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THE PALEOECOLOGY OF MISSISSIPPIAN CORALS IN THE WESTERN CONTERMINOUS UNITED STATES

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In the Mississippian (Early Carboniferous) of the Rocky Mountain and Great Basin regions of the United States, colonial Rugosa occur exclusively in shallow-water lithofacies. Tabulates occur in both deep- and shallow-water lithofacies. Among the solitary Rugosa, which occur in both deep- and shallow-water lithofacies, deep-water forms are predominantly nondissepimented.
Most taxa that occur in both deep- and shallow-water lithofacies first appeared in deep water, then migrated to shallow water later in geologic time. Corals lived predominantly in deep water during Kinderhookian (early and middle Tournaisian) time, despite the existence of large areas of shallow-water deposition. A marked shift in coral occurrence to predominantly shallow-water environments took place in latest Kinderhookian (middle Tournaisian) time, and this trend toward shallow-water continued to the end of the Mississippian (early Namurian).

K e y w o r d s: paleoecology, corals, Lower Carboniferous, North America.
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INTRODUCTION

Aside from scattered, mostly generalized statements, little information has been published on the paleoecology of Early Carboniferous corals (Hill 1938; Hubbard 1966; Sando 1960, 1969; Kachanov 1970; Vassiljuk 1974; Altmark 1975; Armstrong 1975). Most studies have attributed these corals to shallow-water environments, whose inferred characteristics were summarized by Wells (1957) as: 1) 50 m. maximum depth, 2) well within the photic zone, 3) annual minimum temperatures 16°—21°C, 4) well-oxygenated, gently circulating water, and 5) substrate clear or relatively free from rapid accumulation of sediment. Despite Teichert's (1958) admonition that occurrences of corals in deep water may be more common in the ancient record than generally recognized, few Early Carboniferous corals have been attributed to deep-water environments (Kullman 1966, 1968; Sando 1977).

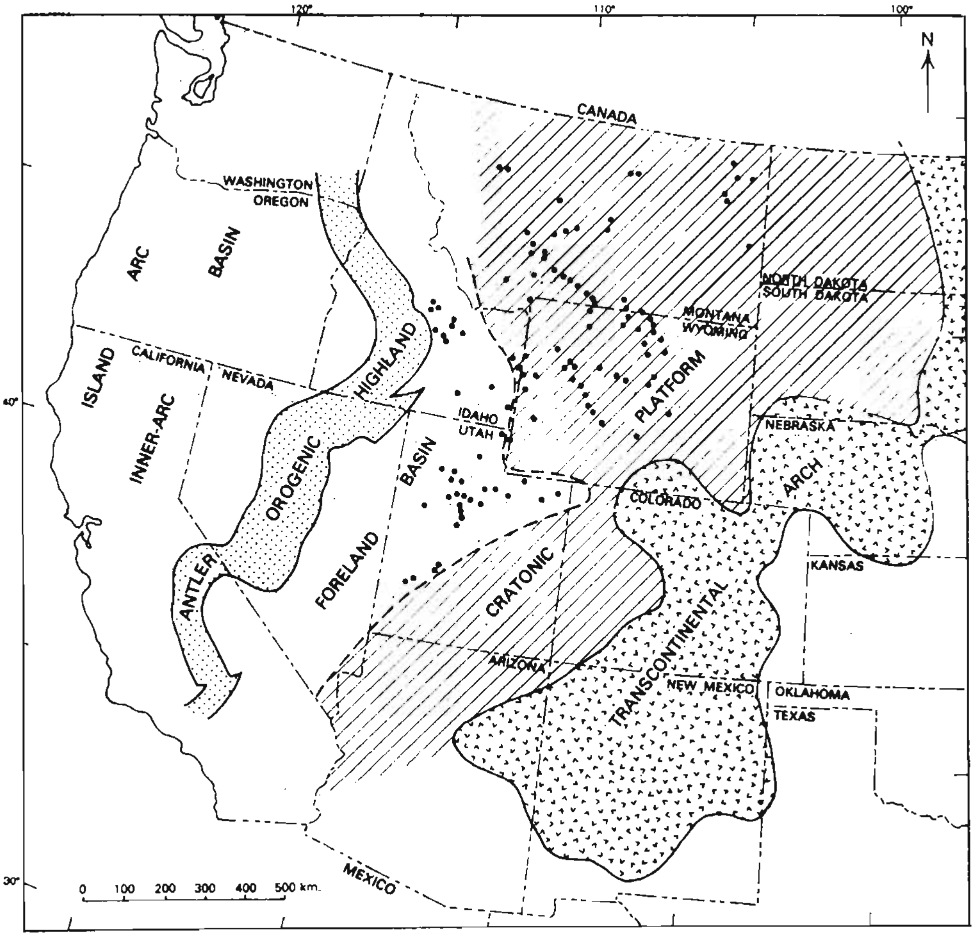

Fig. 1. Paleotectonic map of the western conterminous United States showing locations (dots) of coralliferous Mississippian stratigraphic sections. Paleotectonic units are those of Poole and Sandberg (1977) and Sando (1976).

Abundant corals collected by the writer from a wide range of lithofacies that represent environments ranging from deep water to very shallow water in the Mississippian of the Rocky Mountain and Great Basin regions of the United States provide an excellent basis for paleoecologic study. The present analysis is based on 2,747 occurrences of 46 coral genera and subgenera represented by approximately 9,000 specimens in 117 detailed stratigraphic sections of Mississippian rocks in Utah, Wyoming, Montana, and Ihado (fig. 1). The area is in the Western Interior coral province of Sando and others (1975, 1977) and was in the tropical region during Mississippian time (Fedorowski 1977: figs 2, 3). Taxa are mostly those recognized by Sando and others (1977). The coral zonation used in this paper is the new revised zonation for western North America proposed by Sando and Bamber (1979).

Acknowledgements.—I am indebted to E. W. Bamber, J. T. Dutro, Jr., R. C. Gutschick, W. A. Oliver. Jr., and C. A. Sandberg for stimulating discussions and constructive criticism of the manuscript.

LITHOFACIES, ENVIRONMENTS, AND CORAL HABITATS

Eight lithofacies are distinguished in the rocks studied (asterisks mark coralliferous facies).

A. Deep-water basinal terrigenous facies: Dark-colored, fissile to thin-bedded, commonly phosphatic mudstone, siltstone, and sandstone. Shelly benthos very rare or absent. Benthic calcareous algae and benthic calcareous foraminifera absent. Conodonts rare. Cephalopods and ichnofossils common. *Environment*: deep, disphotic, dysaerobic, poorly circulating waters in basin relatively far from shelf margin or shore. *Depth*: more than 100 m below sea level, possibly as much as 200—300 m below sea level.

**B. Deep-water basinal carbonate facies*: Dark-colored, thinbedded, silty and argillaceous, commonly cherty, commonly phosphatic micrite and biomicrite. Shelly benthos rare. Radiolarians and sponge spicules common. Benthic calcareous foraminifera very rare and probably allochthonous. Benthic calcareous algae absent. Cephalopods and conodonts common. *Environment*: deep, disphotic, dysaerobic, poorly circulating waters in basin adjacent to shallow-water shelf. *Depth*: more than 100 m below sea level.

**C. Deep-water bank carbonate facies*: Dark- and light-colored thin- to medium-bedded micrite and crinoidal biomicrite. Shelly benthos rare. Conodonts rare. Benthic foraminifera rare. Benthic red calcareous algae only. *Environment*: moderately deep, disphotic, dysaerobic, poorly circulating waters on slopes below shallow-water shelf. *Depth*: more than 100 m below sea level but somewhat less than for facies A and B.

**D. Shallow-water basinal carbonate facies*: Dark- and light-colored, moderately cherty, thin- to medium-bedded, cyclically interbedded micrite, biomicrite, crinoidal biosparrite, and oosparite. Shelly benthos and ichnofossils abundant. Benthic red, green, and blue-green calcareous algae common. Benthic foraminifera common. Conodonts rare. *Environment*: moderately deep to shallow, euphotic, aerobic to dysaerobic, poorly circulating to turbulent waters in basin and on slopes adjacent to shallow-water shelf. *Depth*: probably from slightly below sea level to maximum of 100 m below sea level, mostly less than 50 m.

**E. Shallow-water shelf carbonate facies*: Light-colored, poorly cherty, thin- to thick-bedded (commonly crossbedded), micrite, crinoidal biomicrite, biosparrite, and oosparite. Shelly macrobenthos and benthic foraminifera rare near shoreline to abundant near outer edge of shelf. Conodonts and ichnofossils rare. Benthic red, green, and blue-green calcareous algae and stromatolites abundant. *Environment*: shallow, subtidal to supratidal, mostly turbulent, euphotic, aerobic waters from shoreline to edge of broad shelf. *Depth*: supratidal to maximum of 100 m below sea level, mostly less than 50 m.

**F. Red-bed facies*: Red, fissile to thin-bedded mudstone, siltstone and sandstone and rare interbeds of dark micrite and biomicrite. Shelly benthos very rare. Benthic foraminifera very rare. Benthic calcareous algae very rare. Conodonts absent. *Environment*: shallow, poorly circulating, disphotic to euphotic, dysaerobic to aerobic waters in restricted lagoons on shelf. *Depth*: probably less than 100 m below sea level.

G. Evaporite and evaporitic carbonate facies: Light-colored, fissile to medium-bedded interbedded gypsum, anhydrite, halite, mudstone, silstone, and evaporitic micrite or solution breccias resulting from post-depositional leaching of the evaporatic sequence. Fossils absent. *Environment*: shallow, euphotic, anaerobic to dysaerobic, poorly circulating, highly saline waters in restricted lagoons on shelf. *Depth*: probably less than 100 m below sea level.

**H. Shallow water terrgenous facies*: Dark- and light-colored, fissile to medium-bedded (some crossbedded) mudstone, silstone, sandstone, and silty micrite. Shelly benthos absent or very rare. Benthic foraminifera absent. Benthic algae absent or very rare. Conodonts absent to abundant. *Environment*: shallow, poorly circulating to turbulent, disphotic to euphotic, dysaerobic to aerobic waters in basins, estuaries, and shoals marginal to shoreline. *Depth*: probably from sea level to 100 m below sea level.

A generalized environmental model derived mainly from models presented by Rose (1976) and Sando (1976) showing the relative areal and bathymetric distribution of the eight lithofacies is shown in figure 2. Figure 2 also shows the distribution of the lithofacies through Mississippian time with respect to foraminiferal zones of Mamet (*in* Mamet and Skipp 1970*a*, *b*), conodont zones of Sandberg (written communication, 1978), and coral zones of Sando and Bamber (1979), and the occurrence of corals in the lithofacies. Although none of the lithofacies are continuous through the Mississippian, corals as a group were able to survive through most of the period by shifting their habitats from one environment to another. The apparent absence of a coralliferous facies in the latest Mississippian may be the result of incomplete data or of migration outside the area of study. The relationship between coral zones, lithofacies, and stratigraphic units is shown in table 1.

Bathymetric interpretations of lithofacies are based on criteria summarized by Heckel (1972), Mamet (1972), Rhoads and Morse (1971), Byers (1977), and Wray (1977). Deep-water facies in the Mississippian of the western United States have been discussed by Wilson (1969), Stone (1972), Smith (1972, 1977), Bissell and Barker (1977), Yurewicz (1977), and Sandberg and Gutschick (1977, 1978). The term "deep water" is herein used

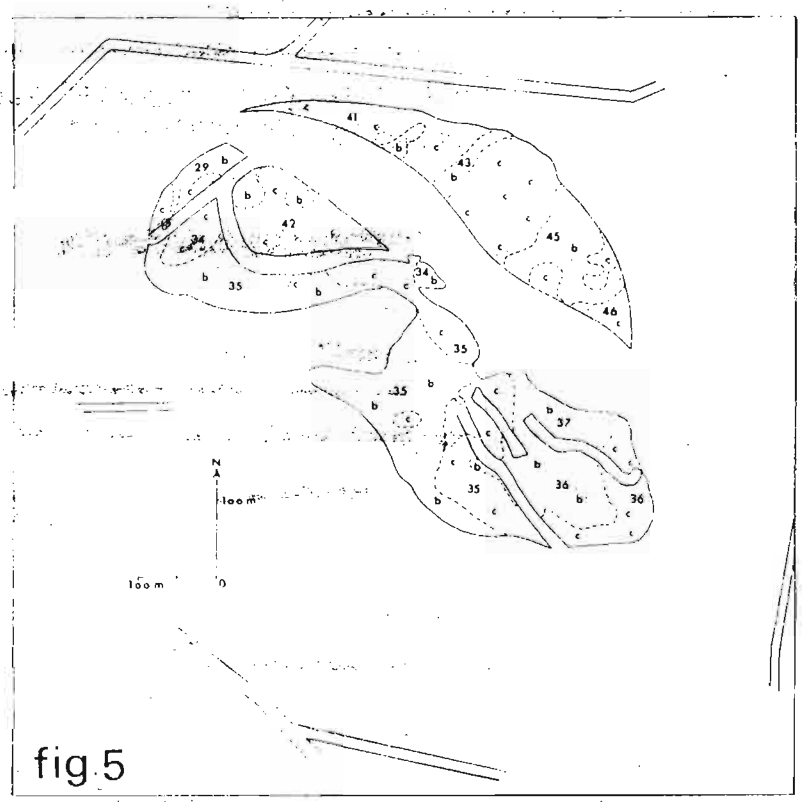

Fig. 5. Sketch of distribution in Fakse Limestone Quarry of bryozoan limestone (*b*) and scleractinian coral limestone (*c*) on part of the floors, 1959, after field sketches by Rosenkrantz. Approximate elevation above the sea in metres.

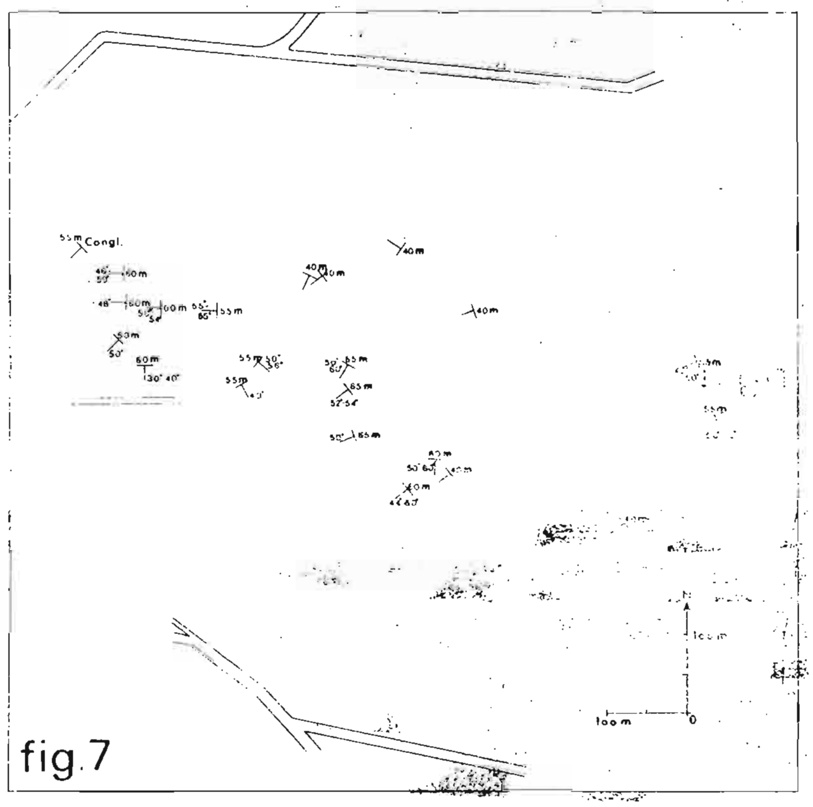

Fig. 7. Strike and dip of zonated coral limestone and of one conglomerate (Congl.) in Fakse Limestone Quarry. Based on Johnstrup (1864) and on measurements in 1933 and 1959 by Rosenkrantz. Approximate elevation above the sea in metres.

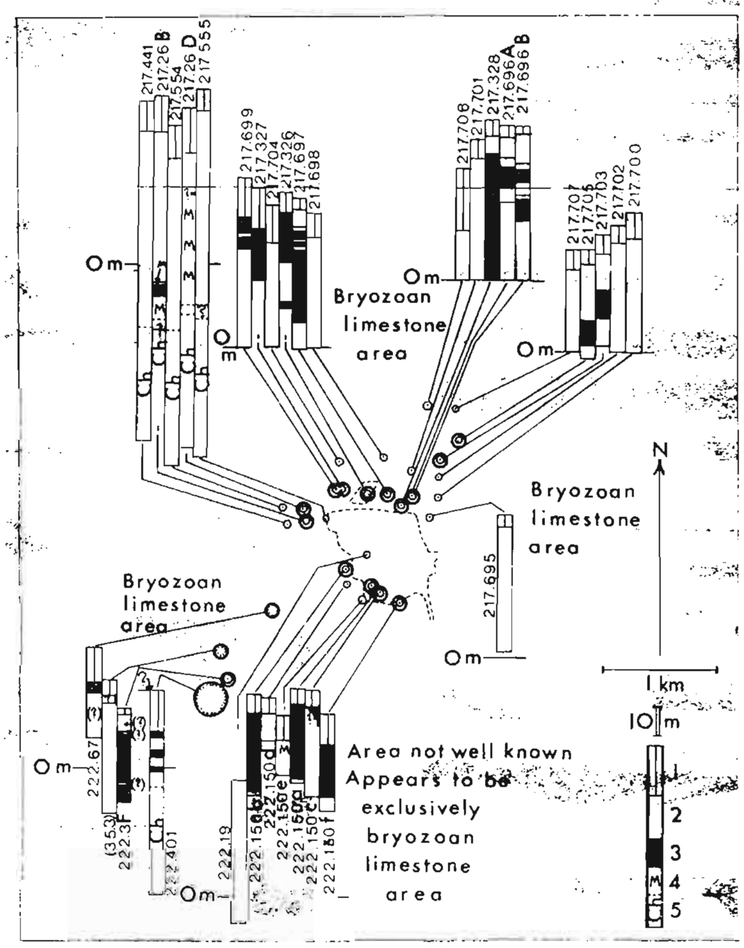

Fig. 6. Location and rocks (often drawn simplified) of boring in the Fakse area, with Fakse Quarry in the centre, outlined as it was in 1977. Including all borings with *Moltkia* limestone and all (double ringed) with scleractinian limestone. With registration numbers of the Geological Survey of Denmark (217.26 B: see Rosenkrantz 1938). *1* Pleistocene, *2* bryozoan limestone, *3* scleractinian limestone, *4 Moltkia* limestone; *5* Chalk. On the Chalk is resting in no. 217.554 Fish Clay (max. 0.5 m), in no. 217.26 B 15 cm Fish Clay and *Cerithium* Limestone, in no. 217.26 D 3.30 m grey micrite. "?" in no. 217.555 means Chalk or bryozoan limestone.

Table 1

Occurrence of lithofacies (see text) in coral zones, stratigraphic units, and geographic areas

CORAL ZONE	LITHO-FACIES	STRATIGRAPHIC UNITS	STATE
I	A	McGowan Creek Formation	Idaho
	B	Paine Member of Lodgepole Limestone	Mont., Wyo., Id., Utah
		Fitchville Formation (middle part)	Utah
		Joana Limestone (lower part)	Utah
		Lower Member of Allan Mountain Limestone	Montana
	E	Lower dolomite member of Madison Limestone	Wyoming
		Fitchville Formation (upper part)	Utah
	H	Cottonwood Canyon Member of Lodgepole Limestone and Madison Ls.	Mont.,Wyo.Ut.
		Bakken Formation (upper part)	Montana
		Unnamed sandstone formation	Wyoming
II	A	McGowan Creek Formation	Idaho
		Phosphatic member of Woodman Formation	Utah
		Phosphatic member of Deseret Limestone	Utah
		Phosphatic member of Little Flat Formation	Idaho, Utah
		Phosphatic member of Brazer Dolomite	Utah
		Deep Creek Formation (lower part)	Idaho
	B	Phosphatic member of Deseret Limestone	Utah
		Phosphatic member of Little Flat Formation	Utah
		Phosphatic member of Brazer Dolomite	Utah
		Deep Creek Formation (lower part)	Idaho
		Middle Canyon Formation (lower part)	Idaho
		Member 1 of Brazer Dolomite	Utah
	D	Woodhurst Member of Lodgepole Limestone and Madison Limestone	Mont.,Wyo.,Id., Utah
		Joana Limestone (upper part)	Utah
		Gardison Limestone	Utah
	E	Member 2 of Brazer Dolomite	Utah
		Mission Canyon Limestone (lower part)	Mont., Wyo.
		Lower member of Castle Reef Dolomite	Montana
		Cliffy limestone member and cherty dolomite member of Madison Limestone	Wyoming
		Lower part of Woodhurst Member of Madison Limestone	Wyoming
	G	Lower solution zone of Mission Canyon Limestone and Madison Limestone and correlative evaporite beds	Montana Wyoming
III	A	Woodman Formation (upper part)	Utah
	B	Woodman Formation (upper part)	Utah
		Phosphatic member and Tetro Member of Deseret Limestone	Utah
		Middle Canyon Formation (upper part)	Idaho
		Deep Creek Formation (upper part)	Idaho
		Little Flat Formation (lower part)	Idaho
	C	Lower part of Uncle Joe Member of Deseret Limestone	Utah
	E	Mission Canyon Limestone (upper part)	Mont., Wyo.
		Bull Ridge Member of Madison Limestone and Mission Canyon Ls.	Mont., Wyo.
		Charles Formation	Montana
		Sun River Member of Castle Reef Dolomite	Montana
		Upper part of Uncle Joe Member of Deseret Limestone	Utah
		Scott Peak Formation (lower part)	Idaho
		Sandy limestone member of Little Flat Formation	Idaho, Utah
		Ochre Mountain Limestone (lower part)	Utah
		Humbug Formation (lower part)	Utah
	G	Upper solution zone of Mission Canyon Limestone and Madison Limestone and correlative evaporite beds	Montana Wyoming
	H	Humbug Formation (lower part)	Utah
		Sandstone member of Little Flat Formation	Idaho, Utah

continued

CORAL ZONE	LITHO-FACIES	STRATIGRAPHIC UNITS	STATE
IV	B	Great Blue Limestone (lower part)	Utah
	E	Humbug Formation (upper part)	Utah
		Ochre Mountain Limestone (lower part)	Utah
		Lower member of Great Blue Limestone	Utah, Idaho
		Scott Peak Formation (middle part)	Idaho
		Monroe Canyon Limestone (lower part)	Idaho
	H	Lower part of Kibbey Fm. equivalent in Big Snowy Fm.	Montana
		Darwin Sandstone Member of Amsden Formation.	Wyoming
V	A	Long Trail Shale Member of Great Blue Limestone	Utah
		Doughnut Formation	Utah
	B	South Creek Formation	Idaho
	E	Scott Peak Formation (upper part)	Idaho
		Surrett Canyon Formation	Idaho
		Upper member of Great Blue Limestone	Idaho, Utah
		Monroe Canyon Limestone (upper part)	Idaho
		Moffat Trail Member of Amsden Formation	Wyoming
		Otter Formation equivalent in Big Snowy Formation	Montana
		Doughnut Formation	Utah
		Ochre Mountain Limestone (upper part)	Utah
	F	Horseshoe Shale Member of Amsden Formation	Wyoming
	H	Darwin Sandstone Member of Amsden Formation	Wyoming
		Kibbey Formation	Montana
		Otter Formation	Montana
VI	A	Manning Canton Shale (lower part)	Utah
	E	Surrett Canyon Formation (uppermost part)	Idaho
		Great Blue Limestone (uppermost part)	Utah, Idaho
	F	Horseshoe Shale Member of Amsden Formation	Wyoming
	G	Ranchester Limestone Member of Amsden Formation	Wyoming
	H	Darwin Sandstone Member of Amsden Formation	Wyoming
		*Bluebird Mountain Formation	Idaho
		*Arco Hills Formation	Idaho
		Heath Formation	Montana

*Proposed new name (B. Skipp, written commun. 1978).

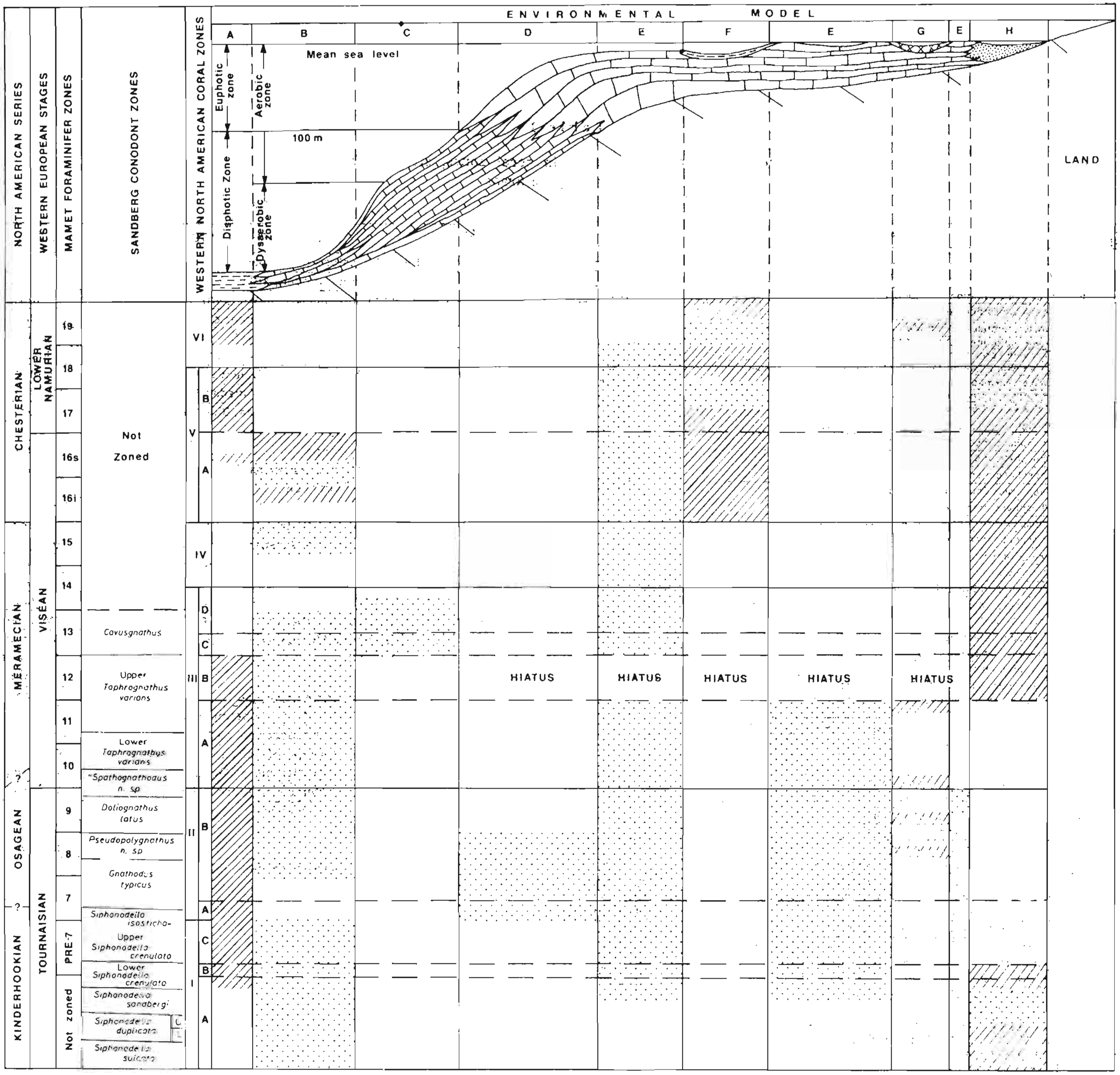

Fig. 2. Distribution of Mississippian lithofacies (see text) with respect to biostratigraphic zonations and generalized environmental model. Coralliferous lithofacies are stippled; noncoralliferous lithofacies are hatched. Non-patterned intervals indicate absence of lithofacies. Environmental model not to scale; vertical dimension greatly exaggerated.

for environments inferred to have been in clear tropical sea water below a depth of 100 m, the effective lower limit of the euphotic zone. The euphotic zone is characterized by red, green, and blue-green calcareous algae. Although blue-green algae are confined to the upper 50 m of the euphotic zone and red algae are found rarely below it in the disphotic zone, green algae occur to the base of the euphotic zone (Wray 1977).

DEEP WATER AND SHALLOW-WATER CORAL BIOFACIES

Table 2 shows the distribution of coral taxa in the six coralliferous lithofacies, which have been grouped into deep-water and shallow-water facies. The term "occurrence" refers to the presence of a taxon in a collection of corals from a stratigraphic section. The shallow-water habitat index (SWHI) is the percentage of occurrences of each taxon in shallow-water lithofacies. Taxa having SWHI = 0 occur exclusively in deep water and those having SWHI = 100 occur exclusively in shallow water. The SWHI permits recognition of a deep-water coral biofacies (SWHI $<$ 50) and a shallow-water coral biofacies (SWHI $>$ 50).

The deep-coral biofacies consists predominantly of small, simple, nondissepimented solitary corals (*Metriophyllum, Permia?, Rhopalolasma, Amplexocarinia, Cyathaxonia, Amplexus, Rotiphyllum*), and a few tabulates (*Beaumontia, Favosites, Palaeacis*). *Caninia* (*Caninia*) is the only dissepimented member of this biofacies. Five of those taxa (*Rhopalolasma, Cyathaxonia, Amplexus, Caninia* (*Caninia*) and *Palaeacis*) were originally listed by Hill (1938: table 1) in her "*Cyathaxonia* fauna", which is associated with poorly-oxygenated shaly limestone of the "black-lias" facies in the British Isles. Kullman (1966, 1968) listed *Cyathaxonia* and *Metriophyllum* in deep-water facies in the Viséan of Spain. Hudson (1945) listed *Caninia* ss., *Cyathaxonia, Permia, Rhopalolasma, Rotiphyllum*, and *Palaeacis* in "*Cyathaxonia*-phase" faunas associated with shales and argillaceous limestones in the Lower Carboniferous of Yorkshire, England. Other taxa commonly found in both deep- and shallow-water biofacies (SWHI = = 50—86) in the western United States (table 2) are the solitary dissepimented genus *Koninckophyllum*, solitary nondissepimented *Canadiphyllum, Amplexizaphrentis*, and *Lophophyllum*, and the tabulates *Cleistopora* and *Michelinia*.

The shallow-water coral biofacies includes principally dissepimented solitary taxa, a few nondissepimented solitary taxa (*Sychnoelasma, Ankhelasma, Barytichisma, Hapsiphyllum*), tabulates, and all the colonial Rugosa (table 2). All the colonial Rugosa are restricted to shallow water. Three tabulate taxa and three nondissepimented solitary taxa also lived exclusively in shallow water. The shallow-water biofacies includes morphotypes of the "Caninid-Clisiophyllid fauna" and "Reef-coral fauna" of

Table 2

Lithofacies distribution and shallow-water habitat index (SWHI) of coral taxa

TAXA (NUMBER OF LOCALITIES)	SW HI	LITHOFACIES					
		DEEP WATER		SHALLOW WATER			
		B	C	D	E	F	H
Solitary Rugosa (*dissepimented)							
Metriophyllum (7)	0	19	—	—	—	—	—
Permia? (9)	5	18	—	1	—	—	—
Rhopalolasma (9)	6	15	—	—	1	—	—
Amplexocarinia (7)	17	10	—	2	—	—	—
Cyathaxonia (39)	18	95	1	13	8	—	—
Amplexus (31)	29	60	—	19	5	1	—
**Caninia (Caninia)* (14)	33	20	—	10	—	—	—
Rotiphyllum (18)	33	18	—	2	7	—	—
**Koninckophyllum* (2)	50	—	1	—	1	—	—
Canadiphyllum (16)	66	3	10	—	25	—	—
Amplexizaphrentis (70)	74	103	4	137	167	—	2
Lophophyllum? (43)	77	29	—	51	46	—	—
**Caninia s. l.* (8)	91	1	—	2	8	—	—
**Ekvasophyllum* (14)	95	—	3	—	52	—	—
**Faberophyllum* (14)	96	3	—	—	66	—	—
Sychnoelasma (62)	97	13	—	189	178	—	—
**Vesiculophyllum* (84)	98	12	—	245	247	—	—
**Caninia (Siphonophyllia?)* (25)	99	1	—	—	64	—	3
Ankhelasma (8)	100	—	—	—	10	—	—
Barytichisma (1)	100	—	—	—	1	—	—
**Clisiophyllum* (7)	100	—	—	—	10	—	—
Hapsiphyllum (4)	100	—	—	1	3	—	—
**Liardiphyllum* (1)	100	—	—	1	—	—	—
**Turbinatocaninia?* (8)	100	—	—	—	12	—	—
**Zaphriphyllum* (17)	100	—	—	—	31	—	—
Colonial Rugosa							
Acrocyathus (Acrocyathus) (5)	100	—	—	—	10	—	—
Aulostylus (4)	100	—	—	3	1	—	—
"Diphyphyllum" (31)	100	—	—	—	42	—	—
Dorlodotia? (1)	100	—	—	—	1	—	—
Lithostrotion (Siphonodendron) (22)	100	—	—	—	33	—	—
Lonsdaleia (Actinocyathus) (5)	100	—	—	—	9	—	—
cf. Petalaxis (1)	100	—	—	—	1	—	—
"Pseudodorlodotia" (7)	100	—	—	—	10	—	—
Schoenophyllum (1)	100	—	—	—	1	—	—
Sciophyllum (1)	100	—	—	—	1	—	—
Stelechophyllum (27)	100	—	—	41	7	—	—
"Thysanophyllum" (2)	100	—	—	—	2	—	—
Tabulata							
Beaumontia (1)	0	2	—	—	—	—	—
Favosites (1)	0	1	—	—	—	—	—
Palaeacis (10)	11	25	—	—	3	—	—
Cleistopora (9)	64	5	—	9	—	—	—
Michelinia (34)	86	9	—	36	20	—	—
Syringopora (78)	95	19	—	127	205	—	3
Duncanopora (11)	100	—	—	—	17	—	—
Multithecopora? (12)	100	—	—	—	21	—	—
Pleurosiphonella (19)	100	—	—	—	31	—	—

Number in parenthesis after taxon name is number of localities where taxon is recorded. Number in column under each lithofacies type is number of occurrences of taxon in that lithofacies. Taxa in each major taxonomic group are arranged in increasing SWHI. Shaded taxa are predominantly deep-water forms (SWHI < 50). Asterisks denote dissepimented solitary forms

Hill (1938: 5—14). In the area of the present study, colonial corals do not occur in reefs, and I am unable to divide the shallow-water corals into two biofacies as Hill did.

TEMPORAL VARIATION IN CORAL HABITATS

When the temporal variations in lithofacies occurrences of the coral taxa are plotted graphically (figs. 3, 4) some significant patterns may be discerned. Among the solitary corals and tabulates, most taxa that occur in both deep and shallow water are first found in deep water, then migrated to shallow water later in geologic time. This pattern does not hold true for the colonial Rugosa, which are exclusively shallow-water forms. However, even in this group, two taxa (*Aulostylus*, *Stelechophyllum*) migrated from a slightly deeper (lithofacies D) to a shallower habitat (lithofacies E).

Analysis of the temporal variation in ecology of the number and percentage of taxa (table 3) and in the number and percentage of occurrences of taxa (table 4) reveals a pattern of increased occupation of shallow-water habitats from the base to the top of the Mississippian. Corals lived predominantly in deep water during Kinderhookian (early and middle Tournaisian) time, despite the existence of large areas of shallow-water deposition. A marked shift in coral occurrence to predominantly shallow-water environments took place in latest Kinderhookian (middle Tournaisian) time. In the Osagean (middle and late Tournaisian), Meramecian (early to late Viséan), and Chesterian (late Viséan and early Namurian), corals lived overwhelmingly in shallow water, although late Osagean (late Tournaisian) and early and middle Meramecian (early and middle Viséan) time was marked by the return of a significant number of Kinderhookian taxa and some younger taxa to deep water.

The presence of predominantly deep-water coral fauna in the Early Mississippian suggests that a resevoir of deep-water corals existed somewhere during latest Devonian (Famennian) time and that these corals provided the gene pool from which the Early Mississippian corals evolved. Famennian time throughout the world was characterized by emergence and shallow-water conditions, and in most areas it was separated from the Early Carboniferous by a period of erosion (C. A. Sandberg, oral communication, 1978). In North America, most well-dated Famennian corals are associated with limited areas of rocks deposited in intermediate to very shallow water depths. These Famennian corals, largely unstudied, occur in the Pinyon Peak Limestone and lower part of the Fitchville Formation of Utah, the Englewood Formation of South Dakota, the Percha Shale of New Mexico, the Three Forks Formation of Montana, the Pilot Shale of Nevada, and the Louisiana Limestone of Missouri. Deep-water Famennian rocks in the Slaven Chert of Nevada and in the Ford Lake

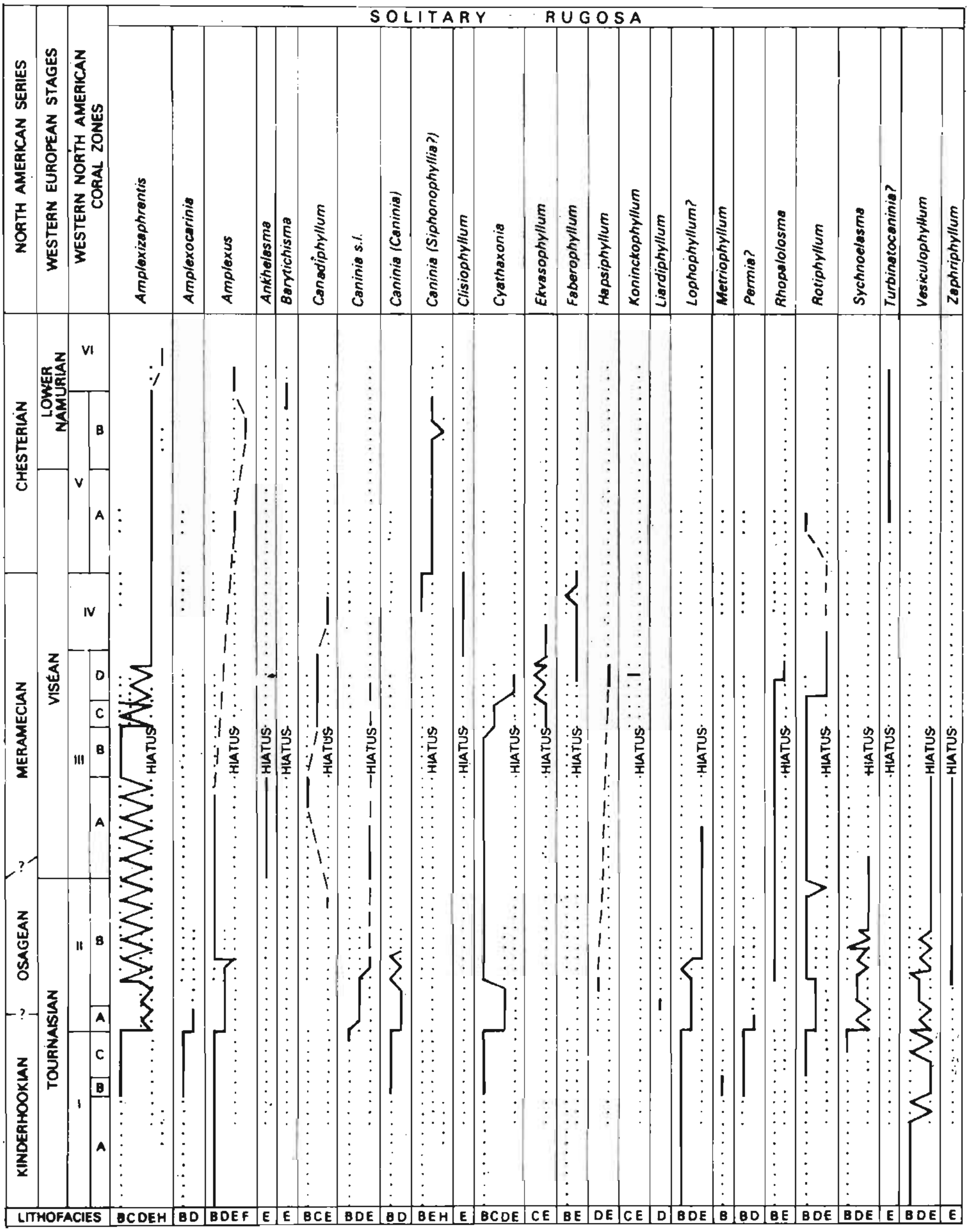

Fig. 3. Distribution of Mississippian solitary Rugosa taxa with respect to coral zones and coralliferous lithofacies. Dotted vertical lines show possible ecologic niches for each taxon. Solid lines show actual occurrences. Dashed lines connect disjunct occurrences. In each column, deeper water is to the left of diagram.

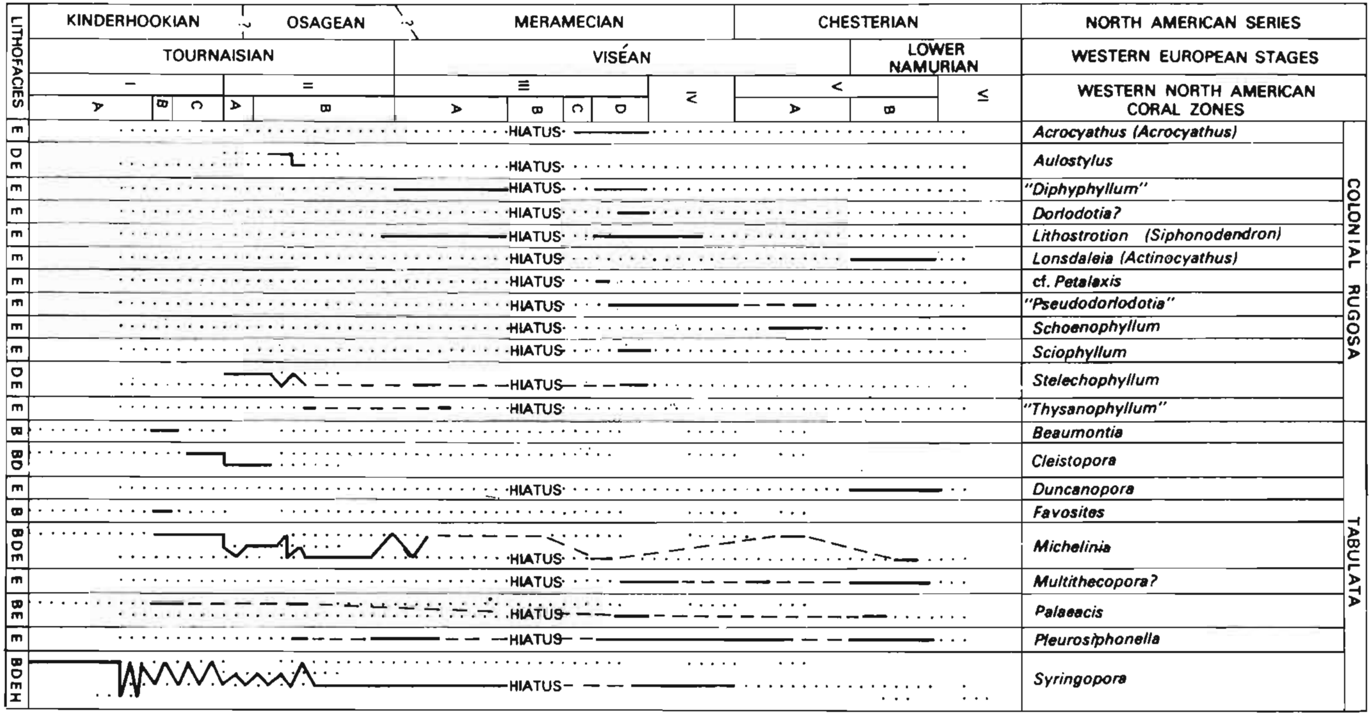

Fig. 4. Distribution of Mississippian colonial Rugosa and Tabulata taxa with respect to coral zones and coralliferous lithofacies. See explanation for fig. 3.

Shale along the Yukon River in Alaska do not contain corals (J. T. Dutro Jr., oral communication, 1978). However, corals similar to *Caninia* (*Caninia*) have been found recently in carbonate pods in greenstone of middle Famennian age in Stevens County, Washington (W. A. Oliver Jr., and W. J. Sando, J. T. Dutro Jr., and A. G. Harris, written communications, 1977). An Eearly Mississippian coral fauna including *Cyathaxonia, Amplexizaphrentis, Lophophyllum*?, and *Vesiculophyllum* has also been found in the same area (Sando, unpublished data). These occurrences may be remnants of a former Famennian-Early Mississippian deep-water coralliferous facies that was mostly lost by subduction at the continental margin during post-Early Mississippian time.

Table 3

Ecologic occurrence of coral taxa in each of the North American Series of the Mississippian

NORTH AMERICAN SERIES	NUMBER OF TAXA		
	Exclusively deep water	Both deep and shallow water	Exclusively shallow water
Chesterian	1 (7%)	1 (7%)	12 (86%)
Meramecian	2 (7%)	9 (32%)	17 (61%)
Osagean	2 (8%)	10 (42%)	12 (50%)
Kinderhookian	4 (21%)	14 (74%)	1 (5%)

Table 4

Temporal variation in numbers and percentages of occurrences of coral taxa in deep- and shallow-water habitats

NORTH AMERICAN SERIES	CORAL ZONES	DEEP WATER	SHALLOW WATER
Chesterian	VI	0 (0%)	3 (100%)
	V	2 (1%)	179 (99%)
Meramecian	IV	4 (3%)	131 (97%)
?	III	64 (15%)	357 (85%)
Osagean ?	II	92 (6%)	1536 (94%)
Kinderhookian	I	330 (87%)	49 (13%)

In summary, toward the end of Devonian time extensive emergence and extreme shallowing of remaining marine habitats caused most of the Devonian coral taxa in the western United States to die out. A few conservative forms survived in deep-water environments, and these corals formed the main gene pool for evolutionary development of a new fauna during the Mississippian. The earliest Mississippian corals continued to live predominantly in deep water but began to migrate to shallow-water habitats, until in latest Kinderhookian time they had established themselves on a shallow-water carbonate shelf that offered optimum conditions for coral growth. During the remainder of Mississippian time, the coral fauna evolved and diversified mainly in shallow water.

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