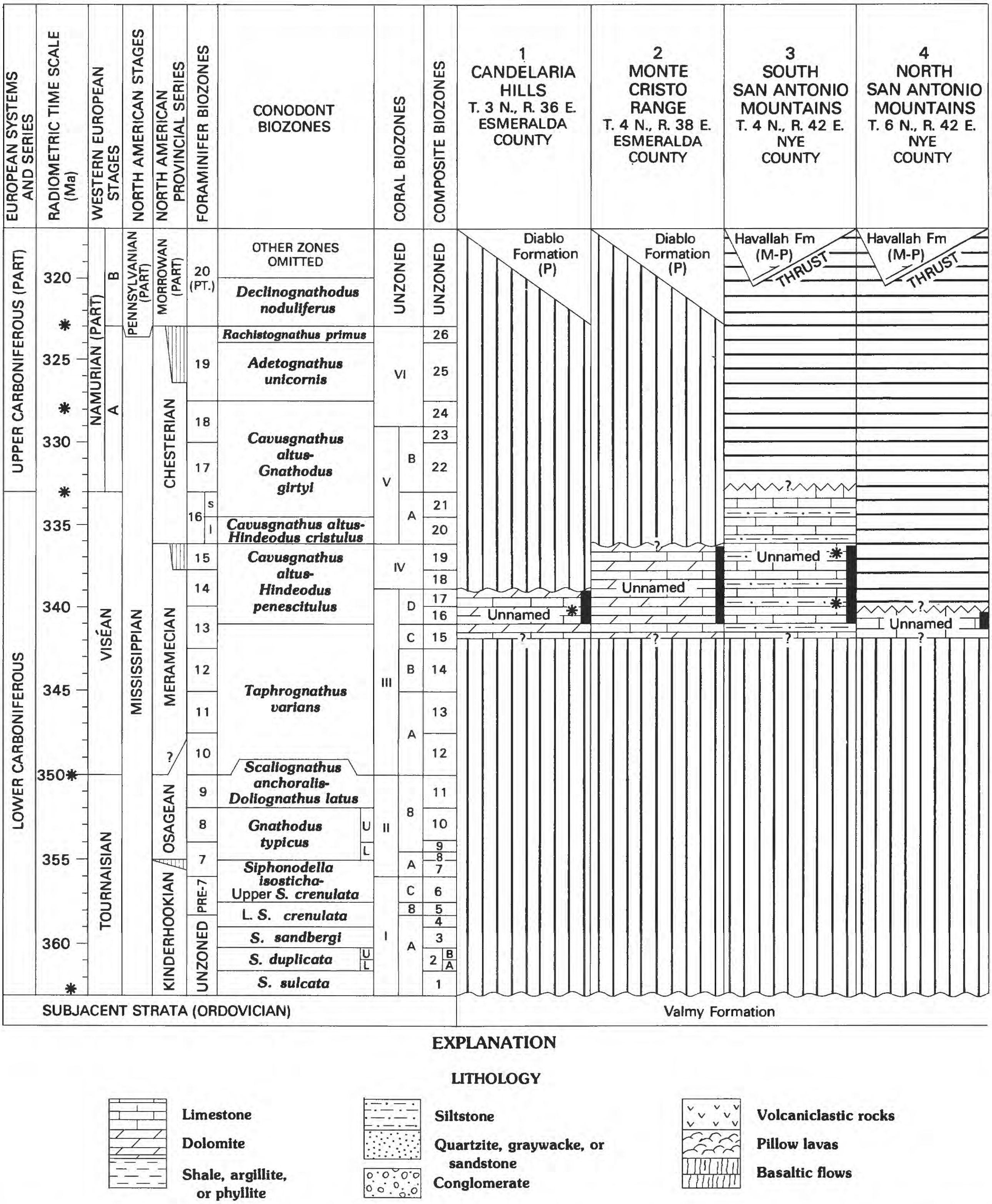


Figure 2 (above and facing page). Biostratigraphic correlation of Mississippian sedimentary sequences in coralliferous areas on west side of Antler orogen. Locations of areas shown by numbers in figure 1. Time scale modified from Sando (1985). See text for sources of lithic and paleontologic data for columns 1–8.

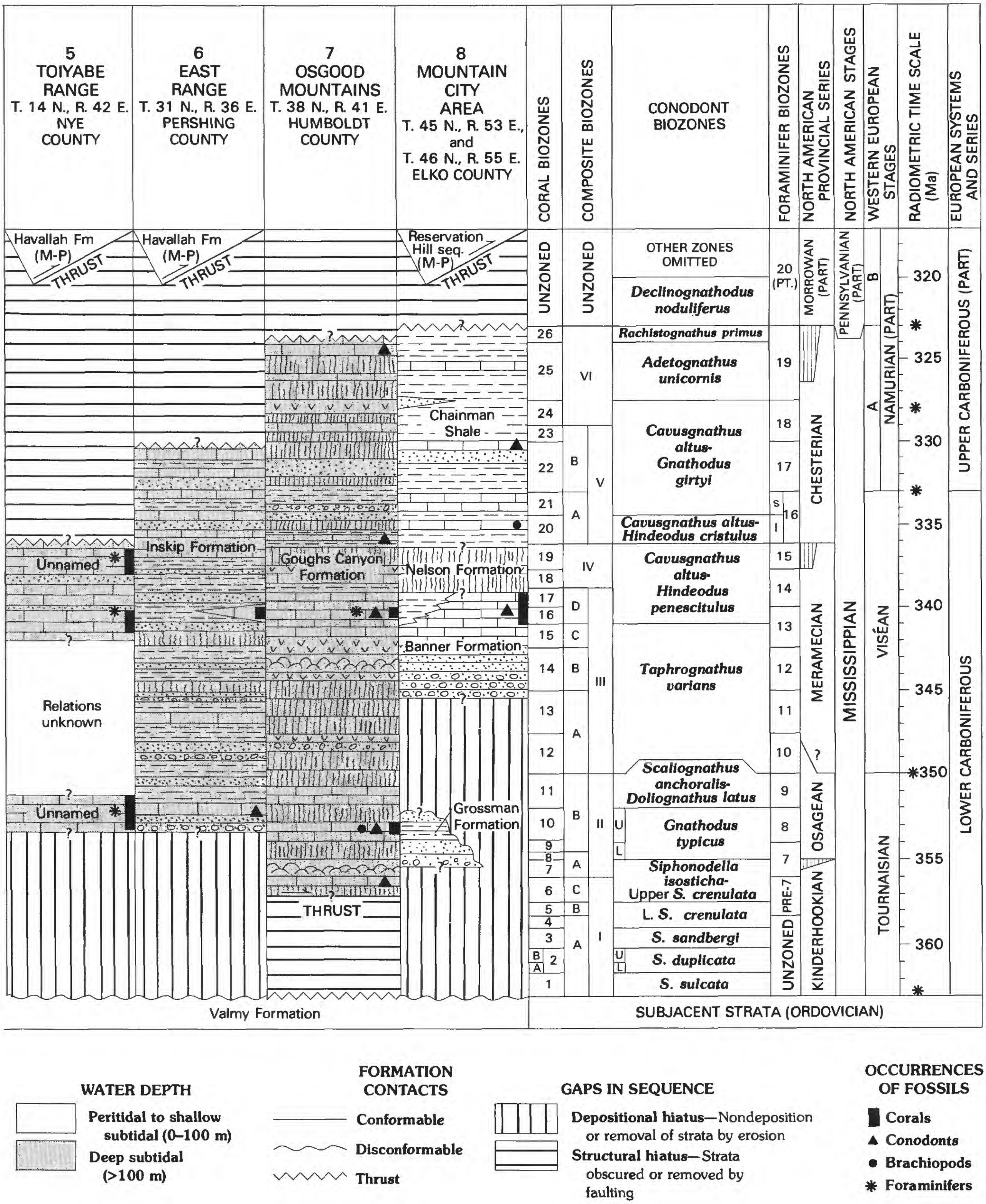

5
TOIYABE RANGE
T. 14 N., R. 42 E.
NYE COUNTY
6
EAST RANGE
T. 31 N., R. 36 E.
PERSHING COUNTY
7
OSGOOD MOUNTAINS
T. 38 N., R. 41 E.
HUMBOLDT COUNTY
8
MOUNTAIN CITY AREA
T. 45 N., R. 53 E., and T. 46 N., R. 55 E.
ELKO COUNTY
CORAL BIOZONES
COMPOSITE BIOZONES
CONODONT BIOZONES
FORAMINIFER BIOZONES
NORTH AMERICAN PROVINCIAL SERIES
NORTH AMERICAN STAGES
WESTERN EUROPEAN STAGES
RADIOMETRIC TIME SCALE (Ma)
EUROPEAN SYSTEMS AND SERIES
Havallah Fm (M-P)
THRUST
Reservation Hill seq. (M-P)
Unnamed
Relations unknown
Inskip Formation
Goughs Canyon Formation
Chainman Shale
Nelson Formation
Banner Formation
Grossman Formation
THRUST
Valmy Formation
UNZONED
OTHER ZONES OMITTED
Declinognathodus noduliferus
Rachistognathus primus
Adetognathus unicornis
Cavusgnathus altus-Gnathodus girtyi
Cavusgnathus altus-Hindeodus cristulus
Cavusgnathus altus-Hindeodus penescitulus
Taphrognathus varians
Scaliognathus anchoralis-Doliognathus latus
Gnathodus typicus
Siphonodella isosticha-Upper S. crenulata
L. S. crenulata
S. sandbergi
S. duplicata
S. sulcata
20 (PT.)
PRE-7
MORROWAN (PART)
CHESTERIAN
MERAMECIAN
OSAGEAN
KINDERHOOKIAN
PENNSYLVANIAN (PART)
MISSISSIPPIAN
NAMURIAN (PART)
VISÉAN
TOURNAISIAN
320
325
330
335
340
345
350
355
360
UPPER CARBONIFEROUS (PART)
LOWER CARBONIFEROUS
SUBJACENT STRATA (ORDOVICIAN)
WATER DEPTH
Peritidal to shallow subtidal (0–100 m)
Deep subtidal (>100 m)
FORMATION CONTACTS
Conformable
Disconformable
Thrust
GAPS IN SEQUENCE
Depositional hiatus—Nondeposition or removal of strata by erosion
Structural hiatus—Strata obscured or removed by faulting
OCCURRENCES OF FOSSILS
Corals
Conodonts
Brachiopods
Foraminifers

Table 2. Distribution of Zone IIID (middle to late Meramecian, middle Viséan) corals in collections from areas of central Nevada.
[See text for descriptions of areas. Collection numbers refer to USGS Upper Paleozoic locality file (–PC). Superscript T indicates collection from which thin sections were made; asterisk (*) indicates genus endemic to Western Interior Province; superscript plus (+) indicates species similar to Western Interior Province species]

Coral taxa	Area/collection 1	2	3	4	5	6	7	8
Nondissepimented solitary rugosans								
Amplexizaphrentis? sp. (may be young	24772?	–	–	–	–	–	14027T	–
Canadiphyllum)	26250	–	–	–	–	–	38082	–
**Canadiphyllum* sp.+	5165	–	14214	26248T	25580?	16459	12108	15384?
	25007	–	14215	–	–	–	14027T	16093?
	25585	–	14216	–	–	–	19807	17659
	26250	–	24451	–	–	–	38080	17662
	–	–	26252?	–	–	–	38081	19526
	–	–	26253?	–	–	–	38083	19527
	–	–	26254?	–	–	–	38084	21588
	–	–	–	–	–	–	–	22813
Cyathaxonia sp.	–	–	–	–	–	–	14029	–
Hapsiphyllum? sp.	5165	–	–	–	–	–	–	–
Dissepimented solitary rugosans								
**Ekvasophyllum* sp.+	5165	–	–	–	–	–	19807	16093
	26250	–	–	–	–	–	38082	17662?
	–	–	–	–	–	–	–	19527?
	–	–	–	–	–	–	–	22813
Koninckophyllum? sp.	25007	28067	14216	–	–	–	–	–
	25583T	–	26254	–	–	–	–	–
Large horn coral aff. *Faberophyllum*	26250	–	–	–	–	–	–	–
Colonial rugosans								
Acrocyathus sp. (cerioid)+	–	–	26253T	–	–	–	–	21588
Sciophyllum sp.	25584T	–	–	–	–	–	–	–
Siphonodendron cf. *S. sinuosum* (Warren)+	25007	–	19778?	26248	–	–	14029	15384T
	24772T	–	24944	–	–	–	–	19527
	25584T	–	26252	–	–	–	–	19528
	–	–	26253	–	–	–	–	21588
	–	–	–	–	–	–	–	22813
Siphonodendron cf. *S. whitneyi* of Meek+	26250	–	19778?	26248	–	–	14029	15384T
	25583	–	24944	–	–	–	–	19527
	–	–	26252	–	–	–	–	19528
	–	–	26253	–	–	–	–	21588
	–	–	–	–	–	–	–	22813
Siphonodendron cf. *S. whitneyi* of Meek	25007	–	14216	26249	–	16459T	–	–
(diphymorph)+	–	–	24450T	–	–	–	–	–
	–	–	26254T	–	–	–	–	–
"*Dorlodotia*" of Sando & Bamber (1985), aff. *S. whitneyi* of Meek+	–	–	–	–	–	–	–	22813
Stelechophyllum? sp.	–	–	–	–	–	–	–	17662

Table 2. Distribution of Zone IIID (middle to late Meramecian, middle Viséan) corals in collections from areas of central Nevada—Continued.

[See text for descriptions of areas. Collection numbers refer to USGS Upper Paleozoic locality file (–PC). Superscript T indicates collection from which thin sections were made; asterisk (*) indicates genus endemic to Western Interior Province; superscript plus (+) indicates species similar to Western Interior Province species]

Coral taxa	Area/collection							
	1	2	3	4	5	6	7	8
Tabulates								
Cladochonus sp.	5165	–	26253	26248	–	–	–	22813
Multithecopora? sp. (cerioid)	25007^{T}	–	–	–	–	–	–	–
Multithecopora morphogroup A of Sando (1984b)?$^{+}$	–	–	24944^{T}	–	–	16459	–	21588^{T}
Pleurosiphonella morphogroup A of Sando (1984b)$^{+}$	–	28067?^{T}	14215?	26248?	25580^{T}	–	–	–
	–	–	24450?^{T}	–	–	–	–	–
	–	–	26252	–	–	–	–	–
	–	–	26254^{T}	–	–	–	–	–
Syringopora morphogroup G of Sando (1984b)$^{+}$	–	–	–	–	–	–	14029^{T}	–

Table 3. Distribution of Coral Zone IV (latest Meramecian, late Viséan) corals in collections from areas of central Nevada.

[See text for descriptions of areas. Collection numbers refer to USGS Upper Paleozoic locality file (–PC). Superscript T indicates collection from which thin sections were made; asterisk (*) indicates genus endemic to Western Interior Province; superscript plus (+) indicates species similar to Western Interior Province species]

Coral taxa	Area/collection		
	2	3	5
Dissepimented solitary rugosans			
**Canadiphyllum* sp.$^{+}$	–	14666	–
	–	26256	–
**Faberophyllum* sp.$^{+}$	28065	14666^{T}	26251^{T}
	28066^{T}	26255	–
	–	26256	–
Colonial rugosans			
Siphenodondron cf. *S. whitneyi* of Meek^{+}	–	14666	–
	–	26255	–
	–	26256^{T}	–
Acrocyathus sp. (cerioid)$^{+}$	–	26256?	–
Tabulates			
Pleurosiphonella morphogroup A of Sando (1984b)$^{+}$	–	14666?	26251
	–	26255?	–
	–	26256?^{T}	–
Cladochonus sp.	–	14666?	–

of corals, 29 from south-central Nevada and 22 from north-central Nevada (locality register, p. F22; tables 1–3), were studied for this report.

SOUTH-CENTRAL NEVADA (AREAS 1–5, FIGS. 1, 2)

Paleozoic rocks crop out in isolated mountain ranges surrounded by Mesozoic and Tertiary sediments in Esmeralda and Nye Counties, where F.G. Poole recognized an unnamed Mississippian carbonate unit in his mapping of selected areas in several mountain ranges in the early 1960's and 1970's (Poole *in* Poole and Sandberg, 1977, p. 79; *in* Speed and others, 1977, p. 302). The unnamed carbonate unit was included previously in the Permian Diablo Formation (dolomite facies) and in a Devonian limestone unit mapped by H.G. Ferguson and his colleagues in the old Hawthorne and Tonopah 1° quadrangles (Ferguson and Muller, 1949; Ferguson, 1952; Ferguson and others, 1953, 1954), where age determinations were based on studies of a few collections of fossils by G.H. Girty (Permian) and Edwin Kirk (Devonian) in the 1920's (see locality register for details). Subsequent restudy of the old collections and studies of new collections from several localities by H.M. Duncan in the 1950's and 1960's and by me in 1970's and 1980's resulted in confirmation of the Mississippian age of the unnamed carbonate unit mapped by Poole (see locality register for details).

The relationships between the unnamed Mississippian carbonate unit and subjacent and superjacent rock units in south-central Nevada have been interpreted differently by different geologists. Poole (*in* Poole and Sandberg, 1977,

Table 4. Shallow-water habitat index (SWHI) of coral assemblages in coral zones and areas of central Nevada
[See text for descriptions of areas and explanation of SWHI. Collection numbers refer to USGS Upper Paleozoic locality file (–PC)]

		Shallow-water habitat index (SWHI)		
Area	Collection number	Collection range	Collection mean	Grand mean
		Coral Zone IIB		
5	25579	97	97	84.8
5	25581	18–98	72.5	
7	14026	6–86	49	67.5
7	19808	86	86	
		Coral Zone IIID		
1	5165	66–100	88.7	83.1
1	24772	74–100	87	
1	25007	50–100	79	
1	25583	50–100	75	
1	25584	100	100	
1	25585	66	66	
1	26250	66–100	86.2	
2	28067	50–100	75	75
3	14214	66	66	84.3
3	14215	66–100	83	
3	14216	50–100	72	
3	19778	100	100	
3	24450	100	100	
3	24451	66	66	
3	24944	100	100	
3	26252	66–100	88.7	
3	26253	66–100	88.7	
3	26254	50–100	79	
4	26248	66–100	88.7	94.3
4	26249	100	100	
5	25580	66–100	83	83
6	16459	66–100	90.3	90.3
7	12108	66	66	71.6
7	14027	66–74	70	
7	14029	39–100	79.7	
7	19807	66–95	80.5	
7	38080	66	66	
7	38081	66	66	
7	38082	74–95	84.5	
7	38083	66	66	
7	38084	66	66	
8	15384	66–100	83	83.5
8	16093	66–95	80.5	
8	17659	66	66	
8	17662	66–100	87	
8	19526	66	66	
8	19527	66–100	87	
8	19528	100	100	
8	21588	66–100	91.5	
8	22813	66–100	90.3	
		Coral Zone IV		
2	28065	96	96	96
2	28066	96	96	
3	14666	66–100	90.5	93.9
3	26255	96–100	98.7	
3	26256	66–100	92.4	
5	26251	96–100	98	98

fig. 2a, col. 6) recognized an unconformity between the Mississippian unit and the overlying Diablo Formation (restricted) in the Candelaria Hills and Monte Cristo Range (areas 1 and 2, figs. 1, 2), whereas Speed (1984) decided that the Mississippian unit is in a different thrust slice of Mesozoic(?) age than that of the Diablo Formation in the Candelaria Hills. Moreover, Poole (*in* Poole and Sandberg, 1977, fig. 2a, cols. 6–8) recognized an unconformity between the Mississippian unit and the underlying Valmy Formation (Ordovician) in areas 1–5 (figs. 1, 2), whereas Stewart (1979), Bonham and Garside (1979), and Kleinhampl and Ziony (1985) decided that the Mississippian unit was in thrust contact on Ordovician rocks in the Candelaria Hills (area 1) and South San Antonio Mountains (area 3) and in the North San Antonio Mountains (area 4), respectively. I follow Poole's (*in* Poole and Sandberg, 1977) interpretations of the contact relations of the unnamed Mississippian carbonate unit.

Mississippian corals were collected from Poole's unnamed carbonate unit in the Candelaria Hills (area 1, 7 collections) and Monte Cristo Range (area 2, 3 collections) in Esmeralda County and in the South San Antonio Mountains (area 3, 13 collections), North San Antonio Mountains (area 4, 2 collections), and Toiyabe Range (area 5, 4 collections) in Nye County (fig. 1).

AREAS 1 AND 2

In the Candelaria Hills (area 1) and Monte Cristo Range (area 2), the unnamed carbonate unit consists of dolomite and limestone as much as 400 ft (120 m) thick (Ferguson and others, 1954) that rest unconformably on the Valmy Formation of Ordovician age and are overlain unconformably by the Diablo Formation of Permian age (fig. 2, cols. 1, 2)(Poole and Sandberg, 1977). F.G. Poole (written commun., 1975) measured a thickness of 325 ft (100 m) for the unnamed unit at his Gates Mill locality in the Candelaria Hills.

In the Monte Cristo Range, two Western Interior coral zones are represented in the collections: Coral Zone IIID (middle to late Meramecian, middle Viséan) and Coral Zone IV (latest Meramecian, late Viséan) (tables 2, 3). Only the older zone is represented in the collections from the Candelaria Hills, probably as the result of a greater depth of pre-Permian erosion in the latter area, although perhaps as the result of poor exposures of the rock unit or incomplete collecting of available coral fauna.

The corals are dolomitized and silicified and are in a matrix of tan-weathering fossiliferous dolomicrite (wackestone and packstone) in four of the seven collections from the Candelaria Hills. In two collections from this area from the lower part of the carbonate unit, the corals are calcitic and are in a matrix of gray-weathering silty biomicrite (wackestone and packstone), and, in a third collection from the upper part of the unit, the matrix is gray crinoidal biomicrite (packstone). A few silicified brachiopod fragments are associated with the corals in two of the dolomite samples, and one limestone sample contains foraminifers and algae of Mamet Foraminifer Zones (MFZ) 13–14 (Mamet *in* Mamet and Skipp, 1970) identified by B.L. Mamet (see appendix). Corals are dolomitized or silicified and are in tan-weathering crinoidal dolobiomicrite (packstone) without other identifiable fossils in all three samples from the Monte Cristo Range.

Shallow-water habitat indices (SWHI)(Sando, 1980) for the eight coral collections from Coral Zone IIID in areas 1 and 2 range from 50 to 100 (grand means 83.1 and 75, respectively)(table 4). The two coral collections from Coral Zone IV have SWHI values of 96. The SWHI values suggest that the corals in both zones lived in shallow-water environments well within the photic zone (about the upper 100 m (300 ft) of the water column). Lack of appreciable abrasion of the solitary corals and good articulation of corallites of the phaceloid corals suggest coral growth in a relatively quiet, subtidal environment. The foraminifer-algal assemblage in Coral Zone IIID suggests a bathymetry of 30–40 m (100–130 ft)(B.L. Mamet, appendix). These data, together with the petrography of the rocks, suggest that the unnamed carbonate unit represents autochthonous accumulation of carbonate sediment on a shallow-water carbonate shelf in south-central Nevada during Late Mississippian (middle to latest Meramecian) time.

AREAS 3–5

Although the unnamed carbonate unit extends eastward and northward into Nye County, the lithology and structural setting of this unit are somewhat different from its occurrences in Esmeralda County. Here the carbonate unit again rests unconformably on the Valmy Formation (Ordovician), but its top is eroded and locally may be truncated by the Golconda thrust, upon which rocks of the Havallah Formation (Mississippian to Permian) were carried over rocks of the Roberts Mountains allochthon (fig. 2, cols. 3–5). Although published geologic maps of the South San Antonio Mountains show a thrust fault separating the unnamed Mississippian carbonate unit from the Ordovician Valmy Formation, F.G. Poole (written commun., 1992) interpreted the contact as a sheared sedimentary contact. In Nye County, the unnamed carbonate unit is mostly limestone, in contrast to its predominantly dolomitic character in Esmeralda County. Moreover, the carbonate unit in Nye County includes an older sequence of limestone not found in Esmeralda County.

In the South San Antonio Mountains (area 3), Coral Zones IIID and IV (tables 2, 3) are represented in the middle part of a limestone sequence 900 ft (275 m) thick (F.G. Poole, written commun., 1975); limestone above the highest coral level may be of Chesterian age (fig. 2, col. 3). In the North San Antonio Mountains (area 4), only Coral Zone IIID (table 3) is represented in a limestone interval 50 ft (15 m) thick (F.G. Poole, written commun., 1975). In the Toiyabe Range (area 5), Coral Zones IIID and IV (tables 2, 3) are represented in a limestone interval 200 ft (60 m) thick (F.G. Poole, written commun., 1975), and Coral Zone IIB (Osagean)(table 1) is represented in limestone of undetermined thickness and uncertain structural relations to the younger limestone beds (F.G. Poole, written commun., 1975). Foraminifers and algae in collections from areas 3–5 were determined by B.L. Mamet (appendix) as Coral Zone IIB=Osagean, Coral Zone IIID=MFZ 13–14, Coral Zone IV=MFZ 15 or younger. I have not verified reports of early Meramecian (MFZ 10–12) foraminifers (B.A. Skipp *in* Bonham and Garside, 1979, p. 17) and uppermost Osagean foraminifers (B.A. Skipp *in* Kleinhampl and Ziony, 1985, p. 86) from the South San Antonio Mountains.

Rock samples from Coral Zones IIID and IV in the South and North San Antonio Mountains are all light-gray-weathering crinoidal biomicrite (wackestone and packstone). Most samples are strongly sheared and veined with calcite. The corals are silicified or calcitic, and they are associated with rare brachiopods. SWHI values for coral collections from Coral Zone IIID from areas 3 and 4 range from 50 to 100 (grand means 84.3 and 94.3, respectively), and those from Coral Zone IV in area 3 range from 66 to 100 (grand mean 93.9)(table 4). The corals are minimally abraded or disarticulated. The foraminifer-algal assemblages from Zones IIID and IV suggest a bathymetry of 30–40 m (100–130 ft) (B.L. Mamet, appendix) These data support an autochthonous shallow-water carbonate shelf environment for both zones, similar to that suggested for areas 1 and 2 in Esmeralda County.

A significantly different environment is postulated for the rock samples from Coral Zones IIB, IIID, and IV in the Toiyabe Range. Rock samples of Coral Zone IIB are dark-gray-weathering, very silty biomicrite (packstone) containing abundant foraminifers, crinoid columnals, and bryozoan fragments. Only solitary corals are represented in the Zone IIB collections, and these are variably abraded. The Zone IIB collections have SWHI values ranging from 18 to 98 (grand mean 84.8)(table 4). One sample from Zone IIB contains a reworked foraminifer-algal assemblage composed of Devonian as well as Osagean forms that B.L. Mamet (appendix) regards as a probable gravity-flow deposit.

Rock samples of Coral Zone IIID and IV are dark-gray-weathering, silty, spiculitic, fossiliferous micrite (wackestone) containing sparse foraminifers, crinoid columnals, and gastropods. The SWHI value for Zone IIID is 83 and that for Zone IV is 98 (one collection each)(table 4). Some corals are strongly abraded. These data suggest that the collections from all three coral zones represent allochthonous sediments derived from a nearby shallow-water carbonate shelf and deposited in deeper water on the foreslope of the shelf. Microfossil assemblages from the Toiyabe Range are impoverished and indicate Zone IIID= MFZ 13–14 and Zone IV=MFZ 15 (B.L. Mamet, appendix).

INTERPRETIVE SUMMARY

I regard the scattered outcrops of Mississippian rocks in south-central Nevada as evidence of a formerly extensive sheet of Mississippian carbonate sediments deposited on eroded lower Paleozoic rocks belonging to the Roberts Mountains allochthon along the west side of the Antler orogen. My interpretation of these rocks coincides essentially with that of Poole and Sandberg (1977, p. 79, 1991, p. 131), who characterized the rocks as "autochthonous to parautochthonous" with respect to their structural setting.

The sedimentary textures and the taxonomic composition of corals, foraminifers, and algae in the Mississippian rocks are consistent with shallow-shelf environments having a bathymetry of about 100 m (300 ft) or less, except for the rocks in the Toiyabe Range, where the Mississippian sequence probably represents a carbonate gravity flow that came to rest in deeper water (>100 m, >300 ft) on the foreslope of the shelf. In situ shelf-rock localities probably represent outer shelf locations because the microfauna and microflora suggest deeper (30–40 m, 100–130 ft) or cooler waters than normally indicated by Cordilleran microfossils of the same age (B.L. Mamet, appendix).

The probable overlap relationship of these Mississippian rocks on the west side of the Antler orogen suggests similarity to the Pennsylvanian and Permian rocks of the Antler overlap sequence of Roberts and others (1958) on the east side of the orogen. Miller and others (1984, fig. 5) recognized an older overlap sequence of Chesterian age on the continental shelf in north-central Nevada. Little (1987, p. 5, 9) placed the Mississippian sequence of the Mountain City area (area 8, figs. 1, 2) in his "Upper Mississippian Antler overlap sequence" and extended this sequence concept southward to include the Mississippian rocks of south-central Nevada (Little, 1987, fig. 5). Little (1987, p. 9) interpreted this overlap sequence as a result of rifting along the continental margin associated with "extensional or borderlands-style tectonics."

The precise structural position of the Upper Mississippian Antler overlap sequence in south-central Nevada is still uncertain. The Mississippian rocks are overlain unconformably by the Permian Diablo Formation in the Candelaria Hills and Monte Cristo Range, but a thrust fault separates them from rocks of the overlying Havallah Formation (Mississippian to Permian) in the San Antonio Mountains and Toiyabe Range (F.G. Poole, oral commun., 1992). Thus, the structural unit overlying the Mississippian rocks probably is the Triassic Golconda allochthon, as shown on geologic maps of Nevada by Miller and others (1984, fig. 1) and Little (1987, fig. 1).

NORTH-CENTRAL NEVADA (AREAS 6–8, FIG. 2)

Occurrences of Mississippian corals in north-central Nevada are in limestone beds in complexly deformed, predominantly terrigenous and volcanic sequences whose structural and stratigraphic relationships are poorly known and controversial. These rocks are being studied by K.B. Ketner and by M.B. and L.B. McCollum. The Mississippian rocks have been interpreted variously as an autochthonous part of the Antler overlap sequence on the Roberts Mountains allochthon (Banner Formation: Little, 1987), as an allochthonous unit within the Golconda allochthon (Inskip and Goughs Canyon Formations: Roberts and others, 1958; Hotz and Willden, 1964), and as a part of an accreted terrane that originated in an oceanic setting west of the Antler orogen (Goughs Canyon Formation: McCollum and McCollum, 1989, 1991; Jones, 1991). Corals were collected from the Inskip Formation in the East Range, Pershing County (area 7, 1 collection), the Goughs Canyon Formation in the Osgood Mountains, Humboldt County (area 8, 11 collections), and the Banner Formation, Mountain City district, Elko County (area 9, 10 collections).

AREA 6

The Inskip Formation consists predominantly of graywacke, conglomerate, chert, greenstone, calcareous shale, and quartzite and some thin beds of limestone (Ferguson and others, 1951); it may be as much as 9,000 ft (3,000 m) thick, but its true thickness is unknown because the top is nowhere exposed (K.B. Ketner, written commun., 1992). The Inskip was originally thought to be Permian in age when it was mapped in the Winnemucca and Mount Tobin 30′ quadrangles (Ferguson and others, 1951; Muller and others, 1951). In 1956, however, R.J. Roberts found corals in a small limestone lens in the lower part of the formation, and these were regarded as probably Mississippian by H.M. Duncan (*in* Roberts and others, 1958, p. 2847; *in* Silberling and Roberts, 1962, p. 13) The Inskip Formation was included in the Golconda allochthon by Roberts and others (1958).

When the Inskip was first described, it was thought to rest conformably on the Leach Formation, which was regarded as Pennsylvanian in age (Ferguson and others, 1951; Muller and others, 1951). After discovery of Mississippian corals in the Inskip, the Leach Formation was regarded as Mississippian or older (Roberts and others, 1958, p. 2847; Silberling and Roberts, 1962, p. 13). Lithologic similarity of the Leach and the Valmy Formation (Ordovician)(Silberling and Roberts, 1962, p. 13) finally led to interpretation of the Leach Formation as a synonym of the Valmy (Roberts *in* Langenheim and Larsen, 1973, p. 26, chart 3, col. 55b). Most recently, conodonts from the Leach Formation, identified by J.E. Repetski, confirmed the Ordovician age of the Leach and its identity with the Valmy (Whitebread, 1978). The base of the Inskip, originally thought to be depositional, was reinterpreted as a thrust fault by Silberling and Roberts, (1962, p. 14; see also Roberts *in* Langenheim and Larsen, 1973, p. 26, chart 3), but more recently, Whitebread (1978) and K.B. Ketner (written commun., 1992) interpreted the base as a depositional contact. I conclude that the Inskip probably rests unconformably on the Valmy Formation, similar to the unnamed Mississippian carbonate unit in south-central Nevada and to the Grossman and Banner Formations in north-central Nevada.

The Inskip Formation was originally thought to lie unconformably beneath the Tallman Fanglomerate and Koipato Formation of Permian age (Ferguson and others, 1951; Muller and others, 1951), but later work in its outcrop area resulted in a thrust interpretation for the contact between the Inskip and overlying beds (Silberling and Roberts, 1962, p. 14; Langenheim and Larsen, 1973, chart 3, col. 55b; Whitebread, 1978; K.B. Ketner, written commun., 1992). I follow Silberling and Roberts (1962), who regarded the overlying beds as Havallah Formation, because this interpretation is confirmed by recent studies of the East Range by K.B. Ketner. Moreover, this interpretation (fig. 2, col. 6) is consistent with the geology of rocks of similar age in areas 3–8. The upper part of the Inskip probably is as young as Chesterian, judging from the postulated thickness of beds above the level of the Mississippian corals in the lower part of the formation. The coral fauna from the limestone lens in the lower part of the Inskip Formation contains three taxa characteristic of Coral Zone IIID (table 2), indicating that the lens is the same age (middle to late Meramecian) as the lower part of the unnamed carbonate unit in south-central Nevada. The corals are in a matrix of strongly sheared and veined, dark-gray-weathering, silty biomicrite (wackestone) containing ostracodes, fragmentary bryozoans, and pelmatozoan columnals. The corals are calcitic, mostly recrystallized, and strongly deformed. Phaceloid corals are well articulated, and solitary corals may or may not be abraded. Although the fauna has an SWHI of 89 (table 4), indicating that the corals lived on a shallow-water carbonate shelf, the lens containing them is in a predominantly terrigenous sequence whose lithologies suggest deposition in deeper water. These data suggest that the limestone lens is a gravity-flow deposit derived from a nearby shallow-water carbonate shelf.

Conodonts collected from limestone beds in a sequence of argillite, quartzite, and gritty quartzite in the lower part of the Inskip Formation by D.H. Whitebread (1978) in his mapping of the Dun Glen 7.5′ quadrangle and identified by A.G. Harris (report on shipments WMR–80–6) provide evidence for older beds of Mississippian age below the coralliferous lens in the Inskip Formation. Harris identified conodonts having a possible range from the upper *Gnathodus typicus* Zone into the *Doliognathus latus* Zone in USGS collection 27593–PC, which formed the basis for an Early Mississippian (middle Osagean) age determination. The conodont fauna includes *Eotaphrus burlingtonensis*, which is restricted to "well-aerated shallow water of the upper foreslope and platform margin" in the bathymetric model of Sandberg and Gutschick (1984, p. 150, fig. 14). Hence, the lower limestone beds probably had the same allochthonous origin as the coralliferous limestone bed above them.

The Inskip Formation is probably an offshore facies of the Upper Mississippian Antler overlap sequence of Little (1987, p. 5), which rests unconformably on the Roberts Mountains allochthon and is structurally beneath the Golconda allochthon. Deposition of terrigenous detritus derived from an eastern highland source and deposited in shallow (<100 m, <300 ft) to deep (>100 m, >300 ft) water offshore probably characterized most of the time represented by the formation. The lithology of the limestone lens and limestone beds below it and the occurrence of these carbonate rocks in a terrigenous sequence suggest, however, that carbonate sediments were transported by gravity flow from a nearby shallow-water (<100 m, <300 ft) carbonate shelf that was present on the west side of the Antler land area during times when terrigenous supply was diminished. Changes in the directions of currents supplying terrigenous detritus to the area of Inskip deposition might also explain the interbedding of terrigenous and carbonate sediments.

AREA 7

The Goughs Canyon Formation is a thick sequence of predominantly metavolcanic rocks and limestone and minor amounts of calcareous sandstone, calcareous shale, siliceous shale, and chert (Hotz and Willden, 1961, 1964, p. 24, 25). An age range of Early Mississippian (early Osagean) to Late Mississippian (Meramecian) was established by H.M. Duncan (corals and bryozoans) and Mackenzie Gordon, Jr. (brachiopods) on collections made from limestone beds during mapping of the formation in the early 1950's (Hotz and Willden, 1964, p. 26–28). The coralliferous limestones were interpreted by Hotz and Willden (1964, p. 28) as shallow-marine deposits, and the associated volcanic rocks were regarded as submarine extrusions into shallow water. The formation is bounded above and below by thrusts and is covered by Tertiary volcanic rocks; its structural position was determined by Hotz and Willden (1964) as below the Farrel Canyon Formation (Pennsylvanian? and Permian?) and above the Valmy Formation (Ordovician) by mapping and by its age based on fossils. The anomalous geographic position of the Goughs Canyon, east of the 0.706-initial-strontium isopleth, as compared to all other sequences of Mississippian carbonate units discussed herein (fig. 1) suggests that it was transported tectonically a greater distance eastward than the other sequences previously described.

The Goughs Canyon Formation was included in the "western sequences of upper Paleozoic rocks" (as "unnamed formation of Late Mississippian age") that make up the Golconda allochthon by Roberts and others (1958, p. 2846). This interpretation was followed by Poole and Sandberg (1977, p. 78, 79), who assigned the formation to their "inner-arc-basin," which was later called "back-arc Havallah basin" by Poole and Sandberg (1991, p. 128) and "Schoonover-Havallah basin" by Miller and others (1984, fig. 2).

Two recent investigations of the geology of the Goughs Canyon Formation in the Osgood Mountains (McCollum and McCollum, 1989, 1991; Jones, 1991) resulted in interpretations of this sequence as a part of an accreted terrane that includes continental-slope to ocean-basin sediments originally deposited west of the Antler orogen during the Mississippian. The McCollums recently traced the Goughs Canyon Formation northward into the Farrel Canyon Formation and found radiolarian cherts typical of the Farrel Canyon interbedded with coralliferous limestones typical of the Goughs Canyon (M.B. McCollum, written commun., 1992). Mississippian fossils collected by the McCollums from Farrel Canyon lithologies suggest at least partial temporal equivalence with the Goughs Canyon. Vesicular pillow basalt interbedded with the limestone in the Goughs Canyon was interpreted by McCollum and McCollum (1989, 1991) as indicative of deep water. According to Jones (1991, p. 788), the Goughs Canyon and Farrel Canyon Formations are both part of a melange within the Golconda accreted terrane. Both the McCollums (1989, p. 244, 1991, p. 737) and Jones (1991, p. 784, 785) interpreted the limestone beds in the Goughs Canyon as debris flows derived from an atoll located on a seamount on the continental slope or continental rise.

Eight conodont collections made by A.E. Jones and analyzed by A.G. Harris (reports on shipments 0–90–8, 0–90–12, and 0–90–19) establish the probable age range of the Goughs Canyon Formation as late Kinderhookian to late Chesterian. Two coral zones are represented in the formation: Coral Zone IIB (Osagean) in two collections from the lower part of the formation (table 1) and Coral Zone IIID (middle to late Meramecian) in nine collections from the middle part of the formation (table 2). Stratigraphic positions of the collections are approximate and were determined from ages indicated by the fossils. The generalized lithic sequence of the Goughs Canyon Formation (fig. 2) is taken from the graphic column presented by Little (1987, fig. 3), which is based on description of the sequence by Hotz and Willden (1964, p. 24, 25); this simplified lithic column will have to be revised after the McCollums complete their studies of these rocks. Hotz and Willden estimated the thickness of the Goughs Canyon as more than 5,000 ft (1,500 m), but McCollum and McCollum (1991, p. 737) estimated a tectonostratigraphic thickness of approximately 1,000 m (3,300 ft).

Zone IIB corals are present in limestone beds interbedded with basaltic flows. In collection 14026–PC, the limestone is dark-gray-weathering ferruginous biomicrite (packstone) containing subrounded fragments of brachiopods, bryozoans, and volcanic rock. In collection 19808–PC, the limestone is dark-gray-weathering crinoidal biomicrite (packstone). Both collections contain well-preserved brachiopods that were dated as early Osagean by Mackenzie Gordon, Jr. (*in* Hotz and Willden, 1964, p. 27). The Zone IIB corals are variably abraded and have a grand mean SWHI of 67.5 (table 4). The coral data, petrography of the limestone, and absence of deep-water conodont assemblages suggest that the limestone was deposited on a shallow-water (<100 m, <300 ft)) carbonate shelf.

Zone IIID corals are present in limestone interbedded with basaltic flows. The limestone weathers light gray to yellowish gray and is classified as crinoidal biomicrite (packstone). Well-rounded fragments of brachiopods, bryozoans, and clasts of volcanic rock, pellets, and intraclasts are abundant. Phaceloid corals are well articulated, and solitary corals are variably abraded. The coral assemblages have a grand mean SWHI of 71.6 (table 4), suggesting that the corals lived in shallow (<100 m, <300 ft) water. Foraminifers of Meramecian age (Skipp, 1979, p. 300; B.L. Mamet, appendix) are common and show evidence of reworking that B.L. Mamet interprets as indicating a possible gravity-flow deposit. Meramecian conodonts were recovered from the coralliferous interval by McCollum and McCollum (1989, p. 242). Conodonts of late Meramecian to early Chesterian age, collected by A.E. Jones from beds presumably above the coral beds, have characteristics of high-energy, shallow-water deposition (A.G. Harris, written commun., 1990). These data suggest deposition of the carbonate sediment on a high-energy, shallow-water shelf and transport by gravity flow into deeper water.

INTERPRETIVE SUMMARY FOR AREA 7

The sedimentary textures, taxonomic composition of the coral faunas of both Zone IIB and Zone IIID, and taxonomic composition of the microfauna and microflora of limestone samples from the Goughs Canyon Formation examined in this study strongly support an originally shallow water (probably 30–40 m, 100–130 ft) origin for the limestone beds. Evidence of reworking of the microfossils supports transport of the sediment by gravity flow. The presence of basalt clasts in the limestone (and vice versa according to M.B. McCollum, written commun., 1992) indicates a sedimentary association with vesicular pillow lavas that have been determined as deep-water features. The intimate association of Goughs Canyon lithologies with associated deep-water radiolarian cherts suggests that the limestone beds belong with the oceanic suite that is present in the Havallah Formation of the Golconda allochthon elsewhere in central Nevada.

The taxonomic composition of the coral faunas seems to rule out an atoll environment for their original life habitat. These corals are virtually identical to corals in rocks interpreted as shallow-shelf deposits in south-central Nevada, where the rocks are in an overlap sequence that unconformably overlies the Roberts Mountains allochthon and are structurally beneath the oceanic suite of the Golconda allochthon. Moreover, the corals of both Zone IIB and Zone IIID in the Goughs Canyon are characteristic of shallow-shelf deposits of the Cordilleran platform east of the Antler foreland basin, where no reefs are known. True atoll corals, such as those of the Akiyoshi Limestone (Carboniferous and Permian) in Japan, show skeletal morphologies that reflect adaptation to a reef environment as framebuilders, binders, and bafflers (Ota, 1968, 1977; Sugiyama and Nagai, 1990, 1991), whereas the Goughs Canyon corals show none of these features. In fact, there are very few places in the world where true coral reefs have been found in the Carboniferous.

A coralliferous island-margin shelf that developed on a basaltic seamount on the continental slope of the Havallah basin may well have been the source of carbonate sediment in the gravity-flow deposits of the Goughs Canyon Formation. Corals living at the steep edge of such a shelf, having no fringing reef, could have been transported into deeper water by periodic gravity flow. The paleogeography may have been similar to that of the west side of Andros Island in the Bahamas today.

These paleogeographic conclusions favor interpretation of the thrust at the base of the Goughs Canyon Formation as the Golconda thrust and are generally consistent with evidence presented by McCollum and McCollum (1989, 1991) and by Jones (1991). The anomalous location of the Goughs Canyon outcrop area east of the 0.706-initial-strontium isopleth requires moving the area northwestward approximately 25 km in order to restore it to a position consonant with the other areas of coeval Mississippian shelf limestone exposed along the west side of the Antler orogen (fig. 1). This distance approximates the amount of eastward movement on the Golconda thrust.

AREA 8

In its type area, the Banner Formation comprises an upper part composed of silty and sandy limestone and a lower part composed of siliceous sandstone and polymict conglomerate; the formation is approximately 600 ft (190 m) thick (Coats, 1969, p. A24; Little, 1987, p. 5–8)(fig. 2). The formation was first described (as Banner limestone) by Granger and others (1957, p. 116), based on an unpublished study of the Mountain City mining district by T.B. Nolan in 1932, and was mapped by Coats (1968, 1971) in the Mountain City 15′ and Owyhee 7.5′ quadrangles. According to Coats, the Banner unconformably overlies the Valmy (Ordovician) and Grossman (Devonian or Mississippian) Formations and grades upward into basaltic lava of the Nelson Formation (Late Mississippian). The Nelson is succeeded conformably by the Chainman Shale (Late Mississippian) (Little, 1987, p. 8), which was formerly called Mountain City Formation by Coats (1969, p. A26). This Mississippian sequence is in fault contact with the overlying Reservation Hill sequence (Mississippian?-Permian?), which is a Havallah equivalent and is part of the Triassic Golconda allochthon (Little, 1987). Thus, according to published studies, the Grossman through Chainman sequence represents an overlap sequence resting on the Roberts Mountains allochthon.

Recent work in the Mountain City area by K.B. Ketner (written commun., 1992) suggests that strata having the lithologic characters of the Banner, Grossman, and Nelson Formations are all in conformable relationships and that they can be in any order, making the formations based on these lithologic distinctions invalid regionally. Moreover, Ketner believes that Coats' Mountain City Formation is more appropriate than Chainman for the sequence that overlies the Nelson Formation because rocks assigned to the Chainman Shale of Little (1987) in the Mountain City area include bedded chert and rocks of Pennsylvanian and Permian ages that are more properly assigned to the Golconda allochthon. Hence, the stratigraphic sequence used in this report (fig. 2, col. 8) is subject to considerable revision when Ketner completes his study.

Corals collected from the limestone by Nolan in 1932 were originally dated as Late Mississippian(?) by G.H. Girty in 1932 but were reinterpreted as Permian(?) by H.M. Duncan in 1955 (see locality register); the latter age determinations formed the basis for the Pennsylvanian to Permian(?) age given by Granger and others (1957, p. 116). Duncan revised her previous dating to Late Mississippian (Meramecian) in 1960, based on better fossils collected by Coats. Sando and Wardlaw (*in* Little, 1987, p. 5, 8, Appendix A) restudied collections previously used for dating the Banner and refined the Late Mississippian age. Conodonts identified by Wardlaw in USGS collection 17662–PC indicate a possible age range of middle Meramecian to Chesterian.

Corals in 10 collections from the upper limestone beds of the Banner Formation belong to Coral Zone IIID (middle to late Meramecian, middle Viséan)(table 2, col. 8). The coral assemblages have a grand mean SWHI of 83.5 (table 4). The rock matrix of the coral collections is light-gray-weathering crinoidal biomicrite (packstone and wackestone) containing well-rounded fragments of brachiopods, bryozoans, and ostracodes. Most samples are strongly sheared and recrystallized, and the corals are mostly deformed and silicified. Phaceloid corals are articulated, and solitary corals show variable abrasion. These data suggest that the limestone represents an autochthonous accumulation of carbonate sediment deposited on a shallow (<100 m, 300 ft) subtidal shelf.

Terrigenous sedimentary rocks that form the lower half of the Banner Formation and the underlying Grossman Formation, which also consists of terrigenous rocks, have not been dated by fossils. I tentatively assign the lower part of the Banner to the early Meramecian and the Grossman Formation to the Osagean (fig. 2). Confirmation of this age assignment and the age of the overlying rocks awaits determination of conodont samples collected by K.B. Ketner (written commun., 1992).

The overlying Nelson Formation, which consists of volcanic rocks, has not been dated by fossils, but its probable latest Meramecian age is determined by its stratigraphic position between the Banner Formation and the overlying Chainman Shale, both of which are dated by fossils. A limestone bed near the base of the Chainman contains fossils of the *Goniatites granosus* cephalopod zone (Mackenzie Gordon, Jr., *in* Little, 1987, p. 8), which corresponds approximately to Mamet Foraminifer Zone 16s (early Chesterian)(Gordon *in* Brew, 1971, p. 43). Fossils from a higher limestone bed in the Chainman, collected from the Mt. Velma 15′ quadrangle by Coats (field locality 58NC56, shipment MD–58–25), include conodonts corresponding to Mamet Foraminifer Zones 17–19 (middle to late Chesterian)(B.R. Wardlaw, written commun., 1984); K.B. Ketner (written commun., 1992) believes that this locality belongs in the Golconda allochthon.

SUMMARY OF GEOLOGIC HISTORY

Data compiled in this study indicate that most of the isolated exposures of Mississippian sedimentary rocks on the west side of the Antler orogen rest on the Roberts Mountains allochthon and are part of a western overlap sequence deposited at the seaward margin of a land area during Mississippian time. These rocks were deposited unconformably on the Valmy Formation (Ordovician) after orogenic uplift in Late Devonian and early Early Mississippian time and were truncated by the Triassic Golconda thrust, which forms the base of the Golconda allochthon. Gravity-flow carbonate deposits of the Goughs Canyon Formation in the Osgood Mountains, which are part of the Triassic Golconda allochthon, are an exception to the rule.

The oldest record of Mississippian sedimentation is in the Goughs Canyon Formation in the Osgood Mountains (area 7), where shallow (<100 m, <300 ft) subtidal carbonate sedimentation began in Early Mississippian time, at least as early as late Kinderhookian (middle Tournaisian), on an island-margin shelf that formed on a basaltic seamount on the continental slope. Evidence of slightly later (Osagean, late Tournaisian) sedimentation is present in three areas: (1) the lower part of an unnamed carbonate unit in the Toiyabe Range (area 5), where a deep-water carbonate gravity-flow deposit betrays the existence of a nearby shallow-shelf carbonate production area; (2) the lower part of the Inskip Formation in the East Range (area 6), where allochthonous carbonate derived from a nearby shallow-water production area is present in a predominantly deep water (>100 m, >300 ft), offshore terrigenous sequence; and (3) in the Grossman Formation in the Mountain City area (area 8), where undated fluvial or nearshore terrigenous sediments may be of Osagean age. The sea may have withdrawn from the Mountain City area after deposition of the Grossman Formation and returned in Late Mississippian (early Meramecian) time, when a second transgression is recorded in shallow-water siliceous clastic sediments that form the lower part of the Banner Formation, followed by shallow-water shelf carbonate deposition in the middle and late Meramecian (based on published data). Most of south-central Nevada (areas 1–4) remained emergent until Late Mississippian (middle to late Meramecian, middle Viséan) time, when transgression produced an extensive shallow-water carbonate shelf.

The total duration of the shallow-water carbonate shelf in south-central Nevada cannot be determined because the Upper Mississippian sequence there is truncated by a pre-Permian erosion surface (areas 1, 2) or by the Triassic Golconda thrust (areas 3–5); biostratigraphic evidence suggests that carbonate sedimentation continued at least into the early Chesterian (late Viséan and early Namurian). In north-central Nevada, truncation by the Golconda thrust also prohibits determination of the total duration of deep-water (>100 m, >300 ft) terrigenous sedimentation represented by the Inskip Formation (area 6) and by predominantly terrigenous sedimentation and volcanic activity represented by the Nelson Formation and Chainman Shale (area 8). Biostratigraphic evidence in the north-central Nevada areas suggests that sedimentation continued at least into late Chesterian (early Namurian) time.

PALEOGEOGRAPHIC SIGNIFICANCE OF CORAL OCCURRENCES

TAXONOMIC COMPOSITION OF CORAL FAUNAS

The central Nevada Mississippian coral faunas are composed of genera and species that belong to the Rugosa and Tabulata, the two major divisions of Paleozoic corals (tables 1–3). The more common forms in each of the three coral zones represented are illustrated in plates 1–4. Rugosan species are much more common than tabulate species in the western Antler faunas, making up 88 percent of Zone IIB, 74 percent of Zone IIID, and 67 percent of Zone IV. Generic distributions of Mississippian rugosans and tabulates are generally more soundly established than species distributions because most of the species have not been studied adequately. Hence, species are not formally defined or described in this study, but similarities to extant species are indicated.

Rugosan genera are generally more useful than tabulate genera for biostratigraphic and biogeographic analysis in the Mississippian because their more complicated morphologies permit finer taxonomic discrimination. Mississippian rugosan genera are strongly endemic; 41 percent of the Mississippian genera are limited to one of the fifteen provinces recognized in the Mississippian, and 25 percent are restricted to two or three provinces (Sando, 1990, table 1). This high degree of endemism makes the Mississippian rugosans very useful for biogeographic fingerprinting.

BIOGEOGRAPHIC AFFINITIES OF CORAL FAUNAS

The central Nevada coral faunas (tables 1–3) show very strong affinities to corals of the same age in the Western Interior Coral Province, which extends from the District of Mackenzie in Canada to southeast California and southern Arizona and occupies the area between the Antler orogen and the Transcontinental arch in the Western United States (Sando and Bamber, 1985, figs. 1, 2). In Coral Zones IIB and IV all the genera are Western Interior forms, and in Zone IIID all the tabulate genera and 75 percent of the rugosan genera are present in the Western Interior. Although none of the Zone IIB genera is unique to the Western Interior, two of the twelve Zone IIID genera and two of the six Zone IV genera are endemic Western Interior forms. Six of the eight species in Zone IIB are similar or identical to Western Interior species, ten of the nineteen Zone IIID species show the same similarity, and five of the six Zone IV species are of Western Interior aspect.

The close similarity of the western Antler corals to the coral faunas east of the Antler orogen prompted Sando and Bamber (1985, fig. 2, explanation; p. 41) to include them in the Western Interior Province. Zone IIID and IV corals in the Milford Group of southwest British Columbia (E.W. Bamber, oral commun., 1991) occupy a paleotectonic position analogous to the western Antler corals. The only other Mississippian corals known from western North America are distinctly different, cosmopolitan faunas in the Pacific Coast Province and Alaska Province of Sando and others (1975, 1977). More recently, I observed Western Interior corals in collections from Chichagof Island (report on shipment A–57–14, 1989), which led me to conclude that the southeastern Alaska area, originally included in the Pacific Coast Coral Province, is actually a seaward extension of the Western Interior Coral Province. At any rate, the western Antler corals have no logical nearby source from the area west of the Antler orogen and most certainly were derived from the Western Interior basin on the east.

PALEOGEOGRAPHIC ANALYSIS

The biogeographic affinities of the western Antler corals require marine connections across the Antler orogen so that the corals could migrate westward from the Antler foreland basin during the time intervals represented by the three Western Interior coral zones. Four lines of evidence (fig. 3) are useful for determining the locations of the marine connections (straits): (1) locations on the Antler orogen where Mississippian rocks were probably never deposited, (2) locations of siliciclastic submarine fans (Poole and Sandberg, 1991, fig. 11) in the Antler foreland basin immediately adjacent to the east side of the Antler orogen, (3) locations of coralliferous habitats in the Antler foreland basin and Cordilleran platform that may have been sources of coral larvae, and (4) probable surface current circulation patterns in the Antler foreland basin controlling migration of coral larvae to the western Antler shelves.

Localities in the Roberts Mountains allochthon east of the coral localities where Mississippian rocks are missing from the stratigraphic record (Langenheim and others, 1973, charts 2, 3) were probable highland areas that were not submerged during the Mississippian. Post-Mississippian terrigenous rocks of the Antler foreland basin do not contain clasts that could be attributed to a pre-existing sheet of Mississippian rocks that covered the orogen. Moreover, many of the postulated highland areas coincide with source areas for the siliciclastic submarine fans (Poole and Sandberg, 1991, fig. 11). The locations of these siliciclastic fans also serve to constrain probable locations for straits across the orogen. The straits must have been between the highland areas and between the siliciclastic fans. The record of sedimentation in the straits was probably removed by post-Mississippian uplift and erosion, although some remnants of the Mississippian sedimentary record may be preserved beneath the cover of younger sediments.

Coralliferous areas from which coral larvae could have migrated during the time intervals represented by Zones IIB, IIID, and IV are common in the Antler foreland basin and on the Cordilleran platform (Sando and Bamber, 1985, fig. 2, p. 32–42). Corals were living mostly in deep-water environments in the Cordilleran basin during earliest Mississippian time (Zone I, Kinderhookian) and became abundant in shallow-water habitats later in the Mississippian (Zone II, Osagean)(Sando, 1980, 1989). During Zone

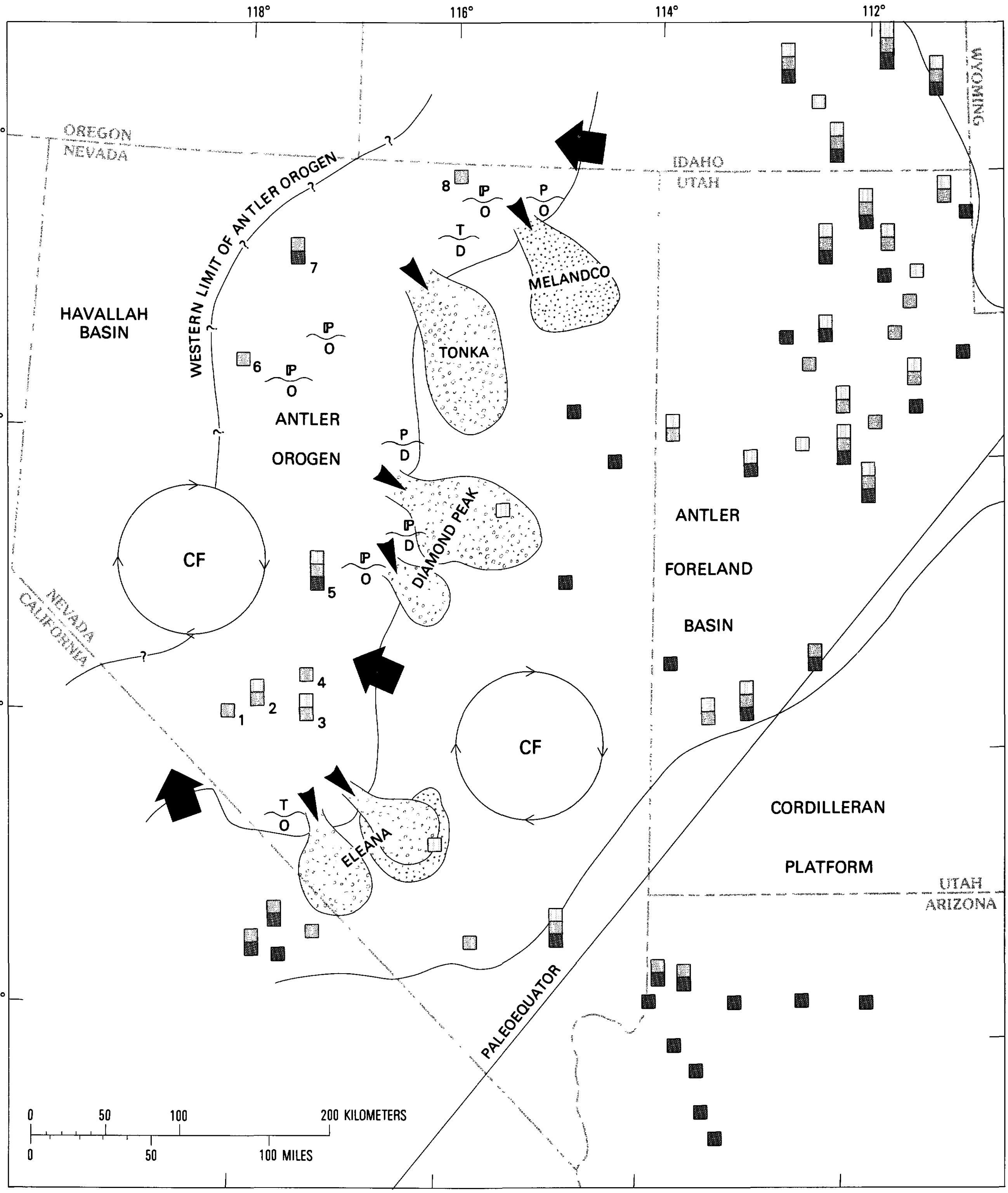


Figure 3 (above and facing column). Nonpalinspastic Mississippian paleogeographic map of Nevada and adjacent States showing evidence bearing on locations of postulated straits across Antler orogen. O, Ordovician strata; IP, Pennsylvanian strata; P, Permian strata; T, Tertiary strata. See text for sources of data.

IIB time they occupied deep-water environments in the Antler foreland basin and shallow-water environments on the Cordilleran shelf (Sando, 1989, fig. 3C). During Zone IIID and Zone IV times, the Antler foreland basin was the locus of shallow-water molasse sedimentation, and coral growth was impeded by terrigenous influx; however, some

EXPLANATION

CORAL OCCURRENCES

Zone IV (late Meramecian)

Zone III D (middle-late Meramecian)

Zone II B (Osagean)

IP / O **Area where Mississippian sediments were never deposited**

Potential location of strait entrance

SILICICLASTIC SUBMARINE-FAN SYSTEMS

Molasse basin

Flysch basin

Transport direction

CF **CORIOLIS-FORCE DIAGRAM**—Paleocurrent circulation

corals were living on small carbonate shelves within the foreland basin, and corals were abundant on the vast Cordilleran shelf to the east (Sando, 1989, figs. 3F, G).

Migration of corals is accomplished principally in the larval stage in surface waters of the sea. Distribution patterns are controlled mainly by currents. The maximum two-month swimming time of the larval stage permits migration over significant distances, particularly if favorable conditions prevail for a long time (Sando, 1984a, p. 439). Approximate migration rates of 1,200–7,600 km/m.y. for 11 groups of Mississippian corals were calculated by Sando (1990, p. 180, 181). The approximate amount of time needed for the Antler corals to migrate from eastern sources to the western Antler shelves can be calculated by applying Sando's (1990) range in migration rates to the distances between the western Antler shelves and possible coral sources (table 5). These calculations range from 0.05 to 0.55 m.y., which is well within the constraints of zonal durations of 2–4.5 m.y. for the three coral zones. The short migration times in relation to zonal durations would also account for the great similarity between the western Antler coral assemblages and Western Interior assemblages from which they are presumed to have been derived.

Surface-water circulation patterns are driven in a clockwise direction in the Northern Hemisphere by the Coriolis force. In a large basin, the general Coriolis pattern is broken up into a number of circulation cells by islands and shallow-bottom areas. In the paleogeographic reconstructions that follow, hypothetical surface-water circulation patterns, derived from the interaction of Coriolis force and topography, are used to test the validity of the coral migration hypothesis.

PALEOGEOGRAPHIC HISTORY

Nonpalinspastic paleogeographic maps (figs. 4–6) for time intervals corresponding to the three coral zones represented on the west side of the Antler orogen are modified from Sando (1989, figs. 3C, F, G) to include new data compiled in this study. The three time intervals coincide with bursts of coral abundance and diversity throughout the Western Interior region of the United States (fig. 7)(see also Sando, 1989). Possible migration paths from eastern sources to western Antler coral areas can be inferred from hypothetical circulation patterns.

CORAL ZONE IIB (OSAGEAN, LATE TOURNAISIAN)(FIG. 4)

Coral Zone IIB marks the greatest burst of shallow-water coral abundance and diversity in the Carboniferous of the Western Interior United States. A major transgression associated with a rise in regional relative sea level expanded optimum coral habitats and facilitated genetic change by evolution of indigenous corals and by influx of exotic elements (internal and external genetic communication of Sando, 1989). Corals were abundant in shallow-water habitats on an expanded Cordilleran shelf and in deep water in the Antler foreland basin.

The Antler orogen was occupied by an island chain that formed the continental margin across central Nevada into northeastern Nevada and southwestern Idaho. The topography of the Antler islands ranged from low hills to high mountains. An apron of terrigenous detritus, including two submarine siliciclastic fans, around the east side of the Antler island chain prohibited carbonate production in that area, but a carbonate shelf was developed in shallow water along the west side of a large island that occupied much of north-central Nevada. A smaller island-margin carbonate shelf was developed on a basaltic seamount on the continental slope northwest of the main island, where influx of terrigenous detritus, derived from the main island, dominated sedimentation. Surface-water currents carried coral larvae from the Cordilleran shelf westward across the Antler foreland basin and through shallow straits separating the main Antler island from smaller islands on the north and south.

CORAL ZONE IIID (MIDDLE TO LATE MERAMECIAN, MIDDLE VISÉAN) (FIG. 5)

Coral Zones IIID and IV together mark a second major burst in abundance and diversity in the Western Interior Carboniferous coral succession (fig. 7). In contrast to the earlier burst, this phenomenon coincided with a lowering of relative regional sea level, reduction in the

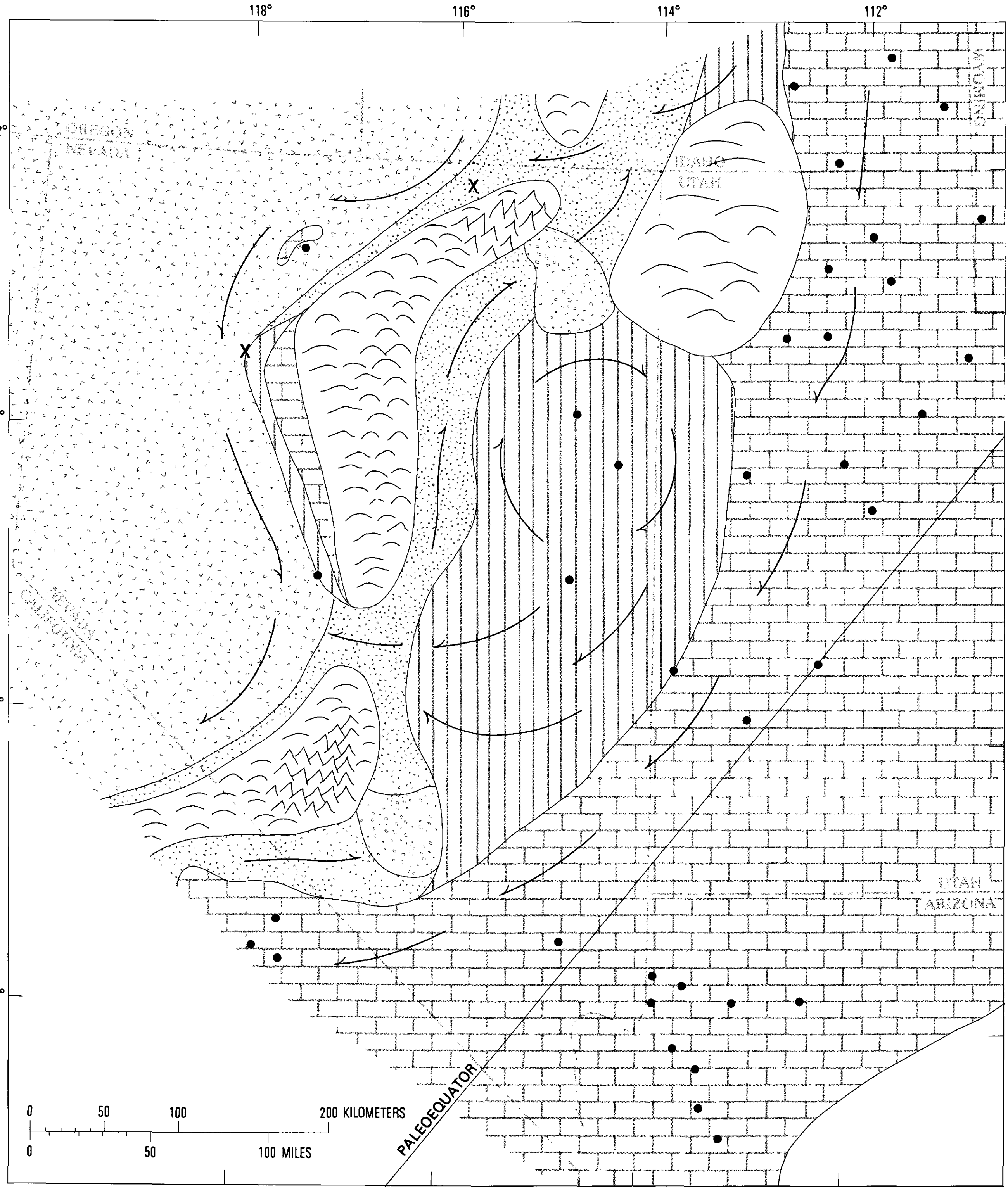
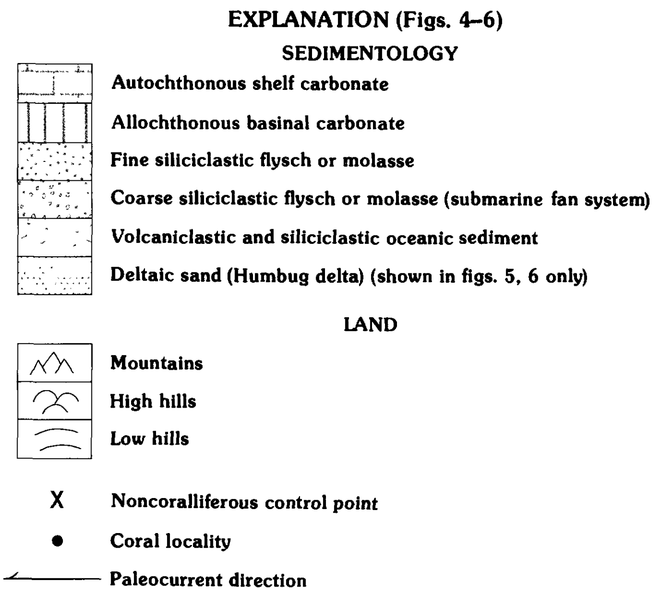


Figure 4 (above and facing column). Nonpalinspastic paleogeographic map of Nevada and adjacent States during Coral Zone IIB (Osagean, late Tournaisian) time showing postulated straits across Antler orogen, inferred paleocurrent circulation, and occurrences of corals. Modified from Sando (1989, fig. 3C).



area of optimum shallow-water coral habitats, increase in terrigenous influx, and poorer internal and external genetic communication (Sando, 1989). During Zone IIID time, the mountainous areas on the Antler island chain were expanded by uplift, doubling the number of siliciclastic submarine fans and flooding the foreland basin with molasse, but the carbonate shelf on the west side of the main island also expanded, and another shelf was developed along the west side of the northern island. The island-margin shelf northwest of the main island continued to contribute gravity-flow carbonate sediments to the deep-water terrigenous sediments of the continental slope. Although coral sources in the foreland basin and on the Cordilleran shelf were much reduced in number, the main surface-water current circulation patterns were maintained, and corals were even more successful than before in populating the western Antler shelves.

CORAL ZONE IV (LATEST MERAMECIAN, LATE VISÉAN)(FIG. 6)

During Zone IV time, continued uplift in the Antler island chain caused expansion of the mountainous areas and terrigenous flooding of the northern parts of the marginal carbonate shelf on the west side of the island chain. Coral habitats were restricted to two small carbonate shelves adjacent to the southern strait that provided a migration path for the corals. By this time, a major carbonate factory, containing many coral habitats, had pushed into the Antler foreland basin from the north and provided a source for coral larvae, and a few small island shelves were developed in the southern part of the molasse basin.

POST-CORAL ZONE IV (CHESTERIAN, LATEST VISÉAN AND EARLY NAMURIAN) (FIG. 2)

The loss of sedimentary record by erosion and structural truncation in the southern part of the Antler island

Table 5. Approximate distances and times for coral migrations from eastern sources on Cordilleran platform and Antler foreland basin to western Antler coralliferous areas.
[See text for sources of data]

Coral zone	Duration of zone (m.y.)	Antler area	Location of eastern source	Distance (km)		Migration time(m.y.)	
				Uncorrected	Corrected	Minimum	Maximum
IIB	4.5	4	Western Utah, shelf margin	240	490	0.07	0.41
		7	Southeast Idaho, shelf margin	345	595	0.08	0.50
IIID	2.0	1	Southeast Nevada, foreland basin	325	575	0.08	0.48
		2	Southeast Nevada, foreland basin	300	550	0.07	0.46
		3	Southeast Nevada, foreland basin	270	520	0.07	0.43
		4	Southeast Nevada, foreland basin	270	520	0.07	0.43
		5	Southeast Nevada, foreland basin	330	580	0.08	0.48
		6	Western Utah, foreland basin	410	660	0.09	0.55
		7	Western Utah, foreland basin	330	580	0.08	0.48
		8	Western Utah, foreland basin	220	470	0.06	0.39
IV	2.5	2	Southeast Nevada, foreland basin	170	420	0.06	0.35
		3	Southeast Nevada, foreland basin	140	390	0.05	0.33
		5	Southeast Nevada, foreland basin	200	450	0.06	0.38

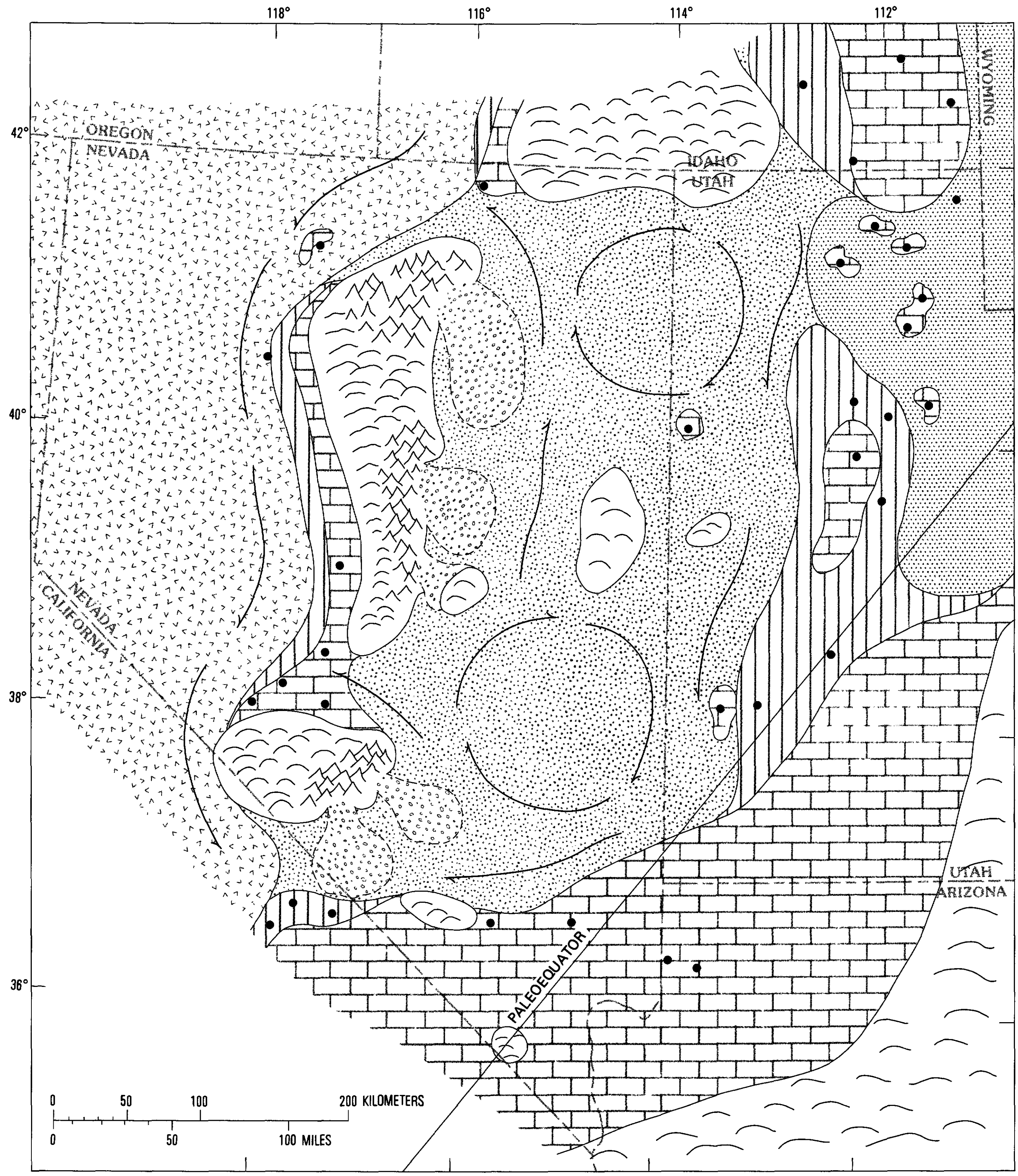


Figure 5. Nonpalinspastic paleogeographic map of Nevada and adjacent States during Coral Zone IIID (middle to late Meramecian, middle Viséan) time. See explanation of figure 4 for additional information. Modified from Sando (1989, fig. 3F).

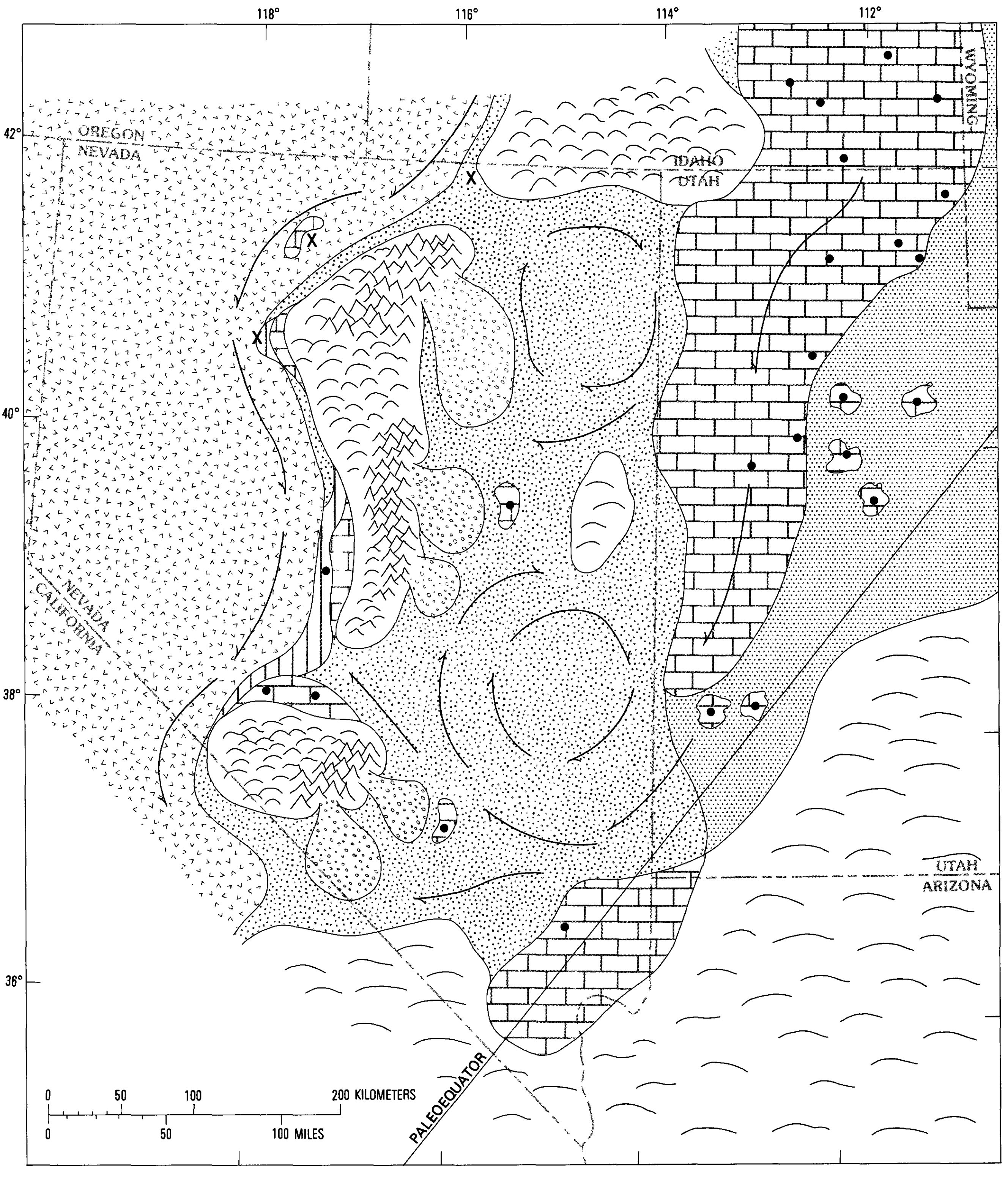


Figure 6. Nonpalinspastic paleogeographic map of Nevada and adjacent States during Coral Zone IV (latest Meramecian, late Viséan) time. See explanation of figure 4 for additional information. Modified from Sando (1989, fig. 3G).

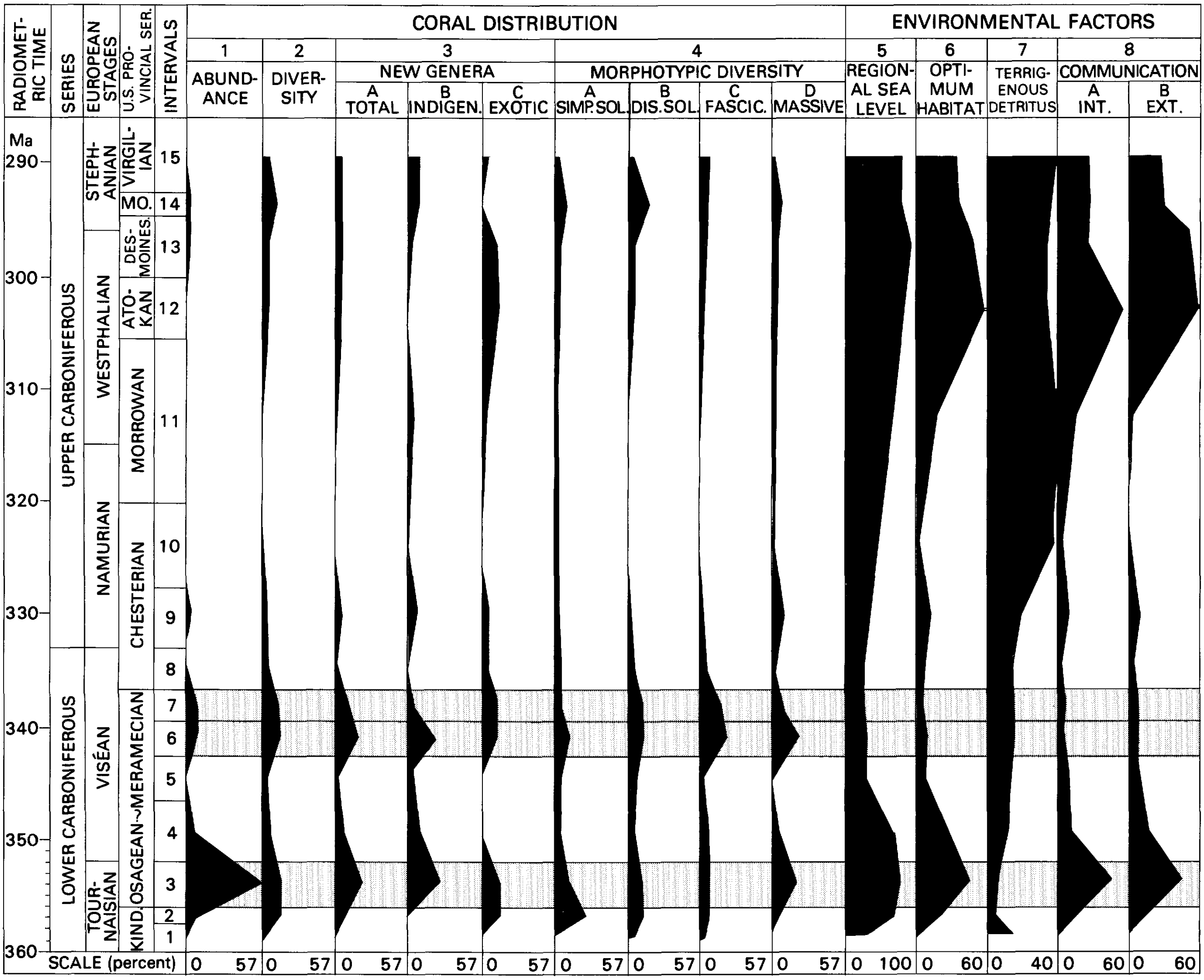


Figure 7. Quantitative variations in various aspects of shallow-water coral distribution and environmental factors that affected these corals in the Western Interior basin of the United States during the Carboniferous. Shading marks time intervals represented by the western Antler coral occurrences. Modified from Sando (1989, fig. 11).

chain and by structural truncation in the northern part prohibits a complete analysis of Chesterian history. What remains of the record in the northern shelves indicates that terrigenous sedimentation greatly reduced carbonate production and prohibited coral growth in that area during the Chesterian and possibly into the Pennsylvanian. Although limestone beds are present in the upper part of the Goughs Canyon Formation, indicating that the island-margin shelf still existed in area 7, no corals have been found in them. The presence of limestone beds above the highest Zone IV corals in area 3 of the southern shelf area suggests that carbonate production continued well into the Chesterian throughout that area, but no evidence has been found for continued coral habitation. A cooler climate may have been a factor in the absence of corals.

LOCALITY REGISTER

All collections are located at the USNM Center of the Paleontology and Stratigraphy Branch of the U.S. Geological Survey, National Museum of Natural History, Washington, D.C. Collection numbers refer to the Upper Paleozoic locality file (–PC) at the same facility. Internal USGS reports on fossils cited are on file with the Paleontology and Stratigraphy Branch. All localities are in Nevada. Locations of areas 1–8 are shown on figure 1.

AREA 1—CANDELARIA HILLS, ESMERALDA COUNTY

5165: Unnamed carbonate unit, mapped as Permian by Ferguson and Muller (1949, pl. 1). Candelaria-Tonopah road, near BM 4829, Tonopah 1° quadrangle (probably in N½ sec. 8, T. 3 N., R. 36 E., Rock Hill 7.5′ quadrangle). 29 coral specimens in dolomite matrix collected by H.G. Ferguson in 1922 and dated Permian by G.H. Girty in 1923.

24772: Same unit as 5165, mapped as Permian by Ferguson and Muller (1949, pl. 1) and as Diablo Formation (Permian) by Ferguson and others (1953). NW¼SE¼ sec. 8, T. 3 N., R. 36 E., Rock Hill 7.5′ quadrangle. 14 coral specimens in dolomite matrix collected by F.G. Poole in 1970 and dated Late Mississippian (Meramecian) by Sando in 1972 (report on shipment RMM–72–3)

25007: Same unit and area as 24772 but from NW¼ sec. 8, T. 3 N., R. 36 E. 16 coral specimens in dolomite matrix collected by F.G. Poole in 1973 and dated Late Mississippian (Meramecian) by Sando in 1975 (report on shipment CMR–74–3).

25583: Same unit as 24772, 125–130 ft (39–40 m) above base. East side of ridge 1 mi (1.6 km) north of Columbus townsite in SW¼ sec. 7, T. 3 N., R. 36 E., Columbus 7.5′ quadrangle. 6 coral specimens in limestone matrix collected by F.G. Poole in 1974 and dated Late Mississippian by Sando in 1975 (report on shipment CMR–74–5).

25584: Same unit and location as 25583 but 195–205 ft (60–63 m) above base of unit. 8 coral specimens in limestone matrix. Collection data same as 25583.

25585: Same unit and location as 25583 but 285–290 ft (87–89 m) above base of unit. 2 coral specimens in limestone matrix. Collection data same as 25583.

26250: Same unit and area as 24772 but 200–275 ft (61–84 m) above base of unit 325 ft (100 m) thick on hill about 0.9 mi (1.4 km) north of Gates Mill in NE¼ sec. 8, T. 3 N., R. 36 E. 95 coral specimens in dolomite matrix collected by F.G. Poole in 1975 and dated Late Mississippian (Meramecian) by Sando in 1976 (report on shipment CMR–76–1).

AREA 2—MONTE CRISTO RANGE, ESMERALDA COUNTY

28065: Unnamed carbonate unit, mapped as Permian by Ferguson and Muller (1949, pl. 1) and as Diablo Formation (Permian) by Ferguson and others (1953). Lat 38°11′36″ N., long 117°47′48″ W., Coaldale NE 7.5′ quadrangle. 12 coral specimens in dolomite matrix collected by F.G. Poole in 1976 and dated Mississippian (late Meramecian) by Sando in 1981 (report on shipment CMR–81–8).

28066; Same unit and area as 28065 but from lat 38°10′02″ N., long 117°47′53″ W. 46 coral specimens in dolomite matrix. Collection data same as 28065.

28067: Same unit and area as 28065 but from lat 38°06′30″ N., long 117°50′47″ W. 1 coral specimen in dolomite matrix collected by F.G. Poole in 1976 and dated Mississippian by Sando in 1981 (same shipment as 28065).

AREA 3—SOUTH SAN ANTONIO MOUNTAINS, NYE COUNTY

14214: Unnamed carbonate unit, mapped as Devonian by Ferguson and Muller (1949, pl. 1), about 200 ft (60 m) above base. Approximately 8 mi (12.8 km) north of Tonopah (probably in N½ sec. 23 or 24, T. 4 N., R. 42 E.), Tonopah 15′ quadrangle. 5 coral specimens in limestone matrix collected by H.G. Ferguson in 1951 and dated Carboniferous by H.M. Duncan in 1951 (report on shipment MD–51–19).

14215: Same unit and area as 14214 but from hill 2.25 mi (3.6 km) north of USLM 206. 4 coral specimens in limestone matrix collected by H.G. Ferguson and dated Devonian by Edwin Kirk in 1922 and as probably Mississippian by H.M. Duncan in 1953.

14216: Same unit and area as 14214 but 2.25 mi (3.6 km) N. 16° W. from USLM 206. 22 coral specimens in limestone matrix. Collection data same as 14215.

14666: Same unit and area as 14214 but 8.5 mi (13.6 km) north of Tonopah. 21 coral specimens in limestone matrix collected by H.G. Ferguson in 1963 and dated early Late Mississippian by H.M. Duncan in 1964 (report on shipment SW–63–2)(see Bonham and Garside, 1979, p. 17).

19778: Same unit and area as 14214 but approximately 10 mi (16 km) north of Tonopah, 34,000 ft N. 39° W. of pumping station located 6.5 mi (10.4 km) northeast of Tonopah (probably in sec. 13, T. 4 N., R. 42 E.). 5 coral specimens in limestone matrix collected by F.J. Kleinhampl in 1962 and dated Late Mississippian by H.M. Duncan in 1963 (report on shipment SW–63–2)(see Bonham and Garside, 1979, p. 17).

24450: Same unit and area as 14214 but on prominent ridge approximately 9 mi (14.4 km) north of Tonopah, near common boundary for secs. 13, 14, 23, and 24, T. 4 N., R. 42 E. 5 coral specimens in limestone matrix collected by F.G. Poole in 1967 and dated Late Mississippian (late Meramecian or Chesterian) by Sando in 1971 (report on shipment HM–67–12).

24451: Same unit and location as 24450. 11 coral specimens in limestone matrix. Collection data same as 24450 but dated Late Mississippian(?).

24944: Same unit and area as 14214 but on hill between SW¼ sec. 13 and SE¼ sec. 14, T. 4 N., R. 42 E. 2 coral specimens in limestone matrix collected by F.G. Poole in 1968 and dated Late Mississippian (Meramecian) by Sando in 1972 (report on shipment RMM–69–9).

26252: Same unit and area as 14214 but from lower part of unit 900 ft (275 m) thick on south side of ridge about 0.25 mi (0.4 km) east of Rays townsite, lat 38°11′52″ N., long 117°13′50″W., T. 4 N., R. 42 E., Tonopah 15′ quadrangle. 15 coral specimens in limestone matrix collected by F.G. Poole in 1975 and dated Late Mississippian by Sando in 1976 (report on shipment CMR–76–1).

26253: Same unit and area as 14214 but from float almost in place from middle part of unit on south side of large hill about 1 mi (1.6 km) east-southeast of Rays townsite at lat 38°11′41″ N., long 117°13′06″ W. 5 coral specimens in limestone matrix. Collection data same as 26252.

26254: Same unit and area as 14214 but from middle part of unit at lat 38°11′40″ N., long 117°13′09″ W. 36 coral specimens in limestone matrix. Collection data same as 26252 but dated Late Mississippian or younger.

26255: Same unit and area as 14214 but 410–460 ft (125–140 m) above base of unit at lat 38°11′37″ N., long 117°13′11″ W. 30 coral specimens in limestone matrix. Collection data same as 26252 but dated Late Mississippian (latest Meramecian).

26256: Same unit and area as 14214 but 470–500 ft (142–150 m) above base of unit at lat 38°11′36″ N., long 117°13′16″ W. 15 coral specimens in limestone matrix. Collection data same as 26255.

AREA 4—NORTH SAN ANTONIO MOUNTAINS, NYE COUNTY

26248: Unnamed carbonate unit 50 ft (15 m) thick, mapped as Permian by Ferguson and Muller (1949, pl. 1). West side of hill 6578, NW1/4 sec. 32, T. 6 N., R. 42 E. 25 coral specimens in limestone matrix collected by F.G. Poole in 1975 and dated Late Mississippian (probably Meramecian) by Sando in 1976 (report on shipment CMR–76–1)

26249: Same unit and location as 26248. 15 coral specimens in limestone matrix. Collection data same as 26248.

AREA 5—TOIYABE RANGE, NYE COUNTY

25579: Unnamed carbonate unit. Spur extending west-northwest from peak 9885 in uppermost part of Tierney Creek drainage in SE1/4 sec. 28, T. 14 N., R. 42 E., North Shoshone Peak 15′ quadrangle. 9 coral specimens in limestone matrix collected by F.G. Poole in 1974 and dated Mississippian (probably Early Mississippian) by Sando in 1975 (report on shipment CMR–74–5).

25580: Same unit and location as 25579 but from lower part of unit. 6 coral specimens in limestone matrix. Same collection data as 25579.

25581: Same unit and location as 25579. 11 coral specimens in limestone matrix. Same collection data as 25579.

26251: Same unit and location as 25579 but from 170–180 ft (52–55 m) above base of unit 200 ft (62 m) thick. 40 coral specimens in limestone matrix collected by F.G. Poole in 1975 and dated Late Mississippian (late Meramecian) by Sando in 1976 (report on shipment CMR–76–1).

AREA 6—EAST RANGE, PERSHING COUNTY

16459: Inskip Formation, limestone lens in graywacke and volcanic sequence in lower half of formation. Approximately 1 mi (1.6 km) from mouth of Reed Canyon, T. 31 N., R. 36 E., Dun Glen 15′ quadrangle. 15 coral specimens in limestone matrix collected by R.J. Roberts in 1956 and dated Mississippian by H.M. Duncan in 1957 (memorandum on shipment MD–51–64)(see Roberts and others, 1958, p. 2847).

AREA 7—OSGOOD MOUNTAINS, HUMBOLDT COUNTY

12108: Goughs Canyon Formation, limestone bed in graywacke and volcanic sequence. East Fork, near intersection with Cherry Creek, west side of Osgood Mountains, near Getchell Mine, SW1/4 sec. 11, T. 38 N., R. 41 E., Adam Peak 7.5′ quadrangle. 9 coral specimens in limestone matrix collected by R.J. Roberts in 1950(?) and dated Mississippian(?) by H.M Duncan in 1950 (report on shipment MD–50–13).

14026: Same unit and area as 12108 but on bank north of main stream of Cherry Creek in NW1/4NW1/4 sec. 27, T. 38 N., R. 41 E. 27 coral specimens in limestone matrix collected by P.E. Hotz in 1952 and dated Mississippian by H.M. Duncan in 1952 and 1953 (reports on shipments MD–52–18 and MD–52–23). Brachiopods in same collection were dated early Osagean by Mackenzie Gordon, Jr., in 1961 (see Hotz and Willden, 1964, p. 26, 27).

14027: Same unit and area as 12108 but from SW1/4NW1/4 sec. 22, T. 38 N., R. 41 E. 2 coral specimens in limestone matrix. Collection data same as 14026.

14029: Same unit and area as 12108 but from southwest corner SE1/4SE1/4 sec. 28, T. 38 N., R. 41 E. 3 coral specimens in limestone matrix. Collection data same as 14026 (see Hotz and Willden, 1964, p. 27).

19807: Same unit and location as 12108. 50 coral specimens collected by P.E. Hotz and R.J. Roberts in 1951 and dated Late Mississippian by H.M. Duncan in 1952 (report on shipment MD–51–26)(see Hotz and Willden, 1964, p. 26).

19808: Same unit and area as 14026 but from center of SW1/4 sec. 11. 8 coral specimens in limestone matrix. Same collection data as 19807 (see Hotz and Willden, 1964, p. 26).

38080: Same unit and area as 12108 but from SW¼SW¼ sec. 11. One coral specimen in limestone matrix collected by L.B. McCollum in 1991 and dated Late Mississippian (middle Meramecian) by Sando in 1991 (letter to McCollum).

38081: Same unit and location as 38080. 1 coral specimen in limestone matrix. Same collection data as 38080.

38082: Same unit and area as 38080 but from NW¼SW¼ sec. 11. 7 coral specimens in limestone matrix. Same collection data as 38080.

38083: Same unit and area as 38080 but from NE¼NW¼ sec. 12. One coral specimen in limestone matrix. Same collection data as 38080.

38084: Same unit and location as 38083. 200 coral specimens in limestone matrix. Same collection data as 38080.

AREA 8—MOUNTAIN CITY DISTRICT, ELKO COUNTY

15384: Banner Formation. Mountain City, Mountain City 15′ quadrangle. 9 coral specimens in limestone matrix collected by T.B. Nolan in 1932 and dated Late Mississippian(?) by G.H. Girty in 1932 and Permian(?) by H.M. Duncan in 1955 (memorandum to Nolan and Ferguson).

16093: Same unit as 15384. Mill Creek, south of Mountain City, above Nelson ranch in SE¼ sec. 3, T. 45 N., R. 53 E., Mountain City 15′ quadrangle. 17 coral specimens in limestone matrix collected by J.R. Coash in 1955 and dated Mississippian(?) by H.M. Duncan in 1958 (letter to Coash on shipment O–56–41)

17659: Banner Formation(?). Same area as 16093 but at coordinates N2,568,100 and E363,800. 8 coral specimens in limestone matrix collected by R.R. Coats in 1957. No previous dating.

17662: Same unit and area as 16093 but near quarter corner secs. 2 and 11, T. 45 N., R. 53 E. 70 coral specimens in limestone matrix collected by R.R. Coats in 1957 and dated Late Mississippian in 1960 by H.M. Duncan (report on shipment MD–57–38). Also dated Late Mississippian (middle and late Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 1).

19526: Same unit and area as 16093 but coordinates N2,573,700 and E38,300, Owyhee 7.5′ quadrangle. 2 coral specimens in limestone matrix collected by R.R. Coats in 1959 and dated Late Mississippian by H.M. Duncan in 1960 (report on shipment MD–59–25). Also dated Late Mississippian (Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 1)

19527: Same unit and area as 19526 but at station 138 of Coats (exact location unstated). 13 coral specimens in limestone matrix. Same collection data as 19526. Also dated Late Mississippian (middle or late Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 1)

19528: Same unit and area as 19526 but 200 ft (62 m) south of station 138 of Coats. 1 coral specimen in limestone matrix. Same collection data as 19526. Also dated Late Mississippian (middle or late Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 2).

21588: Same unit and area as 16093 but from SW¼SE¼SW¼ sec. 8, T. 46 N., R. 55 E., 0.55 mi (0.9 km) southeast of Enright Hill on 7300' contour and N. 45° W. of "2" in 7250' contour, downslope from small hill and trail cutting across south side and 0.05 mi (0.08 km) below trail. 14 coral specimens in limestone matrix collected by R.R. Coats in 1962 and dated Late Mississippian (probably Meramecian) by Sando in 1971 (report on shipment SW–62–23) and Late Mississippian (middle Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 2).

22813: Same unit and area as 16093 but from north slope of Mill Creek opposite and northwest of Idaho-Nevada mine shaft, 100–150 ft (30–46 m) above valley floor in NW¼NE¼ sec. 9, T. 45 N., R. 53 E. 50 coral specimens in limestone matrix collected by R.R. Coats, Mackenzie Gordon, Jr., and Donald Dean in 1964 and dated Late Mississippian (probably Meramecian) by H.M. Duncan in 1967. Also dated Late Mississippian (middle Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 2).

28314: Same unit and area as 16093 but from sec. 17, T. 46 N., R. 55 E. 1 coral specimen in limestone matrix collected by R.R. Coats in 1981 and dated Late Mississippian (early Meramecian) by Sando in 1982 (report on shipment WMR–82–1). Also dated Late Mississippian (early Meramecian) by Sando (*in* Little, 1987, Appendix A, p. 3).

NOTE

After this report had been submitted for publication, M.B. McCollum called to my attention two publications by S.A. Shaver (1987, 1991) in which Devonian corals are reported from area 4 (North San Antonio Mountains). These corals were collected by Shaver from limestone outcrops in sec. 32, T. 6 N., R. 42 E., Nye County, which is essentially the same location as USGS localities 26248–PC and 26249–PC, from which I identified corals of Late Mississippian (Zone IIID) age. The corals were identified as probably of middle Early Devonian age by W.A. Oliver, Jr. (U.S. Geological Survey, Washington, D.C.), and the rocks were assigned to the Nevada Formation by Shaver.

I studied the thin sections of fragmentary solitary and colonial(?) corals that formed the basis for Oliver's age diagnosis and identified *Faberophyllum* sp. and undetermined fragments that may belong to *Siphonodendron*, from which I conclude that the beds regarded as Devonian are actually of Late Mississippian (Zone IV) age and belong to the unnamed carbonate unit of Poole. Hence, the limestone sequence in area 4 probably ranges from

Zone 111D into Zone 1V. 1 discussed this matter with Oliver, and he concurs with my revision of his identification and age assignment.

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APPENDIX—FORAMINIFERA AND ALGAE

By B.L. Mamet (Université de Montréal, Quebec, Canada)

CANDELARIA HILLS (AREA 1)

LOCALITY 25584

Microfacies: Recrystallized crinoid wackestone containing large sponge megascleres.
Biota:
- *Earlandia vulgaris* (Rauzer and Reitlinger)
- *Endothyra* sp.
- *Eoendothyranopsis scitula* (Toomey)
- *Eoendothyranopsis* of the group *scitula* (Toomey)
- *Globoendothyra* sp.
- *Priscella* sp.
- *Tetrataxis* sp.

Age: MFZ 13–14 (late middle to early late Viséan).

SOUTH SAN ANTONIO MOUNTAINS (AREA 3)

LOCALITY 24944

Microfacies: Crinoidal packstone.
Biota:
- *Brunsia* sp.
- *Earlandia* sp.
- *Eoendothyranopsis* sp.
- *Eoendothyranopsis ermakiensis* (Lebedeva)
- *Eotuberitina* sp.
- *Globoendothyra* sp.
- *Mametella* sp.
- *Paracaligelloides* sp.
- *Pseudotaxis* sp.
- *Skippella* sp.
- *Tetrataxis* sp.

Age: MFZ 13–14, most probably 14 (early late Viséan).

LOCALITY 26252

Microfacies: Very recrystallized crinoidal packstone containing brachiopods and corals.
Biota:
- *Earlandia* sp.
- *Endothyra* sp.
- *Endothyranella* sp.
- *Eoendothyranopsis scitula* (Toomey)
- *Mametella* sp.
- *Priscella* sp.

Age: MFZ 13–14 (late middle to early late Viséan).

LOCALITY 26253

Microfacies: Very recrystallized crinoidal packstone containing corals.
Biota:
- *Earlandia* sp.
- *Endothyra* sp.
- *Priscella* sp.
- *Tetrataxis* sp.

Age: Sample too poor for precise zonation.

LOCALITY 26254

Microfacies: Recrystallized, chertified, fuzzy crinoid wackestone containing large sponge megascleres.
Biota:
- *Earlandia vulgaris* (Rauzer and Reitlinger)
- *Endothyra* sp.
- *Eoendothyranopsis* of the group *E. ermakiensis* (Lebedeva)
- *Globoendothyra* of the group *G. tomiliensis* (Lebedeva)
- *Pseudotaxis* sp.
- *Tetrataxis* sp.

Age: MFZ 13–14 (late middle to early late Viséan).

LOCALITY 26255

Microfacies: Recrystallized coral-brachiopod-crinoid packstone.
Biota:
- cf. *Asphaltina*? sp.
- *Endothyra* sp.
- Two-layered Palaeotextulariidae
- *Tetrataxis angusta* Vissarionova

Age: Sample too poor for precise zonation. Two-layered Palaeotextulariidae occur for the first time in MFZ 15, but they range much higher. The sample is MFZ 15 or younger.

LOCALITY 26256

Microfacies: Reworked clasts in crinoid-bryozoan packstone containing brachiopod spines(?).
Biota:
- *Endothyra* sp.
- *Globoendothyra* sp.
- *Pseudotaxis* sp.
- *Tetrataxis angusta* Vissarionova

Age: Sample is similar to 26255, but it is too poor for precise zonation.

TOIYABE RANGE (AREA 5)

LOCALITY 25580

Microfacies: Recrystallized fossil packstone or pseudograinstone containing bryozoans and echinoderm fragments.
Biota:
- *Earlandia vulgaris* (Rauzer and Reitlinger)
- *Endothyra* of the group *E. bowmani* Phillips *in* Brown *emend.* Brady
- *Eoendothyranopsis scitula* (Toomey)
- *Eoendothyranopsis* of the group *E. scitula* (Toomey)
- *Globoendothyra* sp.
- *Globoendothyra* of the group *G. tomiliensis* (Lebedeva)
- *Priscella* sp.
- *Pseudoammodiscus* sp.
- *Tetrataxis* sp.

Age: MFZ 13–14 (late middle to early late Viséan). Similar to 25584 and 26252.

LOCALITY 25581

Microfacies: Sandy, crinoidal, recrystallized pseudograinstone containing angular quartz grains, reworked bryozoan bioclasts, and reworked algal nodules (some with *Girvanella*, others with *Sphaerocodium*). Probably a gravity-flow deposit.
Biota (all reworked)
- *Asphaltina* sp.
- *Latiendothyra* sp.
- *Septabrunsiina* sp.
- *Septaglomospiranella* sp.
- Solenoporid nodules

Age: This is a mixed assemblage of Devonian(?) to Tournaisian age. *Sphaerocodium* is abundant in the Devonian up to the Frasnian but is extremely rare in the Carboniferous.

LOCALITY 26251

Microfacies: Crinoid-bryozoan packstone.
Biota
- *Earlandia vulgaris* (Rauzer and Reitlinger)
- *Endothyra* of the group *E. bowmani* Phillips *in* Brown *emend.* Brady
- *Eoendothyranopsis* sp.
- *Eoendothyranopsis donica* Brazhnikova and Rostoveeva
- *Eoendothyranopsis* of the group *E. ermakiensis* (Lebedeva)
- *Eoendothyranopsis* cf. *E. robusta* (McKay and Green)
- *Globoendothyra* sp.
- *Priscella* sp.
- *Tetrataxis* sp.

Age: MFZ 15 (middle late Viséan).

OSGOOD MOUNTAINS (AREA 7)

LOCALITY 14027

Microfacies: Hematite-stained crinoidal packstone containing fish plates, altered volcanic fragments, and pebbles of fuzzy recrystallized crinoidal wackestone containing bryozoans and sponge spicules. This could be a gravity-flow deposit.
Biota:
- *Earlandia vulagaris* (Rauzer and Reitlinger)
- *Endothyra* sp.
- *Eoendothyranopsis* sp.
- *Epistacheoides* sp.
- *Mametella* sp.
- *Tetrataxis* sp.

Age: Sample is too poor for precise zonation and is extensively reworked. It is at least partly late Meramecian.

GENERAL COMMENT ON THE ECOLOGY AND BIOGEOGRAPHY OF THE MICROFOSSILS

The middle to late Meramecian samples (all but 25581), which contain abundant crinoid and bryozoan remains, have a less diversified microfauna and microflora than most coeval strata on the Cordilleran platform east of the Antler orogen. Although the biota of the Antler samples is typically North American in aspect and contains no exotic elements, the Antler biofacies suggests somewhat deeper (30–40 m, 100–130 ft) or cooler water than normally indicated by other Western Interior shallow-water biofacies.

PLATES 1–4

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

PLATE 1

[All figures ×4]

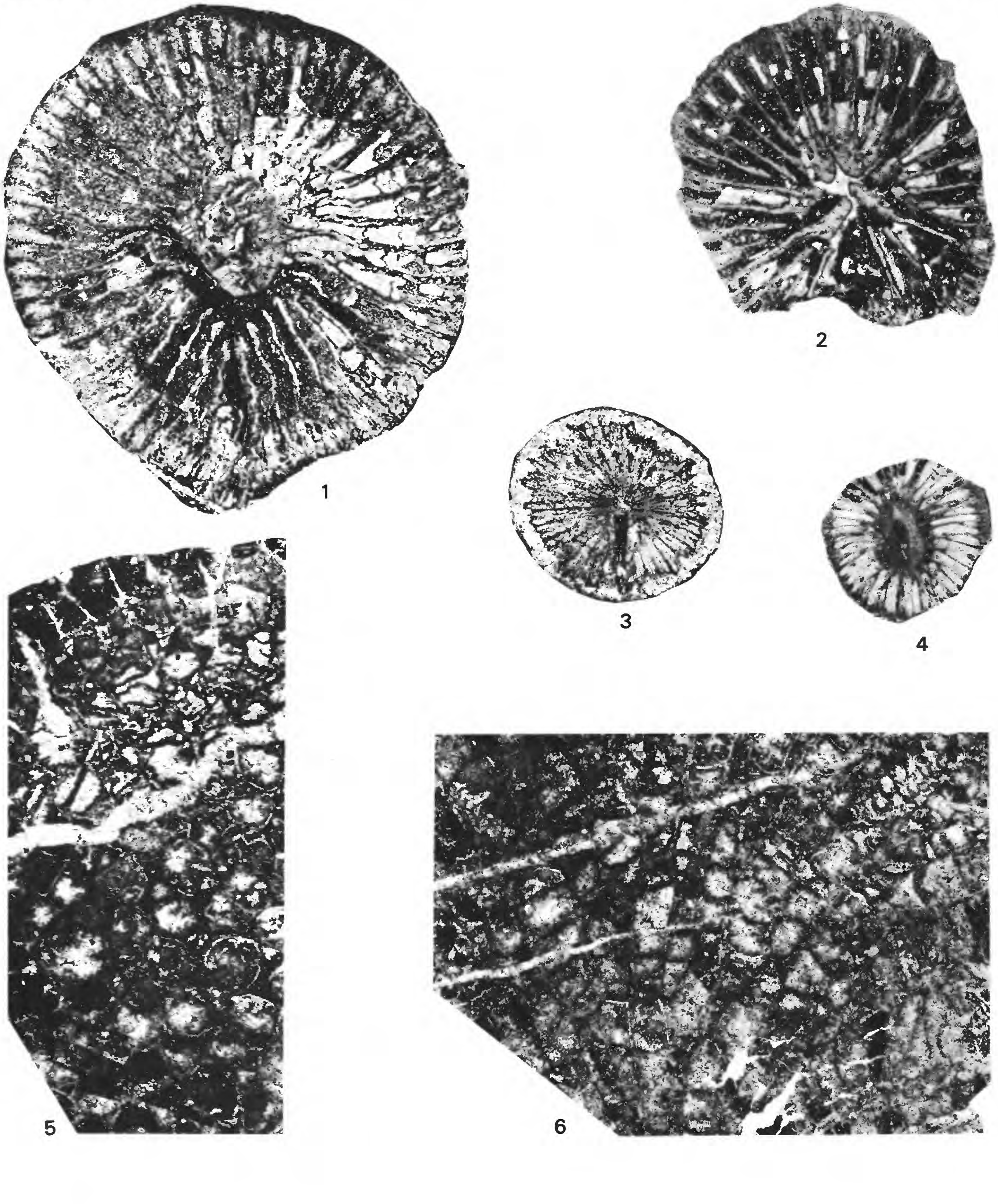
Figure 1. *Lophophyllum*? sp. Transverse thin section, USNM 469351, from USGS locality 14206–PC. Unnamed carbonate unit, area 7.

2. *Ufimia* sp. Transverse thin section, USNM 469352, from USGS locality 14026–PC. Unnamed carbonate unit, area 7.

3. *Sychnoelasma* cf. *S. ulrichanum* (Girty). Transverse thin section, USNM 469353, from USGS locality 25581–PC. Unnamed carbonate unit, area 5.

4. *Cyathaxonia* sp. Transverse thin section, USNM 469354, from USGS locality 14026–PC. Unnamed carbonate unit, area 7.

5, 6. *Michelinia*? sp. Transverse and longitudinal thin sections, respectively, USNM 469355, from USGS locality 14026–PC. Unnamed carbonate unit, area 7.



REPRESENTATIVE CORALS OF CORAL ZONE IIB

PLATE 2

[All figures ×2]

Figure 1. *Koninckophyllum*? sp. Transverse thin section, USNM 469356, from USGS locality 25583–PC. Unnamed carbonate unit, area 1.

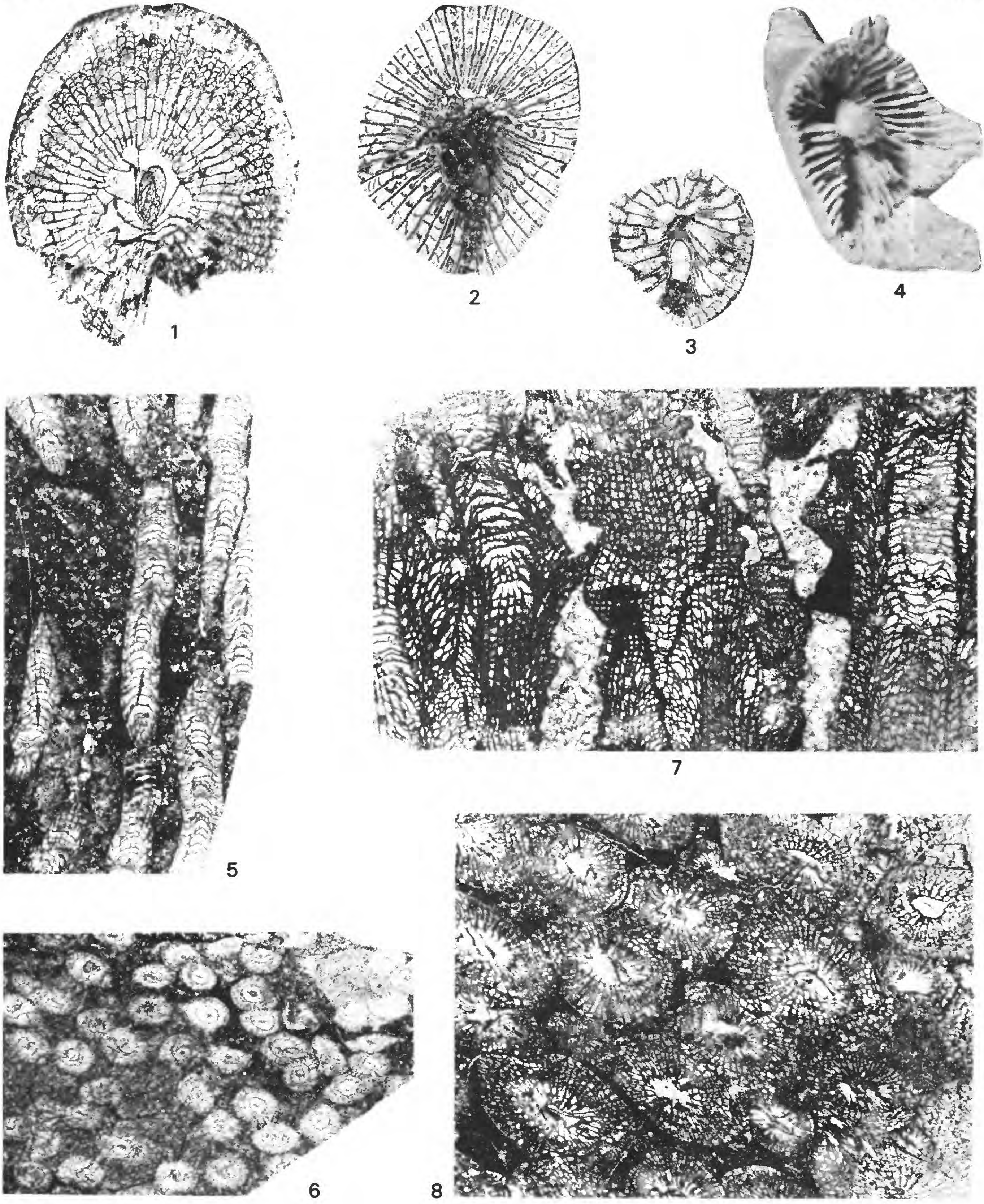
2. *Canadiphyllum* sp. Transverse thin section, USNM 469357, from USGS locality 14027–PC. Unnamed carbonate unit, area 7.

3. *Amplexizaphrentis*? sp. (may be young *Canadiphyllum*). Transverse thin section, USNM 469358, from USGS locality 14027–PC. Unnamed carbonate unit, area 7.

4. *Ekvasophyllum* sp. Oblique calicular view of etched silicified corallum, USNM 469359, from USGS locality 26250–PC. Unnamed carbonate unit, area 1.

5, 6. *Siphonodendron* aff. *S. sinuosum* (Warren). Longitudinal and transverse thin sections, respectively, USNM 469360, from USGS locality 26253–PC. Unnamed carbonate unit, area 3.

7, 8. *Siphonodendron* cf. *S. whitneyi* of Meek (diphymorph). Longitudinal and transverse thin sections, respectively, USNM 469361, from USGS locality 26254–PC. Unnamed carbonate unit, area 3.



REPRESENTATIVE CORALS OF CORAL ZONE IIID

PLATE 3

[Figures ×4 unless otherwise noted]

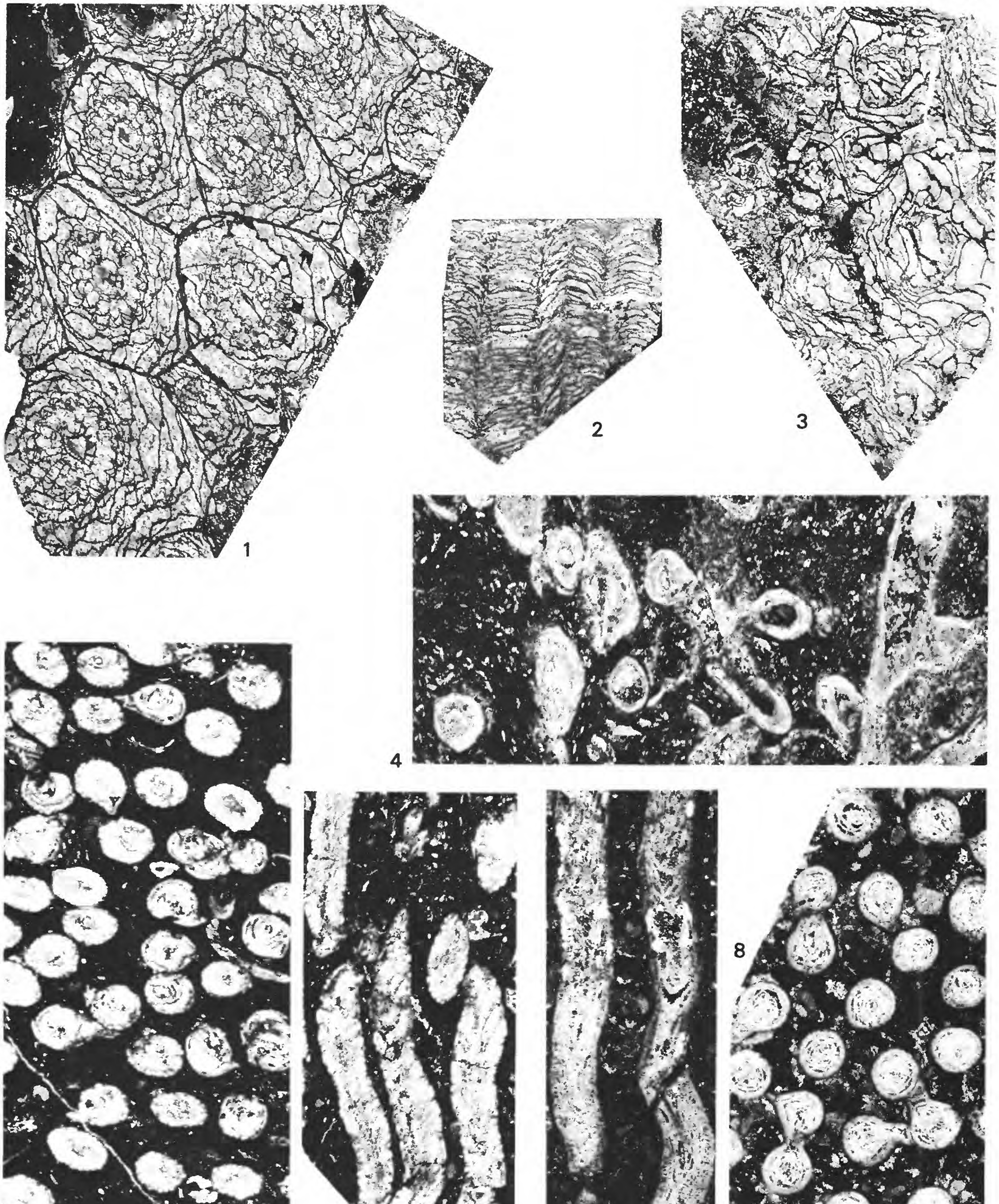
Figure 1. *Stelechophyllum*? sp. Transverse thin section, USNM 469362, from USGS locality 17662–PC. Banner Formation, area 8.

2, 3. *Sciophyllum* sp. Longitudinal and transverse thin sections, respectively, ×2, USNM 469363, from USGS locality 25584–PC. Unnamed carbonate unit, area 1.

4. *Multithecopora* morphogroup A of Sando (1984b). Transverse thin section, USNM 469364, from USGS locality 24944–PC. Unnamed carbonate unit, area 3.

5, 6. *Pleurosiphonella* morphogroup A of Sando (1984b). Transverse and longitudinal thin sections, respectively, USNM 469365, from USGS locality 26254–PC. Unnamed carbonate unit, area 3.

7, 8. *Syringopora* morphogroup G of Sando (1984b). Longitudinal and transverse thin sections, respectively, USNM 469366, from USGS locality 14029–PC. Goughs Canyon Formation, area 7.



REPRESENTATIVE CORALS OF CORAL ZONE IIID

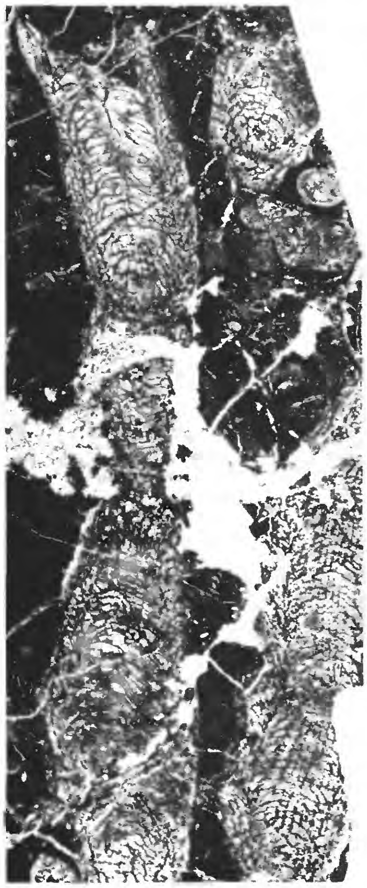
PLATE 4

[Figures ×2 unless otherwise noted]

Figures 1, 2. *Siphonodendron* cf. *S. whitneyi* of Meek. Longitudinal and transverse thin sections, respectively, USNM 469367, from USGS locality 26256–PC. Unnamed carbonate unit, area 3.

3, 4. *Faberophyllum* sp. Transverse and longitudinal thin sections, respectively, USNM 469368, from USGS locality 26251–PC. Unnamed carbonate unit, area 5.

5, 6. *Pleurosiphonella* morphogroup A of Sando (1984b). Longitudinal and transverse thin sections, respectively, ×4, USNM 469369, from USGS locality 26256–PC. Unnamed carbonate unit, area 3.



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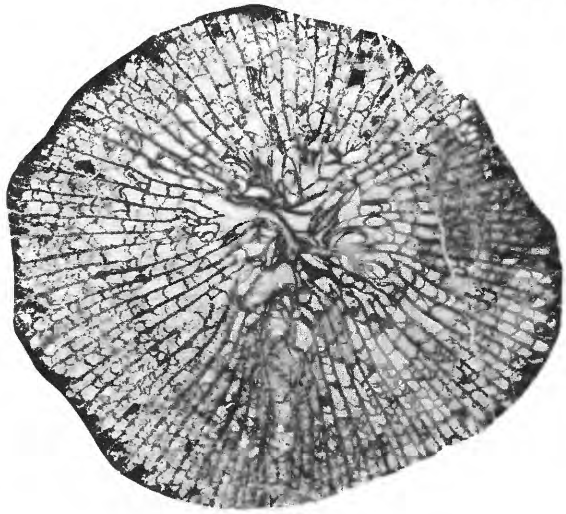

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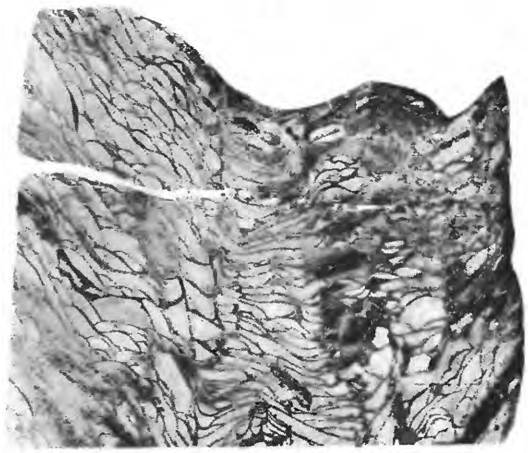

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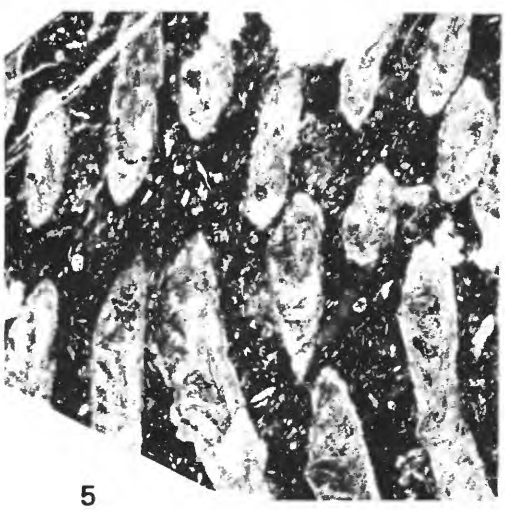

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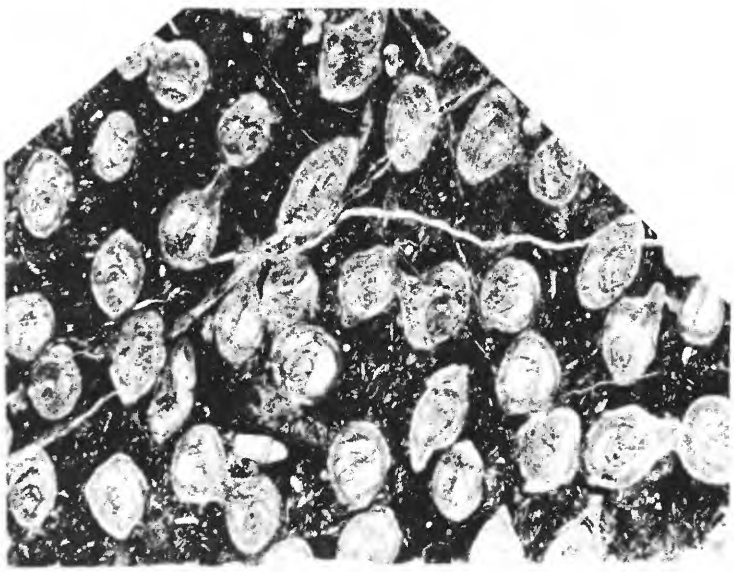

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REPRESENTATIVE CORALS OF CORAL ZONE IV

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