Marine Jurassic Gastropods, Central and Southern Utah

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By NORMAN F. SOHL

CONTRIBUTIONS TO PALEONTOLOGY

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A description of 19 species of gastropods from the Bajocian to Callovian rocks of Utah, supplemented by a discussion of the Jurassic gastropod fauna of North America

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MARINE JURASSIC GASTROPODS, CENTRAL AND SOUTHERN UTAH

By Norman F. Sohl

ABSTRACT

This paper describes a gastropod fauna of 19 species assigned to 17 genera from the lower limy units of the Carmel Formation and from the Twelvemile Canyon Member of the Arapien Shale (Bajocian to Callovian) in central and southwestern Utah. These descriptions constitute the first report for most of the genera from the Jurassic of North America. The Carmel gastropod fauna is a shallow-water one dominated by Archaeogastropoda and Mesogastropoda, primarily the cerithiaceans, naticaceans, and neritaceans such as *Lyosoma.* Neogastropoda are absent, and Euthyneura are represented only by the nerineids and the cephalaspid genus *Cylindrobullina.* Of special note is the neritid *Lyosoma,* which heretofore has been thought to lack an inner lip septum. Silicified specimens retain such a lip and show that its loss is probably due to differential replacement of shell layers.

Gastropods are most common in the central area of outcrop of the Carmel Formation and lessen in diversity and abundance in the thinner sandier, nearer shore sediments to the east.

The fauna is most similar to that found in member B of the Twin Creek Limestone of Utah, Idaho, and Wyoming; but it also has a close relationship to that in the Gypsum Spring Formation and "Lower Sundance Formation" of Wyoming.

A survey of the Jurassic gastropods of North America indicates that they are not so diverse as are those of Europe. Taxonomically, they are dominated by the Archaeogastropoda (especially Neritacea and Amberleyacea) and Mesogastropoda (primarily Pseudomelaniacea and Ceritheacea). No Neogastropoda are present.

The Jurassic gastropods are very provincial. The gulf coast and west Texas gastropod faunas are similar in some respects, but have no species in common with those of the western interior. Similarly, the Alaskan gastropod fauna is distinct from those faunas to the south. Such differences are seen even at the family level where the Neritidae and Nerineacea, so common in the southern faunas, are absent or poorly represented in Alaska. In Alaska the Purpurinidae and Amberleyiidae are common but decrease in abundance southward to Mexico.

In terms of age the Late Jurassic is the time of greatest gastropod diversity in the gulf coast and west Texas, but in the western interior and Alaska, the Middle Jurassic (Bathonian-lower Callovian) interval shows the greatest flowering of gastropod faunas.

INTRODUCTION

Little information on the nature of the molluscan fauna of the Carmel Formation of central and southern Utah has been published. Fieldwork, primarily by geologists of the U.S. Geological Survey, during recent years has provided sufficient collections and detailed stratigraphic information to make a study of this fauna especially profitable.

This report on the gastropods of the Carmel Formation and the Twelvemile Canyon Member of the Arapien Shale supplements the report by Imlay (1964) on the pelecypods. He provided an outline of the stratigraphy, age, and correlation of the Carmel Formation and discussed the relationships of the collecting localities. The stratigraphy and lithology of the units of the formation were described by Baker, Dane, and Reeside (1936) and summarized by Wright and Dickey (1958, 1963).

The Carmel Formation may be divided into two units. A lower limy unit is dominated by gray limestone and shale and, according to Imlay (1964, p. C3–C5), is of Bajocian age. An upper unit is dominated by claystone, siltstone, and gypsum but locally includes some sandstone. The whole formation becomes thinner, sandier, and redder toward the east and finally changes into red beds. From the featheredge in southeastern Utah, the formation thickens and becomes increasingly calcareous to the northwest, and in Sanpete and Juab Counties the total thickness of the equivalent Arapien Shale may reach 3,000 feet or more (Wright and Dickey, 1963).

All the gastropods have come from the lower limy unit of the Carmel Formation, and like the pelecypods (Imlay, 1964), they are most abundant in the middle area (fig. 1), which is approximately 40 miles wide and trends southwestward along the west side of the San Rafael Swell. Abundance of fossils diminishes to the east as the units thin and to the west as they thicken.

The Arapien Shale consists of a lower gray calcareous shale called the Twelvemile Canyon Member and an upper red and gray siltstone and shale member called the Twist Gulch Member. In aggregate thickness they may reach 10,000 feet. Gastropods are rare in the formation and occur only in the Twelvemile Canyon Member. Correlation with the Carmel Formation must rest primarily on fauna other than gastropods.

The gastropod fauna of the Carmel Formation is small, consisting of 19 species assigned to 17 genera. There are a few other gastropods in the fauna, but they are too poorly preserved to merit even generic assignment. The gastropods all come from the lower limy unit of the Carmel Formation (Imlay, 1964) and from equivalent units of the Arapien Shale. This unit of the Carmel Formation has yielded an abundance of fossils, but the gastropods usually are poorly preserved.

As is shown on figure 1 and table 2, gastropods have been collected at 42 localities in the Carmel Formation and Arapien Shale. (See table 1.) Sixty-one collections, many representing different stratigraphic levels at the 42 localities, are reported on herein.

Special thanks are due my colleague R. W. Imlay of the U.S. Geological Survey, who first interested me in the present study. He has not only aided as a critical reviewer but has also guided me to many of the collecting localities and tutored me in Jurassic stratigraphy. James C. Wright, also of the Survey, whose fieldwork precipitated the present paper, is also due many thanks for serving as a field companion, guide, and technical reviewer.

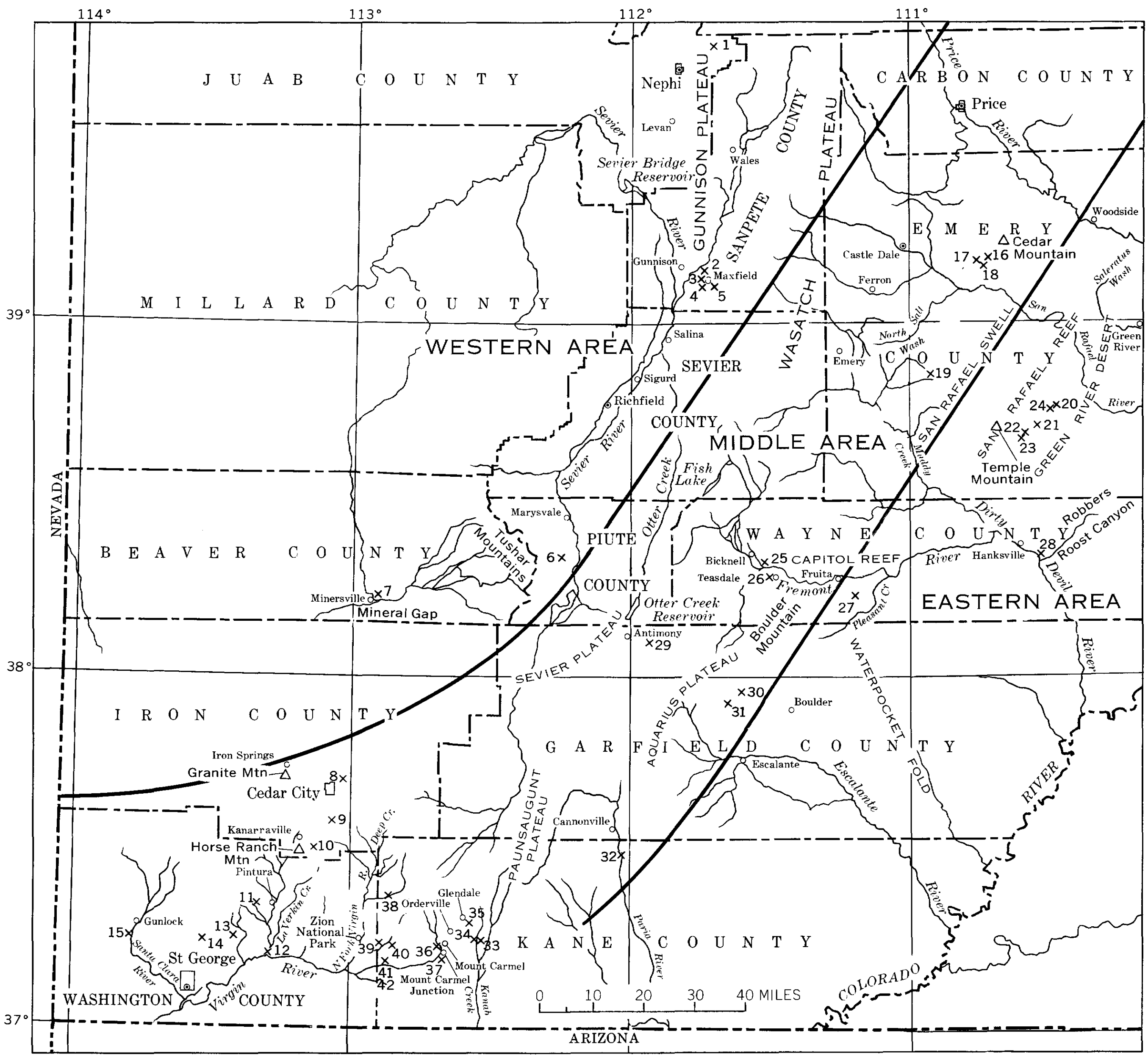

FIGURE 1.—Map of central and southwestern Utah showing localities at which Carmel and Arapien gastropods have been found. Numbers indicate collection localities referred to in text.

TABLE 1.—*Localities at which marine gastropods of Jurassic age have been collected in central and southern Utah*

Locality on fig. 1	*USGS Mesozoic locality*	*Collector, year of collection, description of locality, and stratigraphic assignment*
1	17269	S. L. Schoff, 1936. Red Creek, SE¼ sec. 9, T. 12 S., R. 2 E., Juab County. Arapien Shale.
2	21448	C. T. Hardy, 1948. 2.7 miles northwest of Mayfield, south of Twelvemile Creek, SE¼NW¼ sec. 19, T. 19 S., R. 2 E., Sanpete County. Arapien Shale, about 600(?) ft below Twist Gulch Member.
3	21647	R. W. Imlay, John McIntyre, and C. T. Hardy, 1949. 2.5 miles northwest of Mayfield, south of Twelvemile Creek, SE¼SW¼, sec. 19, T. 19 S., R. 2 E., Sanpete County. Twelvemile Canyon Member of Arapien Shale, about 1,800(?) ft below base of Twist Gulch Member.
4	21446	C. T. Hardy, 1948. 1.9 miles northwest of Mayfield, NE¼NW¼ sec. 30, T. 19 S., R. 2 E., Sanpete County. Arapien Shale, about 1,800(?) ft below Twist Gulch Member.
5	17030	E. M. Spieker, 1930. Near Mayfield-Gunnison road about 1 mile from Mayfield, Wasatch Plateau, Sanpete County. Arapien Shale.
6	16395	J. W. Young 1933. Limestone Gulch, 8 miles south of Marysvale, sec. 20, T. 28 S., R. 4 W., Piute County. Arapien Shale.
7A	18670	P. E. Dennis, 1941. Mineral Gap, Beaver County.
7B	18671	P. E. Dennis, 1941. Mineral Gap, Beaver County.
8	19428	H. J. Bissell, 1944. Northeast of Cedar City, sec. 1, T. 36 S., R. 11 W., Iron County. Carmel Formation, main *Pentacrinus* unit, from lower part of 23 ft of fossiliferous limestone lying 231 ft above base of Carmel.
9A	25672	R. W. Imlay, Paul Averitt, and Hector Ugalde, 1955. North side of Shurtz Creek about 6 miles south of Cedar City, secs. 11 and 14, T. 37 S., R. 11 W., Iron County. Carmel Formation, from pebbly oolitic limestone in lower part of formation about 235 ft above base.
9B	27474	J. C. Wright and R. P. Snyder, 1959. On crestline of north pyramid near Shurtz Creek, SE¼SE¼, sec. 11, T. 37 S., R. 11 W., Iron County. Carmel Formation, 272–282 ft above base.
9C	28461	R. W. Imlay and N. F. Sohl, 1961. North side of Shurtz Creek about 6 miles south of Cedar City, secs. 11 and 14, T. 37 S., R. 11 W., Iron County. Carmel Formation.
9D	28462	R. W. Imlay and N. F. Sohl, 1961. Iron County. Same locality as USGS loc. 28461. Carmel Formation, 229–255 ft above base.
10	27469	J. C. Wright and R. P. Snyder, 1959. On southeast spur of knoll near Sweetwater Spring about 4 miles southeast of Kanarraville, NE¼ sec. 7, T. 38 S., R. 11 W., Iron County. Carmel Formation, 260–305 ft above base.
11	17495	H. E. Gregory, 1937, West of Pintura, sec. 32, T. 39 S., R. 13 W., Washington County. Carmel Formation.
12	16701	C. E. Dobbin, 1934. Sec. 22, T. 41 S., R. 13 W., Washington County. Carmel Formation.
13A	16702	C. E. Dobbin, 1934. NE¼ sec. 34, T. 40 S., R. 14 W., Washington County. Carmel Formation.
13B	28493	R. W. Imlay and N. F. Sohl, 1961. Danish Ranch section, NE corner of sec. 34, T. 40 S., R. 14 W., Washington County. Carmel Formation, 60 ft above base of limestone.
14A	28475	R. W. Imlay and N. F. Sohl, 1961. Cottonwood Canyon, sec. 3, T. 41 S., R. 15 W., Washington County. Carmel Formation, oolitic and crinoidal limestone float, probably from 170 ft above base of limestone but possibly from a unit 240 ft above base.
14B	28477	R. W. Imlay and N. F. Sohl, 1961. Cottonwood Canyon, sec. 3, T. 41 S., R. 15 W., Washington County. Carmel Formation, from oolitic limestone zone about 140 ft above base of limestone member.
15A	28463	R. W. Imlay and N. F. Sohl, 1961. West side of Santa Clara River 1½ miles south of Gunlock near center sec. 32, T. 40 S., R. 17 W., Washington County. Carmel Formation, 287 ft above base.
15B	28465	R. W. Imlay and N. F. Sohl, 1961. West side of Santa Clara River 1½ miles south of Gunlock near center sec. 32, T. 40 S., R. 17 W., Washington County. Float from oolitic sandstone capping ridge about 350 ft above base of limestone member of Carmel Formation.
15C	28467	R. W. Imlay and N. F. Sohl, 1961. West side of Santa Clara River 1½ miles south of Gunlock near center sec. 32, T. 40 S., R. 17 W., Washington County. Limestone member of Carmel Formation, 430 ft above base.
16	28470	R. W. Imlay and N. F. Sohl, 1961. Tributary on northeast side of Buckhorn Wash at crossing of road from Woodside to Castledale, sec. 8, T. 19 S., R. 11 E., Emery County. Carmel Formation.
17A	20351	J. B. Reeside, Jr., and R. W. Imlay, 1946, Head of Buckhorn Wash, sec. 13, T. 19 S., R. 10 E. Emery County. Carmel Formation, platy limestone about 25 ft above base.
17B	25684	R. W. Imlay, 1955. SE¼ sec. 18, T. 19 S., R. 11 E., to SE¼ sec. 13, T. 19 S., R. 10 E., Emery County. Carmel Formation, 20–40 ft above base.
18A	25670	R. W. Imlay, 1955. On small ridge just south of road in NE¼NW¼ sec. 17, T. 19 S., R. 11 E., Emery County. Carmel Formation, about 75 ft above base.
18B	25678	R. W. Imlay, 1955. Near head of small gully draining westward into southwestward-trending tributary of Buckhorn Wash, NE¼ sec. 18, T. 19 S., R. 11 E., Emery County. Carmel Formation, ledge-forming sandy limestone about 40 ft above base.
18C	25680	R. W. Imlay, 1955. On northwest side of gulch in northeastern and central parts of sec. 18, T. 19 S., R. 11 E., Emery County. Carmel Formation, ledge of sandy limestone 20–30 ft above base.
19A	13529	James Gilluly and E. T. McKnight, 1925. Rim of Eagle Canyon, just below road from Rochester (Moore) to Horn Silver Prospect, approximately sec. 33, T. 22 S., R. 9 E. (unsurveyed), Emery County. Basal limestone of Carmel Formation.
19B	28480	R. W. Imlay and N. F. Sohl, 1961. Eagle Canyon Lookout, sec. 33, T. 22 S., R. 9 E., Emery County. Carmel Formation about 20 ft above base in bed of limestone containing very abundant fossil fragments just below green shale.
20	15551	L. G. Henbest and A. A. Baker, 1930. Side of road on east side of Iron Wash, SE¼ sec. 34, T. 23 S., R. 13 E., Green River Desert, Emery County. Carmel Formation, about 90 ft above base.
21	16202	L. G. Henbest, 1930. Green River Desert, NE¼ sec. 19, T. 24 S., R. 13 E., Emery County. Carmel Formation.
22	11137	C. J. Hares, 1921. East side of San Rafael Swell near Temple Mountain, sec. 34, T. 24 S., R. 12 E., Emery County. Carmel Formation limestone at base.

TABLE 1.—*Localities at which marine gastropods of Jurassic age have been collected in central and southern Utah*—Continued

Locality on fig. 1	*USGS Mesozoic locality*	*Collector, year of collection, description of locality, and stratigraphic assignment*
23	17412	A. A. Baker, 1930. About 500 ft east of Swazey's Seep, Green River Desert, Emery County. Upper third of Carmel Formation, oolitic limestone in gypsiferous claystone.
24	10116	W. B. Emery, 1917. Hanksville road, 2 miles south of Straight Wash, Green River Desert, Emery County. Carmel Formation.
25	24258	J. F. Smith, 1952. About ¼ mile west of Sun Glo Park (in Fish Lake National Forest), Capitol Reef area, SW¼ sec. 31, T. 28 S., R. 4 E., Wayne County. Carmel Formation, about 40–60 ft above base.
26A	25669	R. W. Imlay, 1955. ½ mile west of Teasdale, sec. 17, T. 29 S., R. 4 E., Wayne County. Carmel Formation, oolitic limestone about 44 ft above top of Navajo Sandstone, or 7 ft above top of red unit at base of Carmel.
26B	28456	R. W. Imlay and N. F. Sohl, 1961. West of Teasdale, between town and Blueberry Creek. SE¼SE¼ sec. 18, T. 29 S., R. 4 E., Wayne County. Carmel Formation.
27	10436	E. F. Davis, 1920. East side of the Water Pocket fold just north of Capitol Wash, NW¼ sec. 10, T. 30 S., R. 7 E., Wayne County. Carmel Formation.
28	9112	B. S. Butler, 1914. On trail about midway between Hanksville and Robbers Roost, NE¼ sec. 31, T. 28 S., R. 13 E., Wayne County. Carmel Formation, just above Navajo Sandstone.
29	26308	R. W. Imlay, 1956. On west side of gulch draining southward into Antimony Creek in west-central part of sec. 20, T. 31 S., R. 1 W., Garfield County. Carmel Formation, 20–30 ft above base.
30	28492	N. F. Sohl, 1961. Hell's Backbone, about 600 ft south of pre-1961 Hell's Backbone Bridge on west side of road, approximately sec. 5, T. 33 S., R. 3 E., Garfield County. Carmel Formation, about 15–20 ft above base.
31A	25671	R. W. Imlay, 1955. Deep Creek, about 1 mile southeast of road to Hell's Backbone Ridge and about 15 miles north of Escalante, Garfield County. Carmel Formation, from basal bed of 15-ft limestone ledge about 20 ft above top of Navajo Sandstone.
31B	26307	R. W. Imlay, J. D. Strobell, Jr., J. C. Wright, and D. D. Dickey, 1956. On Deep Creek ½ mile southeast of road to Hell's Backbone Ridge, east-central part of sec. 15, T. 33 S., R. 2 E., Garfield County. Carmel Formation, shaly limestone about 12 ft above Navajo Sandstone.
31C	28468	R. W. Imlay and N. F. Sohl, 1961. East side of Deep Creek 4,000 ft downstream from road crossing of Deep Creek by the road to Hell's Backbone Ridge, sec. 15, T. 33 S., R. 2 E., Garfield County. Same as USGS loc. 26307. Carmel Formation.
32	25676	R. W. Imlay, 1955. In Paria Valley, about 5 miles south of Cannonville, Kane County. Carmel Formation, about 12 ft above base of formation in gray shaly limestone. (See Gregory, 1951, p. 58.)
33	16624	C. D. Walcott, 1879. Upper end of box canyon below volcano, Kanab Creek valley, Kane County. (Probably same as locs. 34A, 34B.) Carmel Formation.
34A	28473	R. W. Imlay and N. F. Sohl, 1961. Kanab Creek, west fork at box canyon just below Glendale road and below lava flow, W½ sec. 3, T. 41 S., R. 6 W., Kane County. Carmel Formation, about 10–15 ft below top of limestone member.
34B	28496	R. W. Imlay and N. F. Sohl, 1961. Kanab Creek, west fork at box canyon just below Glendale road and below lava flow. W½ sec. 3, T. 41 S., R. 6 W., Kane County. Carmel Formation, about 10–15 ft below top of limestone member.
35	963	T. W. Stanton, 1892. NW¼ sec. 25, T. 40 S., R. 7 W., Glendale area, Kane County. Carmel Formation.
36	15498	J. B. Reeside, Jr., and others, 1930. West of bridge at south end of Mount Carmel, W½ sec. 18, T. 41 S., R. 7 W., Kane County. Carmel Formation, 15 ft above gypsum bed at Mount Carmel.
37A	28471	R. W. Imlay and N. F. Sohl, 1961. On east side of U.S. Highway 89 just south of pre-1960 bridge, sec. 30, T. 41 S., R. 7 W., Kane County. Carmel Formation, about 93 ft above base of limestone member (at top of "lower lime").
37B	28474	R. W. Imlay and N. F. Sohl, 1961. On east side of U.S. Highway 89, just south of pre-1960 bridge, sec. 30, T. 41 S., R. 7 W., Kane County. Carmel Formation, about 35 ft below top of limestone member.
38A	28494	R. W. Imlay and N. F. Sohl, 1961. South side of canyon of Virgin River at a cabin, Orderville quadrangle, sec. 33, T. 39, S., R. 9 W., Kane County. Carmel Formation, 20–30 ft below top of limestone member and 8–18 ft above top of oolitic ledge former.
38B	28495	R. W. Imlay and N. F. Sohl, 1961. South side of Virgin River, sec. 33, T. 39 S., R. 9 W., Kane County. Carmel Formation, 20–30 ft below top of limestone member.
39	28479	R. W. Imlay, 1961. Orderville Canyon near SE cor. sec. 19, T. 40 S., R. 9 W., Kane County. Carmel Formation, thin-bedded cream-weathering limestone in uppermost 10 ft of formation.
40	17351	H. E. Gregory, 1936. Jolly Gulch, Zion Park, approximately SW¼ sec. 8, T. 41 S., R. 9 W., Kane County. Carmel Formation, top limestone below red sandstone.
41	17054	H. E. Gregory, 1934. East entrance Zion Park, approximately W½ sec. 18, T. 41 S., R. 9 W., Kane County. Carmel Formation, near contact with Navajo Sandstone.
42	17494	H. E. Gregory, 1937. Box Mesa, near Parinuweap Canyon, north of Virgin River, NE¼ sec. 31, T. 41 S., R. 9 W., Kane County. Carmel Formation.

ANALYSIS OF THE GASTROPOD FAUNA

The streptoneurous or prosobranch snails dominate the gastropod fauna of the Carmel Formation. Of the 10 superfamilies and 12 families represented (fig. 2) only *Cylindrobullina*? sp. (Acteonacea, Acteonidae) and *Cossmannea* (Nerineacea) represent the subclass Euthyneura. Of the Streptoneura the orders Archaeogastropoda and Mesogastropoda are about equally diverse, but the order Neogastropoda is absent. This is not unusual, as representatives of this order were not abundant in marine faunas until Late Cretaceous (Sohl, 1964, p. 157).

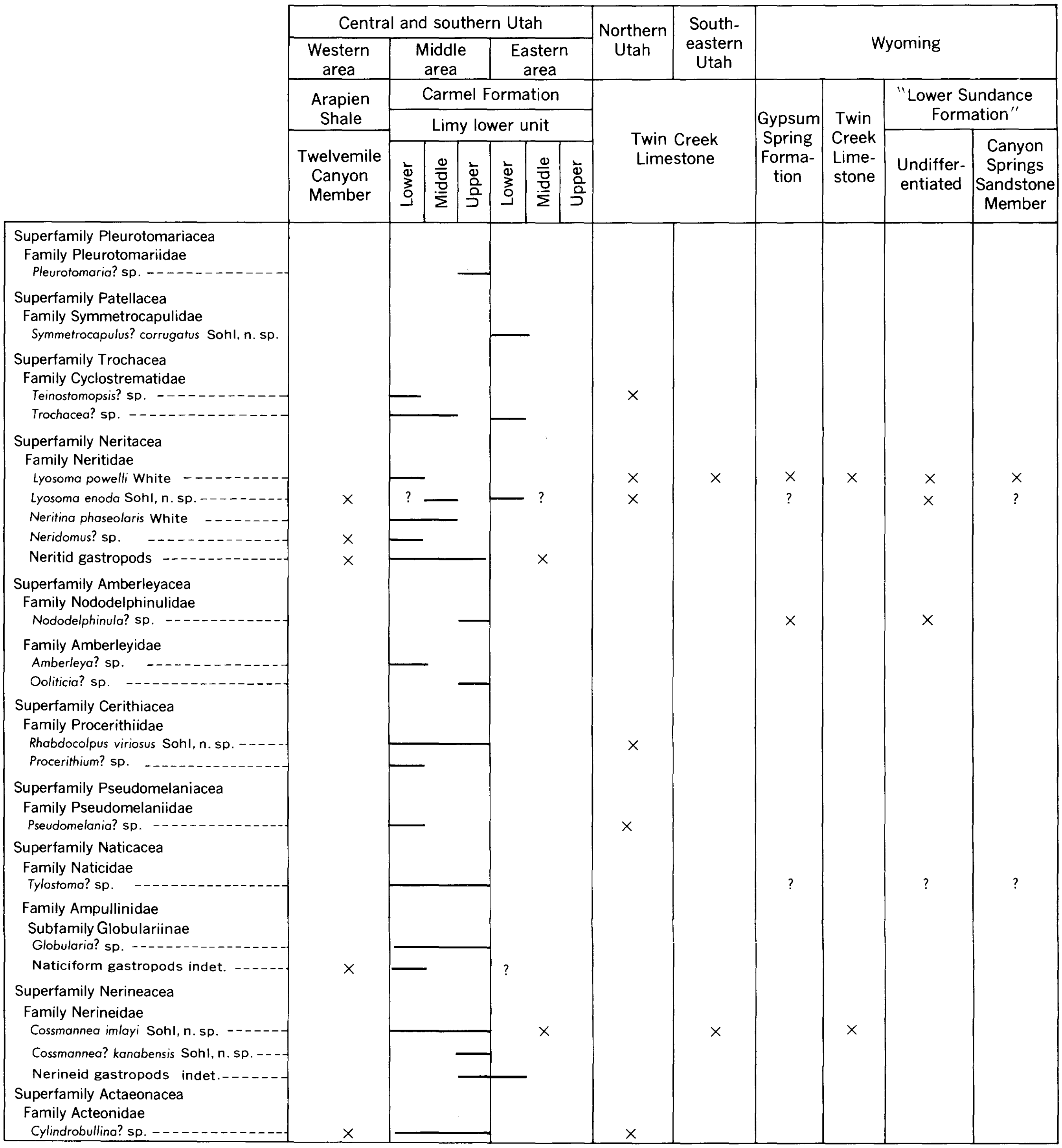

FIGURE 2.—Geographic and stratigraphic distribution of the Gastropoda of the Carmel Formation. Occurrence indicated by ×. Range of species shown by heavy line.

A general paucity of species is the salient characteristic of this otherwise typical Jurassic gastropod assemblage. This lack of diversity most probably reflects the ecologic control of the warm shallow, perhaps somewhat hypersaline, waters of a Jurassic interior seaway.

ABUNDANCE

The abundance of specimens per taxon by locality is given in table 2. The numbers give only a rough approximation of relative abundance, however, as many more specimens could be collected at many localities.

TABLE 2.—*Abundance of the Gastropoda*

[Letters opposite specific name indicate abundance: R, rare (1–5 specimens) NC,

	Localities																												
	1	2	3	4	5	6	7A	7B	8	9A	9B	9C	9D	9E	10	11	12	13A	13B	14A	14B	15A	15B	15C	16	17A	17B	18A	18B
Pleurotomaria? sp																													
Symmetrocapulus? *corrugatus* Sohl, n. sp.																													
Teinostomopsis? sp																													
Trochacea? sp							R		R																				
Lyosoma powelli White																								R					
enoda Sohl, n. sp			R	R								R			R							?	R		NC				
Neritina phaseolaris White.													NC								R			NC					
Neridomus? sp		R																											
Neritid gastropods					R																		R					R	
Nododelphinula? sp																													
Amberleya? sp																									R				
Ooliticia? sp																													
Rhabdocolpus viriosus Sohl, n. sp.								R	NC	R	NC	R	R							R			?	R					
Procerithium? sp																													
Pseudomelania? sp																													
Tylostoma? sp																						R				R	R		R
Globularia? sp																						C							
Naticiform gastropods indet.	R					R							NC	C			R								R				
Cossmannea imlayi Sohl, n. sp.																	R	R	C						R			NC	
Cossmannea? *kanabensis* Sohl, n. sp.																													
Nerineid gastropods indet.																													
Cylindrobullina? sp			R					R	R	R		R	R	R		R					R		A		R				

In addition, other collections were made by fieldmen whose concern was collecting a representative suite for the purpose of age determination. These collections naturally afford little basis for determining relative abundance. In spite of such drawbacks, certain species are obviously more abundant than others.

The small gastropods of the "winnowed" (see notes on ecology in next section) fauna such as *Cylindrobullina*? and *Rhabdocolpus* (pl. 5) may be as numerous as all other mollusks combined. In the slabby limestones they occur in such profusion that they could be collected by the thousands. Hand specimens such as those illustrated on plate 5 show the concentrated occurrence of these species. Aside from these small shells, gastropods are less common than either pelecypods or crinoid columnal remains.

Of the larger gastropods, *Lyosoma enoda* and *L. powelli* are the most widespread species, but specimens are few at any given locality. Whereas species such as *Globularia*? sp. and *Cossmannea imlayi* are less widespread, they are locally abundant; and many more specimens than recorded on table 2 could be collected. The rarest genera such as *Nododelphinula?*, *Ooliticia?*, *Symmetrocapulus?*, and *Pleurotomaria?* are restricted in distribution and in numbers.

No single locality contains a complete gastropod fauna. Some localities have yielded only single specimens of indeterminable snails whereas others have a maximum representation of nine types. The disparity is not entirely due to collecting failure, as at a number of localities at which pelecypods are common, no snails occur. Thus it is apparent that the Jurassic Carmel seas of central and southern Utah were not especially hospitable to gastropods.

PRESERVATION OF THE FOSSILS, AND NOTES ON ECOLOGY

Gastropods of the Carmel Formation occur almost exclusively in the limestones. In general, their state of preservation is poor. They are found as internal and external molds and as crystalline calcite or silica replacements. The replacement of shell by silica is coarse and commonly beekitic (pl. 4, fig. 12), whereas the calcite replacement is fine. Leaching of the shells and their preservation as internal or external molds is most common in the more gypsiferous limestones. Many of the shells show effects of transport. Some specimens exhibit rounded surfaces with sculpture eradicated; others are fragmentary with rounded edges.

The best preserved of the snails are the neritaceans such as *Lyosoma*, some of which even retain their color pattern (pl. 2, fig. 18). Because of their thick dense shell, neritaceans occur well preserved whereas most other gastropod shells have been leached out. Color patterns of the neritaceans are more readily preserved because the pigment is distributed in the deeper shell layers, whereas most gastropod color markings are confined to the surficial layers.

Of special note in dealing with the neritaceans is the fact that the shell layers are differentially preserved. For example, the specimens of the type lot of *Lyosoma powelli* White bear well-preserved details of sculpture, and one would assume that the shells are well preserved. The genus *Lyosoma* was therefore described as lacking *of the Carmel Formation*

not common (6–15 specimens); C, common (15–50 specimens); A, abundant (50+ specimens)]

Localities—Continued																															
18C	19A	19B	20	21	22	23	24	25	26A	26B	27	28	29	30	31A	31B	31C	32	33	34A	34B	35	36	37A	37B	38A	38B	39	40	41	42
																			NC	R											
				R																											
								R		R																					
		R					R	R		NC																			R		
								R										NC	R												
			NC		R	NC				R	R											?						?			
								R							R			R					R								
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																				R	R										
	A	A					A	A	NC	NC			R						R	?											
										C																					
		NC							R																						
R																			R			R			R	R	NC			R	
																NC									R		C				
			?												R																
				R				?						R	R	C	A		R	C	R								?		
																				N					R				R		
					R							R								R	R						R				R
	NC	R						NC	R	NC			R						R												

a strong inner lip septum. However, silicified specimens (pl. 2, fig. 1) in the collections here studied indicate that there is an inner lip septum. The only inference to be drawn is that this feature is composed of shell material considerably less stable than the remainder of the shell.

Evidence of a high-energy environment at many of the localities yielding gastropods is obvious. Many shells are worn or broken. One example is well shown by the small slab from locality 4 figured on plate 2 (fig. 24). This surface shows very poorly sorted sediment consisting of well-rounded silty calcareous pebbles as much as 7 mm in length; subrounded quartz, feldspar, and other pebbles as much as 5 mm in diameter; and a coarse sand fraction of rounded shell fragments and oolites. The only recognizable shells are the durable, thick-shelled nerite *Lyosoma enoda*. Experiments in ball mills (Keith Chave, oral commun., 1963) have shown that shells of the Neritidae are among the most durable when subjected to mechanical wear.

The most common occurrence of gastropods in quantity is exhibited by the hand specimens figured on plate 5. All the snails are small and show gross size sorting, which may indicate winnowing action. Commonly these small (2–5 mm) shells show effects of abrasion, sculpture being virtually eradicated (pl. 5, fig. 2), but in other hand specimens the shells may be well preserved (pl. 5, fig. 3). On some blocks, crude orientation of shell axes appears to indicate current direction; but commonly, orientation is random. The blocks on plate 5 show great concentrations of snails. More commonly, however, these snails occur scattered on the surface of oolitic limestone slabs and are intermixed with a hash of broken shell fragments dominated by oysters, *Camptonectes*, and crinoid columnals.

The gastropods occurring in the finer grained limestones that compose most of the lower member are more diverse and larger than those in other kinds of matrix. In such limestones, gastropods are complete and occur as scattered individuals intermixed with well-preserved valves of pelecypods that sometimes are articulated. The general lack of evidence of transport reflects less agitated conditions, and the more diverse assemblage of infaunal and epifaunal species suggests a life assemblage.

GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION

The Carmel gastropods mirror many of the distributional patterns of the more widespread and diverse pelecypods (Imlay, 1964). Like the pelecypods they are most abundant and diversified (fig. 2 and table 1) in the middle area (fig. 1), a 40-mile-wide belt trending southwestward from the west side of the San Rafael Swell. The gastropods are very poorly represented both in diversity and number in the Arapien Shale of the western area. Likewise, only seven species (one questionable) occur in the nearer shore facies of the eastern area.

The eastern area gastropod fauna is sparse and contains few forms that can definitely be assigned specifically. The numerous small gastropods ("winnowed fauna") that are common at many localities in the middle area are entirely lacking, as are the large *Tylostoma*-like naticids. Such sparsity is similar to that of the pelecypods, of which the eastern area has yielded only about one-quarter of the number of species found in the middle area. Stratigraphically, however, the gastropods of the eastern area are virtually restricted to the lower part of the lower limy unit of the Carmel Formation, whereas many of the pelecypod species either range through the unit or are to be found only in the middle part of the unit.

In the middle area, by contrast, six categories of gastropods range through the entire lower limy unit (fig. 2), although the greater diversity of gastropods occurs in the lower part of the unit.

Obviously, the shallow, perhaps littoral, conditions of the eastern nearer shore area, where interfingering red siltstones and generally sandier sediments were deposited, were not conducive to the development of a diversified fauna. This is substantiated by both the epifaunal pelecypod fauna and the presence of neritas and patelliform snails among the few gastropods present.

All the gastropod species present in the Carmel Formation fauna are restricted elsewhere in the western interior region to beds of Bajocian to Callovian age. In general, their state of preservation is such that it renders them useless for stratigraphic purposes. As can be seen in figure 2, however, *Cossmannea imlayi* occurs widely in Member B (of Bajocian age) of the Twin Creek Limestone, as well as in the Carmel Formation. *Lyosoma powelli* has a wider geographic range (see fig. 2) but also has a greater stratigraphic range, as it occurs in rocks of Bajocian to early Callovian age. The small gastropod assemblage is well represented in Member B of the Twin Peak Limestone of Utah, but is less common elsewhere.

Of all the gastropods, the *Lyosoma* species may prove to be of the greatest stratigraphic utility. Their shells were thick and, hence, are better preserved than most other gastropod shells; they were widespread, and they changed through time. For example, *Lyosoma powelli* is succeeded by an undescribed species (pl. 2, fig. 4) found in middle to upper Callovian rocks from Idaho to Wyoming and Montana.

SURVEY OF JURASSIC GASTROPODS OF NORTH AMERICA

No concentrated effort has been made to describe the gastropod faunas of North America. The number of described species is small; thus, although the Carmel Formation fauna is an impoverished one when compared with described European Jurassic faunas, it is by default the largest described Jurassic gastropod fauna in North America. The reasons for the small number of described species are the following: First, most previous descriptions have appeared as part of a study of the total fauna of a formation (Cragin, 1905) or as single or scattered descriptions (Frebold, 1957); secondly, most of the gastropods are commonly ill preserved when compared with the clams or cephalopods; thirdly, and perhaps most important, the gastropods are only locally abundant, are generally spatially restricted, and do not approach the stratigraphic utility of the Jurassic Ammonoidea. Thus, knowledge of the Jurassic gastropods of North America rests primarily on scanty and scattered records that may distort the understanding of both their abundance and taxonomic diversity.

MEXICO

Mention of gastropods in the Jurassic rocks of Mexico is sparse and usually indefinite. Burckhardt (1930, p. 12) noted unnamed gastropods in the Lias; but before the lower Oxfordian, in what he termed the "Calcaires à Nérinées" of the State of Zacatecas, one does not find any notation that gastropods occur in any profusion. Cerithiid gastropods are also noted by Burckhardt (1930, p. 91) from the Kimmeridgian beds. Imlay (1940, p. 395) noted similar occurrences in northern Mexico in beds of similar age range and indicated that locally some units contain numerous small unidentified snails.

A cursory examination of the Mexican Jurassic collections of the U.S. Geological Survey shows that this sparsity is not a result of lack of interest on the part of various authors but is due to actual rarity. Gastropods occur very rarely in these collections and the degree of diversity is small. Only the following forms, all from the Middle and Upper Jurassic, have been noted:

Pleurotomaria sp.
Naticid gastropods
Harpagodes sp.
Nerineids undet.

The dominantly cephalopod-bearing shales (Imlay, 1940, p. 398), obviously indicate an environment that was inhospitable to the development of a diversified gastropod fauna. It is, on the other hand, difficult to understand why gastropods are scarce in the Upper Jurassic near-shore deposits that contain a diverse pelecypod fauna (Imlay, 1940). Imlay (1940, p. 393) noted the similarity of the pelecypod fauna with that of the Malone Formation of Texas, which, however, does bear a moderately diverse gastropod fauna in addition to the pelecypod fauna.

UNITED STATES (CONTERMINOUS)

GULF COAST

Imlay (1941, 1945) described Late Jurassic (Oxfordian) gastropods recovered from cores in Alabama, Arkansas, Louisiana, and Texas. These consisted of:

Superfamily Neritacea
  Family Neritidae
    Neritopsis? sp.
Superfamily Cerithiacea
  Family Procerithiidae
    Xystrella? aff. *X. papillosa* (Deslongchamps)
    Cryptoptyxis? *formosa* Imlay
    Cryptoptyxis? aff. *C. grimaldi* (Guirand and Ogerien)
    Cryptoptyxis? *diversicostata* Imlay
Superfamily Nerineacea
  Family Itieriidae
    Phaneroptyxis angulata Imlay
  Family Nerineidae
    Aptyxiella (*Nerinoides*?) aff. *A. stantoni* (Cragin)
    Nerinea aff. *N. goodelli* Cragin
    Nerinea aff. *N. eudesii* Morris and Lycett
    Nerinea cf. *N. turbatrix* de Loriol
    Nerinella? sp.

All the preceding come from the Smackover Formation which, on the basis of associated ammonites, Imlay considered to be of late Oxfordian age. These gastropods appear to have affinities with those of Europe. It is interesting to note that the gastropods of the Smackover are like those of the Carmel in abundance of small cerithiaceans.

WEST TEXAS

Cragin (1905) described a rather diversified shallow-water molluscan fauna from the Malone Formation (Kimmeridgian-Portlandian) of west Texas. The mollusks are assigned to 84 species, 56 of which are pelecypods. Compared with many other Jurassic pelecypod faunas, the Malone fauna contains a goodly representation of medium- to deep-burrowing forms. Compared with the gastropod fauna of the Carmel Formation, the gastropods of the Malone are similar in the ample representation of neritids and nerineids, but the number of cerithiaceans is relatively low.

Gastropods from the Malone Formation include:

Superfamily Pleurotomariacea
  Family Pleurotomariidae
    Pleurotomaria circumtrunca Cragin
Superfamily Trochacea
  Family Turbinidae
    Turbo? *beneclathratus* Cragin (=*Purpurina*?)
Superfamily Neritacea
  Family Neritidae
    Nerita nodolirata Cragin (=*Trachynerita*?)
    Nerita finlayensis Cragin
    Nerita peroblata Cragin
Superfamily Amberleyacea
  Family Nododelphinulidae
    Delphinula stantoni Cragin (=*Metriomphalus*)
Superfamily Pseudomelaniacea
  Family Pseudomelaniidae
    Pseudomelania goodelli Cragin
Superfamily Cerithiacea
  Family Turritellidae
    Turritella burckhardti Cragin
  Family Vermetidae
    Vermetus cornejoi Castillo and Aguilera? (=*Chaetopoda*?)
  Family Cerithiacea
    Cerithium arcuiferum Cragin
Superfamily Naticacea
  Family Naticidae
    Natica williamsi Cragin (=*Globularia*)
    Natica inflecta Cragin (=*Globularia*)
    Natica finlayensis Cragin (=*Globularia*)
    Natica bilabiata Cragin (=*Globularia*)
Superfamily Nerineacea
  Family Nerineidae
    Nerinea goodelli Cragin
    Nerinea circumvoluta Cragin
    Nerinella stantoni Cragin
Superfamily Acteonacea
  Family Acteonidae
    Acteonino? *maloniana* Cragin

WESTERN INTERIOR

Few species have been described from this large area. Potentially, a thorough study of the Jurassic gastropods of the western interior would contribute more to the knowledge of North American Jurassic snail faunas than would a study of any other area. As in other areas, the gastropod fauna at most localities shows little diversity, although a few species may locally occur in profusion.

Early workers such as Meek and Hayden (1865), White (1876), and Stanton (1899) reported a few, primarily neritid, species from the Upper Jurassic sequences of the Black Hills and Yellowstone Park areas. A few additional species have appeared in the literature since that time. Aside from these, reports have been limited to faunal lists and notations in measured sections or discussions of stratigraphy of local areas.

Species described from the marine Jurassic of the western interior exclusive of Utah include:

1899. *Neritina wyomingensis* Stanton. Montana (probably Piper Formation).
1876. *Neritina*? *powelli* White (type species of *Lyosoma* White). Twin Creek Limestone, Utah.
1906. *Neritoma*? (*Oncochilus*) *occidentalis* Whitfield and Hovey. Sundance Formation, Wyoming.
1874. *Neritina phaseolaris* White. Twin Creek Limestone, Utah.
1933. *Scalaria* cf. *S. liasinus* (Quenstedt) Sandige. Sundance Formation, Montana.

As can be readily seen from the list of described species, all but one belong in the Neritidae, a family well known for its hardy, strong shells.

In addition to the preceding, numerous species of fresh-water Mollusca have been described from the

Morrison Formation. They were comprehensively reviewed by Henderson (1935) and Yen (1952) and need no further discussion here.

As in Utah (see p. D8), the majority of the Jurassic gastropods of the remainder of the western interior come from Middle Jurassic rocks. The most prolific and perhaps diverse Jurassic fauna occurs in the Gypsum Spring Formation of Wyoming and is as yet (1964) unstudied.

The following lists consist of specimens gleaned from the large Jurassic collections of the U.S. Geological Survey. The identifications of most of these specimens can be viewed only as tentative and are meant to be only an indication of taxonomic diversity and geographic and stratigraphic range of the taxa.

Twin Creek Limestone.—The Twin Creek Limestone throughout its extent in north-central Utah, southeastern Idaho, and western Wyoming contains a gastropod fauna that is very similar to that of the Carmel Formation. Member B of the Twin Creek Limestone, the partial age equivalent of the lower limy unit of the Carmel Formation, contains the largest and most similar gastropod fauna. Assemblages of small gastropods (for example, *Rhabdocolpus*) occur both in members B and F. Gastropods of the Twin Creek include:

- Member B
  - Utah
    - *Teinostomopsis*? sp.
    - *Lyosoma powelli* White
    - *Lyosoma enoda* Sohl
    - *Rhabdocolpus viriosus* Sohl
    - *Pseudomelania*? sp.
    - *Cylindrobullina*? sp.
  - Idaho
    - Assemblage of small gastropods (preservation poor)
    - *Lyosoma powelli* White
    - Naticiform gastropods indet.
    - *Cossmannea imlayi* Sohl
  - Wyoming
    - Assemblage of small gastropods (preservation poor)
    - *Lyosoma powelli* White
    - Naticiform gastropods indet.
    - *Cossmannea imlayi* Sohl
    - *Ceritella* cf. *C. tindonensis* Huddleston
- Member C
  - Wyoming
    - Naticiform gastropods indet.
- Member D
  - Wyoming
    - *Nerinea*? sp.
- Member E
  - Utah
    - *Nerinea*? sp.
    - Naticiform gastropods indet.
  - Wyoming
    - Trochiform gastropods indet.
    - Turriculate gastropods indet.
- Member F
  - Wyoming
    - Assemblage of small gastropods (preservation poor)

Gypsum Spring Formation.—The Gypsum Spring Formation of northwestern Wyoming is the age equivalent of the lower parts of the Twin Creek and Carmel Formations, and a number of species of gastropods are common to these formations. However, some parts of the Gypsum Springs, such as the limestones one-half mile south of Mill Creek, Fremont County, Wyo., contain a preponderance of dissimilar types of snails that are dissimilar to those in the lower parts of the Twin Creek and Carmel. The gastropods are preserved as internal and external molds in a gypsiferous limestone. Surface features on the external molds are well reproduced. Potentially, this unit might produce the most diversified molluscan fauna of the Jurassic of the western interior. The pelecypods are more diverse than the gastropods, and Imlay (1964) noted a number of pelecypod species similar to those of the Carmel Formation. A cursory examination of the collections yielded the following gastropods (asterisk denotes species common to the Carmel Formation):

Leptomaria n. sp.
Trochiform gastropods indet.
Buckmanina? sp.
**Nododelphinula*? sp.
**Lyosoma powelli* White
**Lyosoma* cf. *L. enoda* Sohl
Neritina sp. (very small)
Oonia sp. (small)
Pseudomelania sp.
Cloughtonia cf. *C. pyramidata* (Morris and Lycett)
Procerithium n. sp.
Turriculate gastropods indet.
**Tylostoma*? sp.
Naticiform gastropods indet.
Cossmannea n. sp.
Nerineids undet.

A more thorough study of the Gypsum Spring fauna would undoubtedly bring other species to light. At the Mill Creek locality most species are small, only the nerineids and *Cloughtonia* being of medium size. Most abundant are the small procerithids, which are usually only a few millimeters long.

"*Lower Sundance Formation.*"—The "Lower Sundance Formation" (mid-Bajocian to Callovian) of central and southeastern Wyoming is also a partial age equivalent of the Carmel Formation and bears a gastropod fauna similar to that of the Carmel, both formations having almost all represented genera in common as well as having a number of identical species. *Tylostoma*? sp. and small indeterminate naticiform gastropods preserved as molds are perhaps the most abundant; but *Lyosoma powelli* White is known from four localities. The following gastropods occur in the "Lower Sundance Formation" (an asterisk denotes species common to the Carmel Formation):

Pleurotomaria sp.
**Lyosoma powelli* White
**Lyosoma enoda* Sohl
Neritina? sp.
**Nododelphinula*? sp.
Purpurina cf. *P. cancellata* Huddleston
Pseudomelania sp.
**Tylostoma*? sp.
Naticiform gastropods indet.
Ceritella? sp.
Cossmannea sp.
Cylindrobullina? sp.

Canyon Springs Sandstone Member of the Sundance Formation.—The Canyon Spring Sandstone Member (lower Callovian) of the Sundance Formation of northeastern Wyoming and western South Dakota bears a gastropod fauna distinctive primarily for its numerous internal molds of naticiform gastropods. In addition, the member marks the upper limit for the range of *Lyosoma powelli* and perhaps *L. enoda*. The few species present, which are similar to those of the Carmel Formation, are given in the following list:

Lyosoma powelli White
Lyosoma cf. *L. enoda* Sohl
Tylostoma? sp.
Naticiform gastropods indet.

Piper Formation.—The Piper Formation (Bajocian-Bathonian) of eastern Montana is the approximate age equivalent of the lower limy unit of the Carmel Formation, but the few gastropods collected from it have little relationship to those of the Carmel except at the generic level. The gastropods of the Piper include:

Neritina cf. *N. wyomingensis* Stanton
Pseudomelania sp.
Procerithium? sp.
Exelissia? sp.
Naticiform gastropods indet.
Cossmannea? sp.

Sawtooth Formation.—The Piper Formation grades westward in Montana to the Sawtooth Formation (Bajocian-Bathonian). Both the Piper and the Sawtooth have yielded only a few gastropods that have little diversity and little other than generic similarity to the gastropods of the Carmel Formation. The Sawtooth has yielded the following gastropods:

Pseudomelania sp.
Rhabdocolpus sp.
Naticiform gastropods indet.
Cossmannea? sp.

Preuss Sandstone.—The Wolverine Canyon Limestone Member (Callovian) of the Preuss Sandstone (Imlay, 1952) in southeastern Idaho is slightly younger than the Carmel Formation. It locally bears the following silicified gastropods:

Lyosoma cf. *L. powelli* White n. sp.
Exelissia n. sp.
Procerithium n. sp.
Naticiform gastropods indet.
Cossmannea n. sp.

The *Lyosoma* noted in the preceding list also occurs in the Hulett Sandstone Member of the Sundance Formation in the Black Hills area and in the Rierdon Formation of Montana, both of Callovian age. None of these species occur in the Carmel Formation of Utah.

Hulett Sandstone Member of the Sundance Formation.—The Hulett Sandstone Member (Callovian) of the Sundance Formation has yielded a *Lyosoma* at one locality in Fremont County, Wyo. (USGS 22078). This *Lyosoma* is of the *L. powelli* type but possesses thin, fine incrementals typical of the shell from the Rierdon shown on plate 2, figure 4. The same species also occurs in the slightly younger Wolverine Canyon Limestone Member of the Preuss Formation and may serve well as a Callovian marker in Idaho, Wyoming, and Montana.

Rierdon Formation.—The Rierdon Formation (lower Callovian) is a widespread marine unit in Montana. The most common gastropods are small internal molds of naticid forms, but all identified genera are common to other units of the western interior Jurassic. Most significant is *Lyosoma* cf. *L. powelli* (pl. 2, fig. 5), which is also present in the Hulett Sandstone Member of the Sundance Formation in the Black Hills area and in the Wolverine Canyon Limestone Member of the Preuss Sandstone. The following gastropods were collected from the Rierdon:

Pleurotomaria sp.
Lyosoma cf. *L. powelli* White (n. sp.)
Rhabdocolpus sp.
Tylostoma? sp.
Naticiform gastropods indet.
Cossmannea sp.

Swift Formation.—The Swift Formation (Oxfordian) of Montana is the youngest Jurassic marine unit of the western interior for which we have records of gastropods. The most unusual form is one that may belong to *Dicroloma* and represents the only record of the family Aporrhaidae in the Jurassic of the western interior. The gastropods of the Swift include:

Lyosoma cf. *L. enoda* Sohl (n. sp.)
cf. *Dicroloma* sp.
Pleurotomaria sp.

PACIFIC COAST

The Jurassic sequence of the Pacific coast has yielded but seven described gastropod species. These are:

Turbo paskentaensis Stanton (=*Oolíticia*)
Trochus hinchmanensis Crickmay
Amberleya dilleri Stanton
Cerithium paskentaensis Stanton (=*Paracerithium*?)
Hypsipleura? *occidentalis* Stanton (=*Paracerithium*)
Nerinea thompsonensis Crickmay
Itieria californica Anderson

Stanton's and Anderson's species all come from the latest Jurassic beds (Portlandian) in the Coast Range and show their closest affinities to the species of Alaska. Crickmay's species are from beds of Bajocian age from the Taylorsville area in the Sierra Nevada. A cursory examination of the U.S. Geological Survey collections yielded no additional identifiable gastropods.

CANADA

The Jurassic faunas of Canada have been the subject of studies primarily by Frebold, Warren, Crickmay, McLearn, and others. Although many ammonites and pelecypods have been described in these works, few gastropods have been noted. Personal field experience in the Canadian Rockies indicates that this scarcity of snails is not the result of neglect but of poor representation of gastropods. They are not diverse at any known locality nor are they widespread.

Along the Canadian Rockies, the Nordegg Member (Sinemurian) of the Fernie Shale in the Cadomin area contains numerous large specimens of an undescribed *Pleurotomaria* that are especially noteworthy. Higher in the Fernie sequence, in black shales of the Rock Creek Member (Bajocian) in the vicinity of Blairmore, Dr. Hans Frebold of the Canadian Geological Survey has collected numerous specimens of a potamidid snail. Better known, however, is "*Turbo*" *ferniensis* Frebold, which occurs at many localities throughout Alberta in the upper Oxfordian "Green Beds" of the Fernie Shale (Frebold, 1957, p. 58). This species is one of the few Jurassic gastropod species to have a demonstrated stratigraphic utility in North America. The "Grey Beds" (Callovian to Oxfordian) of the Fernie contain a few poorly preserved gastropods assignable to such common Jurassic genera as *Pleurotomaria* and *Amberleya.*

British Columbia has also yielded records of a few gastropods. *Pleurotomaria skidegatensis* Whiteaves occurs in the Yakoun Formation of Queen Charlotte Island. Crickmay (1930) found *Pseudomelania* in the Opuntia Formation (Bajocian) of the Ashcroft area. Frebold (1959, p. 11) noted the presence in this area of additional undetermined Sinemurian gastropods.

Frebold (1960, p. 4), in speaking of the Jurassic of the Aklavik Range in the Canadian Arctic, stated: "The Lower Jurassic faunas in this area consist mainly of ammonites, nautiloids, pelecypods and gastropods, of which the ammonites form the most important part." Unfortunately the affinities of these gastropods are unknown.

ALASKA

The Alaskan Jurassic sequence may contain a greater diversity of gastropods than any other area on the North American continent. Some of the fauna, primarily the cephalopods, was described by Imlay (1953, 1962). The difficulty of collecting and transporting large samples from Alaska limits the basis for evaluating the relative abundance of gastropods. The following notations serve only as an indication of the presence of taxonomic groups. Obviously, intensive collecting would increase the list considerably.

It should be noted, however, that the greatest diversity of gastropods in Alaska occurs in the Kialagvik Formation and the Tuxedni Group of Bajocian to Bathonian age. This observation correlates well with similar times of maximum diversity of gastropods in the western interior of the United States.

The Early and Middle Jurassic Alaskan gastropods have close affinities with European species groups. The Late Jurassic forms appear dissimilar, but this conclusion is subject to reservations because of lack of diversity among the gastropods, scarcity of specimens, and vagaries of preservation.

The gastropods that occur in Alaska are given in the following list:

Talkeetna Formation (Lower Jurassic)
- *Pleurotomaria* cf. *P. subarenosa* Huddleston
- *Pleurotomaria* sp.
- *Amberleya* cf. *A. densinodosa* Huddleston
- *Oonia* cf. *Oonia subglobosa* (Morris and Lycett)
- *Cloughtonia* sp.
- *Procerithium* cf. *P. vetustum* (Phillips)

Kialagvik Formation (Bajocian)
- *Pleurotomaria* cf. *P. subarenosa* Huddleston
- *Pleurotomaria* sp. A
- *Pleurotomaria* sp. B
- *Monodonta* n. sp.
- *Purpurina* cf. *P. elaborata* Morris and Lycett
- *Purpurina* sp.
- *Pseudomelania* cf. *P.* (*Oonia*) *leymeriei* (d'Archiac)
- *Pseudomelania* cf. *P.* (*Oonia*) *subglobosa* (Morris and Lycett)

Tuxedni Group (Bajocian to Bathonian)
- *Pleurotomaria* sp. A
- "*Margarites*" sp.
- *Amberleya* cf. *A. densinodosa* Huddleston
- *Amberleya* cf. *A. ornata* J. Sowerby
- *Amberleya* sp. indet.
- *Metriomphalus* cf. *M. hamptonensis* (Morris and Lycett)

Tuxedni Group (Bajocian to Bathonian)—Continued
- *"Turbo"* cf. *"T." subpyramidalis* d'Orbigny
- *Purpurina* cf. *P. hellona* d'Orbigny
- *Pseudomelania* cf. *P.* (*Oonia*) *leymeriei* (d'Archiac)
- *Procerithium* cf. *P. michinhamptonense* Cox and Arkell
- *Procerithium?* sp.
- *Cloughtonia* cf. *C. pyramidata* Morris and Lycett
- *Nerinea?* sp.
- *Cylindrobullina?* sp.
- *Tornatellaea* cf. *T. sedgvici* (Phillips)

Chinitna Formation (Callovian)
- *Amberleya* cf. *A. delia* (d'Orbigny)
- *Amberleya?* sp.
- *Procerithium?* sp.
- *Tornatellaea* cf. *T. sedgvici* (Phillips)

Shelikof Formation (Callovian)
- *Amberleya* cf. *A. delia* (d'Orbigny)
- *Amberleya* sp. indet.

Lower part of Naknek Formation (Oxfordian)
- *Amberleya* cf. *A. delia* (d'Orbigny)

Upper part of Naknek Formation (Kimmeridgian)
- *"Margarites"* sp.
- *Amberleya* cf. *A. delia* (d'Orbigny)
- *Amberleya* sp.

The Alaskan species cited in the preceding list contrast very strongly with those of the Carmel Formation. No gastropod species and few genera are common to the two areas. The gastropod fauna of the Carmel Formation is dominated by neritid and naticid forms, whereas the Alaskan faunas are more diversified taxonomically. Neritids that are common in the Carmel fauna are absent from the Alaskan faunas; nerineids, rather common in Utah, are poorly represented to the north, as are naticid gastropods. Members of the Amberleyacea are present in both areas but are rare in the western interior and common in Alaska. Thus, the gastropods of these areas contrast not only in taxonomic representation but also in abundance of common genera; similar differences may be seen in the cephalopods (Imlay, 1953; 1962).

Aside from geographic separation, depth of water and salinity most likely account for, or contribute to, the contrast between the faunas. The Alaskan faunas indicate, in general, a deep-water, open, normal-marine environment. Imlay (1953, p. 57–65) cited the lack of littoral mollusks in the Alaskan Callovian sequence. In contrast, both physical and faunal evidence point to a littoral environment prevailing in many areas of the western interior. The rarity of nerineid gastropods in Alaska supports Imlay's suggestion that northern waters were cooler.

SUMMARY

1. The Jurassic gastropod faunas of North America have little interregional continuity. This provinciality is well displayed by the lack of common species. There is some similarity between the gulf coast, west Texas, and Mexico faunas, but there is a distinct separation between these and the western interior faunas. The Alaskan gastropod faunas appear to be distinct from all of these.

2. In the gastropod faunas of the gulf coast and west Texas areas, diversity is greatest in beds of Late Jurassic age, whereas in the western interior and Alaska, diversity is greatest in units of Bathonian and Bajocian age.

3. Shallow near-shore, perhaps littoral gastropods, such as the Neritidae, are most common in Texas and the western interior but become less common northward to Alaska. The same holds true for the Nerineacea and Naticacea. The lesser numbers of Nerineacea suggest cooler water to the north.

4. The total fauna is taxonomically typical of the Jurassic with strong representation of the Neritacea, Amberleyacea, Pseudomelaniacea, Cerithiacea, and Nerineacea. No Neogastropoda are present, and representation of the Euthyneura is poor except for the Nerineacea.

5. Total fauna is shallow water in origin, but the Alaskan fauna may represent a deeper water environment than that of the western interior and west Texas.

Marine Gastropoda of the Jurassic of North America

[Letters indicate stratigraphic range: S, Sinemurian; Pl, Pliensbachian; Ba, Bajocian; Bt, Bathonian; C, Callovian; O, Oxfordian; K, Kimmeridgian P, Portlandian. Numbers indicate geographic range; 1, Mexico; 2, Gulf coast and Texas; 3, Western interior; 4, Canada; 5, Alaska; 6, Pacific coast]

Subclass Streptoneura
- Order Archaeogastropoda
  - Superfamily Pleurotomariacea
    - Family Pleurotomariidae
      - *Pleurotomaria circumtrunca* Cragin (K–P) (2)
      - *Pleurotomaria? borealis* Warren (Ba) (4)
      - *Pleurotomaria skidegatensis* Whiteaves (Ba–Bt) (4)
      - *Pleurotomaria* cf. *P. subarenosa* Huddleston (Pl, Ba) (5)
      - *Pleurotomaria* spp. (Pl–O) (3–5)
      - *Leptomaria* n. sp. (Ba) (3)
  - Superfamily Patellacea
    - Family Symmetrocapulidae
      - *Symmetrocapulus? corrugatus* Sohl (Ba–Bt) (3)
  - Superfamily Trochacea
    - Family Trochidae
      - *"Trochus" hinchmanensis* Crickmay (Ba) (6)
      - *Buckmanina?* sp. (Ba) (3)
      - *Monodonta n.* sp. (Ba) (5)
      - *"Margarites"* sp. (Ba, Bt, K) (5)
    - Family Skeneidae
      - *Teinostomopsis?* sp. (Ba, Bt) (3)
    - Family Turbinidae
      - *Turbo? beneclathratus* Cragin (=Purpurina) (K, P) (2)
      - *"Turbo" subpyramidalis* (d'Orbigny) (Ba, Bt) (5)

Marine Gastropoda of the Jurassic of North America—Continued
Subclass Streptoneura—Continued
Order Archaeogastropoda—Continued
Superfamily Neritacea
Family Neritopsidae
Neritopsis? sp. (O) (2)
Family Neritidae
Trachynerita? *nodolirata* Cragin (K, P) (2)
Nerita? *finlayensis* Cragin (K, P) (2)
Nerita? *peroblata* Cragin (K, P) (2)
Lyosoma powelli White (Ba–Lower C) (3)
Lyosoma aff. h. *powelli* White n. sp. (C) (3)
Lyosoma enoda Sohl (Ba, Lower C) (3)
Lyosoma cf. *L. enoda* Sohl (O) (3)
Neritina phaseolaris White (Ba, Bt) (3)
Neritina wyomingensis Stanton (Ba, Bt) (3)
Neritina sp. (Ba–Bt) (3)
Otostoma? *occidentalis* (Whitfield and Hovey) (Bt) (3)
Superfamily Amberleyacea
Family Amberleyidae
Amberleya dilleri Stanton (P) (6)
Amberleya cf. *A. delia* (d'Orbigny) (C–K) (5)
Amberleya cf. *A. ornata* Sowerby (Ba, Bt) (5)
Amberleya cf. *A. densinodosa* Huddleston (Pl, Ba–Bt) (5)
Amberleya sp. (Ba–K) (3, 5)
Ooliticia paskentaensis (Stanton) (P) (6)
Ooliticia? *fernieensis* (Frebold) (O) (4)
Ooliticia? sp. (Ba, Bt) (3)
Family Nododelphinulidae
Metriomphalus stantoni (Cragin) (K, P) (2)
Metriomphalus cf. *M. hamptonensis* (Morris and Lycett) (Ba–Bt) (5)
Nododelphinula? sp. (Ba, Bt) (3)
Order Mesogastropoda
Superfamily Littorinacea
Family Purpurinidae
Purpurina cf. *P. cancellata* Huddleston (Ba–Bt) (5)
Purpurina cf. *P. elaboratus* Morris and Lycett (Ba) (5)
Purpurina cf. *P. hellona* d'Orbigny (Ba) (5)
Purpurina sp. (Ba) (5)
Superfamily Pseudomelaniacea
Family Pseudomelaniidae
Pseudomelania goodelli Cragin (K–P) (2)
Pseudomelania sp. (Ba–Bt) (3, 4)
Pseudomelania? sp. (Ba) (3)
Oonia cf. *O. subglobosa* (Morris and Lycett) (Pl, Ba) (5)
Oonia cf. *O. leymeriei* (d'Archiac) (Ba–Bt) (5)
Oonia sp. (Ba–Bt) (3)
Cloughtonia cf. *C. pyramidata* (Morris and Lycett) (Ba) (3)
Cloughtonia sp. (Pl) (5)
Superfamily Cerithiacea
Family Turritellidae
Turritella? *burckhardti* Cragin (P–K) (2)
Family Procerithiidae
Xystrella n. sp. (Ba) (3)
Xystrella? aff. *X. papillosa* (Deslongchamps) (O) (2)
Cryptoptyxis? *formosa* Imlay (O) (2)
Cryptoptyxis? aff. *C. grimaldi* (Guirand and Ogerian) (O) (2)

Marine Gastropoda of the Jurassic of North America—Continued
Subclass Streptoneura—Continued
Order Mesogastropoda—Continued
Superfamily Cerithiacea—Continued
Family Procerithiidae—Continued
Cryptoptyxis? *diversicostata* Imlay (O) (2)
Rhabdocolpus viriosus Sohl (Ba–Bt) (3)
Rhabdocolpus sp. (Ba–Lower C) (3)
Procerithium n. sp. (Ba) (3)
Procerithium cf. *P. vetustum* (Phillips) (Pl) (5)
Procerithium cf. *P. michinhampotnense* Cox and Arkell (Ba–Bt) (5)
Procerithium? spp. (Ba–C) (3, 5)
Paracerithium occidentalis (Stanton) (P) (6)
Paracerithium? *paskentaensis* (Stanton) (Ba–Bt) (6)
Exelissia n. sp. (C) (3)
Exelissia? sp. (Ba–Bt) (3)
Family Cerithiidae
Cerithium arcuiferum Cragin (P–K) (2)
Superfamily Strombacea
Family Aporrhaidae
Harpagodes (Ba–P) (1)
cf. *Dicroloma* sp. (O) (3)
Superfamily Naticacea
Family Naticidae
Globularia williamsi Cragin (P–K) (2)
Globularia inflecta Cragin (P–K) (2)
Globularia finlayensis Cragin (P–K) (2)
Globularia bilabiata Cragin (P–K) (2)
Globularia sp. (Ba–Bt) (3)
Tylostoma? sp. (Ba–Lower C) (3)
Naticids indet. (Ba–C) (3)
Subclass Euthyneura
Order Entomotaeniata
Superfamily Nerineacea
Family Ceritellidae
Ceritella cf. *C. tindonensis* Huddleston (Ba–Bt) (3)
Family Nerineidae
Aptyxiella (*Endiatrachelus*) *goodelli* (Cragin (K–P) (2)
Aptyxiella circumvoluta Cragin (K–P) (2)
Nerinea aff. N. goodelli (Cragin) Imlay (O) (2)
Nerinea aff. *N. eudesii* Morris and Lycett (O) (2)
Nerinea cf. *N. turbatrix* (de Loriol) (O) (2)
Nerinea? *thompsonensis* Crickmay (Ba) (6)
Nerinea? sp. (Ba–Bt) (3, 5)
Nerinoides? *stantoni* Cragin (K–P) (2)
Nerinoides? sp. (O) (2)
Nerinoides? aff. *A. stantoni* Imlay (O) (2)
Cossmannea imlayi Sohl (Ba–Bt) (3)
Cossmannea? *kanabensis* Sohl (Ba–Bt) (3)
Cossmannea n. sp. (Ba–C) (3)
Cossmannea? spp. (Ba Lower C) (3)
Indeterminate nerineids (Ba–P) (1, 3)
Family Itieriidae
Phaneroptyxis angulata Imlay (O) (2)
Itieria californica Anderson (P) (6)
Order Cephalaspidea
Superfamily Acteonacea
Family Acteonidae
Acteonina? *maloniana* Cragin (K–P) (2)
Tornatellaea cf. *T. sedgvici* (Phillips) (Ba–C) (5)
Cylindrobullina? sp. (Ba–Bt) (3, 5)

SYSTEMATIC PALEONTOLOGY

The usage and sequence of treatment of the higher taxonomic categories follows the classification of Taylor and Sohl (1962). Morphologic terminology conforms to that used in the "Treatise on Invertebrate Paleontology" by Knight and others (1960, p. I129–I135.)

Under the heading "Types" the abbreviation USNM indicates that the specimen is deposited in the type collections of the U.S. National Museum. Numbers listed in the sections headed "Occurrence" refer to localities described on pages D3–D4 and diagrammatically located in figure 1. Numbers prefaced by USGS refer to collection numbers recorded in the U.S. Geological Survey Mesozoic locality register.

Class GASTROPODA Cuvier, 1797

Subclass STREPTONEURA Spengel, 1881

Order ARCHAEOGASTROPODA Thiele, 1925

Superfamily PLEUROTOMARIACEA Swainson, 1840

Family PLEUROTOMARIIDAE Swainson, 1840

Genus PLEUROTOMARIA Defrance, 1826

Type by subsequent designation (S. P. Woodward, 1851), *Trochus anglicus* J. Sowerby, 1818.

Discussion.—Pleurotomarians are common in the Jurassic faunas of many areas. In the Jurassic of North America four species have been described. For the most part they are based on poor material, but representatives are to be found from west Texas to Alaska in beds of Bathonian to Portlandian age.

Pleurotomaria? sp.

Plate 1, figures 9, 13

Discussion.—Several poorly preserved internal molds from the Carmel Formation at localities 33 and 34A are questionably assigned to *Pleurotomaria* on the basis of gross shape.

The molds are of medium size, trochiform, and broadly umbilicate (pl. 1, fig. 9), but no distinct selenizone can be discerned. The whorls are biangulate (pl. 1, fig. 13). The upper whorl angulation separates the moderately broad, subsutral ramp above from the flat outer-whorl face, whereas the second angulation delimits the rounded base. One mold retains the faint impression of fine widely spaced spiral lirae on the base.

I have found record of only four described species of *Pleurotomaria* from the Jurassic of North America.

P. skidegatensis Whiteaves, Yakoun Formation, Vancouver, B.C.
P. circumtrunca Cragin, Malone Formation, Texas.
P.? borealis Warren, Fernie shale, Canada.
P. cf. *P. rozete* (de Loriol) Spath, Portlandian, East Greenland.

None of these species are well preserved, and none retain sufficient character for confident placement.

The molds from Utah are similar to *Pleurotomaria? borealis* Warren (1932, p. 33) in gross form, but because of poor preservation no close comparison can be made. Warren's species is evidently from the Rock Creek Member (Bajocian) of the Fernie shale and of approximately the same age as the Carmel species.

Type: Figured specimen USNM 144826.
Occurrence: Utah: Carmel Formation at loc. 33, 34A.

Superfamily PATELLACEA Rafinesque, 1815

Family SYMMETROCAPULIDAE Wenz, 1938

Genus SYMMETROCAPULUS Dacque, 1933

Type by original designation, *Patella rugosa* J. Sowerby, 1816.

Symmetrocapulus? corrugatus Sohl, new species

Plate 1, figures 22–24

Diagnosis.—Medium-sized patelliform shell bearing coarse concentric folds and having the apex situated at anterior third quarter of length.

Description.—Shell medium size, patelliform, rather high and moderately thick; apex situated at about anterior third quarter of length. Protoconch unknown. Anterior slope moderately steep and somewhat concave; posterior slope less steep and roundly convex. Sculpture consisting of coarse concentric growth rugae most closely spaced below the beak and usually coarsening at later growth stages. Aperture ovate, muscle scars unknown, interior of shell crenulate in harmony with the coarse concentric corrugations of the exterior.

Measurements.—The holotype measures 32.7 mm in length, 24 mm in diameter, and 13.2 mm in height.

Discussion.—I was unable to find any record of described species of patelliform gastropods from the Jurassic of North America. Preliminary examinations of the Geological Survey Jurassic collections from the western interior yielded no specimens assignable to the Patellacea. In addition, there appear to be no closely similar species from Europe. The type species *Symmetrocapulus rugosa* J. Sowerby is proportionally lower and has distinctive radial sculpture that is absent on the species from the Carmel Formation.

Placement of this species in *Symmetrocapulus* is questioned as the internal musculature is unknown.

Types: Holotype USNM 144827.
Occurrence: Utah: Carmel Formation at loc. 21.

Superfamily TROCHACEA Rafinesque, 1815

Family CYCLOSTREMATIDAE Fischer, 1885

Genus TEINOSTOMOPSIS Chavan, 1954

Type by original designation, *Teinostomopsis saharae* Chavan.

Teinostomopsis? sp.

Plate 1, figures 2–4, 7

Discussion.—Smooth-surfaced rotelliform shells, usually not exceeding 2 mm in diameter, occur weathered out on limestone slabs at several localities. Most specimens show only the low spire and its slightly convex whorls. I was able to excavate one specimen (pl. 1, fig. 3) that has the aperture partly weathered out. The base of the shell is anomphalus, but slightly depressed over the umbilical region. A callus pad covers much of the base. The pad edge can be only faintly seen extending from the umbilical area to the base of the inner lip. The inner lip is strongly curved and bears a broad callus tooth that partially infringes the aperture low on the inner lip but extends onto the parietal surface. The outer lip is highly inclined and appears to thin toward the edge.

In shape and in the apertural features that can be seen, these little shells most closely resemble *Teinostomopsis*, but the sutural characteristics and the placement of the inner lip callus differ somewhat. Better preserved specimens are necessary before placement is certain.

Types: Figured specimens USNM 144829–144831.

Occurrence: Utah: Carmel Formation at locs. 25, 26B; Twin Creek Limestone (member B) at loc. USGS 28458, near Thistle. Utah County.

Trochacea? sp.

Plate 1, figures 1, 6, 8

Discussion.—Small trochiform snails occur at several localities in the Carmel Formation. The shells generally do not exceed 2 mm in height and 4 mm in diameter. They consist of 3–4 whorls of circular cross section having an unornamented surface, except for fine rather highly inclined prosocline growth lines. The base and apertural features are unknown. The shells appear to represent only one species, but preservation is so poor that only the broadest assignment can be made.

Similar trochids also occur in the Twin Creek Limestone of the Crab Creek section near Thistle, Utah.

Types: Figured specimens USNM 144828, 144832, 144833.

Occurrence: Utah: Carmel Formation at locs. 7A, 8, 19B, 24, 25, 26B.

Superfamily NERITACEA Rafinesque, 1815

Family NERITIDAE Rafinesque, 1815

Subfamily NERITININAE Rafinesque, 1815

Genus LYOSOMA White, 1883

Type by subsequent designation (Fischer, 1885, p. 801), *Neritina powelli* White, 1876.

Diagnosis—The original diagnosis by White (1883, p. 152) was as follows:

Shell resembling certain forms of *Neritina* and *Nerita* in general aspect; volutions few, the last one much expanded; outer lip moderately thin; inner lip not thickened and apparently without any callus; the portion of the body exclusive of the last volution, very small and without a proper columella. Both of the only two species yet known have a slight flattening or lessening of the convexity of both the upper and outer sides of the last volution; the upper side having a more or less distinct but shallow revolving depression along its middle portion.

This diagnosis must be amended to state: inner lip thickened, aperture constricted by a rather straight nondentate inclined septum that is continuous with thickening of outer lip.

Discussion.—Binkhorst (1873) noted that the inner lip callus and septum are lost in some species of fossil neritaceans. White (1883, p. 153) was aware of this, but he was convinced that the material upon which he based his genus *Lyosoma* was sufficiently well preserved to show a septum had it been present. Although the genus *Otostoma* d'Archiac was originally described as a nonseptate form, Fischer (1885, p. 801) found impressions of an inner lip septum on internal molds assigned to this genus. For this reason Fischer thought the two genera *Otostoma* and *Lyosoma* might be synonyms. Cossmann (1925, p. 205), however, retained *Lyosoma* as a separate section under *Desmieria* Douvillé, an objective synonym of *Otostoma*. Wenz (1938, p. 418) later considered *Lyosoma* a subgenus of *Otostoma*, but more recently, Keen and Cox (in Knight and others, 1960, p. I285) again assigned *Lyosoma* as a questionable synonym of *Otostoma*.

More than 80 specimens of *Lyosoma powelli* from various localities in Utah, Wyoming, and Montana are present in the U.S. Geological Survey collections. An inner lip septum is present on only two of these. One specimen (USNM 144834) from Wyoming, retaining a strong median septum is silicified; the other specimen is preserved as a crystalline calcite shell. The reason for loss of the septum on the other seemingly well-preserved specimens cannot definitely be determined. The callus is deposited by a different part of the mantle than the part that forms the rest of the shell. I suggest, therefore, that the composition of these two parts of the shell may be mineralogically variable and subject to differential solution.

Inclusion of *Lyosoma* in *Otostoma* is untenable. *Otostoma* possesses denticles on the inner lip septum and lacks the carinate whorl of *Lyosoma*. *Lissochilus* Zittel, on the other hand, is similar in shape to *Lyosoma* and has a nondentate septum but differs in having a higher spire, well-developed transverse sculpture, and a bicarinate periphery.

White (1883, p. 153) proposed *Lyosoma* to include two species, *Neritina? phaseolaris* White and *Neritina? powelli*, but did not designate a type species. Fischer

(1885, p. 801) was the first subsequent author to mention a type species. The only subsequent list of included species was that provided by Cossmann (1925, p. 206), but no mention of *N. phaseolaris* was made by him. As is discussed herein, under *Lyosoma enoda*, White's cotype lot (USNM 118587) contains specimens of two different species, *Neritina phaseolaris* and *Lyosoma enoda*.

Cossmann's (1925, p. 206) list of species included in *Lyosoma* contains: *Neritina capduri* Cossmann, from the Barremian of France; *Stomatia ornatissima* Coquand, from the Aptian of Spain; *Stomatia bicarinata* Guererra, from the Cenomanian of France; *Lissochilus benahensis* Böhm (1900, p. 193), from the Turonian of Lebanon; and *Lyosoma squamosum* White (1888, p. 179), from the Senonian of Brazil. On the basis of available material it is difficult to say whether any of these species belong in *Lyosoma*. As an example, *Lyosoma squamosum* White fits well within the genus in most features, but the one available specimen, the holotype, lacks a median septum. One cannot be sure whether, like the holotype of *L. powelli*, the lack of a septum is a result of preservation or whether this lack is a primary feature. Now that the presence of a median septum is proved for *Lyosoma powelli*, the assignment of these other species must be questioned until their inner lip features are known.

Lyosoma powelli White

Plate 2, figures 1–3, 7–10, 14

1876. *Neritina? powelli* White, U.S. Geol. and Geog. Survey Terr. (Powell), p. 110, 111.
1883. *Lyosoma powelli* White, U.S. Geol. and Geog. Survey Terr. (Hayden) 12th Ann. Rept. (for 1878), p. 152, 153, pl. 38, figs. 6a–d.
1899. *Lyosoma powelli* White. Stanton, U.S. Geol. Survey Mon. 32, pt. 2, p. 630.
1925. *Desmieria (Lyosoma) powelli* (White). Cossmann, Essais de paléoconchologie comparée, v. 13, p. 205, 206.
1938. *Otostoma (Lyosoma) powelli* (White). Wenz, Handbuch der Paläozoologie; Gastropoda pt. 2, p. 418, fig. 1019.

Diagnosis.—Whorls having a subsutural welt and angular periphery, both of which bear elongate nodes.

Description.—Neritiform medium to moderately small low-spired shells; pleural angle 150°–160°. Shell about as high as wide. Whorls rapidly expanding, 2½–3 in number; suture slightly impressed. Whorls having a rather flat, narrow subsutural area bounded by a noded angulation; surface depressed or sulcate below angulation to the noded peripheral carination; below periphery, body rounds down rapidly. At maturity, near aperture, upper whorl surface is almost flat from suture to peripheral angulation. Sculpture dominated by thin strong collabral transverse ribs that form elongate nodes on angulations but that die out on base shortly below periphery. Growth lines, strong raised threads, strongly prosocline in trend between suture and upper whorl angulation, becoming more gently prosocline below. Aperture broad, open; outer lip slightly angulated in harmony with the whorl angulation. Inner lip well rounded and deeply excavated medially; medium septum, nondentate and inclined, having callus thickening extending to lower part of aperture.

Measurements.—

Locality	*Height (mm)*	*Maximum diameter (mm)*
Lectotype (USNM 144835)	24.5	23.8
Syntype (USNM 8181)	21.9	22.2
24668	14.7	14.2
24668	10.5	10.9

Discussion.—As indicated by the preceding measurements, the body proportions of shells of *Lyosoma powelli* maintain a uniform ratio through all the latter growth stages. In sculpture, however, there does appear to be considerable variation with growth. In the syntypic series (seven specimens, plus additional fragments), one may note that the transverse riblets are more closely spaced on the early whorls than on the latter whorls (pl. 2, contrast figs. 2, 9). The strength of the peripheral nodings also may vary much between individuals. The largest cotype (pl. 2, figs. 7–9), here selected as the lectotype (USNM 144835), shows a suppression of noding and a gradual loss of subsutural angulation. When the aperatural views of the lectotype (pl. 2, fig. 8) and that of the small hypotype (pl. 2, fig. 6) are compared it is seen that the outer lip angulation becomes rounded with increased size. This lends the aperture an almost quadrate outline.

The preservation of some specimens is sufficient to retain traces of original color pattern. This coloration consists of at least two spiral bands. One band is situated on the upper whorl angulation; the second and wider band covers the lower part of the peripheral whorl angulation.

Compared with *Lyosoma enoda* Sohl, which is from approximately the same stratigraphic interval, this species differs most noticeably in the presence of transverse ribs and nodings of the whorl angulations. Other species tentatively assigned to *Lyosoma* differ by having rather well-defined spiral sculpture. Another closely related, undescribed species occurs in the Preuss Sandstone on Dry Fork in Bingham County, Idaho (USGS 28499), in the Hulett Sandstone Member (Callovian) of the "Lower Sundance Formation" (USGS 22078), in Fremont County, Wyo., and in the Rierdon Formation of Montana (pl. 2, fig. 4). This species, characterized by its closely spaced sharp transverse ribs, seems to be a direct descendant of *L. powelli* and is restricted to beds of Callovian age.

Lyosoma powelli has been cited in faunal lists as being of wide occurrence in the western interior. I have verified its occurrence at 13 localities in Utah, Wyoming, and Montana. Although it is not abundant in Utah, *L. powelli* is the most widespread of the gastropod species represented in the Carmel Formation throughout the western interior. Throughout its geographic range only the most minor and seemingly inconsistent variance in sculpture and body proportions can be detected. No consistent criteria for separation can be noted. The type lot from the mouth of Thistle Creek, Spanish Fork Canyon, Utah, contains the largest specimens of the species known.

Types: Lectotype USNM 144835; syntypes USNM 144836, 8181; hypotype USNM 144834.

Occurrence: Utah: Carmel Formation at locs. 15C, 25, 32, 33; Twin Creek Limestone (member B) at loc. USGS 28458, near Thistle. Wyoming: Gypsum Spring Formation at loc. USGS 4995, near Cody on the Shoshone River; Sundance Formation (lower) at locs. USGS 17651, 17652, 17669, 17670, 19337, 24668, Big Horn Basin; at loc. USGS 9246, Little Dry Gulch, 15 miles below Dubois, at loc. USGS 9230 Gros Ventre River, east of Jackson; Twin Creek Limestone (member B) at loc. USGS 16036, near Lookout Peak, Afton quadrangle. Idaho: Twin Creek Limestone at loc. USGS 28585, Bingham County.

Lyosoma enoda Sohl, new species

Plate 2, figures 11–13, 15–24

1877. *Neritina? phaseolaris* White (part), U.S. Geog. and Geol. Survey W. 100th Meridian (Wheeler), v. 4, pt. 1, p. 167–168, pl. 13, figs. 1e, 1f, (not figs. 1a–c).

Diagnosis.—Whorls having nonnoded subsutural welt and peripheral angulation.

Description.—Medium to moderately small, low-spired shells; pleural angle 130°–145°. Whorls rapidly expanding, 2–3 in number; sutures slightly impressed. Whorls having a rather flat, narrow subsutural area bounded below by a rounded welt; surface depressed or sulcate between welt and peripheral angulation; below periphery, body rounded. Body devoid of sculpture except for fine, usually faint growth lines. Color markings, as known, consisting of two moderately broad spiral bands of dark brown placed at the subsutural welt and peripheral carination respectively. Growth lines having a moderately high prosocline inclination (30°) over entire length. Aperture broad, presumably constricted by a nondentate straight-edged septum; outer lip angulated at intersection, having subsutural welt and roundly angulated periphery, almost straight below periphery to rounded anterior; inner lip incompletely known.

Measurements.—

Locality	Height (mm)	Maximum diameter (mm)
23 (Holotype, USNM 144838)	16	17.5
23	14.5	15.0
Syntype *N. phaseolaris* (USNM 144837)	7.5	8.0

Discussion.—The syntypic series separated by White (1877, p. 167, USNM 8587) and described by him as *Neritina? phaseolaris* contains specimens here assigned to two species. Of the specimens White illustrated, the largest (1877, pl. 13, fig. 1e) is not contained in the U.S. National Museum collections and is evidently lost. I herein designate as lectotype of White's species *Neritina phaseolaris*, the specimen figured by him on his plate 13, figures 1a, 1b, 1c. The remaining figured specimen, his figure 1d, is herein assigned to *Lyosoma enoda* (USNM 144837), which differs from *N. phaseolaris* by having a proportionally higher spire and by having a subsutural welt and peripheral angulations as well as less inclined growth lines.

In shell proportions the known specimens of *Lyosoma enoda* are all very slightly wider than they are high. The strength of the subsutural welt and peripheral angulation varies moderately in sharpness. The most extreme variance in these features, however, appears to be on worn specimens; the wearing lends the body whorl a more rounded appearance than is typical.

The median apertural septum characteristic of *Lyosoma powelli* has not been noted on any specimens of *L. enoda*. Its lack in known specimens of *L. enoda* is laid to vagaries of preservation.

The close relationship of *Lyosoma enoda* and the type species *L. powelli* is well shown by their similar body proportions and whorl angulations as well as growth-line trend. On the other hand, the two can be easily distinguished. *L. enoda* lacks noding on the subsutural welt and peripheral angulation and has a different pattern of coloration.

Lyosoma enoda is restricted to beds of Bajocian and Bathonian age but appears to be related to undescribed forms in the Canyon Springs Sandstone Member of the "Lower Sundance Formation" of Wyoming and the Swift Formation (Oxfordian) of Montana.

Types: Holotype USNM 144838; paratype USNM 144841; figured specimens USNM 144842, 144843, 144840, 144837, 144839 (last two are former cotypes of *Neritina phaseolaris*).

Occurrence: Utah: Carmel Formation at locs. 3, 4, 15B, 16, 20, 21, 23, 26B, 27, on Salt Creek near Nephi, and questionably at locs. 9C, 10, 15A, 35, 39; Twin Creek Limestone (member B) at loc. USGS 17064, near Thistle, and at loc. USGS 21623, Duchesne County. Wyoming: "Lower Sundance Formation" at loc. USGS 17670 Sykes Mountain, 6½ miles north of Kane, Big Horn County.

Genus NERITINA Lamarck, 1816

Type by opinion 119 of International Commission of Zoological Nomenclature (1931), *Nerita puligera* Linné (1766).

Discussion.—According to Keen and Cox (in Knight and others, 1960, p. I282), this genus is restricted to the Eocene. The Jurassic species described here is included with question. In outline and growth form it simulates *Neritina*, but the full character of its shell is unknown, as no specimens preserve either the inner lip callus or septum. Until better preserved specimens are found, it seems best to follow White's (1877) original placement and retain them with question in *Neritina*.

Neritina? phaseolaris White

Plate 3, figures 12–21

1874. *Neritina phaseolaris* White, Prelim. Rept. Invertebrate Fossils, U.S. Geog. and Geol. Survey W. 100th Meridian (Wheeler), p. 24.

1877. *Neritina? phaseolaris* White (part), U.S. Geog. and Geol. Surveys W. 100th Meridian (Wheeler), v. 4, pt. 1, p. 167–168, pl. 13, figs. 1a–c (not figs. 1d, 1e.)

1883. *Lyosoma phaseolaris* White, U.S. Geol. and Geog. Survey Terr. (Hayden), 12th Ann. Rept. (for 1878), p. 152.

Diagnosis.—Low-spired neritid devoid of surface sculpture.

Description.—Moderately small neritiform shells of subglobular outline. Spire very low, only slightly protruding above body of adult. Suture slightly impressed. Whorls expand rapidly, well rounded, and devoid of sculpture. Growth lines highly prosocline and straight, inclined about 53° from the horizontal. Aperture broad, outer lip well rounded, inner lip incompletely known, callus wash rather thin, protruding slightly onto body; septum unknown.

Measurements.—The lectotype (USNM 144845) from Salt Creek near Nephi, Utah, measures 9 mm in height and has a maximum diameter of about 13 mm.

Discussion.—Shells closely conforming to the type specimen are rare in the Jurassic collections under study. The generalized shape and lack of sculpture cause difficulties in characterizing *Neritina phaseolaris*, and identification has rested on shape and shell proportions. Amount of variability within the species is poorly known because of the few specimens available from any given locality and because most show effects of abrasion, crushing, or weathering. All the specimens from localities other than Nephi, cited under "Occurrence," have a low spire and smooth, rounded, unornamented whorls, but their identification must be viewed as questionable.

Compared with *Neritina wyomingensis* Stanton (1899, p. 629) from beds of Middle Jurassic age in Yellowstone Park, this species is much lower in outline and has much more highly inclined growth lines.

Types: Lectotype USNM 144845; figured specimens 132843, 144844, 144846.

Occurrence: Utah: Salt Creek near Nephi, Juab County. Carmel Formation, questionable occurrences at locs. 9D, 31A, 32, 37A, 14B, 15C, 25.

Genus NERIDOMUS Morris and Lycett, 1851

Type by subsequent designation of Cossmann (1925, p. 187), *Nerita hemisphaerica* Morris and Lycett, 1851.

Neridomus? sp.

Plate 1, figures 18–21

Discussion.—Two specimens—one from the Arapien Shale of Sanpete County, Utah (USGS 21448), and one from the Carmel Formation (loc. 25)—may belong to this genus; but the inner lip features are incompletely known and definite placement is therefore impossible. The figured specimen is moderately small (9 mm high), has a low spire, and is about as high as it is wide. The whorls are well rounded and devoid of sculpture except for fine slightly arcuate prosocline growth lines. A few growth lines are sufficiently raised and strengthened to form a coarse surficial corrugation. The aperture is broad and has a well-rounded outer lip. The inner lip is broken and preserves no trace of callus.

Type: Figured specimen USNM 144851.

Occurrence: Utah: Arapien Shale at loc. 2; Carmel Formation at loc. 25.

Neritid gastropods

Indeterminable internal molds or distorted specimens of gastropods probably belonging in this family and possibly to one of the species previously discussed are present in the collections from the Carmel Formation of Utah at localities 5, 15B, 18A, 19B, 25, 27, 34A, 34B, 36, and 37B.

Superfamily AMBERLEYACEA Wenz, 1938
Family NODODELPHINULIDAE Cox, 1960
Genus NODODELPHINULA Cossmann, 1916

Type by original designation, *Delphinula buckmani* Morris and Lycett, 1851.

Nododelphinula? sp.

Plate 1, figures 10–12

Discussion.—Several incomplete specimens from the Carmel Formation of Utah may represent the genus *Nododelphinula*. All are incomplete but have a bicarinate periphery. One specimen (pl. 1, figs. 10, 12) from Kanab Canyon (loc. 33) is an external mold lacking the aperture and umbilicus. It bears a spiral row of coarse nodes on the upper sloping whorl surface. The periphery is delimited above by a sharp strong nodose carination and below by a second but weaker carination. Below the second carination, the body whorl constricts strongly.

Another figured specimen (pl. 1, fig. 11) from Orderville Canyon (loc. 39) may belong to a different species, as the noded sculpture is absent. The specimen has bicarinate whorls, however, and the lack of nodes may be due to the poor preservation.

One fragment (USNM 132638) ascribed to this species is part of the rounded base of a specimen and bears three strong spinose lirations.

Compared with the type species *N. buckmani* (Morris and Lycett) from the Middle Jurassic of England, this species has a proportionally lower spire. The sculpture is more highly nodose than is typical of the genus, but transverse sculpture is probably not as strong.

A similar and possibly conspecific form is present in the Gypsum Spring Formation and "Lower Sundance Formation" of Wyoming.

Types: Figured specimens USNM 144848, 132637; mentioned specimen USNM 132638.

Occurrence: Utah: Carmel Formation at locs. 33, 34A, 37B, questionable occurrence at loc. 39. Wyoming: "Lower Sundance Formation" at USGS loc. 17670; Gypsum Spring Formation at USGS loc. 19357, Sykes Mountain.

Family AMBERLEYIDAE Wenz, 1938

Genus AMBERLEYA Morris and Lycett, 1851

Type by subsequent designation, *Amberleya bathonica* Cox and Arkell, 1950.

Discussion.—Although only one specimen from the Carmel Formation is here assigned to *Amberleya*, the genus is especially well represented in the Jurassic of the more northerly areas in Canada and Alaska.

Amberleya? sp.

Plate 1, figure 14

Discussion.—The figured specimen consists of an internal and external mold of part of a body whorl. It is unique among the Carmel gastropods and appears to belong to a turbiniform species, possibly assignable to *Amberleya*. The whorl is round sided and covered by fine growth lines. Spiral sculpture is strong and consists of nodose cords that are weaker but more closely spaced on the basal slope than on the upper part of the whorl. A weak subsutural cord is followed by three stronger widely spaced cords over the rounded midwhorl and periphery. The cords are closely spaced on the basal slope but are not quite as broad as the spiral interspaces. The spacing and pattern of placement of these cords parallel those of *Amberleya densinodosa* Huddleston (1887, p. 282) from the Bajocian of England, but the nodes of the spiral cords are coarser and less closely spaced.

Type: Figured specimen USNM 132639.

Occurrence: Utah: Carmel Formation at loc. 16.

Genus OOLITICIA Cossmann, 1894

Type by original designation, *Turbo phillipsii* Morris and Lycett (1857, p. 117)

Ooliticia? sp.

Plate 1, figure 5

Discussion.—External molds of parts of shells from the Carmel Formation in Kanab Canyon, Kane County, Utah, possess characters that suggest their placement in the genus *Ooliticia.* The shell is turbiniform having a moderately high, tapering spire. The body whorl is rather well rounded, and the suture lies in a channel formed by the strong nodes of the subsutural cord. None of the specimens preserve the apertural features. The sculpture of the base is obscured because of poor preservation, but sculpture of the whorl sides consists of two strong widely spaced coarsely noded spiral cords (pl. 1, fig. 5). The upper or subsutural cord nodes project up and out, forming a trough between the cord and suture.

In these features of sculpture this species is somewhat reminiscent of the specimen of *Ooliticia sulcata* (Hebert and Deslongchamps) figured by Huddleston (1887, pl. 23, fig. 15) from the Callovian of Great Britain. Generic placement of this species is tenuous because of lack of knowledge of the apertural features.

Type: Figured specimen USNM 144857.

Occurrence: Utah: Carmel Formation at locs. 34A, 34B.

Order MESOGASTROPODA Thiele, 1925

Superfamily CERITHIACEA Fleming, 1822

Family PROCERITHIIDAE Cossmann, 1905

Subfamily PROCERITHIINAE Cossmann, 1905

Genus RHABDOCOLPUS Cossmann, 1906

Type by original designation, *Melania scalariformis* Deshayes, 1830.

Diagnosis.—Medium to small turriculate shells having strong transverse ribs and spiral cords. Ribs subtuberculate at upper ends.

Discussion.—Cossmann (1906, p. 27) proposed *Rhabdocolpus* as a subgenus of *Procerithium* Cossmann (1902). Both Walther (1951, p. 85) and Haas (1953, p. 234) treated *Rhabdocolpus* as a separate genus. Haas discussed the genus in detail, and his Peruvian species extend the range of the genus downward into the

Triassic. The genus is widespread and well represented in the Jurassic rocks of many areas, but this is the first report of it from North America. Imlay (1941) reported two other members of the family, *Cryptoptyxis* Cossmann and *Xystrella* Cossmann, in the Jurassic Smackover Formation of Arkansas.

Rhadocolpus viriosus Sohl, new species

Plate 3, figures 1–6; plate 5, figure 3

Diagnosis.—Small turriculate shells having 6–8 transverse ribs crossed by 3 spiral ribbons.

Description.—Shell small, slender, and turriculate. Pleural angle 20°–25°. Protoconch incompletely known, consisting of about two erect round-sided whorls expanding much more rapidly than teloconch whorls. Suture impressed, in part obscured by coronation of the transverse ribs of succeeding whorls. Whorls flat sided, base broadly convex, margin subangulate. First teloconch whorl smooth followed by whorls whose sculpture is dominated by 6–8 direct strong transverse ribs that are coronate or noded at their posterior extremity and die out at basal angulation. Spiral sculpture strongest on early whorls consisting of three spiral ribbons that override transverse ribs but are strongest in rib interspaces; ribbons weaken and are more widely spaced on later whorls; on body whorl, spiral sculpture of weak to obsolete ribbons on sides having secondary spiral lirae and low cords on base. Aperture incompletely known, subovate, rounded anteriorly, angulate posteriorly.

Measurements.—

Locality	Height (mm)	Maximum diameter (mm)
25	3.75	1.55
25	4.75	1.9
8	4.25+	1.8

Discussion.—This small species is one of the more common gastropods in the Carmel Formation of Utah and occurs in similar profusion in certain zones of the Twin Creek Limestone. In both formations it occurs with the "winnowed" small fauna that contains abundant *Cylindrobullina* sp. and small turriculate and trochiform species (pl. 5, fig. 3).

Variation in shape is slight, but, as can be seen by the illustrations, strength of sculpture does vary. Some specimens show well-developed spiral sculpture (pl. 3, fig. 2), but others (pl. 3, fig. 1) almost lack it. Similarly, the ribs can be strong and coronate above (pl. 3, fig. 6) or only low folds, depending in part on the state of preservation. Most of these specimens are from weathered limestone surfaces, and their sculpture may be subdued owing to surficial solution. The mode of occurrence indicates at least moderate transport, and thus shell wear can be expected.

No other species of the genus have been described from the Jurassic of North America. Except for being much smaller, *Rhabdocolpus viriosus* compares well in sculpture and shape with the type species *R. scalariforme* (Deslongchamps) from the Bajocian of Normandy, France.

Types: Holotype USNM 144856; paratypes USNM 144852–144855, 14846.

Occurrence: Utah: Carmel Formation at locs. 7B, 8, 9A–D, 14A, 15C, 19A, 19B, 24, 25, 26A, 26B, 33, and questionable occurrences at locs. 15B, 29, 34; Twin Creek Limestone at locs. USGS 28457 and 28459 on Crab Creek near Thistle, Utah County.

Genus PROCERITHIUM Cossmann, 1902

Type by original designation, *Procerithium quinquegranosum* Cossmann.

Procerithium? sp.

Plate 3, figures 8–11

Discussion.—Several small slender, high-spired specimens having strong spiral sculpture but lacking transverse sculpture have been found in the collections from the Carmel Formation.

The shells measure as much as 9 mm in height and have a maximum diameter of 2.5 mm. The whorls are flat sided, having a narrow flat subsutural shelf. Sculpture appears to be limited to thin spiral lirae that cover the whorl sides. The aperture is incompletely known.

Specimens belonging to this species are rare. The proportionately long whorl and its sculpture are most reminiscent of *Cerithium abbas* Huddleston (1887, p. 172) of the Jurassic "Sowerbyi-bed" of England. Compared with that species, these shells are much smaller, and the posterior shelf develops at a much earlier stage. The state of preservation of these specimens obviates further comparison.

Types: Figured specimens USNM 144858–144861.

Occurrence: Utah: Carmel Formation at loc. 26B.

Superfamily PSEUDOMELANIACEA Pchelintsef, 1960

Family PSEUDOMELANIIDAE Fischer, 1885

Genus PSEUDOMELANIA Pictet and Campiche, 1862

Type by original designation, *Pseudomelania gresslyi* Pictet and Campiche.

Pseudomelania? sp.

Plate 3, figure 7

Discussion.—Small aciculate smooth-surfaced shells are common at several localities in the Carmel Formation of Utah. Their assignment to *Pseudomelania* is questioned, as the growth-line character and apertural features are unknown. The shells are 7–10 mm long and 2–2.5 mm in diameter. The whorls are almost flat sided, the basal slope is rounded, and the surface is devoid of sculpture. The sutures are narrowly grooved.

This species occurs with the other small gastropods in the fauna in what appear to be "winnowed" size concentrations. The state of preservation is such that the growth lines cannot be discerned.

Type: Figured specimen USNM 144857.

Occurrence: Utah: Carmel Formation at locs. 19B, 26A; Twin Creek Limestone at loc. USGS 28458 on Crab Creek near Thistle, Utah County.

Turriculate gastropods indeterminate

Small slender gastropods that are too poorly preserved to allow generic assignment occur at localities 3, 7B, 15B, and 15C, and in the Twin Creek Limestone near Thistle, Utah (pl. 5, fig. 2). In general, the specimens are badly weathered, but in outline they resemble *Rhabdocolpus* or *Pseudomelania*. They probably represent one or the other of these forms, as indicated by their occurrence with other elements of the small gastropod fauna discussed before.

Superfamily NATICACEA Theile, 1929
Family NATICIDAE Forbes, 1838

Representatives of this family are moderately common in the Carmel Formation of Utah. Except for a few partially silicified specimens, they are poorly preserved and for the most part consist of internal molds in various states of completeness. They can be divided into two groups, one representing *Tylostoma*-like species and the other a smaller naticid akin to *Globularia*.

Genus TYLOSTOMA Sharpe, 1849

Type by subsequent designation (Wenz, 1941, p. 1026), *Tylostoma globosum* Sharpe.

Discussion.—The type species is based on large globose, naticoid internal molds from the Turonian of Portugal. Since its proposal, *Tylostoma* has served as a receptacle for generically indeterminable globose naticids of large size.

Tylostoma? sp.

Plate 4, figures 16, 19

Discussion.—A moderate number of internal molds generally conforming in shape to the figured specimens occur at 11 localities in the Carmel formation. All localities are in the middle area (fig. 1) of outcrop of the Carmel Formation.

None of the molds show surface or umbilical characters; and as some are distorted or fragmental, it is impossible to say that they all represent the same species. In all specimens the whorls are well rounded and have some indication of a subsutural flattened or ramplike area. One specimen shows the inner lip to be strongly excavated medially, as one would expect in shells having globose whorls. No trace of external ornament is known except for a faint suggestion that there may have been several transverse rugae near the aperture.

Types: Figured specimens USNM 132641, 144844.

Occurrence: Utah: Carmel Formation at locs. 15A, 17A, 17B, 18B, 18C, 33, 35, 37B, 38A, 38B, 41; Wyoming: questionable similar species occur in the Gypsum Spring Formation, Canyon Springs Sandstone Member of the Sundance Formation and the "Lower Sundance Formation."

Subfamily GLOBULARIINAE Wenz, 1941
[Ampullininae]

Genus GLOBULARIA Swainson, 1840

Type by subsequent designation (Hermannsen, 1847), *Ampullaria sigaretina* Lamarck, 1804.

Discussion.—In general, it is somewhat questionable whether any Jurassic shells assigned here actually belong in *Globularia*. For example, the species from the Great Oolite assigned by Cox and Arkell (1950, p. 83, 84) all have a proportionally higher spire and an aperture that is more expanded laterally than is typical of the type and other associated Eocene species. The specimens from the Carmel Formation treated in the following description are similar in character to those from the British Jurassic.

Globularia? sp.

Plate 4, figures 10–15

Discussion.—Nine specimens from the Carmel Formation on Deep Creek in Garfield County, Utah (loc. 31B), preserved sufficient character to allow at least a tenuous placement. They are all partially silicified, but the replacement is coarse and is of a beikitic nature that does not allow for the preservation of fine detail. The shell is globose and moderately small for the genus and has a spire proportionally higher than is typical for the genus. The aperture is broad and well rounded anteriorly. The inner lip is incompletely preserved on all specimens, but an umbilical chink is present. Some specimens suggest that this chink is covered by an umbilical sheath in complete specimens.

Types: Figured specimens USNM 144871–144875.

Occurrence: Utah: Carmel Formation at locs. 15A, 31B, 37B, 38B.

Naticiform gastropods

Generically indeterminate naticiform gastropods occur in the Carmel Formation at localities 1, 6, 9C, 9D, 12, 16, 31A, and questionably at locality 20. For the most part they are preserved as internal molds of rather small size. Some may represent additional specimens of those herein assigned to *Globularia?* sp.

Subclass EUTHYNEURA Spengel, 1881
Order ENTOMOTAENIATA Cossmann, 1896
Superfamily NERINEACEA Wenz, 1940

Family NERINEIDAE Zittel, 1873

Nerineid gastropods are among the most common snails found in the Jurassic rocks of the western interior. In the Carmel Formation they are represented by at least two and perhaps three, species; and in terms of abundance they are the most numerous of the larger snails. Although these species, because of their simple arrangement of internal plaits, seem best placed in *Cossmannea*, most other North American Jurassic described species seem to belong in other genera.

Genus COSSMANNEA Pchelintsev, 1931

Type by original designation, *Nerinea desvoidyi* d'Orbigny, 1850.

Discussion.—This genus is characterized by elongate, rather slender shells whose whorl sides are strongly to moderately concave and have a swollen or weltlike sutural area. The aperture is rhomboidal and has a short anterior canal. Cox (1948, p. 250) stated that two folds are present internally, one on the columella and one on the labial wall. The type species, *Cossmannea desvoidyi* (d'Orbigny) (1850, pl. 261) as originally figured, shows a rather weak columellar fold low on the columella, plus one fold on the outer wall. Pchelintsev (in Pchelintsev and Korobkov, 1960, pl. 12, fig. 8B) figured *C. subdesvoidyi* as having only the most faint and broad plications. The Carmel species described below fit well within this prescribed range.

Species other than those treated in the following description occur in the western interior Jurassic. They are especially abundant in the Gypsum Spring Formation but also occur in the "Lower Sundance Formation," the Preuss Sandstone, and questionably in the Piper and Sawtooth Formations.

Cossmannea imlayi Sorl, new species

Plate 4, figures 1–8

Diagnosis.—Whorl sides concave, having greatest constriction at lower one-third of whorl; columellar fold developed late in growth as a faint, low swelling.

Description.—Elongate, slender, multiwhorled shells. Protoconch unknown, pleural angle 9°–15°. Whorls concave sided having deepest part of concavity about two-thirds of the distance between upper and lower suture; sutural area swollen, suture being in a narrow groove. Body whorl basally carinate; on spire, basal carination slightly protruding over succeeding whorl. Growth lines sigmoidal on whorl sides. Aperture incompletely known, rhomboidal in outline; internally one plait on the midlabial surface persisting from the earliest whorls, but the low, rounded obscure columellar fold did not develop until a late growth stage.

Measurements.—One specimen that lacks about 12 mm of its apical tip measures 62.5 mm in length and 15 mm in diameter. Less complete specimens indicate that this species grew to a larger size. These specimens have a maximum diameter of about 19 mm and, by extrapolation from known proportions of smaller specimens, may have attained a length of 90–100 mm.

Discussion.—This species is abundant at its type locality on Deep Creek, Garfield County, Utah (loc. 31B, 31C); more than 100 incomplete specimens are available for study. Variation within the type lot is difficult to measure because the coarse beikitic replacement of the shell material masks the finer features of ornament and because of wear and the effects of compression on some specimens. For example, it is difficult to ascertain whether the variation in the amount of swelling at the sutural area is natural or if it is a function of the amount of wear or abrasion that the shell has undergone. Moderate variability in shell outline is shown by the apical angle range of 9°–15°. Internally the strength of the plait on the labial surface (pl. 4, compare figs. 7 and 8) is variable. Some specimens (pl. 4, fig. 5) possess a faint subsutural spiral cord similar to that on the type species *Cossmannea desvoidyi*. Other specimens do not show this feature, but it may be obscured because of the coarse silica replacement. The specimens assigned to this species from localities other than the type locality are invariably smaller. This leads one to question their assignment to the species. They do, however, possess the same internal plication plan and swollen subsutural area and compare well in shape with the early growth stages of the larger specimens from the type locality.

I place this species in the genus *Cossmannea* with some misgivings. It compares closely with the type species *C. desvoidyi* from the Oxfordian of France in shape, sutural character, and growth line; but, internally, it lacks the strong columellar plait. However, *C. subdesvoidyi* Pchelintsev (1960) shows a similar weak fold low on the columellar surface. If *C. subdesvoidyi* is properly assigned, then *C. imlayi* falls well within the range of *Cossmannea*.

The species is named in honor of R. W. Imlay of the U.S. Geological Survey.

Types: Holotype USNM 144864; paratypes USNM 14861–14863, 14865–14867.

Occurrence: Utah: Carmel Formation at locs. 12, 13A, 13B, 18A, 21, 30, 31A, 31B, 31C, 34A, 34B, and questionable occurrence at locs. 16, 25, 33, 40; Idaho: Twin Creek Limestone at loc. USGS 28586, Bingham County; Wyoming: Twin Creek Limestone (member B) at loc. USGS 16036, Afton quadrangle.

Cossmannea? kanabensis Sohl, new species

Plate 4, figures 9, 17, 18

Diagnosis.—Whorl sides flat, lacking a pronounced sutural welt.

Description.—Shells small for genus, multiwhorled, elongate, having a slender, even tapering spire. Pleural angle about 15°–18°; suture in a shallow groove. Whorls flat sided, covered by faint microscopic spiral threads of which the immediate subsutural thread is the finest. Body whorl basally carinate. Aperture rhomboidal, anterior canal moderately short and inclined; outer lip having a strong plication situated medially, columellar lip slightly swollen above canal.

Measurements.—The holotype (USNM 144864) measures about 25 mm in height and 6 mm in diameter. A paratype (USNM 144863) has almost exactly the same measurements.

Discussion.—This species is readily distinguishable from *Cossmannea imlayi*, which also occurs in the Carmel Formation, by its flat-sided whorls; but because of this same feature, its placement in *Cossmannea* is very tenuous. The arrangement of the internal plications is, however, very similar to that of *C. imlayi*.

Types: Holotype USNM 144869; paratypes USNM 144868, 144870.

Occurrence: Utah: Carmel Formation at locs. 34A, 37B, 40.

Undetermined nerineids

Discussion.—Nerineid gastropods occur at other localities in the Carmel Formation, Utah. Unfortunately, they are so poorly preserved that they cannot be assigned to one of the species described here. Such gastropods have been found at localities 22, 28, 34A, 34B, 38B, and 42.

Order CEPHALASPIDEA Fischer 1883
Superfamily ACTEONACEA d'Orbigny, 1842
Family ACTEONIDAE d'Orbigny, 1842

Genus CYLINDROBULLINA von Ammon, 1878

Type by original designation, *Acteonina fragilis* Dunker.

Discussion.—The most recent comprehensive classification of the family Acteonidae is that of Zilch (1959). He included *Cylindrobullina* as a synonym of *Acteonina* d'Orbigny. *Acteonina*, however, is characterized by having a low fold on the columella, a low spire, and a collar above the suture. *Cylindrobullina* has a smooth columella and a subsutural collar.

Part of the confusion regarding these genera may have arisen because both Fischer (1883) and Cossmann (1895) ignored Meek's (1863) designation of *Chemnitzia carbonaria* Koninck (1843) as the type species of *Acteonina*. This led Cossmann to consider a smooth columella as typical of *Acteonina*. Knight (1941, p. 31) showed that this is not characteristic of the type species. Other authors (Cox and Arkell 1948; Walther, 1951) considered *Cylindrobullina* as either a separate genus or a subgenus of *Acteonina*.

Cylindrobullina? sp.

Plate 1, figures 15–17, plate 5, figure 1

Discussion.—Small opisthobranch shells that are close to *Cylindrobullina* in terms of their stair-stepped spire, broadly globose whorls, and well developed shoulder are abundant in the Carmel Formation. Unfortunately, no specimens preserve the characters of the aperture sufficiently well to ensure generic placement. The surface of the shells is devoid of sculpture, and the shoulders are rounded. In these features they are similar to *Cylindrobullina bulimoides* (Morris and Lycett) from the Great Oolite of Great Britain, but have less convex-sided whorls and a more elongate aperture.

The lack of sculpture may be due to the type of preservation. However, the group of opisthobranchs to which *Cylindrobullina* belongs usually have very subdued sculpture that is commonly restricted to the anterior part of the shell. Cut sections of the species show no evidence of columellar plications.

Although the generic position of these specimens is doubtful, they are among the more widespread and abundant gastropods in the Carmel Formation of Utah. They apparently also occur in the Twin Creek Limestone in northern Utah.

Types: Figured specimens USNM 132640, 144849, 144850.

Occurrence: Utah: Carmel Formation at locs. 3, 7B, 8, 9A, 9C, 9D, 9E, 11, 14B, 15B, 16, 19A, 19B, 25, 26A, 26B, 29, 33; Twin Creek Limestone at locs. USGS 28457–28459 on Crab Creek near Thistle, Utah County; Idaho: questionable occurrences in the Twin Creek Limestone (member B) at locs. USGS 28500, 28506, Willow Creek, Bingham County.

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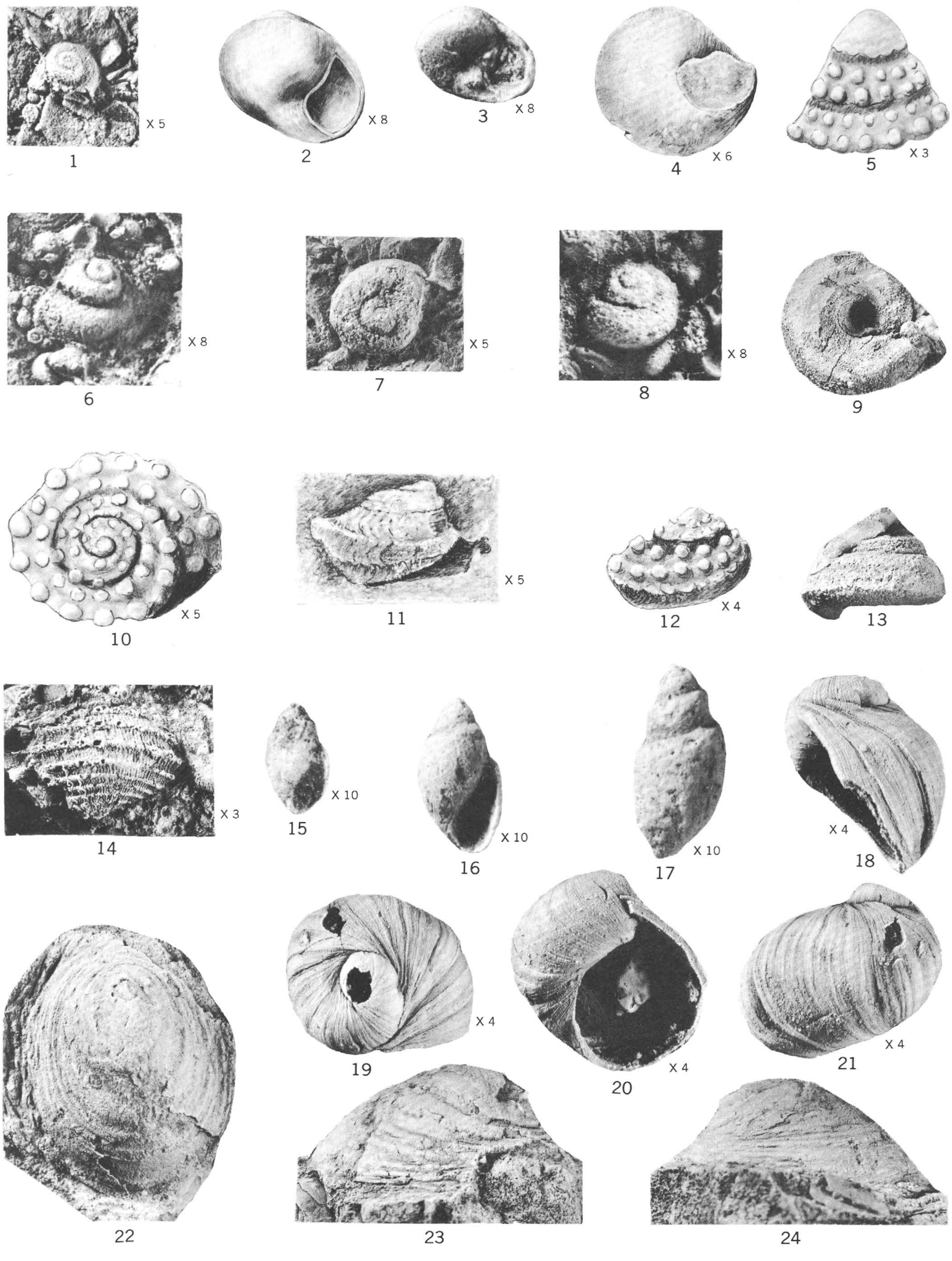

TROCHACEA?, *TEINOSTOMOPSIS*?, *OOLITICIA*?, *PLEUROTOMARIA*?, *NODODELPHINULA*?, *AMBERLEYA*?, *CYLINDROBULLINA*?, *NERIDOMUS*?, AND *SYMMETROCAPULUS*?

PLATE 2

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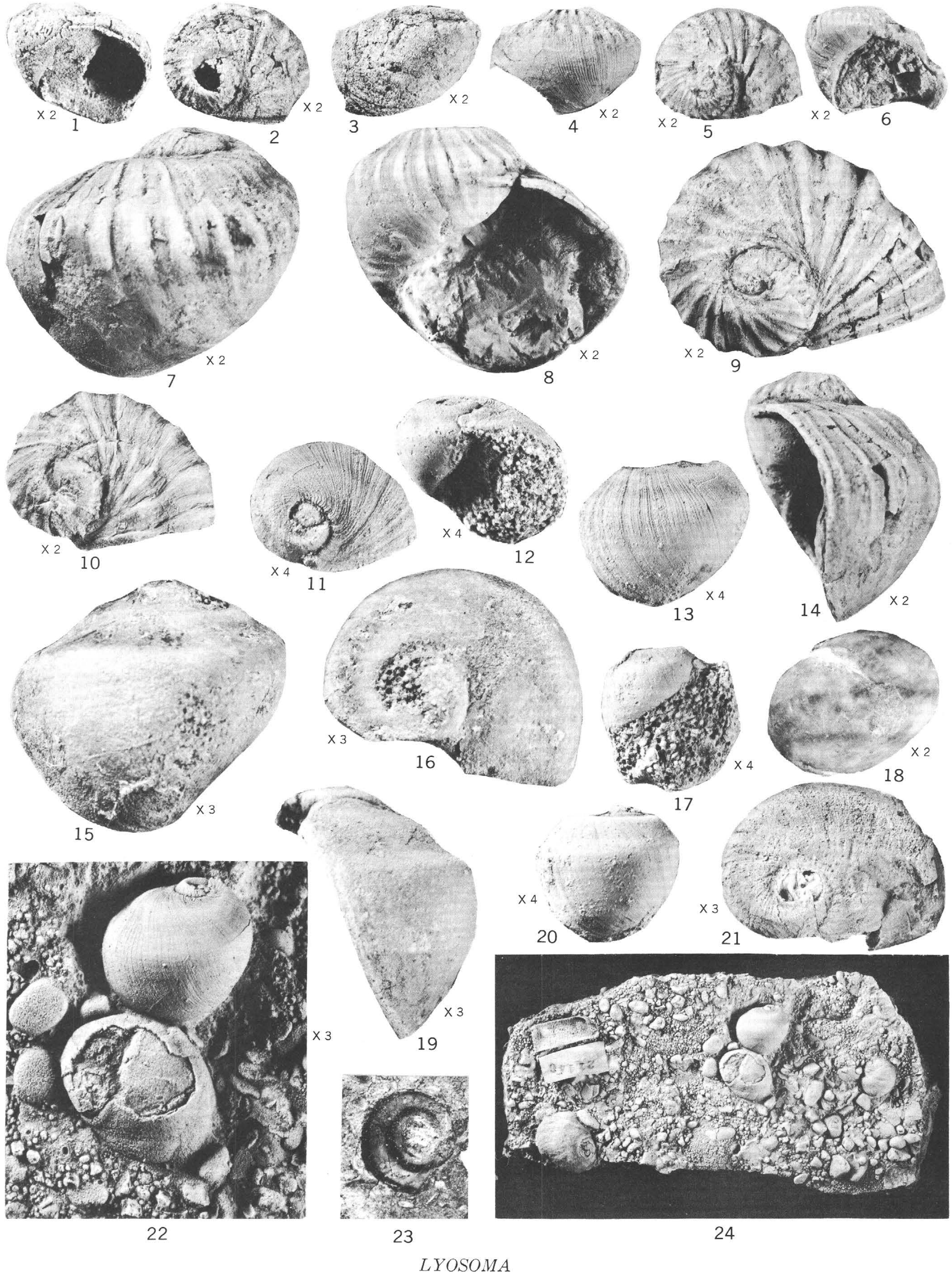
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LYOSOMA

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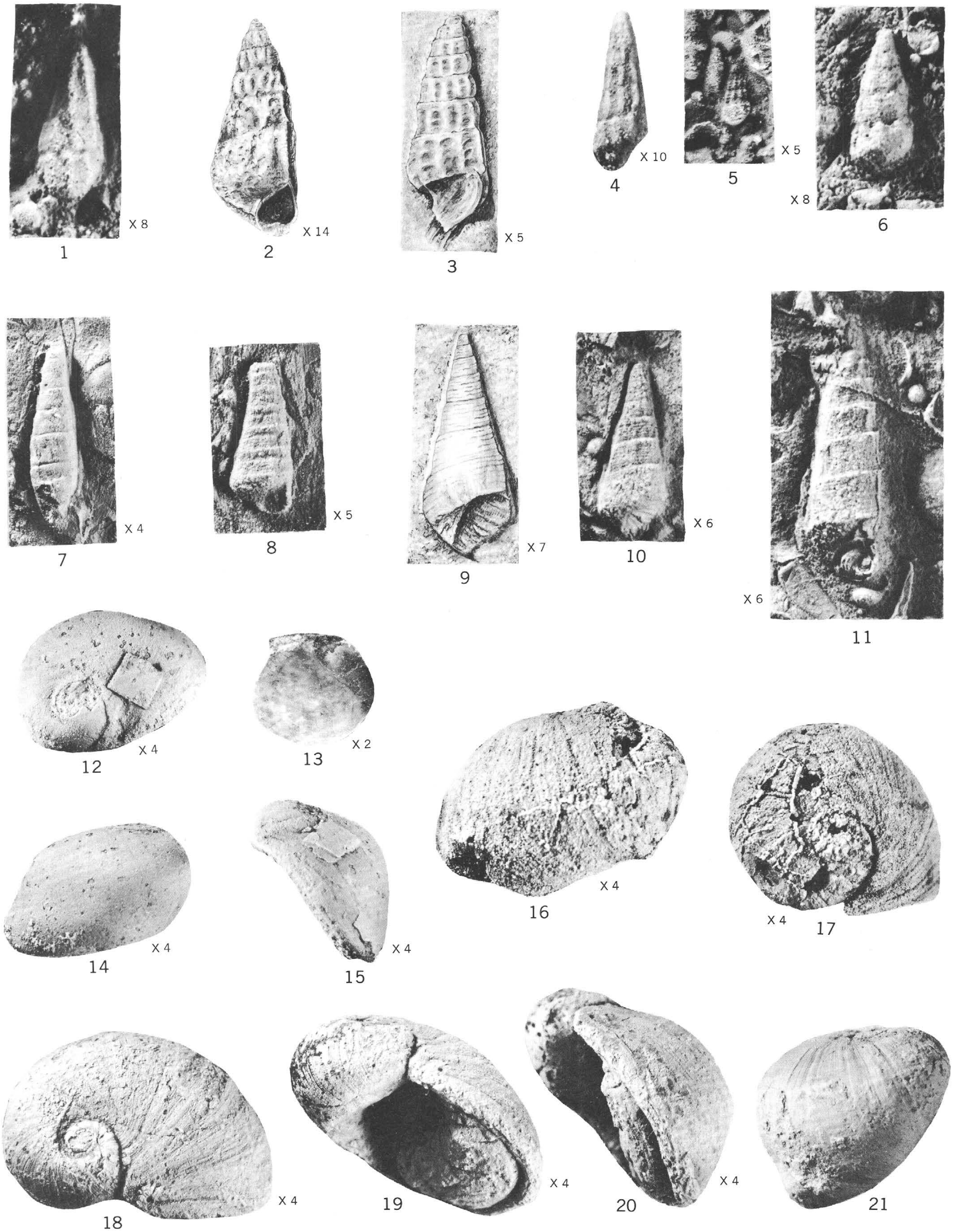

RHABDOCOLPUS, PSEUDOMELANIA?, *PROCERITHIUM*? AND *NERITINA*?

PLATE 4

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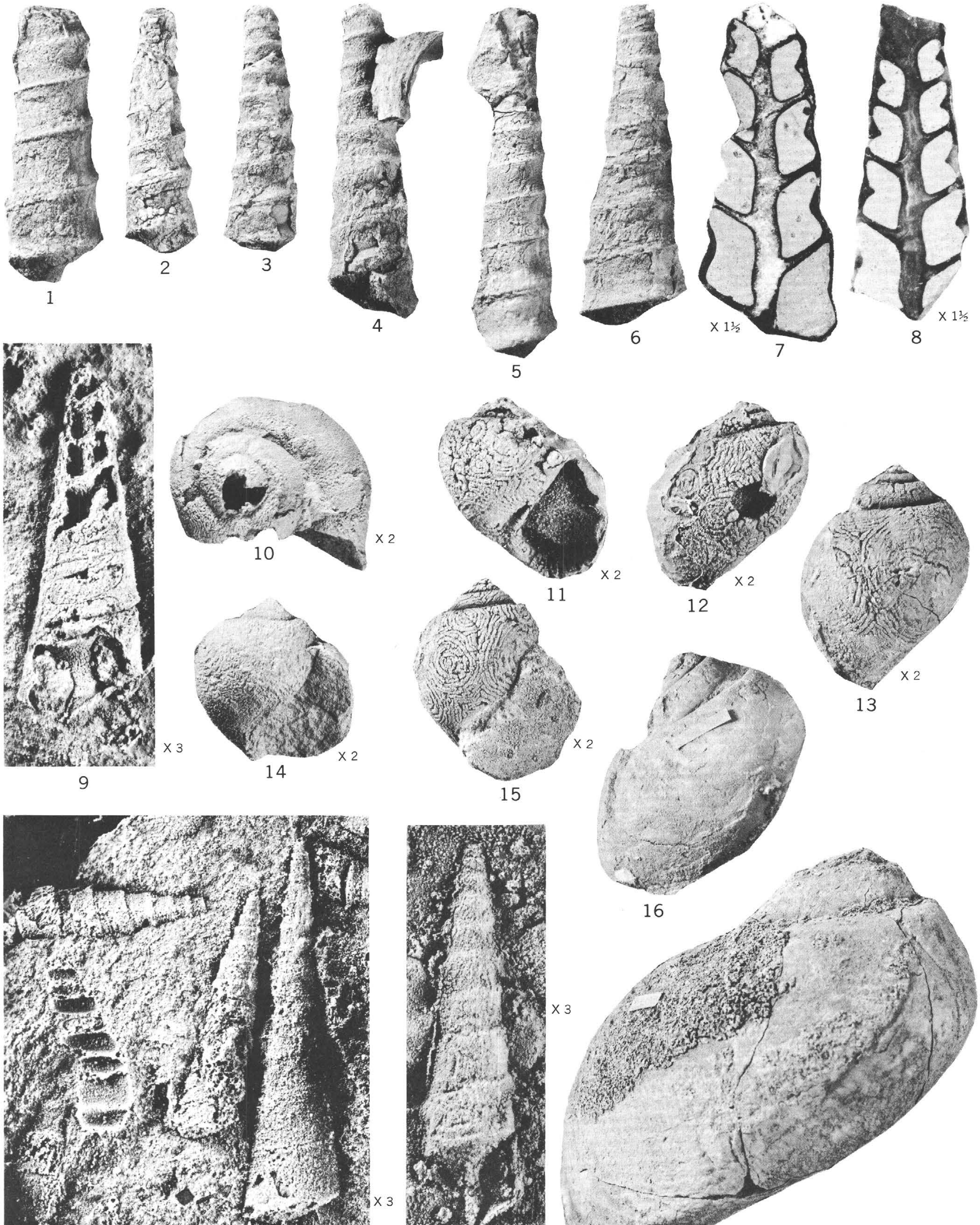

COSSMANNEA, GLOBULARIA?, TYLOSTOMA?

PLATE 5

FIGURES 1–3. Views of weathered limestone surfaces from the Carmel Formation and Twin Creek Limestone showing concentrations of small gastropod species.

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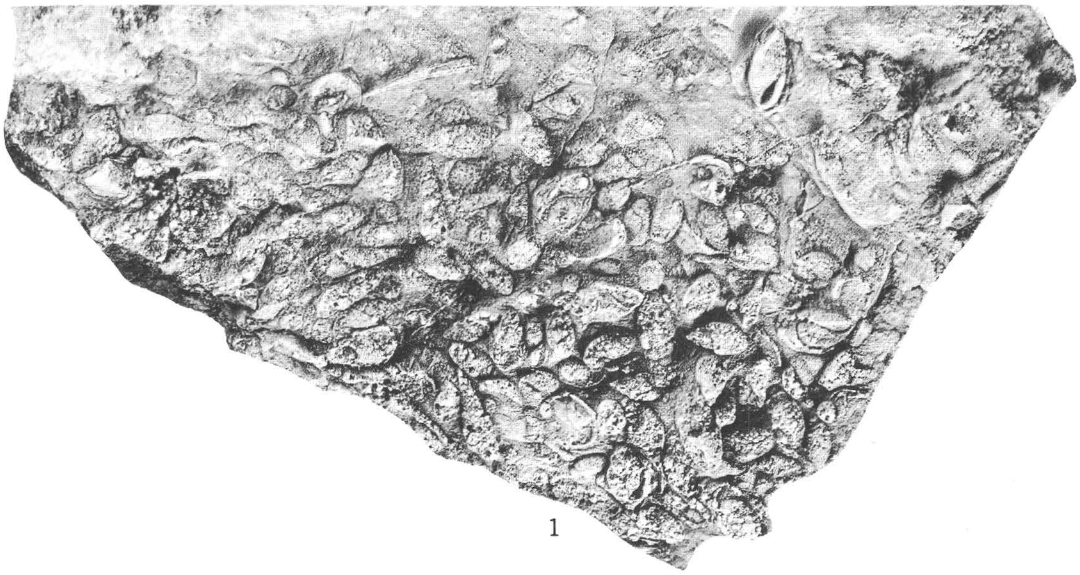

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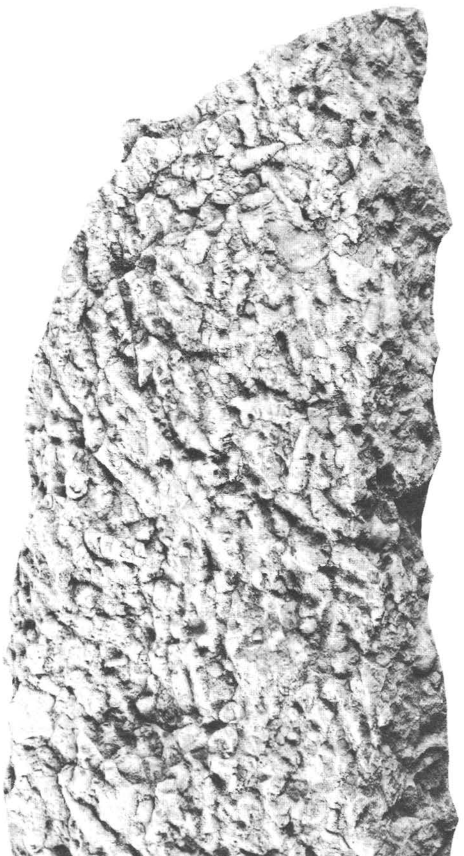

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SPECIMENS OF CARMEL LIMESTONE