Twin Creek Limestone (Jurassic) in the Western Interior of the United States

GEOLOGICAL SURVEY PROFESSIONAL PAPER 540

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By RALPH W. IMLAY

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A description of the stratigraphic and faunal succession in the Twin Creek Limestone and regional comparisons with contemporary formations

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TWIN CREEK LIMESTONE (JURASSIC) IN THE WESTERN INTERIOR OF THE UNITED STATES

By Ralph W. Imlay

ABSTRACT

The Twin Creek Limestone crops out in an area of extensive thrust faulting along the Wyoming-Idaho border and in north-central Utah, extending from the southern end of the Teton Mountains southward to the south end of the central Wasatch Range. It was deposited in the northern end of a northward-trending trough whose axis lay west of the westernmost Jurassic rocks now exposed. The position of the axis is indicated by westward thickening of the formation from about 665 feet in northwestern Wyoming to about 2,720 feet near Idaho Falls and by a similar westward thickening in northern Utah from 440 feet in the Uinta Mountains to about 2,850 feet near Salt Lake City. Facies and thickness changes in the formation near the Snake River indicate that the northern end of the trough curves toward the northwest.

The Twin Creek Limestone is characterized by thick sequences of gray shaly limestone that weathers into long splinters and that forms conspicuous barren slopes. Besides this shaly limestone, the formation contains one sandy member at the top, two red-bed members in the lower third, and one cliff-forming limestone at the top of this lower third. The members of the Twin Creek Limestone from bottom to top are named Gypsum Spring, Sliderock, Rich, Boundary Ridge, Watton Canyon, Leeds Creek, and Giraffe Creek.

The Gypsum Spring Member thickens irregularly westward from 12 to 400 feet. It consists mostly of soft red to yellow siltstone and claystone that is interbedded with brecciated, or vuggy, or chert-bearing limestone. In Wyoming a basal unit of brecciated limestone passes eastward into thick masses of gypsum. Chert-bearing limestone thickens westward from a few feet in Wyoming to thick cliff-forming units in Idaho. The topmost bed in many sections is a green tuff. Both upper and lower contacts of the Gypsum Spring member are sharp. Fossils are scarce and consist mostly of crinoid and echinoid fragments. The member was deposited in very shallow warm marine waters and lagoons in a sea that was transgressing slowly eastward. Its age is probably middle or early late Bajocian.

The Sliderock Member thickens westward from 20 to 285 feet and consists mostly of grayish-black medium to thin-bedded limestone. Its basal beds in Wyoming are oolitic, in Idaho are sandy, glauconitic, crossbedded, and pebbly, and in Utah are sandy and oolitic. It grades upward within several feet into soft shaly limestone at the base of the Rich Member and generally forms a low ridge between adjoining members. The member was deposited in a shallow warm sea that either terminated a short distance east of the Twin Creek trough or that passed eastward into lagoons and basins in which were deposited red beds and gypsum. The association of the ammonite genera *Spiroceras, Megasphaeroceras, Stemmatoceras,* and Stephanoceras indicates an early late Bajocian age. The pelecypod *Gryphaea planoconvexa fraterna* Imlay is characteristic of the middle and upper parts of the member.

The Rich Member thickens westward from 40 to 500 feet and consists mostly of gray shaly splintery limestone that is very soft basally. It becomes more clayey northward. Throughout the extent of the member its upper few feet grades upward either into hard sandy limestone or into soft red siltstone of the overlying member. It was deposited as soft calcareous mud in a shallow sea that trangressed eastward far beyond the Twin Creek trough into central Utah, much of Montana, northern Wyoming, and southernmost Canada. The age of the Rich Member is probably late Bajocian. The member is characterized by the pelecypods *Gryphaea planoconvexa* Whitfield and *Gervillia montanaensis* Meek and by the new ammonite genera *Sohlites* and *Parachondroceras.* It marks the top of the range of *Prorokia fontenellensis* Imlay, n. sp., *Goniomya montanaensis* Meek, and *Thracia weedi* Stanton, and the first appearance of many other pelecypod species.

The Boundary Ridge Member thickens westward from 30 to 285 feet and consists of soft red, green, and yellow siltstone that is interbedded with silty to sandy or oolitic limestone. The member changes eastward into soft gypsiferous red siltstone and claystone and westward into cliff-forming oolitic to dense limestone that is interbedded with some red siltstone. It is overlain sharply by cliff-forming limestone at the base of the Watton Canyon Member. It was deposited in a shallow warm retreating sea and in lagoons. The stratigraphic position of the member and regional correlations indicate that its age is probably Bathonian.

The Watton Canyon Member thickens westward from 60 to 400 feet. It consists mostly of gray dense compact brittle medium- to thin-bedded limestone that forms prominent cliffs and ridges. It is characterized by a conspicuous rectangular fracture pattern and by even bedding. The basal bed is generally massive and oolitic. Some oolitic beds occur throughout. Silty or sandy beds are uncommon. The upper part of the member is transitional into the soft shaly limestone of the overlying Leeds Creek Member. The Watton Canyon Member is of early Callovian age and was deposited in a shallow sea that trangressed eastward to the Black Hills area, northward across most of Montana, and southward probably as far as central and southwestern Utah. It contains *Myopholas hardyi* Imlay near the middle and *Gryphaea* cf. *G. nebrascensis* Meek and Hayden near the top. It passes eastward in the Jackson Hole area, Wyoming, into beds that contain *Cadoceras* and *Warrenoceras.*

The Leeds Creek Member thickens westward from about 260 to 1,600 feet and consists mostly of soft dense light-gray shaly limestone that weathers into slender splinters. It contains some beds or units of oolitic silty or sandy ripple-marked limestone and becomes more clayey northeastward in Idaho and Wyoming and southward in Utah. It is the least resistant of all the members of the Twin Creek Limestone and commonly forms valleys. The member grades upward into harder silty to sandy limestone of the overlying member. It was deposited

rapidly as soft calcareous mud in a shallow sea that deepened westward and that was probably somewhat deeper than the sea during Watton Canyon time. The sandy and silty material was derived mostly from the east or southeast. The age of the member is early Callovian, as shown by the presence of *Gryphaea nebrascensis* Meek and Hayden.

The Giraffe Creek Member thickens westward and southward from 25 to 295 feet and generally forms low cliffs or ridges. It consists mostly of yellowish-, greenish-, pinkish-gray silty to sandy ripple-marked thin-bedded limestone and sandstone but includes some thicker beds of oolitic sandy limestone. It becomes more sandy and glauconitic westward, and grades upward within 10 feet, or less, into soft red siltstone at the base of the Preuss Sandstone. The Giraffe Creek Member was deposited in a shallow marine to littoral environment in a sea that was retreating westward. Its sandy material was derived from the west. The stratigraphic position and regional correlations indicate an early Callovian age for the member.

The Twin Creek Limestone is not very fossiliferous, and most of the fossils are poorly preserved. It has a more varied fauna than the Carmel Formation or the Arapien Shale of Utah and a less varied fauna than equivalent beds in Montana and northern Wyoming. The Carmel Formation has a greater abundance of *Ostrea* but lacks the pelecypod genera *Gryphaea, Opis, Prorokia, Protocardia, Corbula,* and *Platymya*, and lacks ammonites except at the northwest end of the San Rafael Swell. Equivalent beds north of the Twin Creek trough contain more ammonites, more Myas, and a greater abundance of fossils. Factors influencing the growth of marine organisms, such as depth of water, salinity, bottom conditions, and food supply, apparently became more favorable northward.

Pelecypods are more common than any other megafossils in the Twin Creek Limestone. They are represented by 1,575 specimens distributed among 43 genera and subgenera and 50 species. The common genera in order of decreasing abundance include *Gryphaea, Camptonectes, Ostrea, Pronoella,* and *Pleuromya.* Much less common genera in order of decreasing abundance include *Astarte, Trigonia, Vaugonia, Grammatodon, Pinna, Myophorella, Modiolus, Lima, Plicatula, Quenstedtia, Prorokia, Mactromya?, Ctenostreon, Thracia, Pholadomya, Goniomya, Protocardia,* and *Isognomon.* Genera represented by less than three specimens include *Gervillia, Mytilus, Lopha, Myopholas, Platymya, Homomya, Trigonopis* and *Nucula.* New species and subspecies include *Gryphaea planoconvexa fraterna* Imlay, *Prorokia fontenellensis* Imlay, and *Platymya rockymontana* Imlay.

Cephalopods are represented in the Twin Creek Limestone by 143 specimens of which 5 are from the Rich Member; the rest are from the Sliderock Member. Genera present in the Sliderock Member include *Stephanoceras, Stemmatoceras, Normannites?, Eocephalites,* n. gen., *Megasphaeroceras,* and *Spiroceras.* Genera present in the Rich Member include *Stephanoceras?, Sohlites,* n. gen., and *Parachondroceras,* n. gen. New species include *Stemmatoceras arcicostum* Imlay, *Sohlites, spinosus* Imlay, *Parachondroceras andrewsi* Imlay, *P. filicostatum* Imlay, and *Eocephalites primus* Imlay.

INTRODUCTION

This study of the stratigraphy and paleontology of the Twin Creek Limestone is based on the publications of many geologists, on fieldwork by the writer in 1944–47, 1949–51, and 1960–64, and on 197 fossil collections made by 47 geologists since 1892. In addition, 28 collections of Bajocian ammonites from other formations in the western interior region are included in the study because they supplement the data furnished by the Bajocian ammonites from the Twin Creek Limestone and because the total number of specimens involved is not very large. Ammonites of Callovian age are not described herein because only one nondescript specimen of that age has been found in the Twin Creek Limestone. Most of the collections from that formation consist of pelecypods of late Bajocian age, but some are of early Callovian age. The stratigraphic and biologic data furnished by study of the pelecypods are supplemented, as with the ammonites, by examination of fossil collections from other formations.

Special thanks are due to W. W. Rubey for help in locating many complete unfaulted sections of the Twin Creek Limestone in western Wyoming and southeastern Idaho. Other people who have assisted in locating sections in Idaho include L. S. Gardner and M. H. Staatz, in Wyoming include A. J. Eardley and H. R. Wanless, in Utah include A. A. Baker, M. D. Crittenden, A. E. Granger, J. W. Huddle, and T. E. Mullens.

STRATIGRAPHY OF THE TWIN CREEK LIMESTONE

STRATIGRAPHIC SUMMARY

The Twin Creek Limestone was defined by Veatch (1907, p. 56, chart opposite p. 50) for exposures of marine limestone, shale, and sandstone along and near Twin Creek between Sage and Nugget in western Wyoming. The term has subsequently been used over a large area in southeastern Idaho (Mansfield, 1920, p. 53; 1927, p. 97, 98; 1952, p. 36–38), in western Wyoming (Imlay 1950a, 1952b, p. 965; 1953a, Horberg, 1938, p. 11, 19, 20; Dobrovolny, 1941, p. 430–433; Wanless and others, 1955, p. 49, 50; Rubey, 1958, Oriel, 1963), and in north-central Utah (Thomas and Kruger, 1946, p. 1275–77; Baker and others, 1947; Imlay, 1953a; Granger, 1953, p. 4, 10, 11; Richardson, 1941, p. 30; Eardley, 1944, p. 834, 836). The formation was divided by Imlay (1950a) into seven members that from bottom to top were called members A–G. Of these, member A was renamed the Gypsum Spring Member by Oriel (1963), and the others are herein assigned new names (table 1).

TABLE 1.—*Generalized stratigraphic section and characteristics of the Twin Creek Limestone*

Member	Lithologic features	Thickness (feet)	Contacts	Characteristic fossils	Age	Origin
Giraffe Creek	Mostly gray silty to sandy ripple-marked thin-bedded limestone and sandstone. Some thicker beds of oolitic sandy limestone. Becomes sandier and glauconitic westward. Forms ridges.	25–295. Thickens westward and southward irregularly.	Grades upward within a few feet into soft red beds at base of Preuss Sandstone.	Coquinas of crinoid, echinoid, and *Camptonectes* fragments. *Ostrea* present locally.	Callovian	Shallow marine to littoral. Sea regressive westward. Sand derived from west. Much wave action.
Leeds Creek	Mostly light-gray soft dense shaly splintery limestone. Some oolitic silty or sandy ripplemarked limestone. Becomes clayey northeastward in Wyoming and southward in Utah. Forms valleys.	260–1,600. Thickens westward.	Grades upward evenly into silty to sandy thin-bedded limestone.	*Gryphaea nebrascensis, Platymya rockymontana,* and *Cadoceras*? sp. Megafossils uncommon.	Early Callovian	Shallow marine. Soft calcareous mud formed rapidly. Sand and silt derived mostly from east.
Watton Canyon	Mostly gray dense compact brittle even-bedded medium- to thin-bedded limestone. Basal bed generally massive and oolitic. Forms prominent cliffs and ridges.	60–400. Thickens westward.	Grades upward evenly into shaly limestone of the Leeds Creek Member.	*Gryphaea* sp. juv. cf. *G. nebrascensis* near top. *Myopholas hardyi* Imlay near middle. Megafossils uncommon.	do	Shallow sea transgressive eastward. Shallower than during deposition of Leeds Creek Member.
Boundary Ridge	Red, green, and yellow soft siltstone interbedded with silty to sandy or oolitic limestone. Changes eastward into red siltstone and westward into limestone.	30–285. Thickens westward irregularly.	Overlain sharply by cliff-forming limestone of Watton canyon Member.	*Astarte* (*Coelastarte*) *livingstonensis* Imlay found near top. Megafossils rare.	Probably Bathonian.	Shallow marine to littoral or lagoonal. Sea regressive westward. Climate probably hot and dry.
Rich	Medium-gray shaly limestone, very soft basally; contains some thin beds near top. Becomes clayey and fossiliferous eastward. Forms ravines.	40–500. Thickens westward irregularly.	Grades upward within several feet into harder sandy limestone or softer red siltstone.	*Gryphaea planoconvexa, Gervillia montanensis, Sohlites spinosus,* and *Parachondroceras* spp.	Late Bajocian	Shallow sea transgressive eastward. Bottom probably muddier and deeper than during Sliderock time.
Sliderock	Grayish-black medium- to thin-bedded limestone. Basal beds in Wyoming are oolitic; in Idaho, sandy cross-bedded and pebbly; in Utah, sandy and oolitic. Sandiness increases westward. Forms low ridges.	20–285. Thickens westward.	Grades upward within several feet into soft shaly limestones of the Rich Member.	*Gryphaea planoconvexa fraterna* Imlay n. var., *Megasphaeroceras* spp., *Spiroceras* sp., *Stemmatoceras* spp., and *Stephanoceras* spp. Fossils common.	do	Shallow warm sea transgressive eastward. Sand and pebbles derived from west.
Gypsum Spring	Mostly red soft siltstone and brecciated vuggy or chert-bearing limestone. Basal brecciated limestone passes eastward into thick gypsum mass. Chert-bearing limestone thickens westward. Forms ravines.	12–400. Thickens irregularly toward west and southwest.	Contacts sharp	Crinoid and echinoid fragments. Fossils rare.	Probably middle or late Bajocian.	Shallow marine to lagoonal. Sea transgressive eastward. Climate probably hot and dry.

The Twin Creek Limestone was deposited in the northern part of a trough that extended from southwestern Utah northeastward into central Utah and then northward through north-central Utah into southeastern Idaho (Peterson, 1954, p. 474; 1957a, p. 401–403). The northernmost part of the trough near the Snake River in Idaho curves toward the northwest as shown by facies and thickness changes in the Twin Creek Limestone and perhaps by present structural trends. The axis of the trough lay at least as far west as the westernmost outcrops of Jurassic rocks as shown by westward thickening of those rocks.

The limestone and the associated beds deposited in the deeper part of this trough during Middle and early Late Jurassic time are similar lithologically throughout its extent and conceivably could have been called by a single name. Nevertheless, the term Carmel Formation is used in the southern part of the trough because the Jurassic rocks are continuous with those at Mount Carmel and in other areas to the east and northeast in southern Utah. The term Twelvemile Canyon Member of the Arapien Shale is used for marine beds in the central part of the trough that differ from the Carmel Formation by being thicker, shalier, less gypsiferous, and grayer and that are separated from the Carmel Formation geographically by areas with few Jurassic outcrops. The northernmost exposures of the Twelvemile Canyon Member northeast of Nephi, Utah, are only 15 miles southwest of lithologically smiliar exposures of the Twin Creek Limestone south and southeast of Thistle. Overall, the Twin Creek Limestone differs by being divisible into well-defined mappable members and by its upper part being more calcareous, less shaly, and less red. The actual southern limit of the formation appears to have been chosen arbitrarily, however, in an area that has not yet been studied in detail.

The Twin Creek Limestone crops out in an area of extensive thrust faulting along the Idaho-Wyoming border and in north-central Utah, extending from the southern end of the Teton Mountains west of Jackson, Wyo., southward to near the south end of the Wasatch Range a few miles south of Thistle, Utah (figs. 1–8). The westernmost outcrops are a few miles east of Salt Lake City, Utah, and Idaho Falls, Idaho, and the easternmost outcrops in Wyoming are about 5 miles east of a north-south line drawn through Kemmerer. The Twin Creek Limestone also occurs in the Uinta Mountains, Utah, as far east as Lake Fork. Its extent from north to south is about 170 miles and from east to west about 60 miles.

Within this area the formation thickens southwestward from about 665 feet in northwestern Wyoming to about 2,720 feet at Willow Creek near Idaho Falls. In northern Utah it thickens westward from about 440 feet at Lake Fork in the Uinta Mountains to about 2,850 feet near Burr Fork in the Wasatch Range (table 2).

The Twin Creek Limestone consists mainly of medium- to light-gray limestone, most of which is shaly and weathers into long splinters. The formation also contains one sandy member at the top, two persistent red-bed members in the lower third, and one cliff-forming limestone member at the top of this lower third. These make possible the division of the Twin Creek Limestone into seven mappable members.

The term Twin Creek Limestone is not used east of the Darby-Absaroka line of thrusting because the equivalent beds east of the faulted area, such as those exposed at Lower Slide Lake on the Gros Ventre River, Wyo., are much thinner, much less calcareous, and much more fossiliferous than the typical Twin Creek Limestone, and may more properly be classified according to the terminology used in north-central Wyoming. Nevertheless, the Jurassic sequence at Lower Slide Lake contains units that are similar lithologically and stratigraphically to the lower six members of the Twin Creek Limestone. The presence of these units and particularly of the fossils (fig. 9) that they contain aids greatly in correlations and age determinations of members of the Twin Creek Limestone.

The type locality of the Twin Creek Limestone on Twin Creek (fig. 1, loc. 29) includes only the lower four of the seven members present in the formation. The nearest exposed complete section of the formation is on Leeds Creek about 8 miles due north of the type locality in the same fault block. On Leeds Creek the lower four members are not as well exposed as at the type locality, but the upper three members are excellently exposed. The section at Leeds Creek (fig. 1, lock 28), therefore, supplements the type section and may be considered as a standard of reference for the upper part of the formation. Both sections are described below.

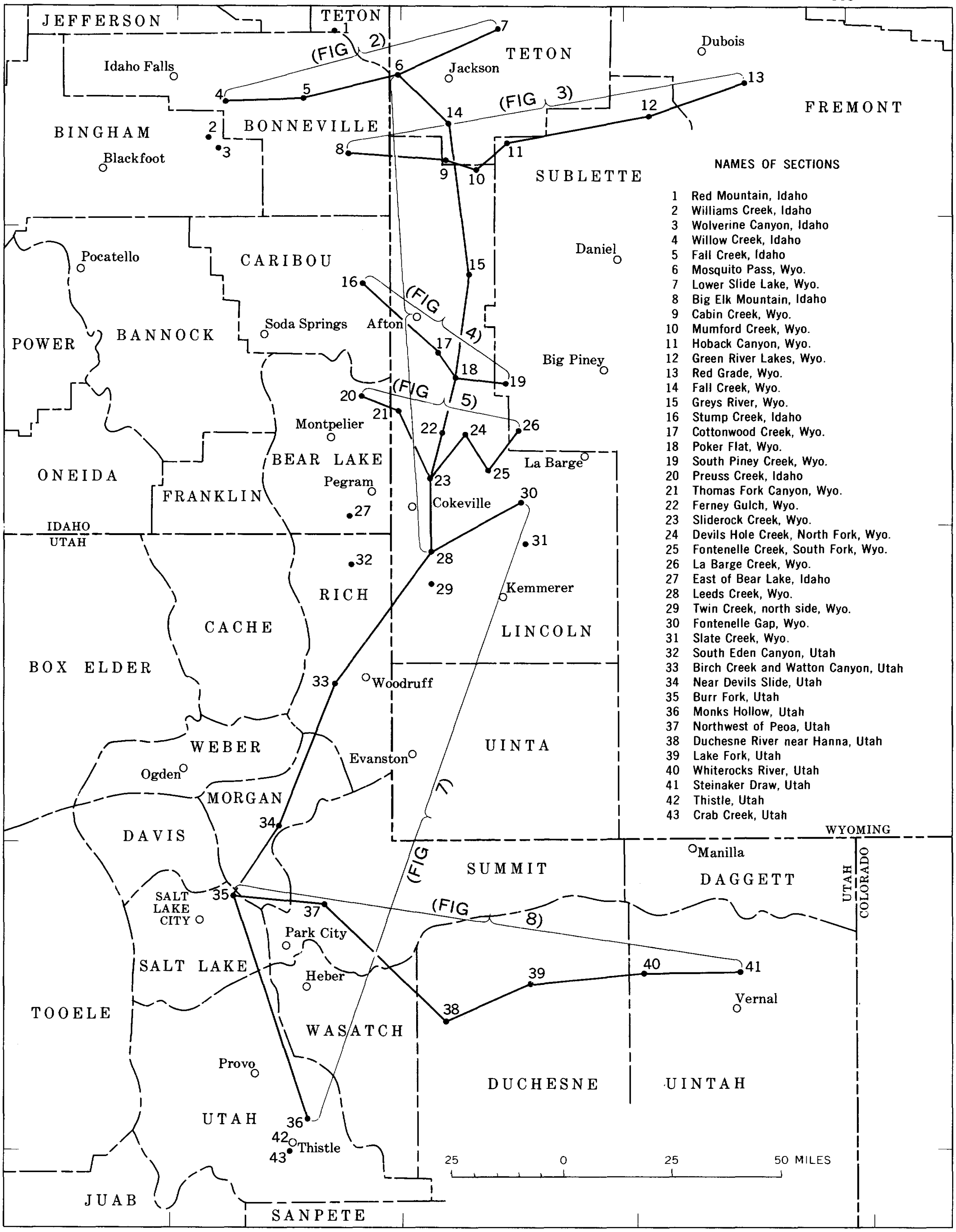

FIGURE 1.—Index map of western Wyoming, southeastern Idaho, and northern Utah showing locations of columnar sections illustrated in figures 2–8 and some other sections or places discussed in text. Locations of sections are given in more detail in table 2.

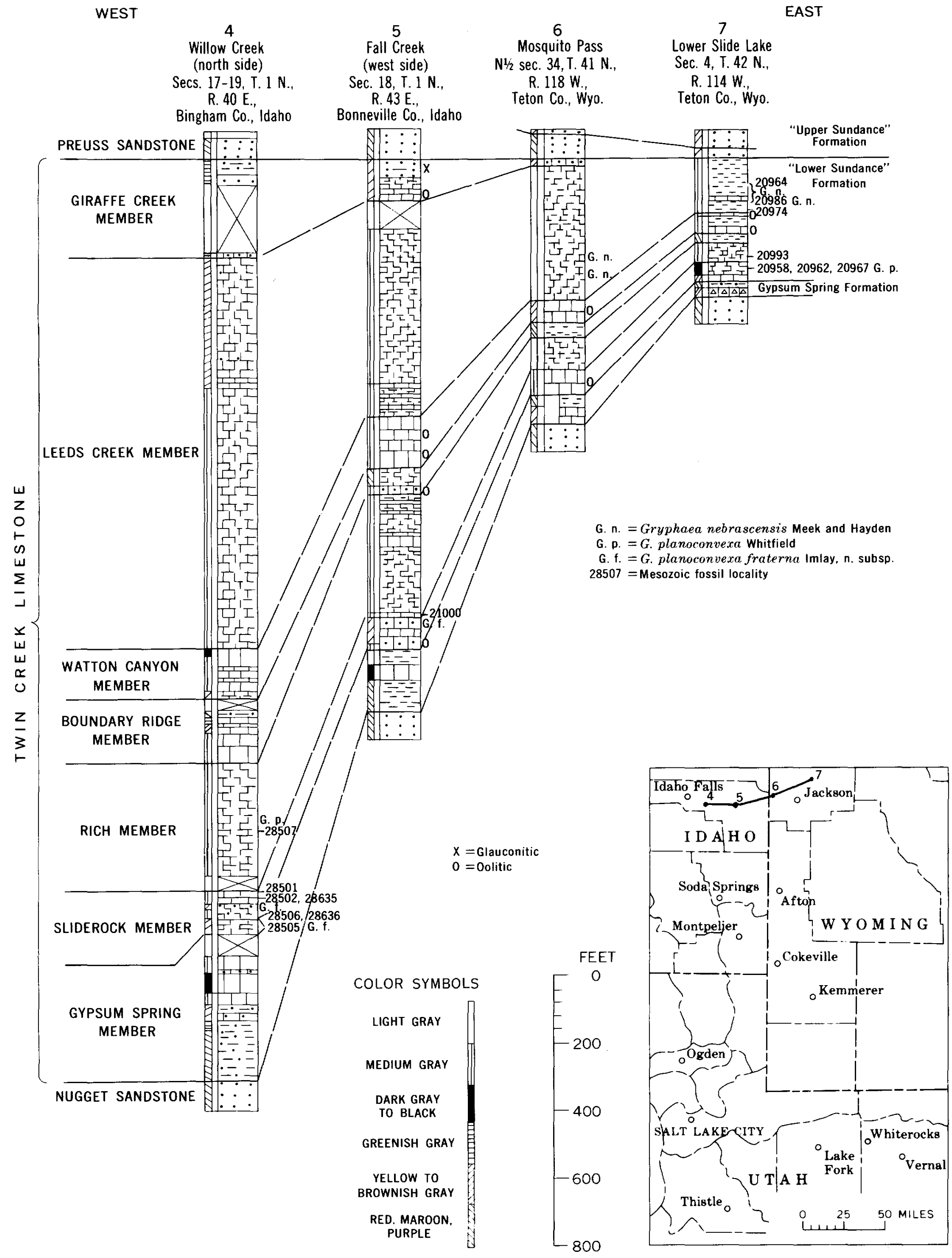

Figure 2.—Columnar sections from Willow Creek, Idaho, to Lower Slide Lake, Wyo. Explanation of lithologic symbols shown in figure 3.

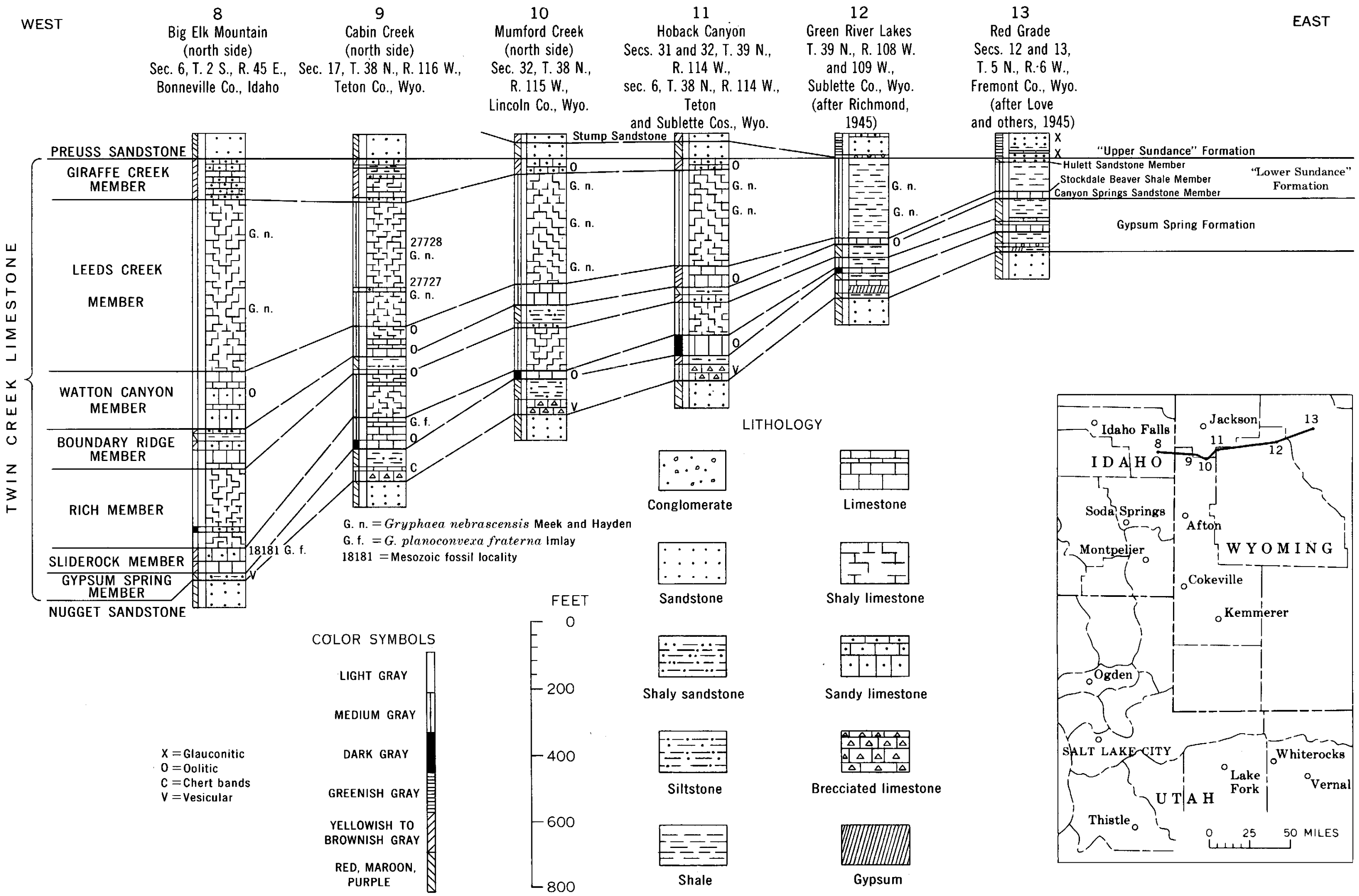

Figure 3.—Columnar sections from Big Elk Mountain, Idaho, to Red Grade, Wyo.

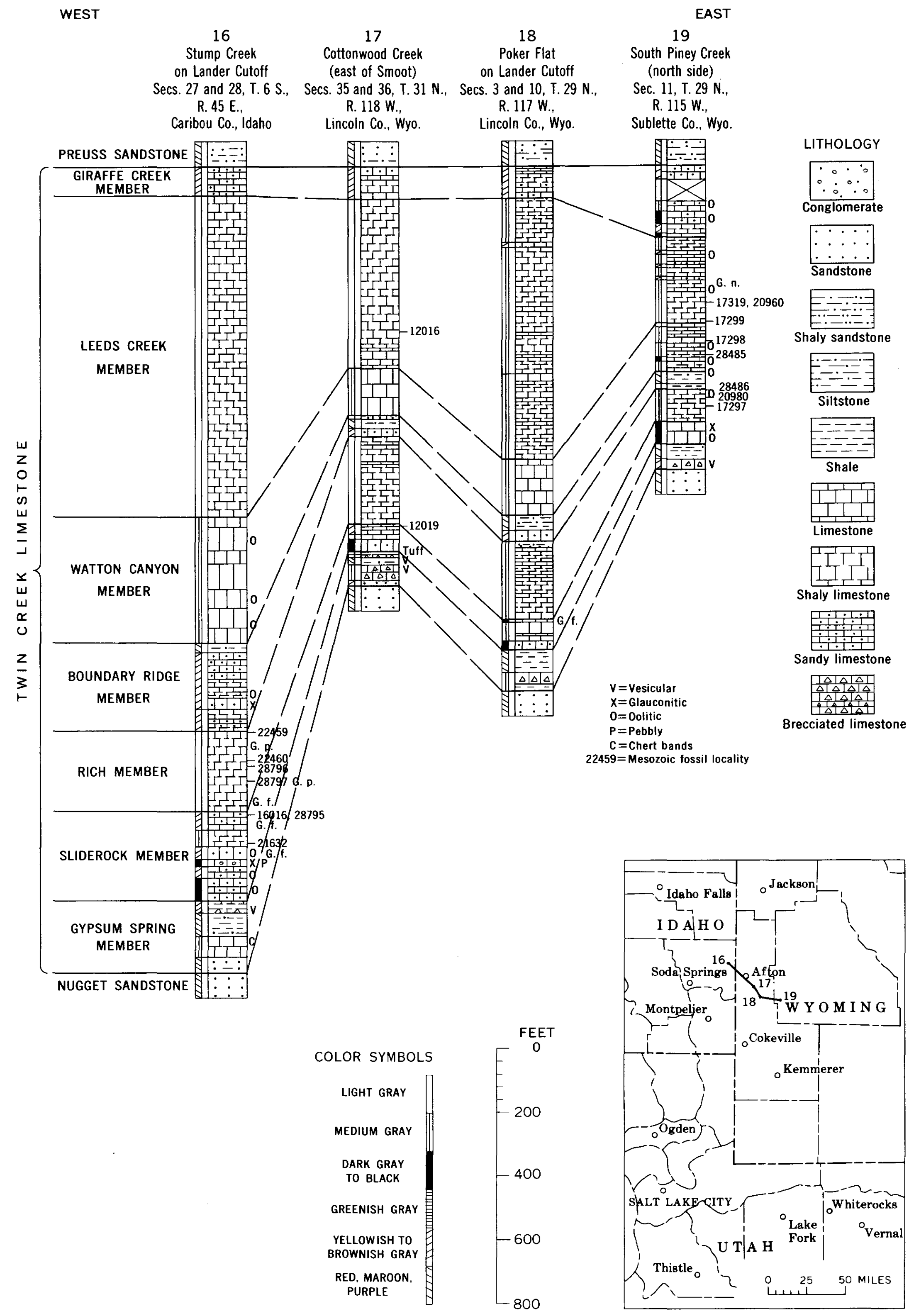

FIGURE 4.—Columnar sections from Stump Creek, Idaho, to South Piney Creek, Wyo.

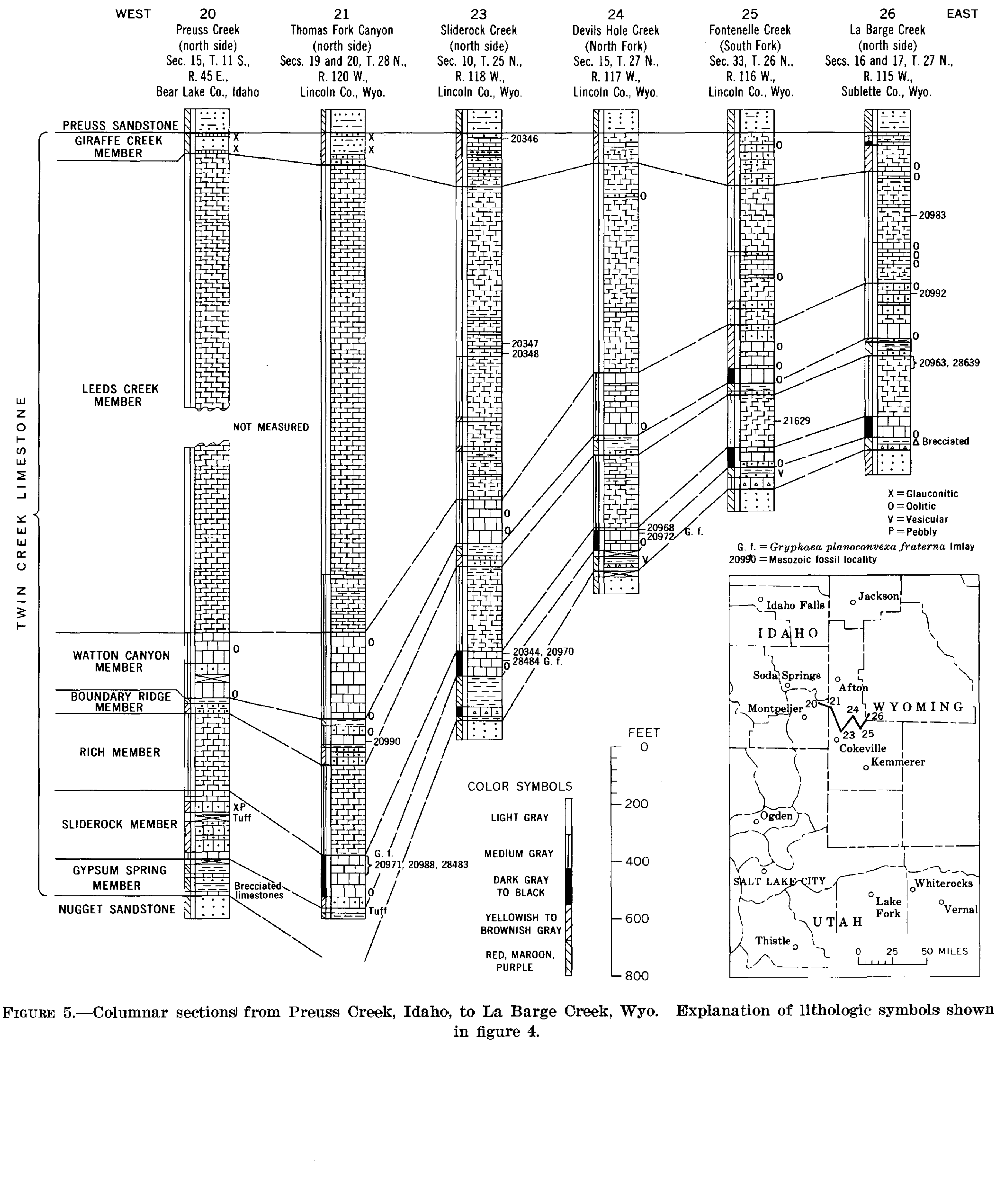

FIGURE 5.—Columnar sections from Preuss Creek, Idaho, to La Barge Creek, Wyo. Explanation of lithologic symbols shown in figure 4.

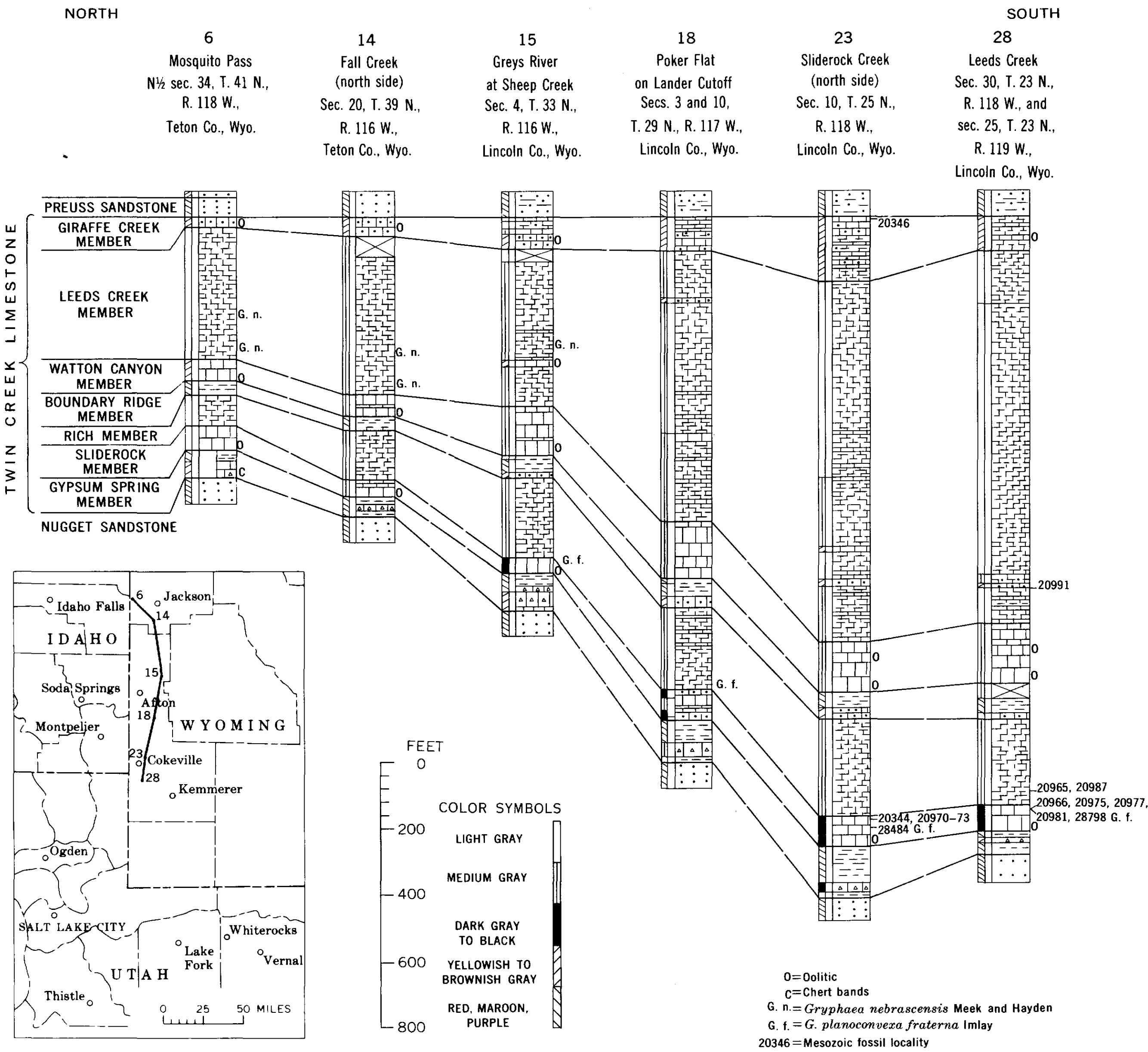

FIGURE 6.—Columnar sections from Mosquito Pass to Leeds Creek, Wyo. Explanation of lithologic symbols shown in figure 4.

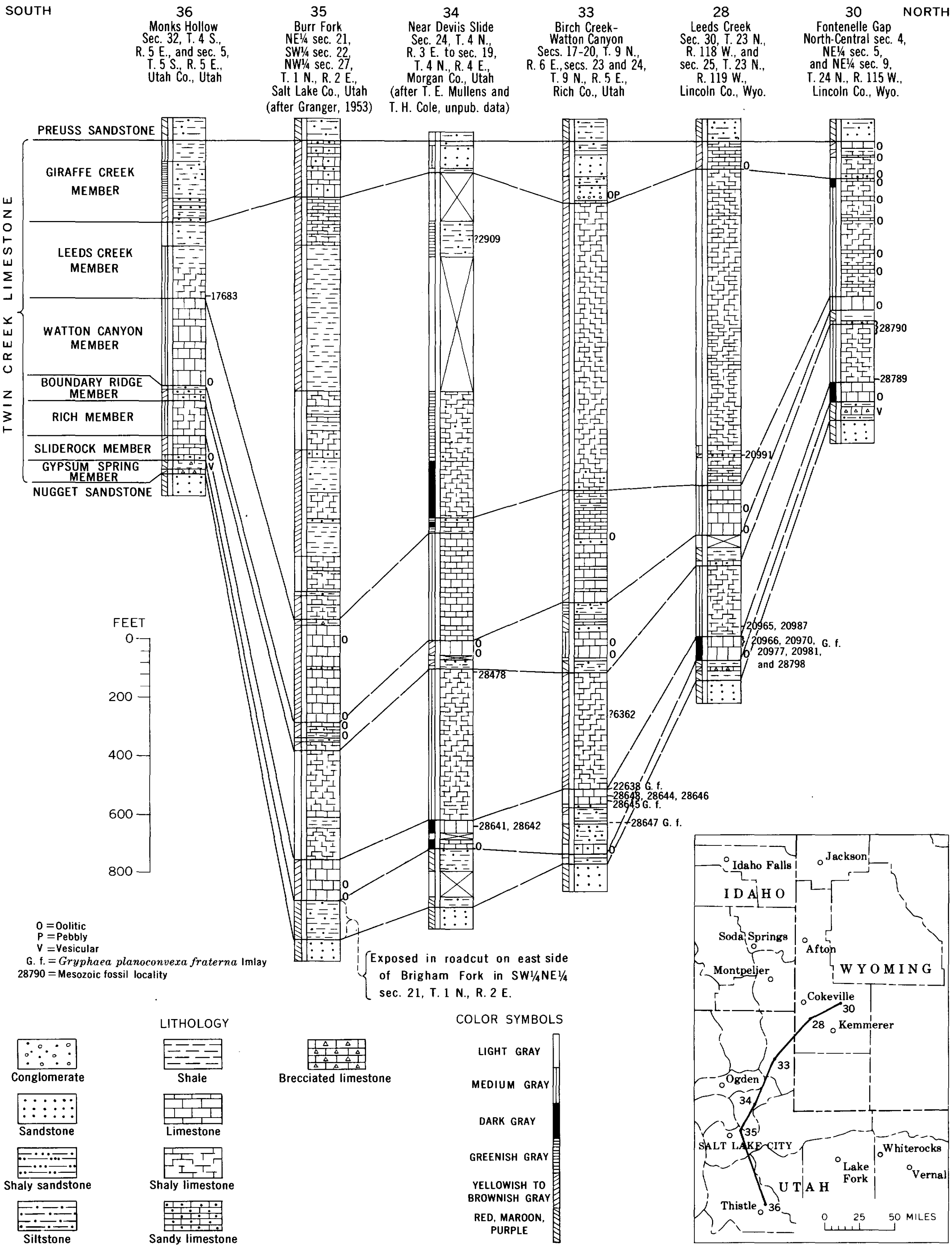

FIGURE 7.—Columnar sections from Monks Hollow, Utah, to Fontenelle Gap, Wyo.

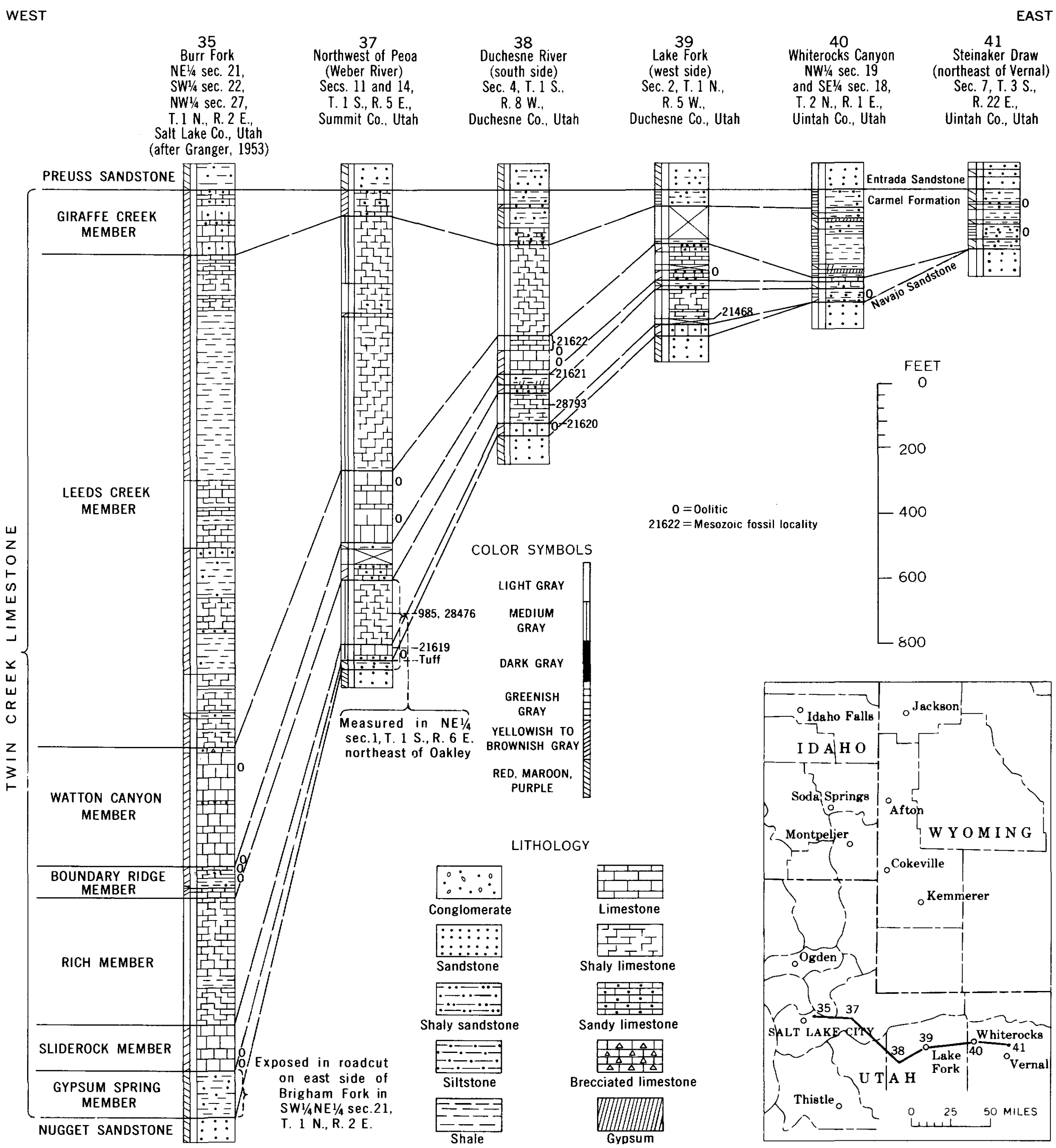

FIGURE 8.—Columnar sections from Burr Fork to Steinaker Draw, Utah.

TABLE 2.—*Stratigraphic thickness in feet of the members of the Twin Creek Limestone in Idaho, Wyoming, and Utah*

[Letters A-G refer to usage of Imlay (1950a)]

Locality (fig. 1)	Name of section	Location of section	Gypsum Spring Member A	Slide-rock Member B	Rich Member C	Boundary Ridge Member D	Watton Canyon Member E	Leeds Creek Member F	Giraffe Creek Member G	Total thickness
	Idaho									
1	Red Mountain	SW¼ sec. 33 T. 4 N. T. 44 E.	12	69	208	36	75	471	26	897
5	West side of Fall Creek	SW cor. sec. 18 T. 1 N. R. 43 E.	183	113	374	77	160	628	131	1,666
4	North side of Willow Creek	From NE¼ sec. 19 to south-central part sec. 17 T. 1 N. R. 40 E.	430?	140?	380	187	151	1,145	295	2,728
8	North side of Big Elk Mountain	SW¼ sec 6 T. 2 S. R. 45 E.	20	74	228	123	172	520	120	1,257
16	Stump Creek	SW¼ sec. 27 and SE¼ sec. 28 T. 6 S. R. 45 E.	223	281	250	270	400	1,000	90	2,514
20	Preuss Creek	E½ sec. 15, T. 11 S., R. 45 E.	129	229	271	39	246	1,500+	71	2,485
27	East of Bear Lake	NE cor. sec. 30, T. 15 S., R. 45 E.	246	283	[1]	[1]	[1]	[1]	[1]	[1]
	Wyoming									
7	North side of Lower Slide Lake [2]	Sec. 4, T. 42 N., R. 114 W.	46	21	85	38	57	163	0	410
6	Mosquito Pass	N½ sec. 34, T. 41 N., R. 118 W.	80	75	95	45	65	395	25	780
14	North side of Fall Creek	NE¼ sec. 20, T. 39 N., R. 116 W.	63	55	151	40	69	477	48	903
9	North side of Cabin Creek	N½ sec. 17, T. 38 N., R. 116 W.	97	97	130	50	89	370	83	916
10	North side of Mumford Creek	SE¼ sec. 32, T. 38 N., R. 115 W.	107	24	125	71	65	330	41	763
11	North side of Hoback Canyon	E½ sec. 32 and SE¼ sec. 31, T. 39 N., R. 114 W., NE¼ sec. 6, T. 38 N., R. 114 W.	76	60	104	43	65	290	28	666
15	North side of Sheep Creek near Greys River.	Sec. 4, T. 33 N., R. 116 W.	110	45	240	64	155	475	89	1,178
17	Cottonwood Creek, 2 miles east of Smoot.	W½ sec. 36 and E½ sec. 35, T. 31 N., R. 118 W	102	87	275	66	146	530?	100	1,306?
18	Poker Flat	Secs. 3 and 10, T. 29 N., R. 117 W.	125	88	247	83	175	813	102	1,633
19	North side of South Piney Creek	Sec. 11, T. 29 N., R. 115 W.	82	70	85	67	157	262	232?	955
21	North side of Thomas Fork Canyon	Secs. 19 and 20, T. 28 N., R. 119 W.	40+	188	315	168	305	1,625?	111	2,752+
22	North side of Ferney Gulch	Secs. 1 and 2, T. 27 N., R. 117½ W., sec. 1, T. 27 N., R. 118 W.	140	91	252	115	400?	575?	86	1,659
24	North Fork of Devils Hole Creek.	Sec. 15, T. 27 N., R. 117 W.	75	79	245	69	218	735	102	1,523
26	La Barge Creek	NW¼ sec. 16 and NE¼ sec. 17, T. 27 N., R. 115 W.	53	75	208	59	186	402	128	1,111
23	Sliderock Creek	Sec. 10, T. 25 N., R. 118 W.	150	85	275	75	154	1,089	186	2,014
25	South Fork of Fontenelle Creek	NW¼ sec. 33, T. 26 N., R. 116 W.	77	68	184	35	212	487	177	1,240
30	Fontenelle Gap	N½ sec. 4, NE¼ sec. 5, NE¼ sec. 9, T. 24 N., R. 115 W.	75	65	210	49	57	420	132	1,008
28	North side of Leeds Creek	Sec. 30, T. 23 N., R. 118 W. and sec. 25, T. 23 N., R. 119 W.	76	95	260	108	182	1,118	102	1,941
29	North side of Twin Creek	NE¼ sec. 1, T. 21 N., R. 119 W.	85	97	300	108	62+	[3]	[3]	[3]
	Utah									
33	Birch Creek and Watton Canyon	Secs. 17 to 20, T. 9 N., R. 6 E., secs. 24-26, T. 9 N., R. 5 E.	36+	227	425	251	399	1,018?	221?	2,577+
34	Weber River near Devils Slide	Sec. 24, T. 4 N., R. 3 E. and sec. 19, T. 4 N., R. 4 E.	208	100	540	97	380	1,289	108	2,722
35	Near Burr Fork and Brigham Fork.	NE¼ sec. 21, SW¼ sec. 22 and NW¼ sec. 27, T. 1 N., R. 2 E.	140?	150	391	102	348	1,520?	200	2,851
37	Weber River near Peoa and Oakley.	SW¼ sec. 11 and NW¼ sec. 14, T. 1 S., R. 5 E., NE¼ sec. 1, T. 1 S., R. 6 E.	22	47	125	107	220	776	82	1,379
38	Duchesne River near Hanna	SW¼ sec. 4, T. 1 S., R. 8 W.	0	42	91	68	104	280	165	750
39	Lake Fork	NW¼ sec. 2, T. 1 N., R. 5 W.	0	32	109	30	109	114	49	443
40	Whiterocks River	NW¼ sec. 19 and SW¼ sec. 18, T. 2 N., R. 1 E.	0	0	40	21	17	182	85	345
36	Monks Hollow	Sec. 32, T. 4 S., R. 5 E. and sec. 5, T. 5 S., R. 5 E.	49	91	123	57	305	275?	288	1,188
42	Thistle	W½ sec. 28, T. 8 S., R. 4 E.	9	71	183	41	345+	[4]	[4]	[4]
43	Crab Creek	SW¼ sec. 5, T. 10 S., R. 4 E.	15	95	140	90	300+	[3]	[3]	[3]

[1] Not measured.
[2] The beds at Lower Slide Lake formerly referred to members B-F (Imlay, 1956a) are now referred to the lower part of the Sundance Formation.
[3] Not exposed.
[4] Faulted.

Fossils	Southeastern Idaho, western Wyoming, and north-central Utah: Twin Creek Limestone: Gypsum Spring Member (A)	Sliderock Member (B)	Rich Member (C)	Boundary Ridge Member (D)	Watton Canyon Member (E)	Leeds Creek Member (F)	Giraffe Creek Member (G)	Central and southwestern Utah: Carmel Formation: Lower limestone member	Upper gypsum-bearing silty shale member	North-central Wyoming: Gypsum Spring Formation (Limestone member only)	"Lower Sundance" Formation	Central and south-central Montana: Piper Formation (Limestone member only)	Rierdon Formation	Western Montana: Sawtooth Formation	Rierdon Formation	Northwestern Wyoming: Lower Slide Lake sequence below "Upper Sundance" Formation: Units 1-6 (A)	Units 7-9 (B)	Units 10-12 (C)	Units 13-15 (D)	Units 16-21 (E)	Unit 22 (F)
Nucula sp.						?		X													
Grammatodon haguei (Meek)		X	X									X		X				X		X	X
Idonearca haguei (Stanton)		X	X									X		X				X			
Modiolus subimbricatus (Meek)		X	X		X			X		X	X	X	X	X				X		X	X
(Musculus) sp.			X																		
Mytilus cf. *M. whitei* Whitfield		?						X													
Gervillia? *montanaensis* Meek			X					X				X		X				X			
Isognomon cf. *I. perplana* (Whitfield)			X					X		X	X	X								X	
Pinna kingi Meek		X	X					X			X	X		X				X		X	
Camptonectes stygius White		X		X	X	X		X		X	X	X	X	X							
platessiformis White		X	X	X		X		X		X	X	X	X	X	X			X			
cf. *C. distans* Stanton	X																				
Plicatula sp.		X	X			X															
Lima (Plagiostoma) occidentalis Hall and Whitfield		?			X	X		X				X	X	X						X	
sp.		X	X			X															
Ctenostreon cf. *C. gikshanensis* McLearn		X			X	X		X			X	X	X	X				X		X	
Ostrea (Liostrea) strigilecula White		X	X		X	X	X	X		X	X	X	X	X							
Lopha sp.		X				X		X				X	X	X							
Gryphaea planoconvexa Whitfield			X											X				X			
planoconvexa fraterna Imlay, n. subsp.		X	X																		
nebrascensis Meek and Hayden					X	X					X		X		X					X	X
Trigonia americana Meek		X	X			X		X		X	X	X	X	X				X		X	X
elegantissima Meek			X	X	X	X		X		X	X	X	X					X		X	
Vaugonia conradi (Meek and Hayden)		?	X		X			X		X	X	X	X	X				X		X	
Myophorella (Promyophorella) montanaensis (Meek)			X	X	X			X		X		X	X	X	X					X	X
(Haidaia) yellowstonensis Imlay			X					X				X		X				X			
Astarte meeki Stanton		X	X	X	X	X						X	X	X				X		X	X
(Coelastarte) livingstonensis Imlay		X	X	X				X		X		X		X				X			

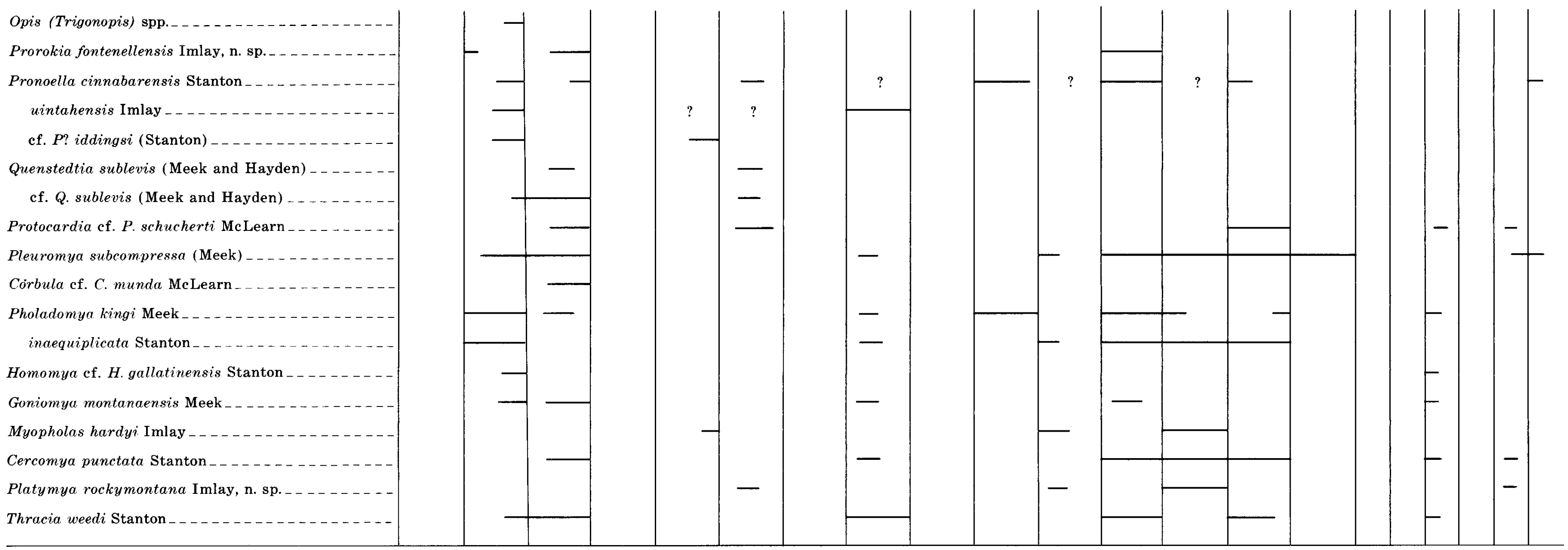

FIGURE 9.—Stratigraphic distribution of Bajocian and Callovian pelecypods in the Twin Creek Limestone and contemporary formations in the western interior of the United States. A question mark (?) indicates that the identification is uncertain; black bars show known stratigraphic ranges of species within the formations and members. The letters A–G show informal member names as previously published by Imlay (1950a, 1953a, 1956a).

Twin Creek Limestone (incomplete type section) measured about three-fourths of a mile north of Twin Creek in a southward draining gulch in NE¼ sec. 1, T. 21 N., R. 119 W., Lincoln County, Wyo.

[Fig. 1, loc. 29]

	Feet
Twin Creek Limestone (incomplete):	
Watton Canyon Member (incomplete):	
17. Limestone, mostly thin bedded, dense, medium-brownish-gray; some medium-bedded limestone	43
16. Limestone, medium-bedded, dense, medium-brownish-gray; forms top of ridge	16
15. Limestone, medium-bedded, oolitic, medium-grayish-brown	3
Boundary Ridge Member:	
14. Siltstone, very soft; brownish red at base, becoming purplish and yellowish brown at top; overlain sharply by oolitic limestone	42
13. Limestone, medium- to thin-bedded, dense, silty to finely sandy, medium-gray	13
12. Limestone, medium- to thin-bedded, oolitic, hard, medium-gray; weathers brownish gray	5
11. Limestone, hard, medium- to thin-bedded, slightly sandy, dense, medium-gray; weathers brownish gray	5
10. Siltstone, very soft, yellow to greenish-gray	10
9. Limestone, thin- to medium-bedded, silty, medium- to light-yellowish-gray, ripple-marked; some cross-bedding; weathers brownish gray	17
8. Siltstone, shaly, soft, medium yellowish-gray	2
7. Limestone, thin-bedded to shaly, silty, light-yellowish-gray, ripple-marked	5
6. Siltstone, shaly, very soft, medium-yellowish-brown; poorly exposed	9
Rich Member:	
5. Limestone, shaly to very thin bedded, light-gray-brown; upper part forms cliff; weathers into plates rather than splinters	182
4. Limestone, shaly, soft, light-grayish-brown; chunky; weathers light gray; some thin hard beds contain crinoid columnals, echinoid spines, and *Camptonectes* fragments; partly covered in bottom of gulch	118
Sliderock Member:	
3. Limestone, medium- to thin-bedded, uneven bedded, medium-grayish-brown, rubbly	82
2. Limestone, thick-bedded, oolitic, grayish-brown; forms ledge	15
Gypsum Spring Member:	
1. Siltstone; soft, red, poorly exposed; some rubbly to vuggy limestone from 10 to 20 ft above base	85
Total thickness	652

Nugget Sandstone.

Twin Creek Limestone on north side of Leeds Creek Canyon in SW¼ sec. 30, T. 23 N., R. 118 W., and SE¼ sec. 25, T. 23 N., R. 119 W., Lincoln County, Wyo.

[Fig. 1, loc. 28]

Preuss Sandstone.

	Feet
Twin Creek Limestone:	
Giraffe Creek Member:	
17. Limestone, thin-bedded to shaly, silty, light-yellowish-gray, ripple-marked; weathers slightly lighter; some hard oolitic beds near base and top contain rounded to angular limestone nodules. Contact with Preuss Sandstone is transitional within several feet	102
Leeds Creek Member:	
16. Limestone, shaly, soft, light-gray; contains a few hard beds, some of which consist mostly of crinoid columnals; others have *Camptonectes* shells in addition	164
15. Limestone, shaly, soft, medium- to light-gray	814
14. Limestone, shaly, medium-gray; a few beds of yellow silty ripple-marked limestone from 3 to 6 in. thick	37
13. Limestone, silty, light-yellow, ripple-marked; contains *Camptonectes* and *Vaugonia* (Mesozoic loc. 20991)	6
12. Limestone, shaly, soft, light-gray	22
11. Limestone, shaly to thin-bedded, medium- to light-gray	75
Watton Canyon Member:	
10. Limestone, medium- to thin-bedded, mostly dense, some oolitic, hard, medium-gray, cliff-forming; becomes thinner bedded upward	182
Boundary Ridge Member:	
9. Covered	45
8. Siltstone, soft, red, partly covered	45
7. Limestone, thin-bedded, silty, yellow	18
Rich Member:	
6. Limestone, shaly, medium- to light-gray; soft at base; forms low ridge at top where some beds are an inch thick; some beds pinkish to yellowish gray; weathers light yellowish gray; contacts sharp (Mesozoic loc. 20965 from 38 to 40 ft above base)	260
Sliderock Member:	
5. Limestone, thin- to medium-bedded, 2–18 in. thick; becomes thicker bedded upward; dense, hard, dark gray to black (Mesozoic locs. 20966 and 20981 from upper 20 ft)	85
4. Limestone, oolitic, hard, dark-gray to black	10
Gypsum Spring Member:	
3. Siltstone, soft, red; 2 ft of yellow siltstone at top; some thin beds of sugary-textured limestone near middle	27
2. Limestone, brecciated, medium-yellowish-gray; some red spots	6
1. Siltstone, very soft, red, poorly exposed; several feet of gray limestone from 6 to 9 ft above base; contact with Nugget covered	43
Total thickness	1,941

Nugget Sandstone.

A summary of the lithologic, stratigraphic, faunal, and ecological features of the Twin Creek Limestone is presented in table 1.

GYPSUM SPRING MEMBER

DEFINITION

The term Gypsum Spring Member of the Twin Creek Limestone was suggested by Imlay (1950a, p. 39) and defined by Oriel (1963) for a basal unit consisting of red beds and associated brecciated limestone and chert-bearing limestone that rest directly on the Nugget Sandstone. These beds were once called member A by Imlay (1950a, p. 37–39; 1953a, p. 54). They were not noted by Veatch (1907, p. 56, 57) in his definitions of the Nugget Sandstone and Twin Creek Limestone, but were included by Mansfield (1927, p. 96, 97) partly in the Nugget Sandstone and partly in the Twin Creek Limestone. The beds were recognized by W. W. Rubey (1958) as forming the basal part of the Twin Creek Limestone.

DISTRIBUTION AND THICKNESS

The Gypsum Spring Member crops out in the same areas as the overlying members of the Twin Creek Limestone except in the Uinta Mountains, Utah, where the easternmost known exposure is northeast of Oakley on the west side of State Highway 213 in the NE¼ sec. 1, T. 1 S., R. 6 E.

The Gypsum Spring Member characteristically thins or thickens markedly within short distances. Regionally it thickens westward in an irregular manner from an average of about 75 feet in western Wyoming to about 400 feet in the Blackfoot Mountains in Idaho (table 2; figs. 2–5). It also thickens considerably southwestward from a minimum of 12 feet at Red Mountain, Teton County, Idaho, toward the Blackfoot Mountains. In northern Utah it thickens westward from a few feet near the west end of the Uinta Mountains to about 200 feet near Devils Slide in the Wasatch Mountains (fig. 7). Southward in the Wasatch Mountains the member thins to 49 feet at Monks Hollow (fig. 7) and 9 feet at Thistle.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Gypsum Spring Member is characterized by soft brownish-red to yellow siltstone and silty claystone that contains interbeds, or units, of brecciated or honeycombed limestone and chert-bearing limestone. In western Wyoming and locally in easternmost Idaho the lower part of the member contains a conspicuous unit of brecciated gray to yellowish-gray limestone that ranges from 10 to 50 feet in thickness (figs. 2–7). This unit is a jumble of sharply angular blocks, generally includes some red siltstone, and shows faint stratification. The position of this brecciated limestone unit is occupied by thick masses of gypsum in the southeast corner of the Jackson quadrangle, Wyoming, in the E½ sec. 36, T. 36 N., R. 115 W., about 32 miles SSE of Jackson, Wyo. Locally, gypsum has been found in the lower part of the member near the head of Crow Creek, Caribou County, Idaho (Mansfield, 1927, p. 96) about 14 miles northeast of Montpelier. In addition, about 60 feet of gypsum is reported from the base of the member in the subsurface of north-central Utah (Peterson, 1957a, fig. 9 on p. 418).

In many places the middle and upper parts of the member contain one or more thin units of yellow honeycombed or brecciated limestone that are generally inconspicuous. Pieces of such limestone lying on soil-covered areas are of considerable aid in recognizing and tracing the member.

In southeastern Idaho the middle and upper parts of the member contain beds or units of dense gray, yellowish-gray, or white limestone that is siliceous and bears nodules and lenses of brownish-gray chert. Such beds are about 70 feet thick on Stump Creek in the SW ¼ secs. 27 and 28, T. 6 S., R. 45 E., Caribou County, and at least 140 feet thick on Williams Creek in the SE¼ sec. 12, T. 2 S., R. 39 E., Bingham County. Similar chert-bearing limestone beds from 1 to 2 feet thick occur near the middle of the member in several sections near the Wyoming-Idaho border. They have been observed on Cabin Creek in the S½ sec. 17, T. 38 N., R. 116 W., Teton County, Wyo., on the South Fork of Fontenelle Creek in the NW¼ sec. 33, T. 26 N., R. 116 W., Lincoln County, Wyo., and at the mouth of Dunns Canyon near center of sec. 10, T. 11 S., R. 44 E., Bear Lake County, Idaho. The chert-bearing limestone beds in Idaho are interbedded with and overlie limestone beds that are silty to finely sandy, a feature that appears to become more common westward.

Sandstone forms a minor part of the Gypsum Spring Member. Most sections, however, contain a little brownish-red fine-grained sandstone interbedded with red siltstone. Fairly thick units of brownish-red sandstone occur near the middle of the member on the South Fork of Fontenelle Creek, Wyo., and on Preuss Creek, Idaho. Yellowish-white sandstone has been noted below the brecciated limestone at or near the base of the member at Sliderock Creek northeast of Cokeville, Wyo., at Cottonwood Creek east of Smoot, Wyo., and on Sheep Creek near Greys River, Wyo. Northeast of Oakley, Utah, the entire 22 feet of the member consists of red, pink, and yellow silty sandstone and sandy siltstone except for a few inches of green tuff at and near the top.

The claystone and siltstone beds and units are mostly brownishred to brick red, but some are gray, yellowish gray, greenish yellow, or green. Green streaks occur rarely in the units that are dominantly red.

The basal beds of the outcropping Gypsum Spring Member may consist of red siltstone, of soft yellow sandstone, or of brecciated limestone that invariably rests sharply on the hard quartzitic Nugget Sandstone. The upper contact is generally marked by an equally sharp change from soft red, pink, or gray siltstone to oolitic, or sandy, or dense limestone at the base of the Sliderock Member. Locally the top of the Gypsum Spring Member consists of green to white volcanic tuff as at Thomas Fork Canyon and Cottonwood Canyon in western Wyoming and northeast of Oakley, Utah. At Red Mountain, Teton County, Idaho, the entire Gypsum Spring Member consists of only 12 feet of limestone breccia that is overlain directly by thin- to medium-bedded granular limestone at the base of the Sliderock Member. Similar limestone breccia elsewhere in Idaho and Wyoming are separated from the Sliderock Member by a unit of soft red siltstone.

In most places the Gypsum Spring Member is poorly exposed because it consists mainly of soft siltstone. Its position is generally marked, however, by a soil-covered ravine lying between the much harder Nugget Sandstone and the limestone of the Sliderock Member of the Twin Creek Limestone. In western Wyoming the unit of brecciated limestone at or near the base of the member forms low ridges or cliffs, and the position of the red siltstone is indicated by red soil, by fragments of yellow honeycombed limestone, and by some outcrops. Westward in Idaho the brecciated unit at the base becomes inconspicuous, but the chert-bearing siliceous limestone beds in the middle and upper parts of the member become locally conspicuous. Well-exposed sections of the member occur in Wyoming at La Barge Creek, Sliderock Creek, and at Cottonwood Creek (see locations in fig. 1 and table 2). In Idaho, fairly complete sections are exposed at Willow Creek, Stump Creek, and on the road from Crow Creek to Sage Valley in the SE¼ sec. 9, T. 9 S., R. 46 E. In Utah the best exposed sections are on the Weber River near Oakley in the NE¼ sec. 1, T. 1 S., R. 6 E., and near Devils Slide. Many of the exposures in Utah and Idaho have been made during road building or quarrying operations.

Many sections of the Gypsum Spring Member have been described previously as member A (Imlay, 1950a, p. 42–45; 1953a, p. 60–62). The following sections of the Gypsum Spring Member illustrate the major lithologic and stratigraphic changes from east to west.

Gypsum Spring Member on north side of South Piney Creek, sec. 11, T. 29 N., R. 115 W., Sublette County, Wyo.

[Fig. 1, loc. 19]

	Feet
3. Siltstone, soft, olive-green; overlain sharply by dark gray to black medium-bedded, oolitic limestone at base of Sliderock Member	5
2. Siltstone, soft, brownish-red	42
1. Breccia of gray to yellowish-gray limestone containing fragments of many sizes; some pieces much honeycombed; weathers medium gray. Rests sharply on Nugget Sandstone	35
Total thickness	82

Gypsum Spring Member on Cottonwood Creek in W½ sec. 36, T. 31 N., R. 118 W., Lincoln County, Wyo.

[Fig. 1, loc. 17]

	Feet
13. Tuff, dense, hard; white at top, light green at base; overlain sharply by sandy, thick-bedded limestone at base of Sliderock Member	6
12. Claystone, soft, yellowish-gray	2
11. Limestone, brecciated, light-gray, honeycombed; contains fragments of red and green siltstone	8
10. Siltstone, soft, mostly brownish red, partly yellowish green to gray	22
9. Siltstone, soft, light-yellow	3
8. Limestone, brecciated, massive, gray	3
7. Breccia of yellow limestone and red siltstone	6
6. Limestone, thick- to medium-bedded, brecciated; contains fragments of red and yellow siltstone	35
5. Limestone, yellow to brown, honeycombed	5
4. Siltstone, soft, yellowish-gray	2
3. Sandstone, massive, fine-grained, light-yellow; some green specks on fresh surfaces	2
2. Sandstone, shaly, fine-grained, rather soft, yellowish-white	7
1. Siltstone, dark-red; rests sharply on Nugget Sandstone	1
Total thickness	102

Gypsum Spring Member near Old Lander Trail south of Stump Creek in SE¼ sec. 28 T. 6 S., R. 45 E., Caribou County, Idaho

[Fig. 1, loc. 16]

	Feet
4. Siltstone, light-gray to pink; interbedded with yellowish-gray thin-bedded limestone that locally is brecciated and honeycombed. Overlain sharply by sandy fossiliferous limestone at base of Sliderock Member	41
3. Siltstone, soft, brownish-red, poorly exposed	65
2. Limestone, medium- to thin-bedded, medium-gray; weathers light gray; contains much brownish- to reddish-gray chert as granules, nodules, and short lenses; contains abundant crinoid fragments	70
1. Sandstone, fine-grained, and siltstone; both brownish red, poorly exposed. Contact with Nugget Sandstone not exposed but mapped as a fault	47
Total thickness	223

Gypsum Spring Member along north side of Willow Creek in NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho

[Fig. 1, loc. 4]

	Feet
22. Covered in ravine. Overlain by fossiliferous shaly to thick-bedded limestone of the Sliderock Member. Assignment to Gypsum Spring Member uncertain	54
21. Limestone, medium-bedded, medium-gray; contains some dark chert near base; becomes sandy and thicker near base; becomes sandy and thicker bedded upward; forms top of ridge	38
20. Limestone, thin-bedded, laminated, finely sandy, light gray; contains several chert bands	9
19. Siltstone, light-yellowish-gray	2
18. Limestone, thick-bedded, dense, silty, dark- to medium-gray, cliff-forming; upper 45 ft contains lenses of brownish-black chert and traces of silicified fossils	60
17. Limestone, medium-bedded, medium-gray; vuggy, much fractured; weathers yellow	4½
16. Limestone, medium-bedded, mostly dense, medium-gray, brittle, much fractured	34
15. Siltstone, calcareous, yellowish-gray, vuggy	2
14. Limestone, thin-bedded, finely laminated, medium-gray, brittle; some lamellae curved; weathers light gray	4
13. Claystone, silty, calcareous, thinly laminated, medium-gray	5
12. Siltstone, sandy, soft, yellowish-gray; some thinly laminated; contains some vuggy calcareous beds	9
11. Limestone, massive, silty, light-grayish-white	4
10. Limestone, medium- to thin-bedded, silty, medium-yellowish-gray, brittle	17
9. Limestone, medium-bedded, sandy, light-yellowish-gray; grades downward into yellow siltstone	2
8. Siltstone, light-yellowish-gray; interbedded with fine-grained thin-bedded sandstone; grades downward into red siltstone	5
7. Siltstone, soft, red; a few white streaks near base	6
6. Limestone, silty, light-yellowish-gray	1
5. Limestone, thin-bedded, thinly laminated, medium-gray	1½
4. Limestone, thinly laminated, massive, granular, dark-gray, chert-bearing	4
3. Siltstone, medium-bedded, thinly laminated, greenish-yellow	1½
2. Siltstone, thin-bedded, thinly laminated, greenish-yellow; grades at base into red siltstone	6
1. Siltstone, soft, and fine-grained brownish-red sandstone. Unit rests on quartzitic Nugget Sandstone	160
Total thickness	430?

FOSSILS, AGE, AND CORRELATIONS

The most abundant fossils found in the Gypsum Spring Member of the Twin Creek Limestone are crinoid columnals and echinoid spines. In addition some fragments of *Camptonectes* similar to *C. distans* Stanton have been obtained from the top of the Gypsum Spring Member in the NE¼ sec 5, T. 24 N., R. 116 W., Lincoln County, Wyo. (USGS Mesozoic loc. 25261).

The age of the Gypsum Spring Member is probably middle Bajocian inasmuch as it is overlain concordantly by the Sliderock Member which contains ammonites of earliest late Bajocian age, as described herein. Furthermore, in northwestern Wyoming the Gypsum Spring Member passes eastward from Jackson Hole into the lower part of gypsiferous red beds (fig. 3, locs. 12 and 13) that grade upward into a limestone member of probable late Bajocian age. This age is based on the presence of the ammonite *Sohlites*, identical with ammonites in the Rich Member of the Twin Creek Limestone, found near the middle of the same limestone member (Imlay, 1956b, p. 583) a few miles south of Cody, Wyo.

Correlation of the Gypsum Spring Member of the Twin Creek Limestone with the lower part of the Gypsum Spring Formation of north-central Wyoming is supported not only by apparent lateral continuity but by a similar stratigraphic position between the Nugget Sandstone below and limestone beds above (fig. 10) and by striking lithologic resemblances. The fact that the brecciated limestone unit in the lower part of the Gypsum Spring Member is replaced by thick gypsum masses in the southeastern part of the Jackson quadrangle implies that the brecciated limestone unit represents beds that collapsed because of the removal by solution of interbedded gypsum. It implies, also, that the honeycombed or vesicular limestone beds in the Gypsum Spring Member represent the positions of former thin beds of gypsum. If these conclusions are correct, the Gypsum Spring Member along the Wyoming-Idaho border must have once been lithologically identical with the lower part of the Gypsum Spring Formation to the east in the Wind River Mountains (Richmond, 1945) and Wind River Basin (Love and others, 1945).

Similarly, an approximate correlation may be made between the Gypsum Spring Member of the Twin Creek Limestone and the lower red-bed member of the Piper Formation in southern Montana by means of close lithologic and stratigraphic resemblances and by tracing beds laterally northward through the Bighorn Basin, as discussed in detail elsewhere (Imlay, 1956b, p. 579, 584, 585, figs. 3–7). This correlation is supported by the fact that the lower red-bed member of the Piper Formation grades upward (Imlay, 1954, p. 54) into a middle limestone member that contains the same ammonites as occur in the Rich member of the Twin Creek Limestone. Inasmuch as these ammonites, described herein, have been found in all parts of the middle limestone member of the Piper Formation, the underlying lower red-bed member probably is equivalent to both the Sliderock and Gypsum Spring Members of the Twin Creek Limestone.

Correlation of the Gypsum Spring Member of the Twin Creek Limestone with beds elsewhere in the west-

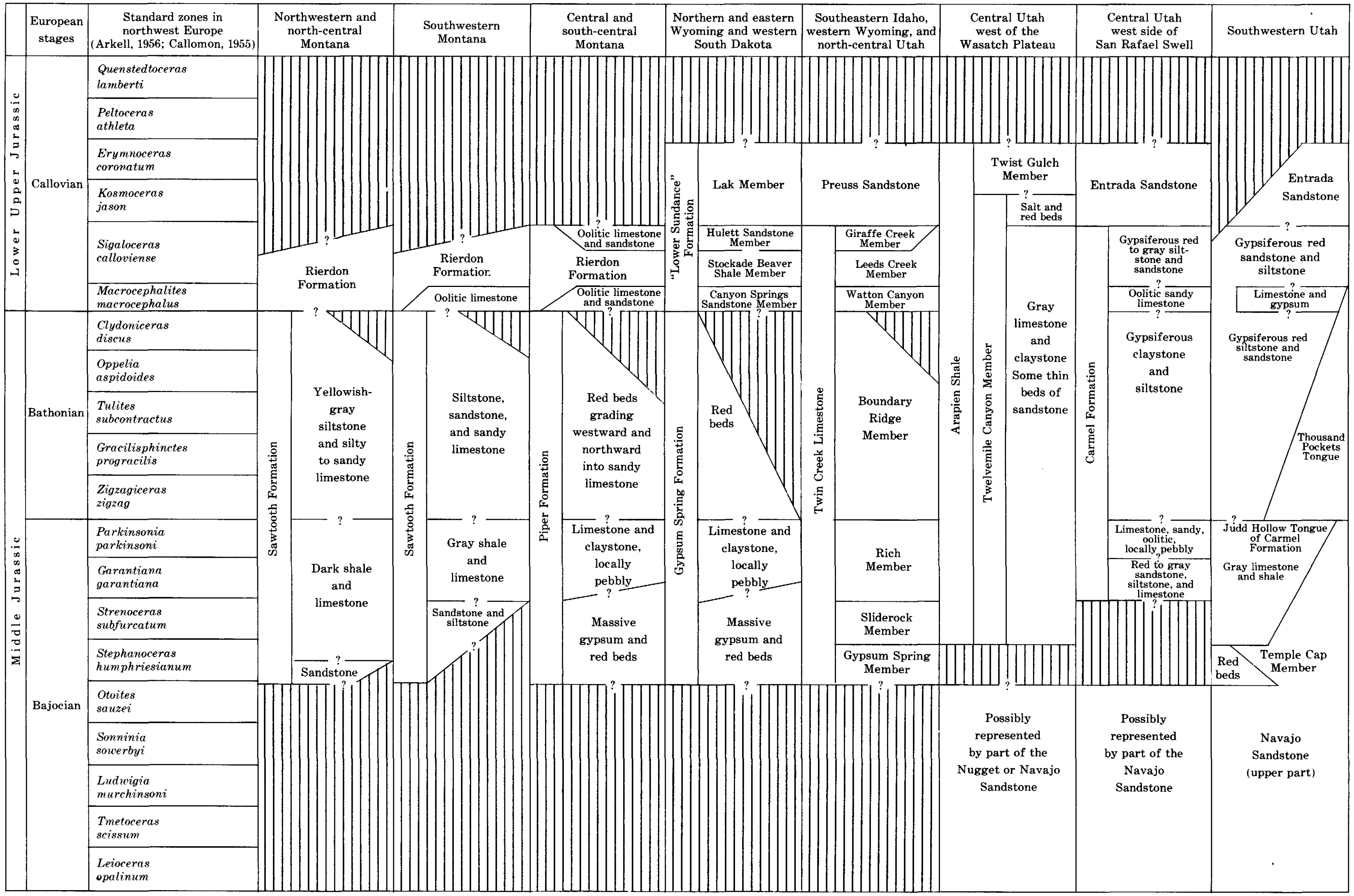

FIGURE 10.—Correlation of Middle and lower Upper Jurassic formations in the western interior of the United States. Vertical ruled lines indicate a hiatus.

ern interior region is much less certain. The member may be in part equivalent to the lower member of the Piper Formation in the subsurface of eastern Montana (Sandberg, 1959), but it shows more resemblance lithologically to the underlying Nesson Formation of Nordquist (1955), and it could be equivalent to both of those units. It must be older than the middle member of the Piper Formation of the subsurface, because that member near its middle has furnished *Gryphaea planoconvexa* Whitfield, a fossil typical of the Rich Member or the Twin Creek Limestone, obtained at a depth of 2,896–2,906 feet in The Texas Co. Bowdoin Unit 1 (822), Phillips County, Mont.

The Gypsum Spring Member of the Twin Creek Limestone should be equivalent to part of the Sawtooth Formation in northwestern Montana (Cobban, 1945, p. 1272–75; Imlay and others, 1948) beneath the upper siltstone member, which contains ammonites of Bathonian or earliest Callovian age (Imlay, 1962a, p. C–12). Inasmuch as the middle shale member of the Sawtooth Formation grades downward from the upper siltstone member and near its base contains the middle Bajocian ammonites *Chondroceras* (Imlay, 1948, p. 19) and *Stemmatoceras* (see *S. arcicostum* Imlay, n. sp.), the upper part of the shale member should be of late Bajocian age, equivalent to the Sliderock and Rich Members of the Twin Creek Limestone. Ammonites of definite late Bajocian age, however, have not been found in the middle shale member, or anywhere to the north in the Fernie Group of Canada (Frebold, 1954, p. 1).

The Arapien Shale of central Utah at one place is marked basally by 1–10 feet of soft red siltstone that is comparable lithologically and stratigraphically to the Gypsum Spring Member of the Twin Creek Limestone. This place is in the bottom of Red Canyon about 2 miles northeast of Nephi, Utah. Elsewhere in Red Canyon (Johnson, 1959, p. 20–25; Imlay, 1964a, p. C6), the Nugget Sandstone is overlain directly by sandy oolitic limestone similar to the Sliderock Member of the Twin Creek Limestone, but the contact is marked by slickensides and could be a fault.

Elsewhere in central Utah the characteristics of the basal beds of the Arapien Shale are unknown. In the area southwest of Marysvale, the Navajo Sandstone is reported to be overlain by 1,000 feet of medium- to thin-bedded limestone (Willard and Callaghan, 1962), but the nature of the contact is not described. A thin unit of soft red siltstone at the base of the limestone could easily be overlooked, or perhaps considered part of the Navajo Sandstone.

The Carmel Formation in southwestern Utah between Gunlock and Cedar City has a basal red-bed unit (Wright and Dickey, 1963a) that is similar lithologically to the Gypsum Spring Member of the Twin Creek Limestone, is overlain by limestone containing pelecypods that are characteristic of the Sliderock and Rich Members (Imlay, 1964a, p. C3), and contains bentonite beds (Schultz and Wright, 1963, p. E67; Wright and Dickey, 1963a, p. E66) that could be related in origin to the green tuff beds at the top of the Gypsum Spring Member. This basal red-bed unit is replaced eastward in Zion National Park by the Temple Cap Member of the Navajo Sandstone (Cook, 1957, p. 34; Wright and Dickey, 1963a, p. E64–65).

ORIGIN

The lithologic and stratigraphic characteristics of the Gypsum Spring Member of the Twin Creek Limestone indicate that it was the initial deposit in a very shallow sea that advanced eastward from a basin whose center lay west of the present western limit of Jurassic outcrops. In westernmost Wyoming the oldest deposits at most places consisted of a few feet of red to white sand or red silt. These were overlain by a thick mass of gypsum that was interbedded with some calcareous mud and red silt. Then followed deposition of red silt and clay that included minor amounts of gypsum and calcareous mud. Some of the mud contained siliceous material that now forms nodules and lenses of chert. This succession was terminated abruptly by deposition of the fossiliferous oolitic limestone of the Sliderock Member that represents a sudden deepening of the sea.

Westward in southeastern Idaho the oldest deposits consisted mostly of red, yellow, or gray silt and sand but included some gypsum and calcareous mud. Then followed deposition of considerable calcareous mud that included some siliceous material, sand, and fossil remains. Deposition of this mud was interrupted at times by an influx of yellow to gray silt and clay and some gypsum. The latest beds deposited generally consisted of red silt and clay that included some calcerous mud and a little gypsum. This succession was terminated abruptly by deposition of sandy dense to oolitic fossiliferous calcareous mud that is included in the Sliderock Member. Overall, the deposition of gypsum increased eastward and the deposition of calcerous mud and siliceous material increased westward. Fossil remains are scarce throughout but become more common westward. These features plus an irregular westward thickening of the member indicate that the sea deepened somewhat westward.

The position of the Gypsum Spring Member of the Twin Creek Limestone at the western edge of a sheet of red beds and gypsum that extends eastward to the Black Hills of western South Dakota (Imlay, 1950b, p. 85) and northward through eastern Montana (Imlay and others, 1948; Rayl, 1956, p. 36; Peterson, 1957a,

p. 406, 422) into Manitoba and Saskatchewan (Francis, 1956, p. 23–25, 46) indicates that the sources of clastic sediment lay to the south and west, or possibly northwest. Probably some sand or silt was derived also from the formations over which the sea transgressed. The presence of extensive masses of gypsum over such an enormous area suggests that the land surrounding the sea were so hot and arid that few streams entered the sea. Highly oxidizing conditions during the deposition of the red beds and gypsum is indicated by a complete lack of fossils in such beds.

SLIDEROCK MEMBER

DEFINITION

The Sliderock Member of the Twin Creek Limestone consists of dark fossiliferous medium- to thin-bedded limestone, from 20 to nearly 300 feet thick, that rests sharply on the red beds or brecciated limestone of the Gypsum Spring Member and is overlain gradationally within a few feet by soft shaly limestone at the base of the Rich Member. The type section (fig. 1, loc. 23) is designated as on the west side of Grade Creek at the junction with Sliderock Creek in NE¼ sec. 10, T. 25 N., R. 118 W., Lincoln County, Wyo. At this locality the lower 12 feet of the member consists of hard black oolitic limestone that overlies soft red siltstone. The upper 73 feet consists of black to medium-gray very fossiliferous compact thin- to medium-bedded limestone that is more resistant than the overlying shaly limestone. The Sliderock Member has previously been called member B by Imlay (1950a, p. 39; 1953a, p. 54, 55).

DISTRIBUTION AND THICKNESS

The Sliderock Member crops out in the same areas as the overlying members of the Twin Creek Limestone. In the Uinta Mountains its easternmost exposures are on Lake Fork (Imlay, 1953a, fig. 3). In northwestern Wyoming east of the area of Twin Creek Limestone it is represented at Lower Slide Lake, Teton County, by units 7–9 of the published section (Imlay, 1956a, p. 70).

The Sliderock Member thickens westward from a minimum of 21 feet in the Jackson Hole area, Wyoming, to about 285 feet in southeastern Idaho. In northern Utah it thickens westward from 32 feet near Lake Fork in the Uinta Mountains to 150 feet near Burr Fork in the Wasatch Range. Southward in that range it thins to less than 100 feet near Thistle (table 2).

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Sliderock Member consists mainly of medium- to thin-bedded grayish-black to brownish-gray dense to granular limestone (figs. 2–8). In Wyoming the basal 5–15 feet is generally a dark hard thick-bedded oolite that contains some sand grains and some pyrite. In southeastern Idaho the basal 20–60 feet generally consists of brownish glauconitic sandy crossbedded limestone that locally contains tiny pebbles of red, green, or gray chert. Pebbles have been noted in the member at Willow Creek, Stump Creek, Preuss Creek, and 1½ miles east of Bear Lake on the road to Pegram. Locally in Idaho, similar sandy beds occur at higher levels. On Willow Creek, east of Idaho Falls, a 4-foot bed of quartzitic sandstone occurs 34 feet below the top of the member beneath a bed of bentonite. Oolites may occur in the basal beds, or higher, but are somewhat less common than in Wyoming. Units of soft claystone occur in the member on Willow Creek, Idaho, and on Birch Creek, Utah. Overall toward the west the Sliderock Member becomes increasingly sandier, more clayey, and less oolitic.

The Sliderock Member in southeastern Idaho also contains some light-green to white volcanic tuff in beds that range from 4 to 10 feet in thickness (Mansfield, 1927, p. 97; Gulbrandsen and Cressman, 1960, p. 458–464). On Preuss Creek, tuff occurs 153 feet above the base of the member and 71 feet below its top. About 2 miles northwest of Pegram in the north-central part of sec. 36, T. 14 S., R. 45 E., tuff occurs in the upper part of the member in two beds separated by 12 feet of limestone. Other occurrences are reported to be 150–200 feet above the base of the member (Gulbrandsen and Cressman, 1960, p. 459).

In northern Utah the Sliderock Member is similar lithologically to the member in southeastern Idaho. The basal units are generally oolitic, or sandy, or both. The upper beds are generally dense to granular. Near Thistle a bed of sandstone 6 feet thick occurs 23 feet above the base of the member. On Birch Creek west of Woodruff the lower 43 feet of the member contains two beds of ripple-marked sandstone as well as a basal unit of highly sandy oolitic limestone.

Many sections of the Sliderock Member in Wyoming and Idaho have been described previously as member B (Imlay, 1950a, p. 42–45; 1953a, p. 60–62). The following sections illustrate the major changes that occur in the member in northern Utah.

Sliderock Member on west side of Lake Fork in NW¼ sec. 2, T. 1 N., R. 5 W., Duchesne County, Utah

[Fig. 1, loc. 39]

	Feet
1. Limestone, medium-bedded, finely sandy; light-yellowish-gray; some crossbedding present; contains fragments of crinoids and *Camptonectes*. Rests sharply on Nugget Sandstone. Contact with the Rich Member is covered in a gully	32

Sliderock Member on southwest side of Duchesne River in SW¼ sec. 4, T. 1 S., R. 8 W., Duchesne County, Near Hanna, Utah

[Fig. 1, loc. 38]

	Feet
2. Limestone, massive, oolitic, medium-yellowish-gray, cliff forming; contains small oysters on upper surface. Overlain by soft shaly limestone at base of Rich Member	12
1. Limestone, medium- to thin-bedded, finely sandy, light-yellowish-gray to pinkish-gray; some beds oolitic; passes laterally into massive crossbedded sandstone; rests sharply on salmon-colored Nugget Sandstone	30
Total thickness	42

Sliderock Member on west side of State Highway 213 northeast of Oakley in NE¼ sec. 1, T. 1 S., R. 6 E., Summit County, Utah

[About 7 miles east-northeast of loc. 37 as shown in fig. 1]

	Feet
5. Limestone, medium-bedded, medium- to dark-gray, cliff-forming; some pink beds near base; weathers medium gray; overlain by soft shaly limestone at base of Rich Member	30
4. Limestone, dense, yellowish-gray, brittle; weathers same	1
3. Limestone, medium- to thin-bedded, brownish-gray; weathers light gray; fossiliferous (USGS Mesozoic loc. 21619 from base)	6
2. Limestone, slightly oolitic, finely sandy, medium- to pinkish-gray	9
1. Limestone, sandy, mottled pink and gray; rests on 3-6 in. of dark-green volcanic tuff at the top of the Gypsum Spring Member	1
Total thickness	47

Sliderock Member on north side of road north of Thistle in W½ sec. 28, T. 8 S., R. 4 E., Utah County, Utah

[Fig. 1, loc. 42]

	Feet
7. Limestone, medium-bedded, moderately soft, dark-yellowish-gray; weathers light gray; contains lenses of crinoidal debris in upper 6 ft and a few fragments of *Gryphaea;* overlain by soft shaly limestone at base of Rich Member	31
6. Limestone, medium-bedded, hard, pink; upper surface greenish pink; weathers light gray	7
5. Limestone coquina of crinoid and echinoid fragments	1
4. Limestone, thin-bedded to shaly, yellowish- to dark-gray	3
3. Sandstone, medium-bedded, hard, pinkish-gray	6
2. Limestone, sandy, soft, pink to gray	8
1. Limestone, oolitic, pink to gray; contains crinoid columnals, echinoid spines, and fragments of *Gryphaea*. Rests sharply on 9 ft of soft red siltstone comprising the Gypsum Spring Member	15
Total thickness	71

Sliderock Member along north side of Birch Creek in NW¼ sec. 20, T. 9 N., 6 E., Rich County, Utah

[Fig. 1, loc. 33]

	Feet
28. Limestone, medium- to thin-bedded, uneven-bedded, medium-gray, ridge-forming, nodular; weathers light gray; overlain by soft shaly limestone at base of Rich Member; contains ammonites and pelecypods (Mesozoic locs. 28644–46, 28648)	62
27. Claystone, soft, medium-gray, fissile to chunky	4
26. Siltstone, soft, reddish-purple	½
25. Limestone, pink to yellow, nodular; contains traces of fossils	1
24. Siltstone, reddish-brown to yellowish-gray	14
23. Limestone, shaly, gray, nodular	2
22. Siltstone, soft, brownish-red to gray	3
21. Claystone, soft, medium-gray, chunky to fissile	9
20. Claystone, calcareous, yellowish-gray, nodular	3
19. Limestone, yellowish-gray, rubbly	1
18. Limestone, shaly, soft, medium-yellowish-gray	3
17. Claystone, soft, purplish-red	1
16. Limestone, yellowish-gray, rubbly	2
15. Claystone, fairly soft, yellowish-gray, chunky	5
14. Limestone, yellowish-gray, rubbly; contains *Camptonectes*	1½
13. Claystone, soft, medium-gray	18
12. Limestone, shaly, medium-gray	5
11. Limestone, gray, rubbly; contains *Gryphaea* and *Camptonectes* (Mesozoic loc. 28647)	5
10. Sandstone, medium-bedded, very fine grained, pinkish-gray, ledge-forming; weathers brownish gray; passes at top into brownish-gray sandy limestone	16
9. Siltstone, sandy, yellowish- to pinkish-gray; bedding irregular	5
8. Covered	10
7. Sandstone, medium-bedded, very fine grained, pinkish- to yellowish-gray	3
6. Covered	10
5. Sandstone, thin-bedded, very fine grained, pinkish-gray, ripple-marked	4
4. Mostly covered; some red to light-green soft siltstone exposed at top	12
3. Sandstone, medium- to thin-bedded, fine-grained, pinkish- to greenish-gray, ripple-marked	5
2. Siltstone, soft, red, poorly exposed	2
1. Limestone, thick- to medium-bedded, oolitic, very sandy, brownish- to yellowish-gray, cliff-forming; some crossbedding; contains fragments of fossils throughout; underlain by a covered interval of 16 ft and then by 20 ft of reddish-brown purple, and lavender siltstone of the Gypsum Spring Member. Contact with Nugget Sandstone is not exposed	20
Total thickness	227

In the above sequence only the upper 62 feet of ridge-forming limestone and the lower 20 feet of cliff-forming oolitic limestone resemble the Sliderock Member as exposed in western Wyoming. In between are seven units

TABLE 3.—*Geographic distribution of marine Jurassic megafossils in the Sliderock Member of the Twin Creek Limestone*

[Gastropod identifications are by N. F. Sohl. All one- and two-digit numbers refer to localities in figs. 16 and 17. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Idaho																							Wyoming														
	2	3								4	10	12				13	16	18	19	20	21	23		31	34	36	38	40	45				46	47	48			49
	28586	13491	28500	28501	28502	28505	28506	28635	28636	21000	18181	16016	21632	21633	28795	9090	12116	7432	6370	4081	28637	6638	6639	16036	9102	12018	12119	12019	20971	20988	27729	28483	6364	21628	20961	20968	20972	22017
Worm tubes	X																									X												X
Echinoid spines	X																																					
Crinoid columnals		X										X												X			X										X	
Grammatodon haguei (Meek)													X																			X						
Idonearca haguei (Stanton)																																						
Modiolus subimbricatus (Meek)																																						
Mytilus cf. *M. whitei* Whitfield																																						
Pinna kingi Meek																																X	X					
Camptonectes stygius White																																						
platessiformis White							X					X			X																			X			X	
sp	X										X	X							X							X		X										
Chlamys? sp				X																																		
Plicatula sp																																						
Lima (*Plagiostoma*) sp																																						X
Ctenostreon cf. *C. gikshanensis* McLearn																											X										X	X
Ostrea (*Liostrea*) *strigilecula* White	X																			X		X						X										
Lopha sp												X		X																								
Gryphaea planoconvexa fraterna Imlay, n. subsp		X			X	X		X	X	X	X	X		X	X		X	X			X				X				X	X	X	X	X		X	X	X	
Trigonia americana Meek																								X														
Myophorella (*Promyophorella*) *montanaensis* (Meek)																																X						
Astarte meeki Stanton		X									X																											
(*Coelastarte*) *livingstonensis* Imlay																																						
Opis (*Trigonopis*) sp																																						
Prorokia fontenellensis Imlay, n. sp																																						
Pronoella cinnabarensis (Stanton)																													X									
uintahensis Imlay																																						
cf. *P.*? *iddingsi* (Stanton)																																						
sp																								X					X			X						
Mactromya? sp																																						
Tancredia? sp																							X															
Quenstedtia sp																							X															
Pleuromya subcompressa (Meek)								X					X																	X	X	X	X			X		
Pholadomya kingi Meek																														X							X	
inaequiplicata Stanton								X																														
Homomya cf. *H. gallatinensis* Stanton																																						
Goniomya montanaensis Meek																													X									
Thracia weedi Stanton																																						
Teinostomopsis? sp																																						
Lyosoma powelli White																								X														
Rhabdocolpus sp																																						
Pseudomelania? sp																																						
Naticiform gastropods																																						
Cossmannea sp	X																							X														
Ceritella sp																								X														
Cylindrobullina? sp																																						
Gastropods undet			X				X																															
Spiroceras cf. *S. orbignyi* Baugier and Sauze																																						
Stephanoceras cf. *S. skidegatensis* (Whiteaves)													X																									
aff. *S. nodosum* (Quenstedt)																																						
Stemmatoceras arcicostum Imlay, n. sp																																						
n. sp. aff. *S. albertense* McLearn												X			X															X		X						
sp												X																										
Normannites? cf. *N. crickmayi* (McLearn)																X																						
Megaspaheroceras cf. *M. rotundum* Imlay																												X				X						
aff. *M. rotundum* Imlay								X				X																										
sp. undet																																						
?sp																																						
Eocephalites primus Imlay, n. sp																														X	X	X		X	X	X		
sp																															X							
?sp. undet. A																																						
?sp. undet. B																																						
?sp. undet. C																																						
?sp																														X					X			
Eutrephoceras sp. undet																																						

TABLE 3.—*Geographic distribution of marine Jurassic megafossils in the Sliderock Member of the Twin Creek Limestone*—Continued

	Wyoming																	Utah																				
	54		55				56	57	58	63	64	65					66	68	69	71					72	73	75	77	81		82	83	84	93	95	96		
	20979	20985	20344	20970	20973	28484	28794	20978	20345	20969	20984	20966	20975	20977	20981	28798	3391	21618	8177	28644	28645	28646	28647	28648	22638	28642	28641	21619	3218	3219	17964	17961	17985	17674	17673	28457	28458	28459
Worm tubes																																						
Echinoid spines																																	X	X				
Crinoid columnals																																						
Grammatodon haguei (Meek)																					X								X	X								X
Idonearca haguei (Stanton)			X						X												X																	
Modiolus subimbricatus (Meek)							X		X												X																	
Mytilus cf. *M. whitei* Whitfield																																						
Pinna kingi Meek									X		X			X			X				X			X						X	X							X
Camptonectes stygius White									X																													
platessiformis White									X																								X	X				X
sp.			X		X								X				X	X								X			X						X			
Chlamys? sp.																																						
Plicatula sp.									X																								X	X				
Lima (*Plagiostoma*) sp.									X																													
Ctenostreon cf. *C. gikshanensis* McLearn						X			X		X													X														X
Ostrea (*Liostrea*) *strigilecula* White																															X	X	X					X
Lopha sp.																																						
Gryphaea planoconvexa fraterna Imlay, n. subsp.			X	X	X	X			X			X	X	X				X	X	X	X		X	X	X					X								
Trigonia americana Meek																X																		X				
Myophorella (*Promyophorella*) *montanaensis* (Meek)			X		X											X				X	X			X														
Astarte meeki Stanton											X						X	X						X					X	X								
(*Coelastarte*) *livingstonensis* Imlay			X																		X							X										
Opis (*Trigonopis*) sp.			X																																			
Prorokia fontenellensis Imlay, n. sp.																												X										
Pronoella cinnabarensis (Stanton)																																						
uintahensis Imlay																								X								X						
cf. *P.*? *iddingsi* (Stanton)														X																								
sp.			X	X	X				X		X			X			X			X				X							X	X			X			X
Mactromya? sp.												X		X																X								
Tancredia? sp.				X																																		
Quenstedtia sp.																																						
Pleuromya subcompressa (Meek)			X	X		X			X	X	X	X	X	X		X	X	X	X	X	X			X		X		X	X									X
Pholadomya kingi Meek			X																		X							X										
inaequiplicata Stanton																																	X					
Homomya cf. *H. gallatinensis* Stanton									X																													
Goniomya montanaensis Meek														X		X																						
Thracia weedi Stanton														X																								
Teinostomopsis? sp.																																					X	
Lyosoma powelli White																																					X	
Rhabdocolpus sp.																																				X		X
Pseudomelania? sp.																																					X	
Naticiform gastropods									X																													
Cossmannea sp.																																						
Ceritella sp.																																						
Cylindrobullina? sp.																																				X	X	X
Gastropods undet.									X								X												X					X				
Spiroceras cf. *S. orbignyi* Baugier and Sauze		X								X																												
Stephanoceras cf. *S. skidegatensis* (Whiteaves)																																						
aff. *S. nodosum* (Quenstedt)																		X																				
Stemmatoceras arcicostum Imlay, n. sp.																					X																	
n. sp. aff. *S. albertense* McLearn			X				X		X									X		X	X	X			X													
sp.										X															X		X											
Normannites? cf. *N. crickmayi* (McLearn)							X	X													X																	
Megasphaeroceras cf. *M. rotundum* Imlay			X				X											X		X	X			X														
aff. *M. rotundum* Imlay								X																														
sp. undet.													X																									
?sp.										X																												
Eocephalites primus Imlay, n. sp.			X	X	X	X			X			X						X		X	X			X	X													
sp.																																						X
?sp. undet. A																								X														
?sp. undet. B	X																	X		X				X														
?sp. undet. C																				X																		
?sp.							X									X			X			X			X													
Eutrephoceras sp. undet.															X																							

of soft red siltstone and claystone that resemble red beds in the Gypsum Spring Member and have not been found elsewhere in the Sliderock Member. Interbedded with these red units, however, are many units of gray claystone, shaly to nodular limestone, and medium- to thin-bedded sandstone that can be matched readily in the lower part of the Sliderock Member in southeastern Idaho and in north-central Utah and are unknown in the Gypsum Spring Member. The lithologic evidence, therefore, favors assigning the entire sequence, as described, to the Sliderock Member. It is possible, of course, that the base of that member becomes older toward the west and that most of the sequence below the highest ridge-forming limestone on Birch Creek was never deposited farther east in western Wyoming, or in the western part of the Uinta Mountains.

The following section is of interest because it is the most western in Idaho, is exceptionally well exposed, and contains units of soft fissile claystone as does the section on Birch Creek, Utah.

Sliderock Member on north side of Willow Creek in NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho

[Fig. 1, loc. 4]

	Feet
8. Limestone, thin- to medium-bedded, nodular, medium-gray; interbedded with calcareous silty claystone; contains *Gryphaea planocovexa fraterna* Imlay and the ammonites *Stemmatoceras* and *Megasphaeroceras* (Mesozoic locs. 28501 and 28635). Contact with overlying Rich Member covered by soil in gully	30+
7. Claystone, papery, soft, gray to yellowish-gray (Mesozoic loc. 28502); bentonitic at base	4
6. Sandstone, thin-bedded, quartzitic, yellowish-gray, crossbedded, ripple-marked; weathers yellowish gray	14
5. Claystone, silty, soft, gray, fissile; interbedded with thin beds of nodular limestone (½–3 in. thick); grades upward into quartzitic sandstone; Gryphaeas occur near base; one thin bed of limestone 13 ft. above base contains small gastropods and pebbles (Mesozoic loc. 28500)	28
4. Limestone, shaly, soft, medium-gray, nodular; contains *Gryphaea* (Mesozoic locs. 28506, 28636)	7
3. Claystone, soft, medium-gray, fissile (Mesozoic loc. 28505)	6½
2. Limestone, medium-brownish-gray; soft and shaly at base; becomes moderately hard and massive toward top; weathers yellow; contains many fossil fragments	50
1. Limestone, medium-gray; forms ledge; weathers yellow; contains *Camptonectes*, *Ostrea*, and *Pleuromya*. Overlies a covered interval 40 ft thick marked by a ravine and interpreted as the top of the Gypsum Spring Member	1
Total thickness	140?

FOSSILS, AGE, AND CORRELATIONS

The Sliderock Member is fairly fossiliferous and becomes more fossiliferous upward. Cepahalopods have been found only in the upper half. Pelecypods and cephalopods are much more common than gastropods. Worm tubes, echinoid spines, and crinoid columnals are fairly common but generally have not been collected. All the megafossils are given by localities in table 3. In addition some megafossils that are probably in part from the Sliderock Member are given in table 4.

The known stratigraphic ranges of the pelecypods within the Twin Creek Limestone and contemporary formations in the western interior are shown in figure 9; the stratigraphic ranges of the ammonites are shown in figure 11. These figures show that ammonites in the Sliderock Member belong to different genera than those in the overlying Rich Member except possibly for some fragments assigned questionably to *Stephanoceras*. In contrast all the pelecypod species that occur in the Sliderock Member range higher. In practice, the pelecypod *Gryhaea planoconvexa fraterna* Imlay, n. subsp., is a useful marker for the Sliderock Member, although it occurs rarely in the lower part of the Rich Member. It has not been found outside of the area of distribution of the Twin Creek Limestone.

Other pelecypods of stratigraphic value include *Astarte* (*Coelastarte*) *livingstonensis* Imlay, *Prorokia fontenellensis* Imlay, n. sp., *Goniomya montanaensis* Meek, and *Thracia weedi* Stanton. Of these, the first species ranges from the Sliderock to the Boundary Ridge Member, inclusive. The other three species have been found only in the Sliderock and Rich Members. Elsewhere in the western interior these four species have been found only in formations or members of Bajocian, or probable Bajocian, age, including the lower limestone member of the Carmel Formation in southern Utah, the limestone member of the Gypsum Spring Formation in Wyoming, the middle limestone member of the Piper Formation in Montana, and the lower part of the Sawtooth Formation in southwestern Montana (fig. 9).

The age of the middle and upper parts of the Sliderock Member of the Twin Creek Limestone is late Bajocian as shown by the presence of the ammonites *Megasphaeroceras* and *Spiroceras* in association with *Stephanoceras*, *Stemmatoceras*, and questionable *Normannites*. Of these, *Megasphaeroceras* has been recorded previously only in southern Alaska (fig. 12) in beds of late Bajocian age (Imlay, 1962b, p. A1–A3, A9–A11). In Eurasia, *Spiroceras* ranges from upper Bajocian to lower Bathonian (Arkell and others, 1957, p. L 206); *Stemmatoceras* occurs only in the middle Bajocian zones of *Otoites sauzei* and *Stephanoceras humphriesianum* (Arkell and others, 1957, p. L 289); *Stephanoceras* ranges

TABLE 4.—*Geographic distribution of marine Jurassic megafossils in the lower part of the Twin Creek Limestone and probably mostly from the Sliderock and Rich Members*

[Gastropod identifications are by N. F. Sohl. All one- and two-digit numbers refer to localities shown in figs. 16 and 17. Higher numbers are USGS Mesozoic locality members identifying individual collections]

	Idaho					Wyoming						Utah									
	5	8	15	18		35	39	40	60	16	66	67	81	85	86		87			95	
	8621	8623	9096	7430	7438	9101	16058	12019	3800	3822	3392	6373	3221	17982	17983	17984	17976	17977	17978	3548	22657
Coral undet									X												
Worm tubes				X					X								X				
Crinoid columnals										X			X				X		X		X
Starfish arm																		X			
Grammatodon haguei (Meek)								X										X		X	
Gervillia? *montanaensis* Meek																		X			
Mytilus cf. *M. whitei* Whitfield											X										
Pinna kingi Meek																		X			
Camptonectes platessiformis White												X			X	X		X			
sp.		X		X	X	X					X										
Lima (*Plagiostoma*) *occidentalis* Hall and Whitfield					X				X					X							
Ctenostreon cf. *C. gikshanensis* McLearn				X																	
Ostrea (*Liostrea*) *strigilecula* White		X	X									X					X	X		X	X
Gryphaea sp.	X																				
Trigonia americana Meek											X										
elegantissima Meek										X											
Vaugonia conradi (Meek and Hayden)											X										
Myophorella (*Promyophorella*) *montanaensis* (Meek)																					
(*Haidaia*) *yellowstonensis* Imlay										X											
Astarte meeki Stanton																		X			
Pronoella uintahensis Imlay											X		X								
cf. *P.*? *iddingsi* (Stanton)							X														
Mactromya? sp.																		X			
Tancredia? sp.																					
Corbicella? sp.										X											
Quenstedtia sublevis (Meek and Hayden)										X											
Pleuromya subcompressa (Meek)						X				X								X			
Pholadomya inaequiplicata Stanton										X								X			
Goniomya montanaensis Meek																		X			
Lyosoma powelli white																X					
Naticiform gastropods											X										
Cossmannea sp.											X										
Gastropods undet																		X			X

from the middle Bajocian (upper part of *Sonninia sowerbyi* zone) into the lower part of the upper Bajocian (*Strenoceras subfurcatum* zone) (Arkell, 1956, p. 232, 264, 300; 1952, English Bathonian Ammonites, p. 74); and *Normannites* ranges from the middle Bajocian (upper part of *Otoites sauzei* zone) into the lower part of the upper Bajocian (Westermann, 1954, p. 124; Arkell, 1956, p. 176, 232, 300).

These ranges indicate that the Sliderock Member correlates with the lower part of the upper Bajocian Stage and probably with the zone of *Strenoceras subfurcatum*. In fact, the presence of *Stemmatoceras* indicates a position near the boundary of the middle and upper Bajocian. As no ammonites were obtained from the lower part of the Sliderock Member, that part could be as old as middle Bajocian.

A late Bajocian age for most of the Sliderock Member is indicated also by the presence of *Megasphaeroceras*, which in Alaska is associated with the typical late Bajocian genus *Leptosphinctes*. It is indicated by the absence of *Chondroceras* which is common in beds of middle Bajocian age but has not been reported in beds of late Bajocian age. A late Bajocian age is favored by the presence of *Eocephalites*, n. gen., that greatly resembles *Paracephalites* from beds of probable Bathonian age in Canada (Frebold, 1963, p. 8–13, pls. 1, 2, 4) and northwestern Montana (Imlay, 1962a, pls. 3–5) and likewise resembles *Cranocephalites* from beds of Bathonian to possible late Bajocian age in Greenland (Spath, 1932, p. 14–31; Callomon, 1959, p. 507–511) and in the Canadian Arctic (Frebold, 1958, p. 8, 9; 1961, p. 12–15). These resemblances plus the absence of any closely similar genera in beds of middle Bajocian age in Alaska, or elsewhere, suggest an age at least as young as late Bajocian for the Sliderock Member.

The Sliderock Member is traceable as a lithologic unit into the "Lower Sundance" Formation exposed along the north side of Lower Slide Lake, Teton County, Wyo. At this place it is represented by 5 feet of soft shaly limestone and claystone and by the overlying 16 feet of oolitic medium- to thin-bedded limestone (units 7–9 of Imlay, 1956a, p. 70). The member is overlain by 85 feet of soft shaly limestone typical lithologically and faunally of the Rich Member, and is underlain by about 45 feet of red siltstone, yellow to pink limestone, and brecciated limestone typical of the Gypsum Spring Member of the Twin Creek Limestone.

	Southeastern Idaho, north-central Utah, and western Wyoming		Central Utah		North-central Wyoming			South-central Montana			Southwestern Montana			Northwestern and west-central Montana		
			West side of San Rafael Swell		Bighorn Basin			Gallatin Range and north side of Pryor and Beartooth Mountains			Madison, Tobacco Root, Gravelly and Centennial Ranges and Tendoy Mountains			Drummond area and Swift Reservoir		
	Twin Creek Limestone (Lower part)		Carmel Formation		Gypsum Spring Formation			Piper Formation			Sawtooth Formation			Sawtooth Formation		
	Sliderock Member	Rich Member	Lower limestone member	Upper gypsiferous shaly silt member	Lower red-bed member	Middle limestone member	Upper red-bed member	Lower red-bed member	Middle limestone member	Upper red-bed member	Sandstone member (generally absent)	Middle limestone and shale member	Upper siltstone member	Sandstone member (absent at Drummond)	Middle shale member	Upper silty to sandy member
Spiroceras cf. *S. orbignyi* Baugier and Sauze	—															
Stephanoceras cf. *S. skidegatensis* (Whiteaves)	—															
Stephanoceras aff. *S. nodosum* (Quenstedt)	—															
Stephanoceras ? sp.		—														
Stemmatoceras arcicostum Imlay, n. sp.	—														—	
Stemmatoceras cf. *S. arcicostum* Imlay, n. sp															—	
Stemmatoceras n. sp. aff. *S. albertense* McLearn	—														?	
Stemmatoceras cf. *S. palliseri* McLearn															—	
Stemmatoceras sp.	—															
Sohlites spinosus Imlay, n. sp.		—	—			—			—			—				
Normannites? cf. *N. crickmayi* (McLearn)	—	—													—	
Chondroceras cf. *C. allani* (McLearn)															—	
Parachondroceras andrewsi Imlay, n. sp.		—							—							
Parachondroceras cf. *P. andrewsi* Imlay, n. sp.												—				
Parachondroceras filicostatum Imlay, n. sp.		—							—			—				
Parachondroceras cf. *P. filicostatum* Imlay, n. sp.		—							—							
Megasphaeroceras cf. *M. rotundum* Imlay	—															
Megasphaeroceras aff. *M. rotundum* Imlay	—															
Megasphaeroceras sp. undet.	—															
Megasphaeroceras ? sp.	—															
Eocephalites primus Imlay, n. sp.	—															
Eocephalites sp.	—															
Eocephalites ? sp. undet. A	—															
Eocephalites ? sp. undet. B	—															
Eocephalites ? sp. undet. C	—															
Eocephalites ? sp.	—															

FIGURE 11.—Stratigraphic distribution of Bajocian ammonites in the western interior of the United States. A question mark (?) indicates that the identification is uncertain. Black bars show stratigraphic ranges of species within the formations and members.

	European stages	Standard zones in northwest Europe (Arkell, 1956; Callomon, 1955)	Suggested guide fossils in the western interior of the United States (Imlay, 1953b, 1962a)		Characteristic fossils in the western interior of Canada (Frebold, 1963, 1964)	Suggested guide fossils in southern Alaska (Imlay, 1964b)
Early Late Jurassic	Callovian	*Quenstedtoceras lamberti*				
		Peltoceras athleta				
		Erymnoceras coronatum				*Pseudocadoceras grewingki*
		Kosmoceras jason			*Imlayoceras miettense*	
		Sigaloceras calloviense	*Kepplerites mclearni* *Kepplerites* aff. *K. tychonis* *Gowericeras subitum* *Gowericeras costidensum*	*Gryphaea nebrascensis*	*Kepplerites mclearni* *Kepplerites* aff. *K. tychonis* Not identified *Warrenoceras henryi*	*Xenocephalites vicarius*
		Macrocephalites macrocephalus	*Warrenoceras codyense* ?	*Gryphaea impressimarginata*		
Middle Jurassic	Bathonian	*Clydoniceras discus*	*Paracephalites sawtoothensis*		*Paracephalites glabrescens*	?
		Oppelia aspidoides	?		?	*Cranocephalites pompeckji*
		Tulites subcontractus	Not identified		Not identified	
		Gracilisphinctes progracilis				?
		Zigzagiceras zigzag	?			
	Bajocian	*Parkinsonia parkinsoni*	*Sohlites spinosus* and *Parachondroceras andrewsi*	*Gryphaea planoconvexa*		
		Garantiana garantiana				
		Strenoceras subfurcatum	*Megasphaeroceras* cf. *M. rotundum* and *Gryphaea planoconvexa fraterna*			*Megasphaeroceras rotundum*
		Stephanoceras humphriesianum	*Chondroceras* and *Stemmatoceras*		*Teloceras, Stemmatoceras, Stephanoceras* and *Chondroceras*	*Teloceras itinsae*
		Otoites sauzei	Not identified		Not identified	*Skirroceras kirschneri* *Parabigotites crassicostatus*
		Sonninia sowerbyi				*Sonninia* sp. ?
		Ludwigia murchisoni				*Tmetoceras regleyi*
		Tmetoceras scissum				?
		Leioceras opalinum				

FIGURE 12.—Correlation of some Middle and early Late Jurassic faunas in North America.

Near Green River Lakes in the Wind River Mountains, Wyo., the Sliderock Member is possibly represented (Imlay, 1953a, fig. 1) by 14 feet of dense medium-bedded limestone overlying 75 feet of red beds and gypsum that Richmond (1945) assigned to the Gypsum Spring Formation. Above the limestone are 33 feet of gray calcareous shale that resembles the Rich Member and above follows a red unit that probably correlates with the Boundary Ridge Member of the Twin Creek Limestone.

Farther east in the Wind River Basin neither the Sliderock Member or the Rich Member are recognizable as lithologic units. Limestone occurring in the middle or upper parts of the Gypsum Spring Formation (Love and others, 1945) of the Wind River Basin could be equivalent to either the Sliderock Member, or the Rich Member, or both. Likewise neither member is recognizable lithologically in the Gypsum Spring Formation in the Bighorn Basin of northern Wyoming or in the Piper Formation in southern Montana. In both areas, however, limestone members within these formations contain mollusks that in the Twin Creek Limestone are either restricted to the Rich Member or have never been found below the Rich Member. These facts, which are discussed in detail in the description of the Rich Member (p. 33, 34), suggest that limestone deposition during the time represented by the Sliderock Member did not extend very far east or north of the area in which the Twin Creek Limestone occurs.

Beds equivalent to the Sliderock Member of the Twin Creek Limestone probably exist in both central and southwestern Utah. In central Utah the the lowermost limestone unit of the Arapien Shale exposed on the south side of Red Canyon about 2 miles northeast of Nephi consists of 50–80 feet of oolitic sandy medium- to thick-bedded limestone that greatly resembles the Sliderock Member. This limestone is overlain by at least 100 feet of light-olive-gray shaly limestone that resembles the Rich Member (Imlay, 1964a, p. C6). It is underlain locally by 1–10 feet of soft red siltstone, but in most places is underlain directly by the Nugget Sandstone.

In southwestern Utah near Gunlock and along the south side of the Pine Valley Mountains (Cook, 1957, p. 34, 41–44; Wright and Dickey, 1963a, p. E63–E67, fig. 197; 1963b), the Carmel Formation consists of a basal red-bed unit overlain by 300 feet or more of limestone and shale. From the limestone beds near the top (Mesozoic loc. 27466) and near the bottom (Mesozoic loc. 28493) has been obtained the pelecypod *Thracia weedi* Stanton which is characteristic of the Sliderock and Rich Members of the Twin Creek Limestone and has not been found higher. The limestone and shale beds are not divisible lithologically into two members comparable to the Sliderock and Rich Members and have not furnished any fossils that are restricted to just one of those members.

ORIGIN

The Sliderock Member of the Twin Creek Limestone was deposited in shallow marine waters of normal salinity as shown by the presence of oolites and *Ostrea* in the basal beds, by the presence of *Ostrea* and *Gryphaea* throughout the remainder of the formation, by the dark-gray to black color of the limestone, and by a fair abundance of bottom-dwelling as well as free-swimming and free-floating organisms. Deepening of the sea bottom during deposition is shown by an upward increase in the number and variety of organisms and particularly by the appearance of cephalopods. The presence of nerineid gastropods and a coral (Mesozoic loc. 3800) suggests that the waters were warm. A western source for the clastic sediments is shown by a westward increase in the amount of sandy, silty, and clayey material and by the occurrence of small pebbles in the member in Idaho but not in Wyoming.

RICH MEMBER

DEFINITION

The Rich Member of the Twin Creek Limestone consists mostly of medium-gray shaly limestone that is very soft basally but becomes harder upward, contains some thin beds of limestone near its top, ranges in thickness from a few feet to about 500 feet, and grades fairly abruptly into the adjoining members. Its base is generally marked topographically by a shallow depression where it overlies the harder thicker bedded limestone of the Sliderock Member. The top of the Rich Member is generally marked by a change upward from silty yellowish-gray shaly limestone to red siltstone, or to finely sandy thin- to thick-bedded yellowish-gray limestone, or to yellowish-gray sandy siltstone. It weathers characteristically into long slender pencillike splinters. The Rich Member has previously been called member C by Imlay (1950a, p. 39, 1953a, p. 55).

The type section (fig. 1, loc. 33), is designated as the north side of Birch Creek about 8 miles west of Woodruff, Rich County, Utah, near the line of secs. 18 and 19, T. 9 N., R. 6 E. The base of the section starts about half a mile west of the confluence of Birch Creek and Watton Canyon on the west side of the westernmost of the three small anticlines that are developed in the Twin Creek Limestone west of the middle of sec. 20. At this locality the Rich Member consists of about 425 feet of light-yellowish-gray shaly limestone that weathers a little darker and is fairly soft in its lower 75 feet but becomes harder and ledge-forming upward. The lower beds weather into chunky fragments. The upper beds weather into long, slender fragments. The basal shaly limestone beds pass downward rather abruptly into much harder limestone beds at the top of the Sliderock Member. The uppermost shaly limestone beds of the Rich Member are overlain gradationally by 5 feet of sandy thin-bedded to shaly limestone at the base of the Boundary Ridge Member.

DISTRIBUTION AND THICKNESS

The Rich Member crops out in the same areas as the Sliderock Member except in the Unita Mountains where it is recognizable lithologically as far east as Whiterocks Canyon (Imlay, 1953a, p. 55, fig. 3).

The Rich Member thickens westward from less than 100 feet in its easternmost exposures in western Wyoming to about 380 feet at Willow Creek near Idaho Falls, Idaho (table 2). In northern Utah the member thickens westward from about 40 feet on the Whiterocks River, where it is included in the basal part of the Carmel Formation, to about 390 feet near Burr Fork and to more than 500 feet near Devils Slide in the Wasatch Range. Southward in that range it thins to about 180 feet near Thistle. This westward thickening is not uniform. Locally there is considerable variation in thickness which could be depositional, or could be a consequence of strong deformation. This last possibility is suggested because of the softness of the member, its position between more competent limestone members, and the pronounced folding and thrusting that exists throughout most of its area of outcrop.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Rich Member changes very little lithologically throughout its area of outcrop (figs. 2–8). Most sections show a marked resemblance to the type section as previously described. Toward the east as the member thins it becomes slightly more clayey and fairly fossiliferous. Toward the west as the member thickens it becomes more calcareous and poorly fossiliferous. Near the middle of the member in Idaho at Stump Creek, Willow Creek, and Red Mountain is a unit of limestone that contains the pelecypod *Gryphaea planoconvexa* Whitfield. At Fall Creek, Idaho, a unit of medium-bedded limestone 32 feet thick occurs above the middle of the member. Near the top of the member in most sections are thin beds of limestone, from 1 to 6 inches thick, that may be dense, granular, oolitic, or silty, or composed of a mass of crinoid columnals. These thin beds in Wyoming locally weather as low ledges.

The contact between the Rich and Sliderock Members is easy to select because of marked differences in the hardness and competency of the members. The contact between the Rich Member and the overlying Boundary Ridge Member is more difficult to select and generally has been chosen at the base of the lowest medium-bedded silty to sandy or oolitic yellowish- to brownish-gray limestone. In some places in the northern part of Jackson Hole, Wyo., the shaly limestone typical of the Rich Member is overlain directly by red siltstone or greenish-gray claystone.

FOSSILS, AGE, AND CORRELATIONS

The Rich Member is fairly fossiliferous in Wyoming and in the Uinta Mountains, Utah (figs. 9, 11, and table 5), where the member is thinnest and most clayey. Elsewhere the member has furnished few fossils. Compared with the Sliderock Member, it is much less fossiliferous but has furnished a greater variety of pelecypods and a much smaller variety of gastropods and cephalopods. The gastropods are sparse, poorly preserved, and undeterminable. The cephalopods are uncommon and belong to different genera than occur in the Sliderock Member except possibly for one specimen assigned questionably to *Stephanoceras*. The pelecypods include the same species as occur in the Sliderock Member and, in addition, include some species that have been found only in the Rich Member or that begin in the Rich Member and range higher.

Pelecypods that have been found only in the Rich Member include *Gervillia? montanaensis* Meek, *Gryphea planoconvexa* Whitfield, *Myophorella* (*Haidaia*) *yellowstonensis* Imlay (fig. 9). Pelecypods that have been found only in the Sliderock and Rich Members include *Gryphaea planoconvexa fraterna* Imlay, n. subsp., *Prorokia fontenellensis* Imlay, n. sp., *Goniomya montanaensis* Meek, and *Thracia weedi* Stanton. Pelecypods that begin in the Rich Member and range higher include *Isognomon* cf. *I. perplana* (Whitfield), *Trigonia elegantissima* Meek, *Vaugonia conradi* (Meek and Hayden), *Myophorella* (*Promyophorella*) *montanaensis* (Meek), *Quenstedtia sublevis* (Meek and Hayden), and *Cercomya punctata* (Stanton). There are 13 species listed above that may be useful in correlating the Rich Member with equivalent beds elsewhere in the western interior region.

The age of the Rich Member is not as well established as that of the Sliderock Member. It is probably late Bajocian inasmuch as it grades downward into the Sliderock Member which has furnished substantial faunal evidence of an early late Bajocian age. Furthermore, it grades upward into the Boundary Ridge Member which is probably of Bathonian age, as indicated by regional correlations with the upper siltstone member of the Sawtooth Formation in northwestern Montana (Cobban, 1945, p. 1270–77; Imlay and others, 1948; Imlay, 1962a, p. C5–C14; Frebold, 1963, p. 28, 29).

The ammonites in the Rich Member (fig. 11), although belonging mostly to new genera, also favor a late Bajocian age assignment. Thus *Sohlites*, n. gen., resembles *Zemistephanus* McLearn from beds of late middle Bajocian age in British Columbia (McLearn, 1927, p. 72; 1929a, p. 18) and Alaska (Imlay, 1964b, p. B51–B53). It shows some resemblance, also, to *Ermoceras* Arkell (1952, p. 272) from beds of late Bajocian age in Arabia. *Parachondroceras*, n. gen., resembles the middle Bajocian genera *Chondroceras Mascke* (Westermann, 1956, pls. 1–12) and *Labyrinthoceras* Buckman (1919, pl. 134) more than any described ammonites of Bathonian age. These ammonites, therefore, along with the fragments assigned questionably to *Stephanoceras* (USGS Mesozoic loc. 22459) suggest an age older than Bathonian.

The Rich Member is traceable as a lithologic unit into the lower part of the "Lower Sundance" Formation at Lower Slide Lake, Teton County, Wyo. At this place it is represented by 85 feet of shaly limestone (units 10–12 of the section published by Imlay, 1956a, p. 70) that contains ammonites and pelecypods (fig. 9) character-

TABLE 5.—*Geographic distribution of marine Jurassic megafossils in the Rich Member of the Twin Creek Limestone*

[Gastropod identifications are by N. F. Sohl. All one- and two-digit numbers refer to localities shown in figs. 16 and 17. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Idaho						Wyoming																		Utah										
	2	3	12			13	42		50		51	52	53	61		62						65		66	68		70	75	79	89	90			91	92
	28585	28507	22459	22460	28796	28797	17297	20980	20963	28639	22796	3815	21629	28789	28790	3821	17815	28785	28786	28787	28788	20965	20987	20350	6363	8181	6362	28478	985	21620	17048	20349	28793	28792	21468
Echinoid fragments																	×																		
Crinoid columnals							×			×		×	×			×	×		×		×		×						×						
Grammatodon haguei (Meek)									×									×			×	×	×							×					
Barbatia? sp									×																										
Idonearca haguei (Stanton)																																		×	
Modiolus subimbricatus (Meek)							×			×																									
(*Musculus*) sp																					×														
Gervillia? *montanaensis* Meek								×																											
Isognomon cf. *I. perplana* (Whitfield)										×			×		×																				
Pinna kingi Meek							×		×									×			×	×											×		
Camptonectes platessiformis White							×						×																						×
stygius White																×																			
sp																	×				×			×						×			×	×	
Plicatula sp																		×	×		×									×					
Lima (*Plagiostoma*) sp	×							×																											
Ostrea (*Liostrea*) *strigilecula* White								×					×			×		×							×		×			×					
Gryphaea planoconvexa Whitfield	×	×			×																														
cf. *G. planoconvexa* Whitfield							×																												
Gryphaea planoconvexa fraterna Imlay, n. subsp				×		×																													
Trigonia americana Meek																		×			×									×			×		
elegantissima Meek									×	×								×			×	×													×
Vaugonia conradi (Meek and Hayden)							×				×					×																×	×		
Myophorella (*Promyophorella*) *montanaensis* (Meek)									×								×							×										×	
(*Haidaia*) *yellowstonensis* Imlay									×								×																		
Astarte meeki Stanton		×							×			×	×					×				×								×			×		
(*Coelastarte*) *livingstonensis* Imlay							×		×														×												
Prorokia fontenellensis Imlay, n. sp							×								×						×														
Pronoella cinnabarensis (Stanton)															×																				
sp		×					×	×	×		×				×			×		×	×														
Lucina? sp																		×			×														
Mactromya? sp														×																			×		
Tancredia? sp														×																					×
Quenstedtia sublevis (Meek and Hayden)							×													×															
cf. *Q. sublevis* (Meek and Hayden)												×																							
sp									×																				×						
Protocardia cf. *P. schucherti* McLearn		×							×																										
Pleuromya subcompressa (Meek)							×		×	×			×					×			×	×			×		×		×	×			×	×	×
Corbula cf. *C. munda* McLearn									×				×						×	×	×														
Pholadomya kingi Meek																		×																	
cf. *P. kingi* Meek																														×					
Goniomya montanaensis Meek									×									×																	
Cercomya punctata (Stanton)									×			×									×														
Thracia weedi Stanton							×		×				×					×			×												×		×
Rhabdocolpus? sp													×																						
Lyosoma powelli White	×																																		
Naticiform gastropods																												×							
Gastropods undet	×																													×					
Stephanoceras? sp			×																																
Sohlites spinosus Imlay, n. sp																															×				
Parachondroceras andrewsi Imlay, n. sp													×													×									
filicostatum Imlay, n. sp									×																										
cf. *P. filicostatum* Imlay, n. sp																																			×

istic of the member. The Rich Member also may extend as far east as Green River Lakes (Imlay, 1953a, fig. 1) and as far south as Nephi, Utah, (Imlay, 1964a, p. C6) as discussed with correlations of the Sliderock Member. (p. 29, 30).

The Rich Member correlates closely with the lower 40–65 feet of the limy lower unit of the Carmel Formation exposed along the west side of the San Rafael Swell in central Utah (fig. 10). This correlation is shown by the presence in the Carmel Formation of species that in the Twin Creek Limestone are restricted to the Rich Member or that have not been found below that member. These species include in particular *Sohlites spinosus* Imlay, n. sp., (USGS Mesozoic loc. 12555) and *Trigonia elegantissima* Meek (USGS Mesozoic loc. 12555) from 6 to 12 feet above the base of the Carmel Formation, *Myophorella* (*Haidaia*) *yellowstonensis* Imlay (USGS Mesozoic loc. 13531) from 17 feet above the base, and *Goniomya montanaensis* Meek (USGS Mesozoic loc. 20351) from 25 feet above the base. With these are associated such species as *Gervillia* cf. *G. montanaensis* Meek, *Vaugonia conradi* (Meek and Hayden), and *Myophorella* (*Promyophorella*) *montanaensis* (Meek) which range throughout most or all of the limy lower unit of the Carmel Formation. Clearly the Carmel Formation along the west side of the San Rafael Swell does not include any beds as old as the Sliderock Member of the Twin Creek. On the basis of these fossils the Rich Member may be correlated approximately with units 50–66 of the section at the south end of Cedar Mountain (Gilluly and Reeside, 1928, p. 98, 99) and units 100–108 on Muddy River (Gilluly and Reeside, 1928, p. 85–87).

Similarly the Rich Member is correlated with the basal part of the Carmel Formation in some areas in southern Utah. At Teasdale, *Vaugonia conradi* (Meek and Hayden) (USGS Mesozoic loc. 25669), which has not been found below the Rich Member, was collected about 44 feet above the base of the Carmel Formation in an interbedded limestone-claystone member about 85 feet thick. In Antimony Canyon, *Gervillia montanaensis* Meek (USGS Mesozoic loc. 26308), which is characteristic of the Rich Member, was collected 20–30 feet above the base of the Carmel Formation in a limestone member about 110 feet thick. Near Hells Backbone bridge, northwest of Boulder, the lower 15–20 feet of the Carmel Formation has furnished *Vaugonia conradi* (Meek and Hayden) and *Cossmannea* n. sp. (USGS Mesozoic loc. 28492; identified by N. F. Sohl). At Deep Creek north of Escalante the lower 12–20 feet of the Carmel Formation has furnished many fossils (USGS Mesozoic locs, 25671 and 26307) including the coral *Actinastrea hyatti* (Wells), the nerineid gastropod *Cossmannea* n. sp., and the pelecypods *Thracia weedi* Stanton, *Cercomya punctata* Stanton, and *Vaugonia conradi* (Meek and Hayden). Of these fossils, the coral is characteristic of the Middle Jurassic, although ranging higher, the gastropod has been found elsewhere only in the Sliderock Member of the Twin Creek Limestone, and the pelecypods in association are characteristic of the Rich Member, as discussed on page 31.

In southwest Utah between Mount Carmel in Kane County, and Shurtz Creek in Iron County, the middle and upper parts of the limy lower unit of the Carmel Formation may likewise be correlated with the Rich Member by means of the association of such species as *Thracia weedi* Stanton, *Trigonia elegantissima* Meek, and *Vaugonia conradi* (Meek Hayden) (Imlay, 1964a, p. C 3, 4). The lowest 50–100 feet of the limy part of the Carmel Formation, however, is poorly fossiliferous and could be equivalent to the Sliderock Member. Still farther west along the south side of the Pine Valley Mountains the limy lower unit of the Carmel Formation could include beds older than the Rich Member as discussed previously under correlations of the Sliderock Member.

The Rich Member correlates faunally with the limestone and shale in the lower part of the Sawtooth Formation in southwestern Montana, with the limestone member of the Piper Formation in southern Montana (Imlay, 1954, p. 58; 1956b, p. 576, 577), and with at least the middle and upper parts of the Middle Jurassic limestone exposed near Cody on the west side of the Bighorn Basin (Imlay, 1956b, p. 581–585). The Gypsum Spring Formation along the east side of the Bighorn Basin has furnished only a few long-ranging pelecypod species that do not permit close age determinations (Imlay, 1956b, p. 580, 581). The Gypsum Spring Formation in the Wind River Basin has furnished few fossils except near the top of the formation at one locality on Mill Creek (Love and others, 1945) west of Lander. The species present at this place (USGS Mesozoic loc. 19357) are mostly undescribed, however, and at present are not useful for correlation with any member of the Twin Creek Limestone.

Most of the Middle Jurassic limestone exposed near Cody, Wyo., is correlated with the Rich Member of the Twin Creek Limestone on the basis of the ammonite *Sohlites* (table 6), formerly called *Teloceras* (*Zemistephanus*) (Imlay, 1956b, p. 583), such pelecypods as *Trigonia elegantissima* Meek, *Vaugonia conradi* (Meek and Hayden) and *Isognomon perplana* (Whitfield), and the coral *Actinastrea hyatti* (Wells) (1942). Of these, *Sohlites* and the coral were found about 6 miles south of Cody (USGS Mesozoic loc. 17105) near the top of the lower third of the limestone (Imlay, 1956b, p. 567–583). *Vaugonia conradi* (Meek and Hayden) was found in the gorge 2 miles west of Cody in the lower 5 feet (USGS Mesozoic loc. 17093) as well as in the uppermost 2½ feet (USGS Mesozoic loc. 20361) of the limestone. *Trigonia elegantissima* Meek, *Isognomon perplana* (Whitfield), and the coral were found in the gorge near the middle of the limestone sequence (USGS Mesozoic locs. 20336, 20375). Of these fossils, *Sohlites* is characteristic of the Rich Member (fig. 11), the pelecypods have not been found below the Rich Member (fig. 9), and the coral is widespread in the western interior in beds of Bajocian age (Imlay, 1956b, p. 577, 578; 1964a, p. C4), although occurring also in the Wolverine Canyon Limestone Member of the Preuss Sandstone in Idaho (Imlay, 1952a, p. 1740–1742).

The middle limestone member of the Piper Formation in southern Montana (Imlay, 1956b, p. 576, 578) and the Sawtooth Formation in southwestern Montana contain many fossils that permit close correlation with the Rich Member and do not contain any fossils that indicate a correlation with the Sliderock Member. Significant fossils include the ammonites *Sohlites* and *Parachondroceras* (table 6 and fig. 11), described herein

TABLE 6.—*Geographic distribution of marine Bajocian ammonites in Montana and northwestern Wyoming north of area of Twin Creek Limestone*

[All two-digit numbers refer to localities shown on fig. 18. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Sawtooth Formation									Piper Formation														Gypsum Spring Formation		"Lower Sundance" Formation			
	Montana																							Wyoming					
	98			99	100		101	102		103	104		105				106		107	108		109		110		111			
	19192	28825	28826	27337	21391	22170	28758	28670	28800	8096	19153	19158	15635	19214	25866	27628	19630	27624	27035	5738	19621	17662	20864	17096	17105	20962	20967	22112	27724
Stemmatoceras arcicostum Imlay, n. sp.				×																									
cf. *S. arcicostum* Imlay, n. sp.		×	×																										
aff. *S. albertense* McLearn				×																									
cf. *S. palliseri* McLearn				×																									
Sohlites spinosus Imlay, n. sp.					×		×							×	×			×	×	×	×			×	×				
Normannites? cf. *N. crickmayi* (McLearn)				×																									
Chondroceras cf. *C. allani* (McLearn)	×																												
Parachondroceras andrewsi Imlay, n. sp.											×			×		×			×			×	×				×		×
cf. *P. andrewsi* Imlay, n. sp.						×		×																					
filicostatum Imlay, n. sp.									×			×	×	×	×	×	×	×					×			×		×	
cf. *P. filicostatum* Imlay, n. sp.																						×							

and the pelecypods *Gryphaea planoconvexa* Whitfield, *Thracia weedi* Stanton, *Prorokia fontenellensis* Imlay, n. sp., and *Goniomya montanaensis* Meek. Associated with these fossils are certain pelecypods that occur also in the Rich Member (fig. 9) but range higher, including *Trigonia elegantissima* Meek, *Vaugonia conradi* (Meek and Hayden), *Myophorella* (*Promyophorella*) *montanaensis* Meek, *Isognomon perplana* Whitfield, and *Coelastarte livingstonensis* Imlay. Inasmuch as these fossils occur in all parts of the limestone member of the Piper Formation as well as farther west in the lower to middle parts of the Sawtooth Formation, there appears to be no normal marine equivalent of the Sliderock Member in southern and southwestern Montana. Equivalent beds, if present, must be represented by red beds in the lower part of the Piper Formation or possibly by unfossiliferous sandstone beds locally in the basal part of the Sawtooth Formation.

Marine equivalents of the Rich Member of the Twin Creek Limestone are present also in north-central Montana in the Bearpaw Mountains and in the subsurface. The evidence from the Bearpaw Mountains consists partly of a fossil collection (USGS Mesozoic loc. 8096) made from several Jurassic formations in the SW¼SW¼ sec. 1, T. 28 N., R. 20 E., about 5 miles southeast of Cleveland. The fossils present include belemnites and the pelecypod *Oxytoma* from the Swift Formation and *Gryphaea nebrascensis* Meek and Hayden from the Rierdon Formation. They also include two external molds of *Sohlites spinosus* Imlay, n. sp., and two specimens of *Gryphaea planoconvexa* Whitfield. These and some other pelecypods are preserved in a dense grayish-black limestone identical with that constituting the lower 70 feet of the Sawtooth (Piper) Formation (Reeves, 1924, p. 93).

Confirmation of the presence of *Gryphaea planoconvexa* Whitfield in the basal limestone of the Jurassic sequence is furnished by a fossil collection made at the same locality by Frank Reeves (1924, p. 93, 94). His collection (USGS Mesozoic loc. 18757) contains one well-preserved specimen of *G. planoconvexa* Whitfield plus *Trigonia americana* Meek, *Pinna kingi* Meek, *Camptonectes platessiformis* White, *Idonearca* cf. *I. haguei* (Stanton), *Isocyprina* cf. *I. cinnabarensis* (Stanton), *Isognomon* cf. *I. perplana* (Whitfield), and *Astarte* (*Coelastarte*) *livingstonensis* Imlay.

The presence of the last two species shows that the basal limestone is not older than the Rich Member of the Twin Creek Limestone. The presence of *Sohlites spinosus* Imlay, n. sp., and *Gryphaea planoconvexa* Whitfield provides definite correlation with the outcropping middle limestone member of the Piper Formation in southern Montana, the lower to middle parts of the Sawtooth Formation in southwestern Montana, and the Rich Member of the Twin Creek Limestone.

The evidence for marine equivalents of the Rich Member in the subsurface of north-central Montana consists mainly of some fossils obtained in cores at the depth of 2,896–2,906 feet in The Texas Co.'s Bowdoin Unit 1 (822) test well in the center of the SW¼SW¼ sec. 8, T. 32 N., R. 32 E., Phillips County, Mont. In this well the top of the middle limestone member of the Sawtooth (Piper) Formation was picked at the depth of 2,845 feet and the bottom at 2,945 feet. The fossils include *Gryphaea planoconvexa* Whitfield, *Gervillia montanaensis* Meek, *Isocyprina* cf. *I. cin-*

nabarensis (Stanton), *I.? iddingsi* (Stanton), and fragmentary specimens of *Astarte*, *Pinna*, and *Camptonectes*. Of these species, the first two are diagnostic of the Rich Member as well as of the outcropping limestone of the Piper Formation.

Another bit of evidence concerning the age and correlation of the subsurface Piper Formation is the presence of the coral *Actinastrea hyatti* (Wells) (1942, p. 1–3) in cores from depth of 5,243–5,248 feet in the Socony Vacuum Rhodes well F–11–6 in sec. 6, T. 33 N., R. 47 E., Daniels County, Mont. This species, originally obtained from an oolitic limestone in the gorge 2 miles west of Cody, Wyo., has been found at several localities in the Middle Jurassic limestone near Cody (Imlay, 1956b, p. 583, 584); in the Gypsum Spring Formation at Sykes Mountain northeast of Lovell in the SW¼ sec. 2, T. 47 N., R. 95 W., Bighorn County, Wyo.; in the middle limestone member of the Piper Formation in the Pryor Mountains (Imlay, 1956b, p. 577, 578), Carbon County, Mont.; in the limy lower unit of the Carmel Formation in southern Utah (Imlay, 1964a, p. C4); in the Wolverine Canyon Limestone Member of the Preuss Sandstone in southeastern Idaho (Imlay, 1952a, p. 1740–42); and as pebbles at the base of the Swift Formation in the Centennial Range, Beaverhead County, Mont. (Imlay, 1952a, p. 1744).

Except for the last two occurrences, the only corals found in the Jurassic of the western interior region have been in beds of Middle Jurassic (Bajocian) age. The presence of corals, therefore, is of some value for correlation purposes. For this reason, all coral occurrences (identifications by J. W. Wells, Feb. 8, 1949, and Sept. 10, 1962) are given below by formation and localities.

Swift Formation (pebbles only):
- *Actinastrea hyatti* (Wells) (USGS Mesozoic loc. 20999)
- *Thamnasteria* sp. (USGS Mesozoic loc. 20999)

Preuss Sandstone (Wolverine Canyon Limestone Member):
- *Actinastrea hyatti* (Wells) (USGS Mesozoic locs. 9748, 16192)
- *Actinastrea* n. sp. (USGS Mesozoic locs. 9748, 13897)
- *Periseris* n. sp. (USGS Mesozoic loc. 9749)

Twin Creek Limestone (probably Sliderock Member) Coral undet. (USGS Mesozoic loc. 3800)

Carmel Formation (limy lower unit):
- *Actinastrea hyatti* (Wells) (USGS Mesozoic locs. 24258, 26307, 26309, 28468, 28473)
- *Thamnasteria* sp. (USGS Mesozoic locs. 28461, 28470)
- *Oppelismilia* sp. (USGS Mesozoic locs. 28461, 28462)

Gypsum Spring Formation or Middle Jurassic limestone:
- *Actinastrea hyatti* (Wells) (USGS Mesozoic locs. 17097, 17103, 17105, 17107, 17096, 17659, 19403, 24669, 27721)

Piper Formation (middle limestone member):
- *Actinastrea hyatti* (Wells) (USGS Mesozoic locs. 13794, 17659, 17662, 17665, 17666, 17667, 24644, 24673, 24675)
- Coral undet. (USGS Mesozoic loc. 25866)

Sawtooth Formation (limestone member):
- *Actinastrea hyatti* (Wells) (USGS Mesozoic loc. 29273).

The Rich Member of the Twin Creek Limestone should be equivalent to part of the middle shale member of the Sawtooth Formation in northwestern Montana (Cobban, 1945, p. 1270–1277; Imlay and others, 1948). The stratigraphic evidence is based partly on correlation of the Rich Member with the middle limestone member of the Piper Formation, as just described, and on the fact that this limestone member in north-central Montana is overlain (Reeves, 1924, p. 93; Imlay and others, 1948; Schmidt and others, 1961, p. 165) by sandstone, siltstone, and silty to sandy limestone that is identical lithologically and stratigraphically with the upper member of the Sawtooth Formation of northwestern Montana. Furthermore, in the Sweetgrass Hills, the middle member of the Sawtooth Formation consists of interbedded black limestone and shale (Cobban, 1945, p. 1274–1275) which is intermediate in character between the limestone member of the Piper Formation and the middle shaly member of the Sawtooth Formation.

The faunal evidence for correlating the Rich Member with part of the medium shale member of the Sawtooth Formation is convincing only in the Sweetgrass Hills. From 27 feet of interbedded dark shale and limestone exposed on East Butte of the Sweetgrass Hills (Cobban, 1945, p. 1274; Imlay and others, 1948) have been obtained the pelecypods (USGS Mesozoic loc. 19190) *Ostrea* sp., *Modiolus subimbricatus* (Meek), *Trigonia americana* Meek, *Myophorella montanaensis* (Meek), *Camptonectes platessiformis* White, *Astarte* (*Coelastarte*) *livingstonensis* Imlay, *Pseudolimea* cf. *P. cinnabarensis* (Stanton), *Gervillia? montanaensis* Meek, *G. dolobrata* Crickmay, *Idonearca haguei* Stanton and *Isocyprina* cf. *I. iddingsi* (Stanton). Of these, *Gervillia? montanaensis* in association with *M. Montanaensis* and *Astarte livingstonensis* is good evidence for correlation with the Rich Member. Furthermore, *Pseudolimea cinnabarensis* (Stanton) and *Gervillia dolobrata* Crickmay are characteristic of the Piper Formation near Livingston and on Cinnabar Mountain in southern Montana and have not been found in higher formations.

The middle shale member of the Sawtooth Formation west of the Sweetgrass Arch has furnished very few fossils (Imlay, 1962a, p. C21). Near the base was obtained the ammonite *Chondroceras* (Imlay, 1948, p. 19, pl. 5, figs. 1–5) which shows that the basal part of the shale member is older than either the Rich or Sliderock Members of the Twin Creek Limestone. Higher beds have furnished belemnite fragments, undetermined gastropods, and a few pelecypods. Of these, *Astarte* *morion* Crickmay (1936, p. 549, 559, pl. 3, fig. 1, 2) may be of some value stratigraphically because the type specimens are from the middle limestone member of the Piper Formation on Cinnabar Mountain, Mont. *Myophorella montanaensis* (Meek), obtained from the lower part of the shale member (USGS Mesozoic loc. 18711), has not been found below the Rich Member of the Twin Creek Limestone.

ORIGIN

The Rich Member was deposited in a shallow sea that deepened westward or southwestward. This deepening is shown by the fact that the pelecypod fauna is fairly abundant and varied in easternmost Idaho and western Wyoming where the member is thinnest and most clayey but rather sparse elsewhere. It is shown, also, by the presence of *Ostrea* and *Gryphaea* mostly in the eastern exposures in Utah and Wyoming and in the northern exposures in Idaho. The abrupt change from fairly fossiliferous medium-bedded limestone at the top of the Sliderock Member to very soft poorly fossiliferous shaly limestone at the base of the Rich Member suggests a sudden deepening of the sea accompanied by rapid deposition of calcareous mud. Shallowing of the sea during deposition is indicated by the presence of some oolitic or coquinoid beds, or units of thin-bedded to medium-bedded limestone in the middle and upper parts of the member. The sea bottom in most places was probably much softer and muddier than during deposition of the Sliderock Member as indicated by an increase in the variety of benthonic pelecypods, by a marked decrease in the numbers of gastropods and of the pelecypod *Gryphaea*, and perhaps by a paucity of ammonites.

BOUNDARY RIDGE MEMBER

DEFINITION

The Boundary Ridge Member of the Twin Creek Limestone consists of interbedded soft red, green, or yellow siltstone, silty to finely sandy limestone, oolitic limestone, and greenish-gray silty claystone. It ranges in thickness from about 30 to 285 feet. It grades downward within 1 to 2 feet into the shaly limestone of the Rich Member and at most places is overlain sharply by the cliff-forming limestone of the Watton Canyon Member. The Boundary Ridge Member has previously been called member D (Imlay, 1950a, p. 39; 1953a, p. 55). It is named after Boundary Ridge which lies east and southeast of the type locality. The type section is designated as the exposures at and immediately north of the railroad cut about 1 mile southwest of Pegram in the NW¼ sec. 12, T. 15 S., R. 45 E., Bear Lake County, Idaho. This section from top to bottom may be described as follows:

Boundary Ridge Member (type section) of Twin Creek Limestone exposed at and immediately north of railroad cut, 1 mile southwest of Pegram, in NW¼ sec. 12, T. 15 S., R. 45 E., Bear Lake County, Idaho

	Feet
Twin Creek Limestone (incomplete):	
Watton Canyon Member (incomplete):	
Limestone, medium- to thin-bedded, even-bedded, dense, medium- to brownish-gray; about 150 ft. exposed.	
Boundary Ridge Member:	
16. Limestone, oolitic, slightly sandy, yellowish-gray; weathers pinkish gray; forms ledge	2
15. Siltstone, sandy, soft, yellowish-gray	6
14. Claystone, soft, medium-gray	18
13. Covered	24
12. Limestone, dense to granular, yellowish-gray, vuggy, partly brecciated; forms cliff	11
11. Siltstone, soft, reddish brown	25
10. Limestone, thin-bedded to shaly, slightly sandy, granular light-yellowish-gray, poorly exposed	36
9. Limestone, thin- to medium-bedded, brownish-gray; weathers light yellowish gray; forms low ridge; makes sharp contact with underlying unit	52
8. Limestone, thick-bedded (beds ½–5 ft thick), oolitic, medium-brownish-gray; weathers yellowish gray; forms prominent ridge; *Camptonectes* common on bedding surfaces	72
7. Siltstone, soft, sandy; yellowish gray at top, becoming greenish gray at bottom; overlain abruptly by massive oolitic limestone along an undulating bedding plane; grades into underlying unit	5
6. Siltstone, soft, sandy, purplish- to reddish-brown; contains some green streaks near base	6
5. Siltstone, thin-bedded to shaly, calcareous, slightly sandy; exhibits some crossbedding; yellowish-gray at top, becoming greenish gray at base; surfaces wavy and crenulated; makes sharp contacts with adjoining units	9
4. Siltstone, soft, yellowish-gray	1
3. Siltstone, soft, brownish-red	5
2. Siltstone, soft, yellowish-gray	3
1. Claystone, thinly laminated, silty, soft, medium-gray, crinkled	10
Total thickness of Boundary Ridge Member	285
Rich Member:	
Limestone, shaly, medium-brownish-gray, chunky; only 7 ft. exposed.	

DISTRIBUTION AND THICKNESS

The Boundary Ridge Member crops out in the same areas as the Twin Creek Limestone as a whole but extends eastward in the Uinta Mountains, Utah, as far as the Whiterocks River (Imlay, 1953a, fig. 3) and in northwestern Wyoming passes gradually eastward into red beds (Imlay, 1950a, p. 40; 1953a, fig. 1) that have been included in the "Lower Sundance" Formation.

The Boundary Ridge Member thickens westward in a highly irregular manner (table 2). On the north it thickens westward from about 40 feet in the Jackson

Hole area, Wyoming, to 187 feet at Willow Creek, Idaho (fig 2). Farther south it thickens westward from about 50 feet at Fontenelle Gap (fig. 7) Wyo., to 285 feet near Pegram, Idaho. In northern Utah the Boundary Ridge Member thickens westward from 30 feet at Lake Fork to about 100 feet near Burr Fork and Devils Slide (fig. 8). Southward in the Wasatch Range from Devils Slide, it thins to about 40 feet near Thistle.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

Overall, the Boundary Ridge Member is characterized by yellow silty sandy and oolitic limestone interbedded with soft red siltstone. As the member thickens westward, the proportion of limestone increases, and that of the red beds decreases as does the amount of silty and sandy material. Gypsum was noted in red siltstone at one place and is indicated locally by brecciated limestone, but probably was never common. A limestone unit commonly occurs at the base of the member. In Idaho and north-central Utah the sequence of beds appears to vary within short distances.

The easternmost exposures of the Boundary Ridge Member in Wyoming consist mostly of soft brownish-red siltstone that is underlain by a thinner unit of silty to sandy or oolitic yellowish-gray thin- to medium-bedded limestone. The upper part of the siltstone in most sections changes upward within the top 1–15 feet from red to pinkish- greenish- or yellowish-gray. Vuggy limestone occurs near the top at Fontenelle Gap. Westward in Wyoming, as the member thickens, interbeds of similar limestone appear within or at the top of the member (figs. 2–9).

Near the boundary of Wyoming with Idaho and Utah and westward for about 15 miles the member is represented by the same lithologic types as in the type section near Pegram. In this area the member is characterized by silty, sandy, or oolitic yellowish-gray thin- to thick-bedded limestone of which some units are cliff forming. Some of the limestone is vuggy and brecciated, which features suggest the former presence of gypsum such as reported from the subsurface (Peterson, 1957a, fig. 9 on p. 418). Between the limestone units are subordinate units of soft claystone, siltstone, and sandy siltstone that are mostly reddish brown but locally are gray, greenish gray, or yellowish gray. The softer beds are generally poorly exposed and lenticular. Still farther west in Idaho near Willow Creek the member consists dominantly of dense, or oolitic, or silty thin- to thick-bedded limestone but includes a few feet of red beds in its upper part.

In the Uinta Mountains, Utah, similar westward changes occur in the Boundary Ridge Member (fig. 8.). Between Lake Fork and Peoa the basal unit consists of shaly to thin-bedded grayish-yellow limestone that is sandy and ripple marked. This unit is overlain by a somewhat thicker unit of soft brownish-red siltstone that near the Duchesne River contains a little gypsum. At Lake Fork the red unit is overlain by several feet of greenish-gray claystone and on the Duchesne River near Tabiona by 10 feet of brownish-gray soft limestone. Still farther west at Devils Slide the member consists mostly of massive brownish-gray oolitic limestone that rises vertically as high cliffs but basally includes some fine grained sandstone and silty limestone. Red beds were not observed but could be present beneath soil-covered intervals totaling 26 feet. A similar section near Burr Fork includes 10 feet of red soft siltstone a little below the middle of the member. These westernmost sections of the member at Devils Slide and Burr Fork resemble the sections to the north at Birch Creek, Utah, and near Pegram, Idaho, except for a scarcity of red siltstone. South of Burr Fork near Monks Hollow and Thistle the Boundary Ridge Member consists of a fairly thick unit of silty to sandy ripple-marked shaly to thin-bedded limestone overlain by a thin unit of soft red to green siltstone.

The contact of the Boundary Ridge Member with the underlying Rich Member is transitional, as described previously. The contact with the overlying Watton Canyon Member is generally marked by a sharp change from soft red, green, or gray siltstone or claystone to massive cliff-forming gray limestone. Locally in western Wyoming, as at Thomas Fork Canyon and Cottonwood Creek, the contact is marked by an abrupt change from silty yellowish- or brownish-gray shaly limestone to medium-gray medium-bedded compact dense to oolitic cliff-forming limestone. Locally in north-central Utah, as at Devils Slide and Burr Fork, the highest beds of the Boundary Ridge Member consist of thick-bedded brownish-gray oolitic limestone. This limestone is overlain by medium- to olive-gray medium- to thin-bedded limestone that is generally dense and is characterized by remarkably even bedding and by conspicuous rectangular jointing. These bedding and jointing features characterize the limestone of the Watton Canyon Member and generally differentiate it readily from the limestone of the adjoining members.

Many sections of the Boundary Ridge Member in Wyoming and Idaho have been described previously as member D (Imlay, 1950a, p. 42–45; 1953a, p. 60–62). The following sections illustrate the major changes that occur in the member in northern Utah.

Eastward extension of equivalents of Boundary Ridge Member and adjoining marine members of Twin Creek Limestone in lower part of Carmel Formation on east side of Whiterocks River in SE¼SE¼ sec. 18, T. 2 N., R. 1, E., Uintah County, Utah.

[Fig. 1, loc. 40]

	Feet
Carmel Formation (incomplete):	
Watton Canyon equivalent:	
12. Limestone, lithographic, grayish-white; overlain by soft green claystone and massive gypsum	11
11. Limestone, shaly, light-gray	6
Boundary Ridge equivalent:	
10. Limestone, thin-bedded, slightly sandy, oolitic, light-yellowish-gray, ripple-marked	4
9. Siltstone, soft, red	17
Rich equivalent:	
8. Claystone, bentonitic, soft, greenish-gray	2
7. Sandstone, fine-grained, soft, white	2
6. Claystone, very soft, greenish-gray	6
5. Limestone, yellowish-gray; thin bedded in middle; oolitic at top and bottom; contains *pleuromya* and *Camptonectes*	4
4. Claystone, soft, yellowish-gray; contains thin beds of yellow nodular limestone that bear oysters	12
3. Claystone and sandy siltstone, soft, light-gray	8½
2. Limestone, sandy, oolitic, brown; contains *Camptonectes*	½
1. Claystone, soft, yellowish-green; contains many thin beds (¼–½ in. thick) of light-yellowish-gray shaly sandstone; rests sharply on asphaltic Navajo Sandstone	5
Navajo Sandstone (not measured).	

Boundary Ridge Member on west side of Lake Fork in NW¼ sec. 2, T. 1 N., R. 5 W., Duchesne County, Utah

[Fig. 1, loc. 39]

	Feet
3. Claystone, calcareous, greenish-gray; overlain by 2 ft of medium-gray oolitic limestone at base of Watton Canyon Member	3
2. Siltstone, soft, brownish-red	14
1. Limestone, mostly thin bedded, some shaly, silty to sandy, light-yellow, ripple-marked; forms low cliffs; underlain by light-gray shaly soft limestone of Rich Member	13
Total thickness	30

Boundary Ridge Member on south side of Duchesne River in SW¼ sec. 4, T. 1 S., R. 8 W., Duchesne County, near Hanna, Utah

[Fig. 1, loc. 38]

	Feet
3. Limestone, medium-bedded, silty, soft, brownish-gray; overlain by 8 ft of massive oolitic limestone at base of Watton Canyon Member	10
2. Siltstone, soft, brownish-red; pieces of white gypsum present about 6 ft above base	32
1. Limestone, shaly to thin-bedded, finely sandy, light-grayish-yellow, ripple-marked; becomes harder and thicker bedded upward, some beds as much as 10 in. thick; forms low cliff, underlain by shaly limestone of Rich Member	26
Total thickness	68

Boundary Ridge Member 1 mile northwest of Peoa in NW¼ sec. 14, T. 1 S., R. 5 E., Smumit County, Utah

[Fig. 1, loc. 37]

	Feet
5. Siltstone, soft, red to brown; overlain by medium-bedded cliff-forming limestone of Watton Canyon Member	10
4. Covered	60
3. Limestone, thin-bedded to shaly, partly sandy to silty, yellowish-gray	21
2. Limestone, shaly, pinkish- to greenish-gray	8
1. Limestone, shaly to thin-bedded, slightly sandy; yellowish-gray; underlain by light-gray shaly soft limestone of Rich Member	8
Total thickness	107

Boundary Ridge Member on north side of Emigrant Canyon along east side of Brigham Fork in SW¼NE¼ sec. 21, T. 1 N., R. 2 E., Salt Lake County, Utah

[Half a mile west of Burr Fork, fig. 1, loc. 35]

	Feet
6. Limestone, massive, oolitic, yellowish-gray; some beds contain fragments of *Camptonectes, Modiolus,* echinoid spines, and crinoid columnals. Overlain by medium-bedded, even-bedded limestone at base of Watton Canyon Member	15
5. Limestone, medium-bedded, silty, yellowish-gray	30
4. Limestone, massive, oolitic, yellowish-gray	5
3. Limestone, thin-bedded to shaly, silty, yellowish-gray	5
2. Siltstone, soft, brownish-red	10
1. Limestone, shaly to thin-bedded, silty to finely sandy, medium-yellowish-gray, ripple-marked; transitional within several feet into underlying light-gray shaly soft limestone of Rich Member	37
Total thickness	102

Boundary Ridge Member along spillway of reservoir on north side of Birch Creek in NW¼ sec. 19, T. 9 N., R. 6 E., Rich County, Utah

[Fig. 1, loc. 33]

	Feet
26. Claystone, gray, chunky; grades within several inches into medium- to thin-bedded, even-bedded limestone at base of Watton Canyon Member	3
25. Limestone, dense, yellowish-gray	1
24. Sandstone, thin-bedded to shaly, fine-grained, gray to pinkish-gray, crossbedded	5
23. Siltstone, thin-bedded to shaly, soft, yellow, greenish-gray, red; makes sharp contact with overlying sandstone. Well exposed in spillway below upper dam	34
22. Limestone, oolitic, sandy, gray, yellowish-gray, partly brecciated	5
21. Siltstone, soft, red	5
20. Limestone, thin- to thick-bedded, dense, light-yellowish-gray; forms low cliff; upper 2 ft brecciated	10
19. Siltstone, soft, light-red, much crumpled	4
18. Sandstone, thin-bedded to shaly, light-red	3
17. Siltstone, soft, medium-red	5
16. Limestone, thin-bedded, sandy, pinkish-gray, crossbedded, ripple-marked; weathers pink	12
15. Sandstone, thin-bedded, silty, soft; pink at base; becomes yellowish gray above	28

Boundary Ridge Member along spillway of reservoir on north side of Birch Creek in Rich County, Utah—Continued

	Feet
14. Limestone, shaly to thin-bedded, dense, light-yellowish-gray	8
13. Limestone, thin- to medium-bedded, dense light-yellowish-gray, even-bedded	10
12. Limestone, medium-bedded, medium-gray; contains oolitic streaks	4
11. Limestone, massive, oolitic, medium-gray	17
10. Limestone, thin-bedded, partly oolitic, yellowish-gray; forms recess in cliff	4
9. Limestone, massive, oolitic, medium-gray; fragmented fossils present; shows traces of bedding at an angle to the top and bottom of the unit; slightly sandy near base	40
8. Covered	10
7. Siltstone, very soft, brownish-red	10
6. Siltstone, very soft, greenish-gray	3
5. Sandstone, very finely bedded to shaly, yellowish- to pinkish-gray, ripple-marked	2
4. Siltstone and silty claystone, very soft, yellowish- to pinkish-gray	6
3. Sandstone, calcareous, fine-grained, grayish-red	1
2. Siltstone, very soft, greenish- to yellowish-gray	16
1. Limestone, thin-bedded to shaly, sandy to silty, light-yellowish-gray, wavy-bedded; some crossbedding; gradational into underlying light-gray shaly limestone of the Rich Member	5
Total thickness	251

FOSSILS, AGE, AND CORRELATIONS

The Boundary Ridge Member has furnished very few identifiable species (table 7), although fragments of *Camptonectes*, crinoid columnals, and echinoid spines are moderately common. The only species present that appears to have much stratigraphic significance is *Astarte* (*Coelastarte*) *livingstonensis* Imlay, which was collected near the top of the member. Elsewhere it has been found (fig. 9) in the Sliderock and Rich Members of the Twin Creek Limestone, in the limy lower part of the Carmel Formation in central and southwestern Utah, in the Arapien Shale in central Utah, in limestone of middle Jurassic age in the Bighorn Basin, and in the Piper and Sawtooth Formations in Montana. All occurrences that can be dated by ammonites are of Bajocian age. The occurrence in the Boundary Ridge Member, however, is probably of Bathonian age inasmuch as the underlying members are of late Bajocian age and the overlying Watton Canyon Member within the Jackson Hole area, Wyoming, passes eastward at Lower Slide Lake into beds containing the Callovian ammonite *Cadoceras* (Imlay, 1956a, p. 70).

In north-central Wyoming the Boundary Ridge Member continues far to the east (figs. 3, 10) as a soft red claystone and siltstone that locally contains nodules and lenses of gypsum and that in most places contains a thin unit of dolomitic or laminated limestone. This

TABLE 7.—*Geographic distribution of marine Jurassic megafossils in the Boundary Ridge Member of the Twin Creek Limestone*

[Gastropod identifications by N. F. Sohl. Two-digit numbers refer to localities shown in figs. 16 and 17. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Wyoming	Utah	
	45	80	89
	20990	28791	21621
Camptonectes platessiformis White	×		
Trigonia elegantissima Meek			×
Astarte meeki Stanton			×
(*Coelastarte*) *livingstonensis* Imlay			×
Pronoella uintahensis Imlay		×	
sp.	×	×	×
Nerinea? sp.	×		

red-bed member in the Wind River Mountains (Richmond, 1945) and in the Wind River Basin has generally been included in the lower part of the "Lower Sundance" Formation (Love and others, 1945). In the Bighorn Basin it has been included in the upper part of the Gypsum Spring Formation (Imlay, 1956b, p. 578, units 6–8) and in the upper part of a sequence of Middle Jurassic age (Imlay, 1956b, p. 582).

In south-central, central, and eastern Montana the equivalents of the Boundary Ridge Member are called the upper red-bed member of the Piper Formation (Imlay and others, 1948; Imlay, 1954; 1956b, p. 575; Sandberg, 1959) and the Bowes Member of Nordquist (1955, p. 102) of the Piper Formation (Rayl, 1956, p. 43). In southwestern Montana this red-bed member passes westward in the Madison Range into brownish-gray siltstone that is called the upper member of the Sawtooth Formation (Imlay and others, 1948). Similarly in north-central Montana the upper red-bed member of the Piper Formation is replaced westward in both surface and subsurface by silty to sandy beds (Imlay, and others, 1948; Peterson, 1947, p. 407; Rayl, 1956, p. 42, 43; Nordquist, 1955, p. 102) that are lithologically identical with the upper siltstone member of the Sawtooth Formation in northwestern Montana (Cobban, 1945, p. 1270–1277; Schmidt and others, 1961, p. 165). Thus the red-bed member of the Piper Formation shows the same facies changes westward and northward as occur in the Boundary Ridge Member of the Twin Creek Limestone from western Wyoming westward into eastern Idaho.

The validity of these facies changes has been confirmed by many surface and subsurface sections as well as by superposition of the beds in question between marine beds of late Bajocian and early Callovian ages. It appears reasonable, therefore, to correlate the Boundary Ridge Member of the Twin Creek Limestone with the upper siltstone member of the Sawtooth Formation in northwestern Montana which contains ammonites of probable Bathonian age (Imlay, 1962a, p. C12–C13; Frebold, 1963, p. 28, 29).

The Boundary Ridge Member in the Uinta Mountains of northwestern Utah pinches out eastward between the Whiterocks River and Steinaker Draw near Vernal (Imlay, 1953a, p. 58). In the Wasatch Range its southernmost known exposure is on Crab Creek, a few miles south of Thistle. It has not been identified definitely in the Arapien Shale in central Utah but is possibly represented by about a hundred feet of yellow-sandy oolitic limestone and some interbedded red siltstone cropping out on the south side of Red Canyon northeast of Nephi (Imlay, 1964a, p. C6). On the west side of the San Rafael Swell in central Utah some soft gypsiferous gray green to red claystone, siltstone, and sandstone may be correlated with the Boundary Ridge Member on the basis of the fact that they overlie basal limy beds that contain the same fossils as the Rich Member and underlie some ledge-forming sandstone and sandy to oolitic limestone that stratigraphically occupy the same position as the Watton Canyon Member of the Twin Creek Limestone. The possible equivalents of the Boundary Ridge Member on Muddy Creek include units 89–99 of the section described by Gilluly and Reeside (1928, p. 87) and at the south end of Cedar Mountain include units 46–49 (Gilluly and Reeside, 1928, p. 98).

Southwest of the San Rafael Swell near Teasdale and Antimony Canyon the Boundary Ridge Member is probably represented by gypsiferous siltstone and claystone that lie between limestone members. The correlation is based again on the presence low in the lower limestone member of such pelecypod species as *Gervilla? montanensis* Meek and *Vaugonia conradi* (Meek and Hayden) that characterize or are not known below the Rich Member of the Twin Creek Limestone. The correlation is based also on the assumption that the highest limestone member is equivalent to the Watton Canyon Member.

In southern Utah the approximate equivalent of the Boundary Ridge Member appears to be the Thousand Pockets Tongue of the Navajo Sandstone (Wright and Dickey, 1963a, p. E64–E65). This tongue overlies the thin Judd Hollow Tongue of the Carmel Formation which has furnished fossils of Middle Jurassic age. At two localities (see p. 33) fossil collections made from 12 to 20 feet above the base of the Carmel Formation contain an association of pelecypods that is characteristic of the Rich Member. It seems reasonable, therefore, that the overlying sandstone beds forming the Thousand Pockets Tongue are equivalent to at least part of the Boundary Ridge Member of the Twin Creek Limestone. If so, the uplift and erosion of the Navajo Sandstone that furnished the sand of the tongue coincide in time with the marine regression represented by the Boundary Ridge Member and with an uplift in Canada that furnished the sand and silt present in the upper member of the Sawtooth Formation in north-central and northwestern Montana.

In southwestern Utah between Mount Carmel and Gunlock the equivalents of the Boundary Ridge Member should include some part or all of the red siltstone and sandstone directly overlying the limy lower part of the Carmel Formation. This correlation is indicated by the presence of fossils of Middle Jurassic age not younger than the Rich Member of the Twin Creek Limestone near the top of the limy part of the Carmel Formation at several places between Mount Carmel and Pintura (USGS Mesozoic locs. 28494, 28495, 27465, 27466). The Boundary Ridge Member is therefore apparently equivalent at least in part to the Entrada Sandstone as used by Gregory (1950a, p. 94–96, 125–127; 1950b, p. 40, 41, 80, 83, 89) in the area from Mount Carmel westward.

ORIGIN

The Boundary Ridge Member was deposited in a shallowing retreating sea under climatic conditions similar to those that existed during deposition of the Gypsum Spring Member. Such an origin is indicated by its stratigraphic position between marine limestone members that represent transgressive deposits, by the red color of much of the claystone and siltstone, by the interbedding of irregular lenses of oolitic or silty to sandy crossbedded limestone with the red beds, and by a general scarcity of fossils except for fragments of echinoids, crinoids, and mollusks in some limestone beds. The scarcity of gypsum and the scanty evidence for the former presence of gypsum suggests that there were fairly broad marine connections with the main seaways to the west, or that the basins in which gypsum might form were very shallow and transient, or even that the deposition was partly intertidal or subaerial.

The fairly thick lenticular units of oolitic limestone within the Boundary Ridge Member along and a little west of the western boundary of Wyoming contrast with the chert-bearing limestone units in the Gypsum Spring Member in the same area and suggest deposition in shallower waters. The fact that the oolitic limestone units attain their greatest development at the western edge of a facies that consists mostly of red siltstone and claystone and that they pass westward at Willow Creek, Devils Slide, and Burrs Fork into a facies that is mostly limestone shows that they were formed at the margin between two different environments of deposition. To the west, deposition evidently occurred in a very shallow agitated sea containing abundant calcium carbonate. To the east, deposition occurred in an even shallower sea or in intertidal areas, or subaerially. Possibly some of the oolitic and sandy crossbedded limestone was formed as offshore bars or as submarine swells behind which the red and green siltstone accumulated.

WATTON CANYON MEMBER

DEFINITION

The Watton Canyon Member of the Twin Creek Limestone consists mostly of medium- to brownish-gray compact brittle medium- to thin-bedded limestone, and ranges in thickness from about 60 to 400 feet. It becomes thinner bedded upward and grades into the overlying Leeds Creek Member. Most of the beds are dense, but oolitic beds occur throughout. Generally the basal bed is massive and oolitic. The member is characterized by having unusually even bedding and conspicuous rectangular jointing that permit recognition at considerable distance and ready differentiation from adjoining members. In Wyoming and in the Uinta Mountains, Utah, the member is the main ridge former in the Twin Creek Limestone. In Idaho and adjoining parts of north-central Utah, both the Watton Canyon and Boundary Ridge Members form prominent ridges. The Watton Canyon Member has previously been called member E (Imlay, 1950a, p. 40; 1953a, p. 55). The type section is designated as the continuous exposures on the north side of Birch Creek about 8 miles west of Woodruff, Utah. The base of the member is exposed just below the upper dam across Birch Creek. The top of the member is exposed in a small southward-draining gully at the extreme northwest corner of sec. 19. The member is named after Watton Canyon, just south of Birch Creek, where the sequence of beds appears to be the same as on Birch Creek. The type section is described below.

Watton Canyon Member (type section) on north side of Birch Creek in NW¼ sec. 19, T. 9 N., R. 6 E., Rich County, Utah

[Fig. 1, loc. 33]

	Feet
5. Limestone, shaly to thin-bedded, yellowish-gray, splintery; grades upward into soft silty shaly limestone at base of Leeds Creek Member; contact selected at a small gully	75
4. Limestone, thin-bedded, medium-yellowish-gray, platy; weathers light gray	80
3. Limestone, oolitic, slightly sandy, yellowish-gray; shaly at base; becoming medium-bedded and ledge forming at top	17
2. Sandstone, very thin bedded to shaly, calcareous, fine-grained, ripple-marked; grades upward into sandy limestone	22
1. Limestone, medium- to thin-bedded, dense, medium-yellowish-gray, cliff-forming, even- bedded, brittle; becomes thicker bedded upward; weathers to a light yellowish gray; bears a conspicuous rectangular fracture pattern both on bedding surfaces and on cross sections; overlies gray chunky claystone at top of Boundary Ridge Member	205
Total thickness	399

DISTRIBUTION AND THICKNESS

The Watton Canyon Member crops out in the same areas as the Twin Creek Limestone as a whole. In Utah it extends as far south as Crab Creek south of Thistle and at least as far east as the Whiterocks River. The lowest few feet of limestone about 15 feet above the base of the Carmel Formation north of Vernal in sec. 26, T. 3 S., R. 21 E., is probably the easternmost limit of the member. In northwestern Wyoming, east of the area of the Twin Creek Limestone, the member is probably represented at Lower Slide Lake, Teton County, by units 16–21 of the published section (Imlay, 1956a, p. 70).

The Watton Canyon Member thickens westward from about 60 feet in Wyoming to about 400 feet in southeastern Idaho (table 2). In Utah it thickens westward from 17 feet on the Whiterocks River to 380 feet at Devils Slide. In the Wasatch Range its thickness ranges from 300 to nearly 400 feet.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Watton Canyon Member is characterized by dense medium- to thin-bedded medium- to brownish-gray hard brittle limestone that is cliff forming, is remarkably even bedded, weathers into a noticeable rectangular fracture pattern, and persists with little change over large areas (figs. 2–8). Most beds are dense to sublithographic, but some beds are granual or oolitic. Silty to finely sandy limestone beds showing some crossbedding are uncommon but have been noted in Wyoming at La Barge Creek, Fontenelle Gap, and the South Fork of Fontenelle Creek, in Utah at Lake Fork, Burr Fork, and Birch Creek, and in Idaho at Stump Creek and Big Elk Mountain. Sandstone beds occur in Utah at Lake Fork and Birch Creek. Generally the basal limestone bed is massive and oolitic and rises as a cliff above soft beds at the top of the underlying member. In the Wasatch Range near Devils Slide the Watton Canyon Member is quarried for cement and is reported to be a natural cement rock that needs the addition of only a little silica.

The upper part of the Watton Canyon Member in most sections contains units of thin-bedded to shaly ripple-marked limestone that are transitional into the soft shaly limestone of the Leeds Creek Member. Generally the boundary can be selected at the top of a hard bed of oolitic or crinoidal limestone underlying much softer beds, but in some places the boundary must be chosen arbitrarily within an interval of 30–50 feet. The most difficult area in which to select the boundary is in Wyoming between South Piney Creek and Slate Creek where the Leeds Creek Member contains many beds of oolitic limestone. In that area the boundary has been selected arbitrarily at the base of a unit of shaly limestone overlying a series of massive cliff-forming limestone. Overall the two members are readily distinguished by marked differences in bedding, in hardness as expressed by topographic relief, and in fracture pattern.

Many sections of the Watton Canyon Member in Wyoming and Idaho have been described previously as member E (Imlay, 1950a, p. 42–44; 1953a, p. 60–62). Of these the described section near La Barge Creek should be modified by placing the top of the Watton Canyon Member between units 15 and 16 (Imlay, 1950a, p. 42). This position is in harmony with the tops selected in sections to the north and south. The following sections illustrate the lithologic features of the member in northern Utah.

Watton Canyon Member on west side of Lake Fork in NW¼ sec. 2, T. 1 N., R. 5 W., Duchesne County, Utah

[Fig. 1, loc. 39]

	Feet
9. Limestone, thin -bedded, oolitic, sandy, yellowish-gray; underlies soft greenish-gray calcareous claystone	4
8. Mostly covered; some sandy limestone in upper 17 ft	24
7. Limestone, thin-bedded, sublithographic, very light gray; weathers white	37
6. Covered	13
5. Limestone, sandy, light-yellowish-gray	4
4. Covered	12
3. Sandstone, light-yellow	2
2. Limestone, thin- to medium-bedded, dense, hard, light-yellowish-gray	11
1. Limestone, oolitic, medium-gray; overlies greenish-gray calcareous soft claystone at top of Boundary Ridge Member	2
Total thickness	109

Watton Canyon Member on south side of Duchesne River in SW¼ sec. 4, T. 1 S., R. 8 W., Duchesne County, near Hanna, Utah

[Fig. 1, loc. 38]

	Feet
4. Limestone, very thin bedded, sublithographic, very light gray, platy, cliff-forming; weathers nearly white	44
3. Limestone, massive, oolitic, brownish-gray; fossiliferous at top (USGS Mesozoic loc. 21623)	4
2. Limestone, shaly to medium-bedded, mostly thin bedded, light-yellowish-gray, cliff-forming, fossiliferous (USGS Mesozoic loc. 21622)	48
1. Limestone, massive, oolitic, fossiliferous (USGS Mesozoic loc. 21624)	8
Total thickness	104

Watton Canyon Member 1 mile northwest of Peoa in NW¼ sec. 14, T. 1 S., R. 5 E., Summit County, Utah

[Fig. 1, loc. 37]

	Feet
3. Limestone, medium- to thin-bedded, mostly dense, oolitic, medium-gray, cliff-forming; weathers light gray; overlain by soft shaly limestone	105
2. Limestone, shaly, gray to greenish-gray	8
1. Limestone, medium-bedded, medium- to light-gray, cliff-forming; oolitic in part, underlain by soft red to brown siltstone	107
Total thickness	220

Watton Canyon Member on north side of Emigrant Canyon on east side of Brigham Fork in NE¼ sec. 21, T. 1 N., R. 2 E., Salt Lake County, Utah

[Half a mile west of Burr Fork, fig. 1, loc. 35]

	Feet
3. Limestone, medium-bedded, even-bedded, dense, light-yellowish-brown; weathers yellowish gray; fractures in a rectangular pattern; contains one bed of massive oolite about 100 ft above base. Overlain by 4 ft of silty brecciated limestone and then by 7 ft of soft red siltstone	150
2. Limestone, massive, sandy, yellowish-gray	10
1. Limestone, medium-bedded, mostly dense, light-yellowish-gray; weathers a little darker; basal part oolitic; fractures in a rectangular pattern; rests on massive oolitic limestone at top of Boundary Ridge Member	188
Total thickness	348

Watton Canyon Member on north side of road near Thistle in W½ sec. 28, T. 8 S., R. 4 E., Utah County, Utah

[Fig. 1, loc. 42]

	Feet
7. Limestone, medium-bedded, medium-gray; weathers light gray; overlain by soft shaly limestone	30
6. Limestone, thin- to medium-bedded, dense, medium-gray	94
5. Limestone, medium- to thin-bedded, dense, medium- to yellowish-gray	124
4. Limestone, thin- to medium-bedded, yellowish-gray, rubbly	8
3. Limestone, papery to thin-bedded, yellowish-gray	32
2. Limestone, mostly medium to thin-bedded, dense, cliff-forming, yellowish-gray; some beds massive	47
1. Limestone, thick-bedded, dense to oolitic, pink to medium-gray, cliff-forming; upper surface bears many shells of *Camptonectes*; rests sharply on red to green soft siltstone	10
Total thickness	345

FOSSILS, AGE, AND CORRELATIONS

The Watton Canyon Member is not very fossiliferous (table 8) and most of the species present have fairly long ranges (fig. 9). One pelecypod of age significance is *Myopholas hardyi* Imlay, which was obtained a little above the middle of the member near the Duchesne River, Utah. Elsewhere it has been found in the upper 600 feet of the Twelvemile Canyon Member of the Arapien Shale in central Utah, throughout the Rierdon Formation in Montana, and in the lower part of the "Lower Sundance" Formation in north-central Wyoming. All occurrences are in beds of Callovian age.

Other fossils indicative of a Callovian age include small striate Gryphaeas that appear to be immature forms of *Gryphaea nebrascensis* Meek and Hayden. These were noted in the uppermost part of the Watton Canyon Member at Sliderock Creek northeast of Cokeville and at Cottonwood Creek east of Smoot, Wyo.

TABLE 8.—*Geographic distribution of marine Jurassic megafossils in the Watton Canyon Member of the Twin Creek Limestone*

[Gastropod identifications by N. F. Sohl. All one- and two-digit numbers refer to localities shown in figs. 16 and 17. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Wyoming					Utah			
	42				50	88		89	96
	17298	17299	28482	28485	20992	21623	21624	21622	28460
Echinoid fragments	X	X							
Crinoid columnals	X	X				X			
Modiolus subimbricatus (Meek)							X		
Camptonectes stygius White		X					X		X
sp	X				X	X			
Lima (*Plagiostoma*) *occidentalis* Hall and Whitfield					X	X			
Ctenostreon cf. *C. gikshanensis* McLearn					X				
Ostrea (*Liostrea*) *strigilecula* White					X	X	X		
Trigonia elegantissima Meek							X		
Vaugonia conradi (Meek and Hayden)	X					X	X		
Myophorella (*Promyophorella*) *montanaensis* (Meek)							X	X	
Astarte meeki Stanton							X		
Pronoella sp							X		
Myopholas hardyi Imlay						X			
Lyosoma sp						X			
Naticiform gastropods							X		
Nerinea? sp							X		
Gastropods undet			X	X					

The Watton Canyon Member is traceable lithologically and stratigraphically into the "Lower Sundance" Formation exposed along the north side of Lower Slide Lake, in the eastern part of Jackson Hole, Teton County, Wyo. At this place it is represented by a sequence of thick- to thin-bedded oolitic limestone and interbedded shaly limestone and calcareous shale comprising units 16–21 of the published section (Imlay, 1956a, p. 70). This sequence overlies brownish-red siltstone and olive-green shaly limestone which are correlated with the Boundary Ridge Member; the sequence underlies calcareous shale (unit 22) that is correlated with the Leeds Creek Member. The sequence is significant because of its lithologic resemblance to the Watton Canyon Member in the Twin Creek Limestone as exposed nearby on the western side of Jackson Hole, because similar limestone at the same position is traceable far eastward and northward and because its middle and upper parts contain fossils of early Callovian age. These include *Cadoceras*, *Warrenoceras* (Frebold, 1963, p. 13, 14), and *Gryphaea* sp. juv. cf. *G. nebrascensis* Meek and Hayden in unit 19 and typical *G. nebrascensis* in unit 20.

Near Green River Lakes in the Wind River Mountains the probable equivalents of the Watton Canyon Member include 20 feet of shaly and oolitic limestone that overlies 40 feet of red claystone and underlies about 230 feet of gray shale in which *Gryphaea nebrascensis* Meek and Hayden is abundant (Richmond, 1945). In the western part of the Wind River Basin the probable equivalents of the Watton Canyon Member consists of oolitic limestone, sandy limestone, and siltstone that constitute the third member above the base of the "Lower Sundance" Formation as defined by Love and others (1945). For example, at Red Creek in the Owl Creek Mountains the member consists of 35 feet of interbedded oolitic limestone and sandy siltstone that has furnished the ammonites *Cadoceras* and *Warrenoceras*. It underlies soft gray claystone containing *Gryphaea nebrascensis* in abundance, and it overlies red beds that appear to be an eastern extension of the Boundary Ridge Member.

These oolitic and sandy beds pass eastward (fig. 10) along the south side of the Bridger Range and the Bighorn Mountains into an oolitic sandstone, known as the Canyon Springs Sandstone Member of the Sundance Formation (Tourtelot, 1953). This sandstone persists southeastward to the Hartville Uplift (Love and others, 1949) and eastward to the northern part of the Black Hills (Imlay, 1947, p. 247–251) at the base of the Sundance Formation. It persists northward along the flanks of the Bighorn Mountains and Pryor Mountains as oolitic sandstone and oolitic limestone (Imlay 1956b, p. 585, 586, 588, 589) that rests unconformably on the Gypsum Spring Formation (Imlay, 1956b, p. 579, 580).

Westward in the Bighorn Basin and in the Pryor Mountains the basal sandy beds are replaced by oolitic limestone that persists at the same stratigraphic position as far as the Cody area, Wyoming (Imlay, 1956b, p. 592, 593) and across southern Montana (Imlay and others, 1948) as far as the Tendoy Range west of Dillon. In southern Montana this oolitic limestone forms a ledge as much as 20 feet thick at the base of the Rierdon Formation. In south-central Montana it rests sharply on red beds at the top of the Piper Formation that are similar to the eastern facies of the Boundary Ridge Formation in Wyoming. In southwestern Montana west of the Madison Range it rests on silty to sandy limestone, siltstone, and sandstone at the top of the Sawtooth Formation that are similar to the western facies of the Boundary Ridge Formation in Idaho. The oolitic limestone appears, therefore, to be the stratigraphic and lithologic equivalent of the Watton Canyon Member of the Twin Creek Limestone. It differs mainly by being thinner. Similar calcareous beds persist northward in the subsurface of eastern Montana in the basal part of the Rierdon Formation and have been correlated by Peterson (1957a, p. 408, 428) with that part of the Twin Creek Limestone that is now called the Watton Canyon Member.

In central Utah the Arapien Shale probably includes beds equivalent to the Watton Canyon Member of the Twin Creek Limestone. This correlation is suggested by the sequence on the south side of Red Canyon about 2 miles northeast of Nephi (Imlay, 1964a, p. C6). At this place the lower 50–80 feet of limestone resembles the Sliderock Member. The overlying 100 feet or more, of soft shaly limestone resembles the Rich Member. The next overlying 100 feet of yellowish-gray sandy oolitic to dense limestone near the top of the ridge resembles the Boundary Ridge Member. The highest 100 feet or more of limestone capping the ridge consists of thin- to medium-bedded medium-gray dense to granular limestone that resembles the Watton Canyon Member. The overlying soft splintery limestone south of the ridge resembles the lower part of the Leeds Creek Member. The sequence basally at one place includes a few feet of red siltstone comparable to that in the Gypsum Spring Member.

In central Utah on the west side of the San Rafael Swell the highest part of the limy lower part of the Carmel Formation is comparable lithologically and stratigraphically with the Watton Canyon Member. This part consists generally of a cliff-forming oolitic to sandy poorly fossiliferous limestone such as represented by unit 88 of the section on Muddy River measured by Guilluly and Reeside (1928, p. 87). It overlies sequences resembling the Boundary Ridge Member and the Rich Member and underlies a thick sequence of gypsiferous beds that compare in softness, thickness, and stratigraphic position with the Leeds Creek and Giraffe Creek Members of the Twin Creek Limestone. The overall appearance of the Carmel Formation on the west side of the San Rafael Swell resembles that of the westernmost exposures of the Carmel Formation in the Uinta Mountains at Whiterocks River (Imlay, 1953a, p. 58). At that place the Rich, Boundary Ridge, and Watton Canyon Members of the Twin Creek Limestone are recognizable lithologically and stratigraphically, but the overlying beds composing three-fourths of the formation consist of gypsum, red and green siltstone, claystone, and sandstone that are very different than the upper two members of the Twin Creek Limestone as exposed in sections to the west.

In southern Utah southwest of the San Rafael Swell, a cliff-forming limestone similar to the Watton Canyon Member is well developed near Teasdale (Smith and others, 1963, p. 25, 92, 93) and Antimony Canyon (J. C. Wright, written commun., 1960). Near Teasdale it consists of about 72 feet of yellowish-gray cliff-forming sandy limestone and calcareous sandstone (units 26 and 27 of Smith and others, 1963, p. 92). One thin bed of oolitic fossiliferous limestone occurs about 42 feet above the base. This cliff-forming limestone is underlain by about 250 feet of white gypsum, fine-grained gray sandstone, light-green to reddish-brown siltstone, gray claystone, and some very thin bedded limestone that is correlated tentatively with the Boundary Ridge Member. Below is 15–18 feet of interbedded very fossiliferous limestone and fine-grained sandstone (units 8 and 9 of Smith and others, 1963, p. 93). These beds have furnished the pelecypod *Vaugonia conradi* (Meek and Hayden) and *Myophorella montanaensis* (Meek) (USGS Mesozoic loc. 25669), which in the Twin Creek Limestone have not been found below the Rich Member. Between these fossiliferous limestone beds and the Navajo Sandstone are 42 feet of unfossiliferous soft brownish-red to yellowish-gray siltstone and claystone and yellowish-gray sandstone.

In Antimony Canyon the lower limy part of the Carmel Formation likewise is marked at the top by about 70 feet of cliff-forming oolitic limestone that could be equivalent to the Watton Canyon Member. This limestone is underlain by about 90 feet of gypsiferous red beds and then by about 110 feet of beds that are mostly limestone. *Gervillia montanaensis* Meek, a fossil characteristic of the Rich Member, was obtained from 20 to 30 feet above the base of the formation (USGS Mesozoic loc. 26308).

In southwest Utah the only limestone beds that might correspond in stratigraphic position with the Watton Canyon Member of the Twin Creek Limestone are in the upper part of the Curtis Formation as used by Gregory (1950a, p. 96, 125–127) which extends from the Paria River west to near Cedar City (Gregory, 1951, p. 29, 30, 59–60; 1950b, p. 41, 80, 83, 85, 89). If this correlation is correct, then the underlying 100–200 feet of red beds that Gregory (1950a, p. 94, 1951, p. 27) called Entrada Sandstone would be equivalent to the Boundary Ridge Member. Such a correlation is supported by the presence in the upper part of the limestone underlying the Entrada Sandstone as used by Gregory, of certain species that are either characteristic of the Rich Member of the Twin Creek Limestone, or that do not range above that member.

ORIGIN

The Watton Canyon Member of the Twin Creek Limestone was deposited in a shallow sea of early Callovian age that transgressed eastward across the area of Wyoming over the truncated edges of the Middle Jurassic Gypsum Spring Formation and extended far beyond. (Compare figs. 3 and 4 in Imlay, 1950b, opposite p. 80 and 82.) Evidence for truncation is conclusive in the area bordering the Bighorn and Pryor Mountains in north-central Wyoming and south-central Montana (Imlay, 1956b, p. 579, 580, figs. 4–7) and in the northern part of the Black Hills in Wyoming and South Dakota (Mapel and Bergendahl, 1956, p. 87, 88). Evidence for truncation is weak for areas west of the Bighorn Mountains. The abrupt change from red beds at the top of the Boundary Ridge Member to marine limestone at the base of the Watton Canyon Member is proof of an environmental change but is not proof of an unconformity at the contact. Even an abrupt environmental change is not indicated in those places where the upper beds of the Boundary Ridge Member consist of oolitic limestone, as at Devils Slide and Burr Fork, or of calcareous gray shale, as at Birch Creek. Also, the fact that many species of mollusks range throughout most of the Twin Creek Limestone (fig. 9) indicates that marine sedimentation was continuous in parts of the western interior region from Bajocian into Callovian time.

The shallowness of the sea in which the Watton Canyon Member was deposited is indicated by an abundance of oolites and by the presence of such fossils as *Ostrea* and *Gryphaea*. The equivalent Canyon Spring Sandstone Member of the Sundance Formation in central and eastern Wyoming is considered to be of littoral to shallow marine origin on the basis of its fossils (Imlay, 1950b, p. 94).

The source of the silt and sand grains in the Watton Canyon Member is not known. Some silt and sand occur sporadically throughout the area of outcrop of the member, but the amount does not increase in any particular direction. A northern source from Belt Island in Montana is unlikely, considering that the oolitic limestone at the base of the Rierdon Formation in southern Montana is not sandy. A source from the west, locally is suggested by the fact that the Watton Canyon Member at Birch Creek in northern Utah contains more sand than occurs in the member to the north, south, or east. A southeastern source from the area of southeastern Wyoming or northern Colorado is another possibility. That area appears to have been the source of some of the sand in the Canyon Springs Sandstone Member of the Sundance Formation (Imlay, 1947, p. 251; Pipiringos, 1957, p. 19–21), which is an eastern extension of the Watton Canyon Member.

LEEDS CREEK MEMBER

DEFINITION

The Leeds Creek Member is the thickest and most conspicuous member of the Twin Creek Limestone. It supports scant vegetation and consequently forms extensive light-gray bare slopes that are visible for a considerable distance. It ranges in thickness from about 260 to 1,600 feet (table 2), and consists mainly of soft dense light-gray shaly limestone that generally weathers into lighter colored splintery fragments, but in places weathers into chunky fragments. Its lower part in most sections is softer than its upper part and is generally marked by a ravine or valley. At wide intervals the member contains hard thin beds of fossiliferous limestone. In some areas it also contains thin to thick limestone beds or units of which some are oolitic and others are silty to sandy and ripple marked. Its upper part is gradational into the silty to sandy ripple marked cliff-forming limestone of the Giraffe Creek Member. Overall, the member greatly resembles the Rich Member but differs by being much thicker and much less fossiliferous. The Leeds Creek Member has previously been called member F (Imlay, 1950a, p. 40; 1953a, p. 59). The type section is designated as the north side of Leeds Creek and is described along with the type section of the Twin Creek Limestone (p. 16).

DISTRIBUTION AND THICKNESS

The Leeds Creek Member crops out throughout the same areas as the Twin Creek Limestone as a whole. In northwestern Wyoming it terminates eastward at the Darby-Absaroka line of overthrusting. In the Uinta Mountains, Utah, it is recognizable lithologically as far east as Lake Fork. In the Wasatch Range it becomes more clayey and silty southward but is recognizable at least as far south as the Thistle area. Its southernmost exposures at Monks Hollow and Thistle are lithologically similar to the upper shaly part of the Twelvemile Canyon Member of the Arapien Shale above the basal 500–800 feet of medium- to thin-bedded limestone such as is exposed on the south side of Red Canyon about 2 miles northeast of Nephi (Johnson, 1959, p. 20–25, 41; Imlay 1964a, p. C6).

The Leeds Creek Member thickens westward considerably (table 2). In its northern occurrences it thickens westward from a minimum of 330 feet in the Jackson Hole area, Wyoming, to about 1,145 feet at Willow Creek east of Idaho Falls, Idaho (figs. 2, 3). Farther south it thickens westward from about 260 feet at South Piney Creek to about 1,600 feet at Thomas Fork Canyon (figs. 4, 5). In northern Utah it thickens westward from about 115 feet at Lake Fork to 1,290 feet at Devils Slide and about 1,500 feet at Burr Fork (fig. 8). It apparently thins southward in the Wasatch Range, but the thickness of only 275 feet measured at Monks Hollow is not in line with regional thickness trends and may reflect elimination of beds by faulting. Similarly in Cottonwood Creek east of Smoot, Wyo., the measured thickness of the Leeds Creek Member is several hundred feet less than it should be on the basis of regional thickening westward.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Leeds Creek Member is characterized throughout its extent by soft light-gray shaly limestone that commonly weathers into long, pencillike splinters and contains some hard thin beds of limestone (figs. 2–8). These features are modified in certain areas, however, by increases in clay or sand content or in the number of hard beds of limestone. Thus the member becomes distinctly softer, more chunky, and more clayey northward in Idaho and eastward in northwestern Wyoming. In the eastern part of the Jackson Hole area it passes into a very soft claystone facies that is included in the "Lower Sundance" Formation. This claystone facies, which is exposed at Lower Slide Lake, Teton County, Wyo., as well as the more chunky clayey facies of the Leeds Creek Member, contains thin beds of nodular limestone in which are abundant *Gryphaea nebrascensis* Meek and Hayden. This species and the nodular limestone in which it occurs are common in northwestern Wyoming as far south as South Piney Creek and Greys River and in Idaho as far south as Big Elk Mountain and McCoy Creek.

The Leeds Creek Member likewise becomes more clayey southward in the Wasatch Range, Utah, as compared with sections of the member to the east in the Uinta Mountains and to the north at Watton Canyon and Birch Creek. At Burr Fork, for example, the Leeds Creek Member contains many units of soft calcareous claystone interbedded with calcareous gray siltstone, fine-grained sandstone, sandy limestone, some red siltstone, and much shaly limestone. Similar lithologic types occur in the member exposed at Devils Slide. This clayey to sandy facies is lithologically intermediate between the member as exposed to the north at Birch Creek and the upper part of the Twelvemile Canyon Member of the Arapien Shale exposed to the south near Nehpi in central Utah (Hardy, 1952, p. 25, 26). In contrast with the clayey facies in Jackson Hole, Wyo., and adjoining areas, it does not contain thin beds of nodular limestone and associated Gryphaeas and does contain considerable sandstone and siltstone.

Another facies change occurs in the Leeds Creek Member in Lincoln County, Wyo., south of the latitude of Big Piney. This change consists of a marked eastward increase in the number of hard beds of limestone and of silty and sandy material. The limestone beds commonly consist of oolites associated with crinoid columnals, echinoid spines, and shells of *Camptonectes*. Many thin beds of limestone, however, are silty or sandy and show crossbedding and ripple marks. No eastward change in clay content is apparent. In the easternmost sections as exposed at Slate Creek, Fontenelle Gap, La Barge Creek, and South Piney Creek the hard limestone beds form ledges from 1 to 9 feet high separated by thicker intervals of soft shaly limestone. Because of these ledges, the topographic appearance of the member differs considerably from that near the western boundary of Wyoming as at Leeds Creek, Sliderock Creek, and Thomas Fork Canyon. In fact the ledgy character of the member makes the boundary with the Watton Canyon Member more difficult to select than in any other area in which both members are exposed.

The facies changes in the Leeds Creek Member in the Uinta Mountains are different from those just described. Near Peoa the member consists mostly of soft shaly limestone but above its middle contains some beds of hard sandy limestone. Near the Duchesne River the member consists entirely of soft shaly limestone. At Lake Fork it is mostly covered but includes 10 feet of greenish-gray sandy shale basally. At Whiterocks River the probable equivalents consist of gypsum, red sandstone and siltstone, and soft green claystone that by definition are included in the Carmel Formation. These beds overlie 17 feet of sublithographic and shaly limestone that is identical lithologically and stratigraphically with the Watton Canyon Member.

The Leeds Creek Member is overlain gradationally by the silty to sandy beds of the Giraffe Creek Member and consequently their boundary must be selected arbitrarily in most sections. Generally the boundary is placed at the base of a hard bed of silty to sandy ripple-marked limestone that underlies a sequence of similar hard ridge-forming limestone.

Many sections of the Leeds Creek Member in Wyoming and Idaho have been described previously as member F (Imlay, 1950a, p. 42–44; 1953a, p. 60–62). Certain other sections are described below because they illustrate facies changes and suggest sources of clastic sediment. The section at Fontenelle Gap by comparison with the Leeds Creek section indicates a marked shallowing of the sea eastward and an eastern source of clastic sediments. The section at Burr Fork by comparison with that at Birch Creek, Utah, indicates a source of clastic sediment west or southwest of the Wasatch Range. The section at Willow Creek, Idaho, contains some sandstone and sandy beds that were not noted farther east in Idaho.

Leeds Creek Member on north side of Fontenelle Gap in NE¼ sec. 5, T. 24 N., R. 115 W., Lincoln County, Wyo.

[Fig. 1, loc. 30]

	Feet
46. Covered. Overlain by sandy, oolitic thin-bedded rubbly limestone forming low ridge at base of Giraffe Creek Member	12
45. Limestone, medium- to thin-bedded, oolitic, dark-gray; forms low ledge	4½
44. Limestone, shaly, soft, poorly exposed	17
43. Limestone, oolitic, dark-gray; forms low ledge	3
42. Limestone, shaly, soft, medium-gray	32
41. Limestone, thick-bedded, oolitic, finely sandy, dark-gray; shows some crossbedding; weathers dark brownish gray; forms cliff	9
40. Limestone, medium- to thin-bedded, silty to finely sandy, yellowish-gray, crossbedded; weathers brownish gray	4
39. Limestone, oolitic, dark-gray; weathers dark gray; forms base of cliff	5
38. Limestone, shaly, soft, medium-yellowish-gray, poorly exposed	65
37. Limestone, medium-bedded, oolitic, dark-gray; consists of three hard beds 1–2 ft thick separated by softer beds	9
36. Limestone, shaly, soft	3
35. Limestone, medium-bedded, oolitic, dark-gray; weathers dark brownish gray; forms ledge	7
34. Limestone, shaly, soft, poorly exposed	15
33. Limestone, oolitic, dark-gray	1½
32. Limestone, shaly, soft, yellowish-gray; weathers light gray	30
31. Limestone, oolitic, dark-gray; weathers medium gray	1½
30. Limestone, thin-bedded to shaly, silty, yellowish-gray; shows some crossbedding; weathers brownish gray; froms ledge	9
29. Limestone, shaly, soft, medium-gray	6
28. Limestone, oolitic, dark-gray, weathers dark gray; surface bears *Camptonectes*, echinoid spines, and crinoid columnals	1½
27. Limestone, shaly, soft, medium-gray	5
26. Limestone, thin-bedded, silty to finely sandy, yellowish-gray, crossbedded, ripple-marked; weathers brownish gray	10
25. Limestone, shaly, silty, very soft, yellowish-gray	10
24. Limestone, oolitic, silty, hard, yellowish-gray; weathers yellowish gray; forms top of ledge	2
23. Limestone, shaly, silty, yellowish-gray	1½
22. Limestone, oolitic, silty, hard, medium-brownish-gray; weathers same; contains crinoid columnals and echinoid spines	3
21. Limestone, shaly, silty, soft, yellowish-gray; weathers same	12
20. Limestone, thin-bedded to shaly, silty, yellowish-gray, ripple-marked; one 6-in. bed of oolite about 1 ft below top; weathers brownish gray	4
19. Limestone, shaly, soft, medium-gray; in upper 10 ft occur dark-gray oolitic beds 4–12 in. thick	20

Leeds Creek Member on north side of Fontenelle Gap, Lincoln County, Wyo.—Continued

	Feet
18. Limestone, shaly, silty, soft, yellowish-gray, crinkly, ripple-marked	5
17. Limestone, thin-bedded to shaly, silty to finely sandy, yellowish-gray, ripple-marked; some crossbedding present; weathers light brownish gray; forms low ledge at top	20
16. Limestone, medium- to thin-bedded, oolitic, dark-gray; weathers medium gray; upper surface bears many *Camptonectes* and oysters	2½
15. Limestone, thin-bedded, silty to finely sandy, yellowish-gray, ripple-marked; some crossbedding, weathers yellowish brown; forms ledge	6
14. Limestone, shaly, soft, medium-gray; forms recess between ledges	2
13. Limestone, shaly to thin-bedded, silty, yellowish-gray, ripple-marked, weathers same; forms ledge	6
12. Limestone, shaly, soft, medium-gray; weathers yellowish gray; forms recess	5
11. Limestone, shaly, medium-gray, platy; soft at base, becomes harder upward, weathers same	18
10. Limestone, silty to finely sandy, light-yellowish gray; shaly and soft at base, becoming thin bedded and ledge forming at top; some ripple marks and crossbedding present; weathers brownish gray	13
9. Limestone, thin-bedded, silty, medium-gray; weathers yellowish gray; forms upper part of ledge	4
8. Limestone, shaly to thin-bedded, oolitic, medium-gray; weathers yellowish gray; contains echinoid spines and crinoid columnals	3
7. Limestone, shaly, soft, yellowish-gray	3
6. Limestone, thin-bedded, silty to finely sandy, yellowish-gray; small ripple marks present	5
5. Limestone, shaly, soft, medium-gray	2
4. Limestone, finely sandy, hard, yellowish-gray	1
3. Limestone, shaly to thin-bedded, silty to finely sandy, yellowish-gray, ripply-marked; weather same	3
2. Limestone, shaly to thin-bedded, finely laminated, medium gray; contains some silty streaks, becomes shalier at top; weathers light gray; forms ledge	13
1. Limestone, shaly, soft, medium-gray; weathers same; forms recess. Overlies medium- to thin-bedded, even-bedded limestone at top of Watton Canyon Member	6
Total thickness	420

Leeds Creek Member along south side of Watton Canyon in secs. 24–26, T. 9 N., R. 5 E., Rich County, Utah

[Fig. 1, loc. 33]

	Feet
2. Limestone, shaly, soft, medium-yellowish-gray; weathers into light-gray splinters. Contact with Giraffe Creek Member concealed	943+
1. Limestone, shaly, silty, medium-yellowish-gray; contains some thin beds; grades downward into harder thin-bedded limestone at top of Watton Canyon Member	75
Total thickness	1,018+

Leeds Creek Member on north side of Emigrant Canyon between Burr Fork and Brigham Fork from NE¼ sec. 21 to NW. cor. sec. 27, T. 1 N., R. 2 E., Salt Lake County, Utah

[Modified after A. E. Granger (1953, p. 10, 11). Fig. 1, loc. 35]

	Feet
19. Limestone, thin-bedded to shaly, light-gray, locally fissile; weathers orange to yellowish-gray; grades upward into ridge-forming silty to sandy thin- to medium-bedded limestone forming the Giraffe Creek Member	170
18. Claystone, calcareous, light-yellowish-gray, splintery; weathers a little darker	520
17. Limestone, shaly, light-gray, splintery; weathers pale gray	55
16. Claystone, calcareous, pale-olive, splintery	33
15. Limestone, shaly to platy, light-gray, splintery	27
14. Claystone, calcareous, light-gray, splintery	27
13. Limestone, shaly, light-gray, splintery	71
12. Limestone, sandy, yellowish-brown; shows ripple marks; weathers darker	32
11. Claystone, calcareous, locally sandy, pale brown, splintery	115
10. Limestone, shaly, light-yellowish-gray, splintery	95
9. Sandstone, thin-bedded, calcareous, pale-brown; weathers yellowish gray	6
8. Claystone, locally sandy, pale-brown, splintery	120
7. Limestone, shaly to thin-bedded, light-gray, splintery; weathers yellowish gray	125
6. Siltstone, soft, red, greenish- and yellowish-gray	15
5. Limestone, shaly to thin-bedded, light-yellowish-gray, platy	30
4. Limestone, shaly, splintery, and splintery claystone; light-yellowish-gray, weathers light gray	60
3. Limestone, thin-bedded, finely sandy, yellowish-gray	8
2. Siltstone, soft, red and yellowish-gray	7
1. Limestone, silty, yellowish-gray, partly brecciated; overlies medium-bedded, even-bedded limestone typical of the Watton Canyon Member	4
Total thickness	1,520

Leeds Creek Member along north side of Willow Creek in SW¼ sec. 17, T. 1 N., R. 40 E., Bonneville County, Idaho

[Fig. 1, loc. 4]

	Feet
9. Limestone, shaly, soft, medium-yellowish-gray; overlain gradationally by greenish-gray thin bedded to shaly sandy ripple-marked limestone at base of Giraes Creek Member	235
8. Limestone, shaly, soft, medium-gray; contains a few beds of silty limestone and yellow fine-grained sandstone	126
7. Limestone, shaly, soft, medium-gray	19
6. Sandstone, thin-bedded, fine-grained, yellowish-gray	3
5. Limestone, shaly, silty, yellowish-gay	12
4. Sandstone, thin-bedded, very fine grained, light-yellowish-gray; at top a thin bed of limestone bears *Ostrea*, *Camptonectes*, and crinoid columnals	4
3. Limestone, shaly, soft, medium-gray, splintery	513
2. Limestone, thin-bedded to shaly, dense, medium-gray	107
1. Limestone, shaly, soft, medium-gray, splintery, poorly exposed; some hard ledges of thin-bedded limestone crop out 30–50 ft above base; overlies thick-bedded oolitic limestone at top of Watton Canyon Member	126
Total thickness	1,145

FOSSILS, AGE, AND CORRELATIONS

The Leeds Creek Member has furnished few specifically identifiable fossils (table 9). The units of soft shaly limestone do not contain megafossils. The beds of oolitic limestone contain many fragments of crinoids, echinoids, and *Camptonectes*, and rarely other fossils. Most of the identifiable species are represented by only a few specimens at one or two localities. *Gryphaea nebrascensis* Meek and Hayden is the most abundant molluscan species, and it is found only in the northern part of the area of outcrop of the Leeds Creek Member. Most of the identifiable species range upward from the Sliderock Member or the Rich Member of the Twin Creek Limestone and have similar long ranges elsewhere in the western interior region (fig. 9).

Only two pelecypod species found in the Leeds Creek Member have any known age significance. One of these, *Platymya rockymontana* Imlay, n. sp., has been found at one locality near the middle of the member. Outside of the area of the Twin Creek Limestone it has been found only in beds of Callovian age. In Montana it is present throughout the Rierdon Formation and is associated with such ammonites as *Cadoceras* and *Kepplerites*. At Lower Slide Lake in northwestern Wyoming it occurs in unit 19 of the published sequence (Imlay, 1956a, p. 70) in association with *Cadoceras*.

The other pelecypod species of age significance is *Gryphaea nebrascensis* Meek and Hayden which occurs throughout the Leeds Creek Member. Outside of the area of the Twin Creek Limestone it is found through most of the Rierdon Formation of Montana and most of the "Lower Sundance" Formation of northern Wyoming (Imlay, 1948, p. 19; 1953b, p. 7, 8). *G. nebrascensis* is absent in the basal beds of both of these formations. In Wyoming its lowest occurrence is in the uppermost beds of the oolitic limestone and oolitic sandstone that comprise the Canyon Springs Sandstone Member of the Sundance Formation and in equivalent beds (Imlay, 1956b, p. 587, 591, 592). In northwestern Montana in the Sawtooth Range west of Great Falls it is preceded in the lower part of the Rierdon Formation by *G. impressimarginata* McLearn (fig. 12).

Gryphaea nebrascensis Meek and Hayden has been found at many places associated with ammonites of Callovian age, but has not been found in older beds. It has been found rarely in the lower part of the Swift Formation in Montana, but the specimens could have been reworked from underlying beds. Its presence throughout the Leeds Creek Member is excellent evidence for the Callovian age of that member and for correlations with part of the Rierdon Formation and the "Lower Sundance" Formation.

TABLE 9.—*Geographic distribution of marine Jurassic megafossils in the Leeds Creek Member of the Twin Creek Limestone*

[Gastropod identifications by N. F. Sohl. All one- and two-digit numbers refer to localities shown in figs. 16 and 17. Higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Idaho										Wyoming																		Utah			
	1	2					9	11	22		24	25			28		29	30	32	40	42		44	50	55			65	74	76	94	95
	28584	28587	28588	28589	28590	28591	17892	18182	6359	6360	3831	27727	27728	28862	3830	3834	3808	16031	3839	12016	17319	20960	17294	20983	20347	20348	28481	20991	2906	28643	17683	17064
Worm tubes				X		X																										
Echinoid fragments																					X											
Crinoid columnals						X		X	X	X								X	X					X								
Nucula sp																																X
Modiolus subimbricatus (Meek)																																X
Camptonectes stygius White																										X				X		
platessiformis White							X																									
sp								X														X	X	X	X			X			X	
Plicatula sp															X									X								
Lima (*Plagiostoma*) sp																					X											
Ctenostreon cf. *C. gikshanensis* McLearn							X																									
Ostrea (*Liostrea*) *strigilecula* White						X																	X	X								
Lopha sp							X																									
Gryphaea nebrascensis Meek and Hayden	X	X	X	X	X			X			X	X	X		X	X	X	X														
Trigonia americana Meek															X																	
elegantissima Meek																														X		
Vaugonia conradi (Meek and Hayden)																						X										
sp																												X				
Astarte meeki Stanton						X														X												
Pronoella cinnabarensis (Stanton)						X																										
uintahensis Imlay																																X
sp						X		X												X				X					X	X		X
Quenstedtia sublevis (Meek and Hayden)								X																X								
sp																								X								
Protocardia cf. *P. schucherti* McLearn						X		X																								
Platymya rockymontana Imlay, n. sp																				X												
Neritina? sp																																X
Gastropods undet								X																	X		X					
Cadoceras? sp														X																		

A Callovian age for the Leeds Creek Member is suggested also by the presence of a fragment of the body whorl of a large globose ammonite (Mesozoic loc. 28862) obtained about 70 feet above the base of the member on Cabin Creek, Teton County, Wyo. This ammonite has a fairly high, vertical umbilical wall that rounds abruptly into the flanks in a manner that is characteristic of the genus *Cadoceras*. Similar-appearing fragments of ammonites belonging to *Cadoceras* are common in the Rierdon Formation in Montana and in the "Lower Sundance" Formation in Wyoming (Imlay, 1953b, p. 23–25, pls. 7–14).

The Leeds Creek member of the Twin Creek Limestone is correlated on the basis of lithologic continuity and the presence of *Gryphaea nebrascensis* with the Stockade Beaver Shale Member of the "Lower Sundance" Formation of Wyoming and South Dakota and with the middle part of the Rierdon Formation of Montana (fig. 10). Southward in the Wasatch Range, Utah, the member becomes shalier and shows lithologic similarities to the upper shaly part of the Twelvemile Canyon Member of the Arapien Shale such as included by Hardy (1952, p. 15, 16) in his units A–D. Eastward in the Uinta Mountains, Utah, the Leeds Creek Member changes between the Duchesne River and the Whiterocks River (Imlay, 1953a, p. 58, 59) into red beds and gypsum typical of the upper part of the Carmel Formation. This facies change is much greater than that between the southernmost exposures of the Leeds Creek Member near Thistle and the northernmost exposures of the Arapien Shale as exposed east and northeast of Nephi.

On the basis of the facies change in the Uinta Mountains, the Leeds Creek Member may be correlated roughly with the upper gypsiferous siltstone sequence of the Carmel Formation exposed on the west side of the San Rafael Swell. This correlation is substantiated by the presence in the lower fourth of the Carmel Formation of a sequence of units that are similar lithologically, stratigraphically, and in part faunally to the Rich, Boundary Ridge, and Watton Canyon Members of the Twin Creek Limestone.

ORIGIN

The Leeds Creek Member was deposited in very shallow water along its eastern margin in Wyoming and its northern margin in Idaho. All the specimens of *Ostrea* and *Gryphaea* and most of the other benthonic mollusks that have been found in the member are from those marginal areas (compare table 9 and figs. 16, 17) where the member is thinnest, most oolitic, and most clayey or silty. In the Jackson Hole area the member passes eastward and northward into a highly fossiliferous calcareous claystone facies of shallow water origin. Westward in

Wyoming and southward from the Snake River area of Idaho the member thickens, becomes less fossiliferous, less oolitic, and the fossils present are mostly pelagic. Presumably these thicker sections were deposited in somewhat deeper waters. Nevertheless even the thicker sections contain a few beds of silty ripple-marked limestone that bear fragments of *Camptonectes*, crinoids, and echinoids. Such beds could have been formed during storms, but their presence suggests that the bottom of the sea was not very deep.

The shaly limestone that forms the bulk of the Leeds Creek Member was probably deposited rapidly as soft calcareous mud in which most benthonic organisms could not find food or a suitable substratum. A chemical origin for most of the limestone is suggested by its fine texture, general lack of organic matter, and scarcity of fossils. Rapid subsidence is indicated by the considerable thickness of sediment that accumulated during only a part of early Callovian time (Imlay, 1950b, p. 83).

The clastic material in the Leeds Creek Member appears to have been derived from several directions. To the north and northeast the member passes into a soft claystone-siltstone facies that is included in the Rierdon Formation in southern Montana and in the "Lower Sundance" Formation in northern Wyoming. The clastic sediments in these formations apparently came from far to the east and southeast (Imlay, 1950b, p. 77, fig. 4; Peterson, 1954, p. 474).

Toward the east in Lincoln County, Wyo., the Leeds Creek Member gradually becomes siltier and sandier. Toward the west in Idaho the member exposed at Willow Creek contains beds of sandstone that were not noted in sections farther east in Idaho. A western source for this sandstone is suspected because the overlying Giraffe Creek Member is much sandier here than farther east. Toward the south in the Wasatch Range, Utah, the Leeds Creek Member becomes much more clayey, silty, and sandy and passes southward in central Utah into a similar facies in the upper part of the Twelvemile Canyon Member of the Arapien Shale. The source of this clastic material is not known. Presumably part of it could have been derived from the same eastern source as the clay and silt in the upper part of the Carmel Formation, but a western source cannot be excluded.

GIRAFFE CREEK MEMBER

DEFINITION

The Giraffe Creek Member of the Twin Creek Limestone ranges in thickness from about 25 to 295 feet. It consists mostly of yellowish- greenish- or pinkish-gray silty to finely sandy ripple-marked thin-bedded limestone that is interbedded with sandstone, but includes some shaly limestone and some medium-bedded limestone. The thicker beds are commonly oolitic and sandy. Sandy beds generally show crossbedding. Many beds are a coquina of crinoid and echinoid fragments whose upper surfaces are matted with *Camptonectes*. The upper part of the member is generally harder and thicker bedded than the lower part and in many places forms low cliffs or ridges. The member grades upward into much softer red siltstone and sandstone at the base of the Preuss Sandstone. The type section is designated as the north side of Thomas Fork Canyon and is described below. The member is named after Giraffe Creek, which flows into Thomas Fork Canyon about 1 mile east of the type section.

Giraffe Creek Member (type section) on north side of Thomas Fork Canyon in NW¼SW¼ sec. 20, T. 28 N., R. 119 W., Lincoln County, Wyo.

[Fig. 1, loc. 21]

	Feet
4. Limestone, thin-bedded to shaly, silty to finely sandy, grayish-yellow; grades abruptly into soft red siltstone at base of Preuss Sandstone	12
3. Sandstone, thin-bedded, yellowish- to dark-brownish-gray, glauconitic	50
2. Sandstone, thick-bedded, medium-gray, glauconitic; weathers brownish gray	6
1. Limestone, silty, yellowish-gray; interbedded with yellowish-gray sandstone; grades downward into gray shaly limestone of the Leeds Creek Member	43
Total thickness	111

DISTRIBUTION AND THICKNESS

The Giraffe Creek Member is recognizable lithologically in Utah as far south as Monks Hollow near Thistle and as far east as the Duchesne River in the Uinta Mountains. Farther east at Lake Fork and the Whiterocks River the probable correlative beds consist of greenish-gray siltstone, claystone, and sandstone. In northwestern Wyoming the member is present in the western part of the Jackson Hole area but is absent at Lower Slide Lake.

The Giraffe Creek Member thickens westward fairly regularly (table 2) from about 25 feet in the Jackson Hole area of northwestern Wyoming to 295 feet at Willow Creek near Idaho Falls (figs. 2, 3). Farther south in Wyoming and Idaho it thickens irregularly southward (fig. 6) but not westward (figs. 4, 5). In northern Utah it thickens irregularly westward from about 50 feet at Lake Fork to 200 feet near Burr Fork (fig. 8). Part of the irregularity in thickness may be depositional, part may be due to difficulties in selecting boundaries between gradational members, and part may be a result of minor faulting.

LITHOLOGIC AND STRATIGRAPHIC FEATURES

The Giraffe Creek Member is one of the most distinctive members of the Twin Creek Limestone because of its lithologic characteristics and because it generally forms cliffs or ridges between soft red siltstones at the base of the Preuss Sandstone and soft light-gray shaly limestone at the top of the Leeds Creek Member (figs. 2–8). Lithologically it is characterized by thin-bedded limestone that is wavy bedded, ripple marked, silty to sandly and is mostly yellowish, greenish, or pinkish gray.

In the easternmost exposures of the member in Wyoming such limestone is interbedded with some thin units of soft red siltstone, thin- to medium-bedded sandstone, and medium-bedded limestone that is generally oolitic, sandy, and crossbedded. Westward in Wyoming and Idaho the member becomes more sandy, and glauconite becomes common. At Thomas Fork Canyon, Wyo., the member is more than half sandstone, and at Preuss Creek, Idaho, it is mostly sandstone.

In northern Utah, similar westward changes occur in the Giraffe Creek Member. Near the Duchesne River the member consists mostly of shaly limestone but contains interbeds of soft red siltstone, thin-bedded sandy limestone, and gray to yellow ripple-marked thin-bedded sandstone. Near Peoa the member consists of soft gray shaly limestone that contains many thin beds of sandy limestone. At Burr Fork the member consists of thin- to medium-bedded limestone that is ripple marked, silty to finely sandy, crossbedded in part, and light olive gray to yellowish gray, and that weathers orange to gray. South of Burr Fork at Monks Hollow and north of Burr Fork at Watton Canyon the member consists mostly of sandstone and siltstone. At Watton Canyon it includes pebbles of chert, limestone, sandstone, and quartzite as much as an inch across.

The Giraffe Creek Member grades upward into the red Preuss Sandstone. In most sections the boundary can be selected within less than 10 feet and in some sections within a few inches. Difficulty in selecting the boundary arises in only a few sections near the eastern margin of outcrops of the Twin Creek Limestone in Wyoming where the highest limestone unit assigned to the member overlies soft red siltstone that resembles beds at the base of the Preuss Sandstone. Such examples occur near La Barge Creek (Imlay, 1950a, p. 42) and on Cabin Creek (Imlay, 1953a, p. 62). At South Piney Creek the member also contains two ridge-forming limestone units that are separated by a covered interval of 65 feet. This interval is marked by a ravine, is covered by red soil, and evidently is underlain by beds much softer than the outcropping limestone units. In these sections, the highest limestone units have arbitrarily been assigned to the Twin Creek Limestone inasmuch as a marine limestone is apt to be more persistent than a red-bed unit (Imlay, 1953a, p. 59) and is more apt to mark a time plane.

It is possible, however, that the highest limestone units at Cabin Creek and South Piney Creek are eastward extensions of a marine member of the Preuss Sandstone such as occurs a little below the middle of the Preuss Sandstone in the Ammon and Cranes Flat quadrangles, Idaho (Imlay, 1952a, p. 1739–1743). Furthermore, crinoid columnals and oysters (USGS Mesozoic loc. 28638) occur in pinkish-gray sandstone about a hundred feet above the base of the Preuss Sandstone on the north side of Crow Creek, SW¼NE¼ sec. 17, T. 31 N., R. 119 W., Crow Creek quadrangle, Lincoln County, Wyo. Such occurrences show that the Preuss Sandstone passes westward into normally saline marine beds and suggest that the top of the Twin Creek Limestone may not represent a time plane throughout the entire area of its outcrop.

Many sections of the Giraffe Creek Member in Wyoming and Idaho have been described previously as member G (Imlay, 1950a, p. 42–45; 1953a, p. 60–62; 1952a, p. 1740). The following sections show features of special interest. The section at South Piney Creek contains two prominent limestone units and is unusually thick as compared to sections to the west and south. The upper unit is possibly a repetition of the lower unit owing to faulting, but it is lithologically somewhat different, and it may be younger. The section at the Duchesne River is near the eastern limit of the Giraffe Creek Member in Utah and contains interbeds of red siltstone suggestive of the Carmel Formation farther east. The section in Watton Canyon contains more clastic material than any other section of the Giraffe Creek Member and is the only one that contains pebbles.

Giraffe Creek Member on north side of South Piney Creek in sec. 11, T. 29 N., R. 115 W., Sublette County, Wyo.

[Fig. 1, loc. 19]

	Feet
9. Limestone, sandy, slightly oolitic, medium-brownish-gray; locally crossbedded; weathers light brownish-gray; contains a few interbeds of red siltstone and pink sandstone; overlain gradationally within a foot by red soft siltstone at base of Preuss Sandstone	50
8. Covered with red soil	65
7. Limestone, thin-bedded, oolitic, slightly silty, dark-gray; weathers dark brownish gray	2
6. Covered with red soil	5
5. Limestone, thin-bedded, oolitic, silty, gray	5
4. Limestone, shaly to thin-bedded, medium-gray; weathers light gray	18
3. Limestone, thin-bedded, oolitic, slightly silty, dark-gray, brittle; forms ridge; weathers brownish gray	43
2. Limestone, shaly to thin-bedded, silty, light-yellowish-gray to light-olive, ripple-marked, poorly exposed	32
1. Limestone, medium- to thin-bedded, dark-gray; forms low cliff; weathers dark brownish gray; beds near top contain many fragments of crinoids and echinoids; grades downward within several feet into shaly limestone at top of Leeds Creek Member	12
Total thickness	232

Giraffe Creek Member on south side of Duchesne River in SW¼ sec. 4, T. 1 S., R. 8 W., Duchesne County, near Hanna, Utah

[Fig. 1, loc. 38]

	Feet
4. Limestone, shaly, soft, gray, ripple-marked; alternates with red soft siltstone and some ½-in. layers of light-gray fine-grained sandstone; overlain by brownish-red sandstone and siltstone of the Preuss Sandstone	45
3. Sandstone, fine-grained, yellow	4
2. Siltstone, soft, red; interbedded with gray shaly limestone and thin beds of sandy limestone	60
1. Limestone, shaly, soft, light-gray; contains some very thin beds (½–1 in.) of light-gray fine-grained sandstone and yellowish-gray finely sandy limestone; *Camptonectes* shells present; overlies soft shaly limestone of Leeds Creek Member	56
Total thickness	165

Giraffe Creek Member on north side of Watton Canyon about 2½ miles above confluence of Watton Canyon with Birch Creek in sec. 26, T. 9 N., R. 5 E., Rich County, Utah

[Fig. 1, loc. 33]

	Feet
10. Siltstone, sandy, and silty sandstone. Unit is very thin bedded, very soft, medium- yellowish-brown and yellowish-gray; has minor crossbedding; contains green claystone in upper 6 in. that is overlain abruptly by red siltstone of the Preuss Sandstone	24
9. Siltstone, sandy; interbedded with a few thin beds of brown to yellowish-gray fine-grained ripple-marked sandstone. At top is one 4-in. bed of dark-gray sandy limestone	13
8. Covered	16
7. Sandstone, fine- to medium-grained, yellowish-gray; mostly thin bedded but in upper 10 ft occur beds 6–12 in. thick; beds ripple marked; some cross bedding; unit gritty near top; weathers yellowish gray	85
6. Sandstone, shaly to thin-bedded, yellowish- to pinkish-gray, ripple-marked; some beds lenticular; unit weathers darker; contains furrowed trails	32
5. Sandstone, massive, crossbedded; gritty to pebbly in lower 6 ft, becoming fine grained at top; yellowish gray at base, becoming pinkish gray upward; weathers into large rounded pinkish-brown boulders; lower contact sharp	12
4. Sandstone, thin-bedded, fine-grained, medium-brownish-gray, ripple-marked; weathers to a lighter brown	9
3. Sandstone, oolitic, yellowish-gray, slightly pebbly; beds 1–12 in. thick; interbedded with very thin beds of yellow sandstone	9
2. Sandstone, thick-bedded, oolitic, yellowish-gray, pebbly; forms cliff; weathers brownish gray. Pebbles abundant, some as large as 1 in. in diameter, consist mostly of yellow, brown, or black chert, but include some limestone, sandstone, and quartzite. Unit thickens and thins along outcrop from 6 to 10 ft	10
1. Limestone, thin-bedded, sandy, yellowish- to pinkish-gray, ripple-marked; some crossbedding; contact with Leeds Creek Member covered	7+
Total thickness	221+

TABLE 10.—*Geographic distribution of marine Jurassic megafossils in the Giraffe Creek Member of the Twin Creek Limestone*

[Gastropod identifications by N. F. Sohl. Two-digit numbers refer to localities in figs. 16, 17; higher numbers are USGS Mesozoic locality numbers identifying individual collections]

	Idaho		Wyoming		Utah
	14	17	37	55	94
	9309	9315 [1]	12034	20346	17678
Crinoid columnals	×	×	×	×	
Camptonectes sp.			×		
Ostrea (*Liostrea*) *strigicula* White		×			
Pronoella? sp.			×		
Neritina? sp.					×

[1] Mesozoic loc. 9315 is possibly from the Leeds Creek Member.

FOSSILS, AGE, AND CORRELATIONS

Fossil fragments of crinoids, echinoids, and *Camptonectes* are fairly common in the Giraffe Creek Member, but few specimens are worth collecting (table 10), and none is of much age value. The age of the member is determined as Callovian because it lies gradationally above a sequence of early Callovian age and passes eastward in northwestern Wyoming into calcareous shale at the top of the "Lower Sundance" Formation (fig. 10).

The Giraffe Creek Member is similar lithologically and occupies the same stratigraphic position as the Hulett Sandstone Member of the Sundance Formation in central and eastern Wyoming and western South Dakota (Imlay, 1947, p. 255–257; 1952b, p. 966; 1956b, p. 589–593, Tourtelot, 1953; Peterson, 1954, p. 476–479, 487) and as the equivalent ridge-forming sandstone in southern Montana (Imlay, 1954, p. 58, 59; Richards, 1955, p. 40, 41; Peterson, 1954, p. 479; 1957a, p. 431; 1957b, p. 78, 79). It differs mainly by being more glauconitic in its western sections. These sandstone members apparently were formed concurrently near the end of early Callovian time just prior to the deposition of red beds represented on the west by the Preuss Sandstone and on the east by the Lak Member of the Sundance Formation. They differ mainly in the source of the sand because the Giraffe Creek Member coarsens westward and the Hulett Sandstone Member coarsens southeastward. In central Montana the sandstone beds equivalent to the Hulett Sandstone Member pass northward into oolitic and chalky limestone that contains ammonites of early Callovian age (Imlay and others, 1948; Imlay, 1953b, p. 7–10).

In northwestern Wyoming the Giraffe Creek Member is exposed along the western and southern margins of the Jackson Hole area (fig. 1, locs. 6, 9–11, 14) but thins eastward, and is missing in part of western Wyoming. It is not recognizable at Lower Slide Lake (fig. 1, loc.

7). Equivalent beds, if present, at that place probably occur in the highest part of the 160 feet of calcareous claystone and siltstone that contain *Gryphaea nebrascensis* Meek and Hayden and are correlated with the Leeds Creek Member. Such a possibility is suggested by the fact that the *Gryphaea*-bearing beds (unit 22 of Imlay, 1956a, p. 70; unit 12 of Foster, 1947, p. 1565) are overlain conformably by 26 feet of greenish-gray to grayish-pink soft sandy siltstone that lithologically resembles the Preuss Sandstone or the Lak Member of the Sundance Formation, both of which are younger than the Giraffe Creek Member. (Observations by George Pipiringos and R. W. Imlay, July 1964.)

Conformably above this siltstone is 15 feet of soft to ledgy very fine grained greenish-gray nonglauconitic silty sandstone, 1 foot of yellowish-white bentonite, and then 7 feet of glauconitic gray siltstone that contains siliceous nodules and many belemnites. These units are overlain conformably by high cliffs consisting of glauconitic sandstone typical of the "Upper Sundance" Formation, or the Stump Sandstone as used by Foster (1947, p. 1566, 1567). None of the units in the entire section shows any resemblance to the Giraffe Creek Member. Furthermore, if the Preuss Sandstone has been correctly identified, the Giraffe Creek Member must have changed eastward into soft clay to silt facies.

In the Uinta Mountains, Utah, the Giraffe Creek Member changes eastward between the Duchesne River and Lake Fork into poorly exposed beds consisting mostly of soft greenish-gray siltstone and sandstone. Neither the Carmel Formation of central and southern Utah nor the Arapien Shale of central Utah contains any unit comparable lithologically or stratigraphically with the Giraffe Creek Member.

ORIGIN

The Giraffe Creek Member of the Twin Creek Limestone is so similar lithologically and stratigraphically to the Hulett Sandstone Member of the Sundance Formation that both must have had a similar origin (Imlay, 1953b, p. 9, 10; Peterson, 1957a, p. 431). Both were formed in littoral to shallow marine waters during a retreat of the sea near the end of early Callovian time. A shallow-water origin for the Giraffe Creek Member is indicated by such features as an abundance of oscillation ripple marks, crossbedding, oolites, marked thinning and thickening of individual beds, and the presence of some oysters. Bottom conditions in most places were unfavorable for benthonic organisms as shown by the fact that most fossils consist of free-swimming or free-floating forms. The fragmentary condition of most of the fossils suggests deposition in much-agitated water. A western source for the clastic material is shown by a marked increase westward in the amount of sandy material and by the presence of pebbles in one of the westernmost sections. The easternmost section of the Giraffe Creek Member resembles the westernmost sections of the Hulett Sandstone Member in the Wind River and Bighorn Basins. The westernmost sections of the Giraffe Creek Member resemble the Hulett Sandstone Member in the Black Hills except for being much more glauconitic and a little more fossiliferous. The presence of more glauconite in the western area is possibly related to the presence of metamorphic and igneous rocks to the west (Imlay, 1950b, p. 91) or to a greater amount of organic material.

PALEOGEOGRAPHY OF THE WESTERN INTERIOR REGION DURING DEPOSITION OF THE TWIN CREEK LIMESTONE

Marine Jurassic rocks of middle Bajocian to Callovian ages are widespread in the western interior of the United States and Canada (figs. 13–15). These were deposited in an embayment that spread eastward from the Pacific coast region across the northernmost part of the United States and adjoining parts of Canada. At one time it was thought that the embayment in the western interior of Canada was partly separated from the Pacific Ocean by a landmass (Schuchert, 1923, p. 226, fig. 14; Crickmay, 1931, p. 89, map 10) whose position coincided approximately with the present Rocky Mountain trench and that a marine connection with the Arctic Ocean existed through the Yukon territory (Schuchert, 1923, p. 226, fig. 14). Frebold (1954, p. 1, 2; 1957, p. 37–41; 1958, p. 29) has presented evidence however, that both of these ideas are without foundation as far as Canada is concerned. In the United States by contrast, at least part of the embayment in the western interior was bounded on the west by low land masses or islands, or both, that furnished some sand and pebbles from late Bajocian until Oxfordian time (Imlay, 1950a, p. 37–42; 1953a, p. 54–59).

Major marine transgressions in the western interior region occurred during the middle to late Bajocian and early Callovian. Regressions occurred during the Bathonian and middle Callovian. Sedimentation was interrupted marginally during the Bathonian (Imlay, 1956b, p. 564, 579–580; Mapel and Bergendahl, 1956, p. 88, 89) and regionally during the late Callovian (Imlay, 1950b, p. 76; 1952a, p. 1747–52; 1956b, p. 591). In Canada there may have been a hiatus, also, during the late Bajocian (Frebold, 1957, p. 13, 17).

The first Middle Jurassic marine transgression in the western interior region began during the middle Bajocian and reached its climax during the late Bajocian. During the middle Bajocian, normal fossiliferous marine siltstone and sandstone were deposited as far east

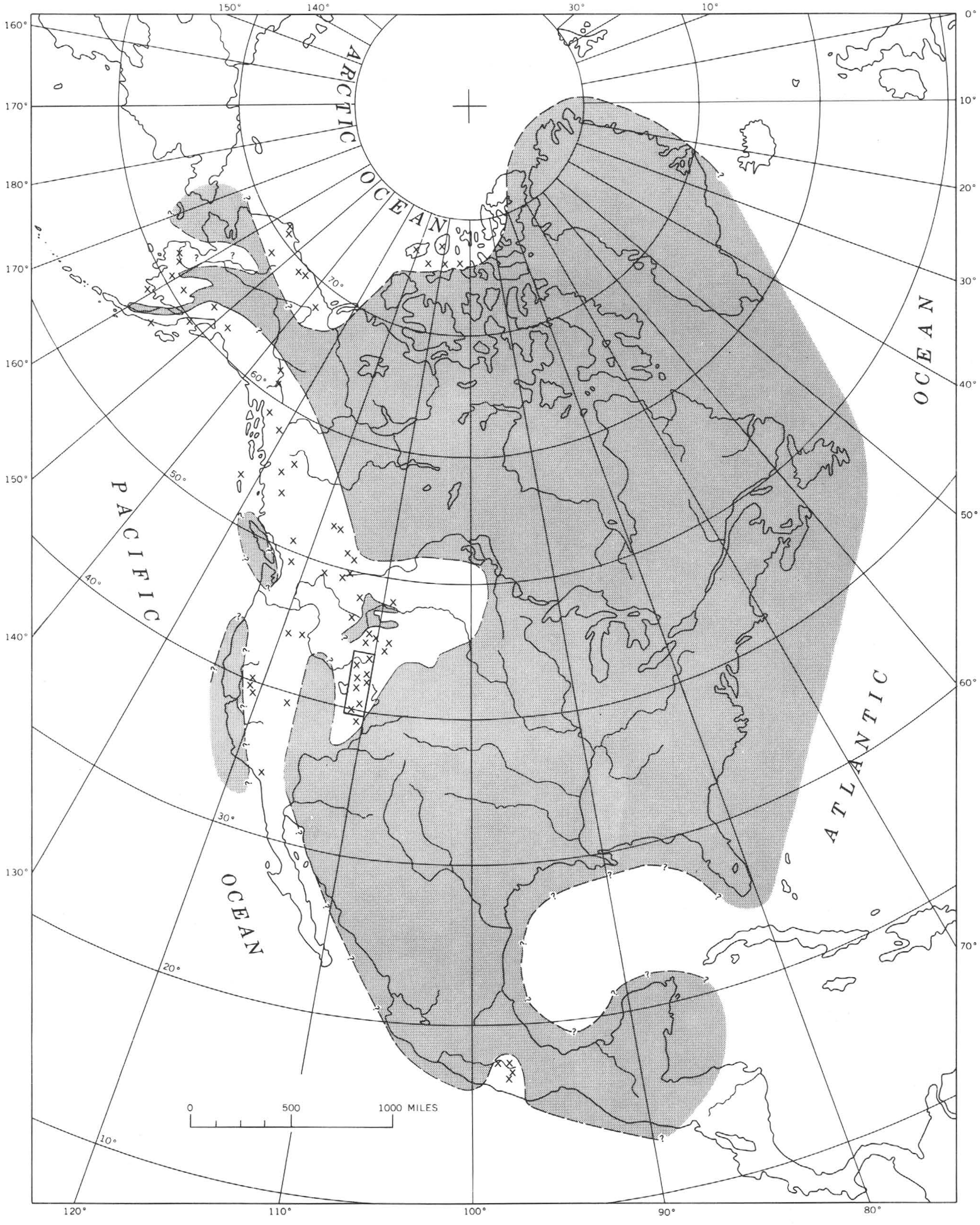

FIGURE 13.—Regional distribution of Bajocian marine rocks in North America. Major occurrences based mainly on ammonites and *Inoceramus* are indicated by ×. Distribution of the Twin Creek Limestone is indicated by the rectangle; land areas stippled.

FIGURE 14.—Regional distribution of Bathonian and Bathonian(?) marine rocks in North America. Major occurrences based on ammonites are indicated by ×. Distribution of the Twin Creek Limestone is indicated by the rectangle; land areas stippled.

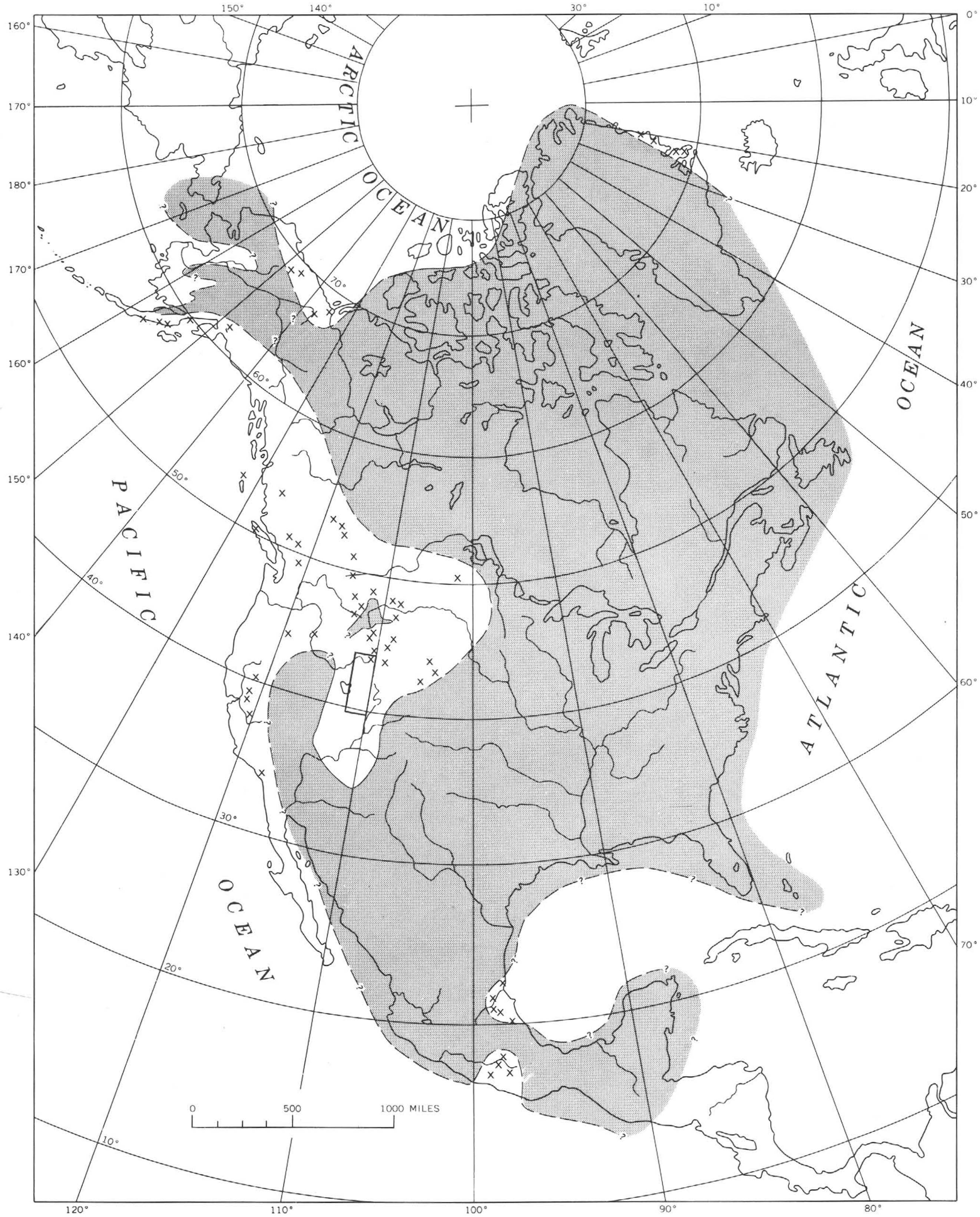

FIGURE 15.—Regional distribution of Callovian marine rocks in North America. Major occurrences based on ammonites and *Gryphaea* are indicated by ×. Distribution of Twin Creek Limestone is indicated by the rectangle; land areas stippled.

as western Alberta and western Montana. Apparently, at the same time, large areas to the east and south were covered with highly saline waters in which were formed soft red beds and gypsum and minor amounts of limestone. Conditions were unfavorable for the growth and preservation of organisms. During the late Bajocian, the sea deepened considerably as shown by the deposition of normal marine highly fossiliferous limestone above red beds and gypsum as far east as the Dakotas and as far south as southwestern Utah. Within the Twin Creek trough, limestone deposition began a little earlier than in areas to the east. The basal limestone beds in the Twin Creek trough become sandier westward, a feature that indicates the presence of a landmass in that direction.

During the Bathonian the sea became much shallower than it was during the late Bajocian. Erosion occurred along the eastern margin, and red beds and gypsum were deposited in much of its eastern part. An eolian sandstone (Thousand Pockets Tongue of the Navajo Sandstone) encroached on the southern margin. Some sand, derived apparently from the northeast, was deposited along its northern margin in Montana and Alberta (upper member of Sawtooth Formation). Deposition of limestone occurred mostly in its western part, and conditions favoring the growth of mollusks existed only in an area that now includes western Montana and western Alberta.

During the early Callovian marine transgression, the western interior sea spread farther south and southeastward than during the late Bajocian. Deposition of normally saline fossiliferous marine limestone, siltstone, claystone, and sandstone was widespread except in the eastern part of the Colorado Plateau. The main source of sand was to the east and southeast. The Twin Creek trough subsided rapidly and accumulated a much greater thickness of limestone and claystone than areas to the east. The northern part of the trough near the end of early Callovian time received some sand derived from the west.

During the middle Callovian regression the western interior sea was partly cut off by a rising landmass in central Montana and northern Wyoming (Imlay, 1952a, p. 1751–1753). Deposition continued south and southeast of the landmass for at least part of late Callovian time and may have continued into Oxfordian time. Apparently marine connections persisted along the west side of the landmass somewhere through western Montana or northern Idaho during deposition of the Preuss Sandstone of middle to late Callovian age. Such is implied for that formation by the presence of bedded salt, some marine fossils, and a westward increase in the amount of fossiliferous marine beds.

PALEONTOLOGY OF THE TWIN CREEK LIMESTONE AND SOME CONTEMPORARY FORMATIONS

BIOLOGIC ANALYSIS

The marine Jurassic pelecypods described herein (fig. 9) were obtained from the upper six members of the Twin Creek Limestone. They are of Bajocian and Callovian ages, number about 1,580 specimens and include 43 genera and subgenera and 50 species and subspecies. These pelecypods are all that have been collected by many geologists during about 60 years. Their distribution by genera, subgenera, and families is shown in table 11. The genus *Gryphaea* is by far the most common, but the genera *Camptonectes*, *Ostrea* (*Liostrea*), *Pronoella*, and *Pleuromya* are represented by 100 specimens, or more, at many localities. The genus *Corbula* is also represented by about 100 specimens, but all were obtained from a few localities in one small area in western Wyoming. The other genera are much less common. Genera or subgenera numbering from 21 to 41 specimens in decreasing order include *Astarte*, *Trigonia*, *Vaugonia*, *Grammatodon*, *Pinna*, *Myophorella* (*Promyophorella*), and *Modiolus*. Genera or subgenera numbering from 10 to 19 specimens in decreasing order include *Plagiostoma*, *Plicatula*, *Quenstedtia*, *Coelastarte*, *Prorokia*, *Mactromya*, and *Ctenostreon*. The other genera are represented by nine or fewer specimens and, therefore, may be considered rare.

Newly described species and subspecies of pelecypods include *Gryphaea planoconvexa fraterna* Imlay, *Prorokia fontenellensis* Imlay, and *Platymya rockymontana* Imlay. The 50 species described do not include *Modiolus isonemus* (Meek) (1877, p. 132, 133, pl. 12, figs. 4, 4a) or *Myophoria lineata* (Münster) of Meek (1877, p. 133, 134, pl. 12, figs. 3, 3a) which probably belongs to *Opis* (*Trigonopis*). Both of these were obtained in Weber Canyon, Utah, and presumably from the Twin Creek Limestone near Devils Slide. Neither have been found subsequently in the Twin Creek Limestone, but *Modiolus isonemus* (Meek) has been found in equivalent beds in the Arapien Shale (Imlay, 1964a, p. C24, pl. 1, fig. 22).

The marine Jurassic cephalopods described herein (fig. 11) were obtained from the Sliderock and Rich Members of the Twin Creek Limestone and from approximately equivalent beds of Bajocian age elsewhere in the western interior region. These cephalopods include 142 specimens from the Twin Creek Limestone and 140 specimens from other formations (table 12). This number is all the generically identifiable Bajocian cephalopods that have been collected by geologists of the U.S. Geological Survey in the western interior region since 1892.

TABLE 11.—*Biological relationships and relative abundance of Bajocian and Callovian pelecypods in the Twin Creek Limestone*

Family	Genus or subgenus	Specimens
Nuculidae	*Nucula*	1
Parallelodontidae	*Grammatodon*	33
Arcidae	*Barbatia?*	2
Cucullaeidae	*Idonearca*	6
Mytilidae	*Modiolus*	21
	Musculus	1
	Mytilus	3
Isognomonidae	*Gervillia?*	3
	Isognomon	5
Pinnidae	*Pinna*	28
Pectinidae	*Camptonectes*	160
	Chlamys?	1
	Velata?	2
Plicatulidae	*Plicatula*	17
Limidae	*Plagiostoma*	19
	Ctenostreon	10
Ostreidae	*Liostrea*	100
	Lopha	3
	Gryphaea	576
Trigoniidae	*Trigonia*	40
	Vaugonia	34
	Promyophorella	21
	Haidaia	3
Astartidae	*Astarte*	41
	Coelastarte	15
	Trigonopis	1
	Prorokia	12
Cyprinidae	*Pronoella*	105
Lucinidae	*Lucina?*	2
Mactromyidae	*Mactromya?*	12
Tancrediidae	*Tancredia?*	7
	Corbicella?	2
Quenstedtiidae	*Quenstedtia*	17
Cardiidae	*Protocardia*	6
Pleuromyacidae	*Pleuromya*	135
Corbulidae	*Corbula*	100
Pholadomyidae	*Pholadomya*	9
	Homomya	1
	Goniomya	7
Pholadidae	*Myopholas*	1
Laternulidae	*Cercomya*	4
	Platymya	1
Thraciidae	*Thracia*	14

The distribution of the Bajocian cephalopods by genera and families is shown in table 12. The Stephanoceratidae is the dominant family and is represented by the genera *Stephanoceras*, *Stemmatoceras*, *Sohlites*, n. gen., and questionable *Normannites*. The Sphaeroceratidae is less than half as common and is represented by the genera *Chondroceras*, *Parachondroceras*, n. gen., and *Megasphaeroceras*. The Cardioceratidae is even less common and is represented by *Eocephalites*, n. gen. The Spiroceratidae is represented by two fragments of *Spiroceras*. The most common and characteristic genera in the Sliderock Member are *Stemmatoceras*, *Eocephalites*, n. gen., and *Megasphaeroceras*. The only ammonites found in the Rich Member consist of one specimen of *Sohlites*, n. gen., three of *Parachondroceras* n. gen., and one questionably assigned to *Stephanoceras*. Both *Sohlites* and *Parachondroceras* are much more common in equivalent beds in Montana. These new genera have not been recorded outside the western interior of the United States. The genus *Megasphaeroceras* has been found elsewhere only in the Cook Inlet region, Alaska (Imlay, 1962b, p. A2, A10, A11). The genus *Spiroceras* has not been recorded previously in the western interior region, although it is fairly common in beds of late Bajocian to late Bathonian age in many parts of the world. The genera *Stephanoceras*, *Stemmatoceras*, and *Chondroceras* are widely distributed in beds of Bajocian age throughout the world.

Among the amonite genera described as new, *Sohlites* shows resemblances to *Reineckeia*, *Zemistephanus*, and *Ermoceras*. The characteristics of its suture line suggest that it is probably most closely related to *Ermoceras*. *Parachondroceras* shows resemblances to both the Bajocian family Otoitidae and the Bathonian to Callovian family Tulitidae. It differs from the described genera of those families by having a narrowly rounded venter. *Eocephalites* shows considerable resemblance to *Paracephalites* and *Cranocephalites* and is possibly ancestral to both.

Newly described species of ammonites include *Stemmatoceras arcicostum* Imlay, *Sohlites spinosus* Imlay, *Parachondroceras andrewsi* Imlay, *P. filicostatum* Imlay, and *Eocephalites primus* Imlay.

TABLE 12.—*Biological relationships and relative abundance of Bajocian cephalopods in the western interior region*

Family	Genus	Specimens: Twin Creek Limestone	Specimens: Elsewhere in western interior
Nautilidae	*Eutrephoceras*	1	------
Spiroceratidae	*Spiroceras*	2	------
Stephanoceratidae	*Stephanoceras*	2	------
	Stephanoceras?	1	------
	Stemmatoceras	44	15
	Sohlites	1	85
	Sohlites?	------	2
	Normannites?	4	1
Sphaeroceratidae	*Chondroceras*	------	1
	Parachondroceras	3	36
	Megasphaeroceras	29	------
Cardioceratidae	*Eocephalites*	43	------
	Eocephalites?	12	------

Pelecypods are much more common than other megafossils in the Twin Creek Limestone; they outnumber cephalopods and gastropods about 13 to 1. Pelecypods attain their greatest variety in the Rich Member, have considerable variety in the Sliderock Member, and are more common than other megafossils in all the upper six members. Cephalopods are moderately common only in the Sliderock Member, are rare in the Rich Member, and are represented by one fragment in the Watton Canyon Member. Gastropods are most abundant in the Sliderock Member but have been found in all the upper six members. Crinoid and echinoid fragments occur throughout the Twin Creek Limestone but generally have not been collected. Worm tubes have been noted in the Sliderock, Rich, and Leeds Creek Members. One colonial coral, probably belonging to *Actinastrea*, was obtained from an oolitic limestone in the lower part of the formation, presumably from the Sliderock Member.

SOME FAUNAL ZONES IN THE WESTERN INTERIOR REGION

CHONDROCERAS-STEMMATOCERAS ZONE

The lower part of the middle shale member of the Sawtooth Formation in northern Montana has furnished one specimen of *Chondroceras* (Imlay, 1948, p. 19, pl. 5, figs. 1–5) and three fragments of *Stemmatoceras* resembling *S. arcicostum* Imlay, n. sp., described herein. The genus *Chondroceras* has been found in many parts of world in beds of middle Bajocian age (Arkell and others, 1957, p. L292), is particularly common in the zone of *Stephanoceras humphriesianum* zone, and is not known above that zone. *Stemmatoceras* is also characteristic of the middle Bajocian but is transitional between *Stephanoceras* and *Teloceras* which range upward into the upper Bajocian.

Chondroceras has not been found elsewhere in the western interior region of the United States, although it is fairly common in Canada from the foothills of the Rocky Mountains westward. The time during which *Chondroceras* lived could be represented in the Twin Creek trough by the lower third of the Sliderock Member or by the Gypsum Spring Member of the Twin Creek Limestone. This possibility is suggested by the presence of ammonites of early late Bajocian age in the middle and upper parts of the Sliderock Member.

MEGASPHAEROCERAS ZONE

The middle and upper parts of the Sliderock Member of the Twin Creek Limestone are characterized by a rotund species of *Megasphaeroceras* that is possibly identical with *Megasphaeroceras rotundum* Imlay (1962b, p. A9–11) from beds of late Bajocian age in the Cook Inlet region, Alaska (fig. 12). Other characteristic fossils include the ammonites (fig. 11) *Stephanoceras*, *Stemmatoceras*, *Spiroceras*, *Eocephalites*, n. gen., and the pelecypod *Gryphaea planoconvexa fraterna* (fig. 9). Of these, *Stephanoceras* is probably represented also in the overlying Rich Member. Associated fossils that range above the Sliderock Member include species of pelecypods and some species of gastropods. The *Megasphaeroceras* zone has not been identified faunally outside the area of the Twin Creek Limestone. Its age on the basis of the ammonite genera is early late Bajocian.

PARACHONDROCERAS ANDREWSI ZONE

The Rich Member of the Twin Creek Limestone is faunally the most distinctive member in the formation. It is characterized by the ammonite genera *Parachondroceras* and *Sohlites* (fig. 11) and by the pelecypod species (fig. 9) *Gervillia*? *montanaensis* Meek, *Myophorella* (*Haidaia*) *yellowstonensis* Imlay, and *Gryphaea planoconvexa* Whitfield. It contains the highest recorded occurrences of the pelecypods *Gryphaea planoconvexa fraterna* Imlay, n. subsp., *Prorokia fontenellensis* Imlay, n. sp., *Goniomya montanaensis* Meek, and *Thracia weedi* Stanton. The Rich Member contains the lowest recorded occurrences of the pelecypods *Isognomon* cf. *I. perplana* Whitfield, *Trigonia elegantissima* Meek, *Vaugonia conradi* (Meek and Hayden), *Myophorella montanaensis* (Meek), *Quenstedtia sublevis* Meek and Hayden, and *Cercomya punctata* (Stanton).

This distinctive association of molluscan genera and species occurring in the Rich Member is widespread in the western interior region. It has been found in the lowest limestone sequence of the Carmel Formation along the west side of the San Rafael Swell in central Utah, in the middle and upper parts of the lowest limestone sequence in southwest Utah, in the middle and upper parts of the limestone member of the Gypsum Spring Formation in north-central Wyoming, and throughout the middle limestone member of the Piper Formation in Montana. Its age is probably late Bajocian, as indicated by its stratigraphic position above beds of early late Bajocian age and the greater resemblances of the ammonites to genera of Bajocian than of Bathonian age.

PARACEPHALITES SAWTOOTHENSIS ZONE

The *Paracephalites sawtoothensis* zone (fig. 12) has been identified in the United States only in the upper siltstone member of the Sawtooth Formation exposed in the front ranges of the Rocky Mountains in west-central and northwestern Montana. In that area it is associated with the ammonite *Cobbanites* and the pelecypod *Gryphaea impressimarginata* McLearn (Imlay, 1962a, p. C21). The zone is probably equivalent to the *Paracephalites glabrescens* zone in the Rocky Mountains of Alberta, Canada (Frebold, 1963, p. 28, 29). In Alberta the ammonite *Paracephalites* was obtained from 35 feet of silty claystone and sandstone underlying a 3½-foot bed of coquina containing *Gryphaea impressimarginata* McLearn. The generic name *Paracephalites* Buckman (1929) is now used by Frebold (1963, p. 8–13, 28, 29) for certain ammonites from Alberta and Montana that were previously referred to *Arctocephalites* (Imlay, 1948, p. 14, 19), *Arctocephalites* (*Cranocephalites*) (Imlay, 1962a, p. C21, C23–C25), and *Cadoceras* (Frebold, 1957, p. 60, 62; 1963, p. 8–12, 28).

WARRENOCERAS CODYENSE ZONE

The generic name *Warrenoceras* (Frebold, 1963, p. 13) is now used for certain ammonites previously referred to *Arcticoceras* (Imlay, 1948, p. 20, 21; 1953b, p. 5, 19–22) and *Lilloettia* (Frebold, 1957, p. 56) from the western interior of the United States and Canada.

A zone characterized by *Warrenoceras codyense* (fig. 12) is widespread in northern Wyoming, western South Dakota, and Montana (Imlay, 1953b, p. 5). Associated ammonites include *Cadoceras* and *Cobbanites*. In western Montana, species of *Warrenoceras* occur in the upper part of the range of *Gryphaea impressimarginata* McLearn.

The *Warrenoceras codyense* zone in the United States may not be equivalent to the *Warrenoceras henryi* zone in Alberta, Canada, according to Frebold (1963, p. 27–20). The evidence presented (Frebold, 1963, p. 24, pl. 9, fig. 2) is meager, but is supported by the fact that in the United States *W. henryi* (Meek and Hayden) has been found only above beds containing *W. codyense* (Imlay).

The *Warrenoceras codyense* zone has not been identified by ammonites in the Twin Creek Limestone proper. The zone probably occurs, however, on the north side of Lower Slide Lake in northwestern Wyoming, in a sequence that by definition is included in the "Lower Sundance" Formation although the lower six members of the Twin Creek Limestone are recognizable lithologically, stratigraphically, and in part faunally. In this sequence, both *Warrenoceras* (=*Arcticoceras* n. sp. indet. of Imlay, 1953b, p. 20) and *Cadoceras* sp. were obtained (USGS) Mesozoic loc. 20974) from unit 19 (Imlay, 1956a, p. 70) in association with several immature striate specimens of *Gryphaea* that probably belong to *G. nebrascensis* Meek and Hayden. This unit is part of a member (units 16–21) consisting of oolitic limestone, granular limestone, and claystone that is correlated stratigraphically with the Watton Canyon Member of the Twin Creek Limestone.

GOWERICERAS AND KEPPLERITES ZONES

No new information concerning the *Gowericeras* and *Kepplerites* zones (Imlay, 1953b, p. 7, 8) in the United States is available. The zones with *Kepplerites* have now been recognized in Canada, and a still younger zone has been added (Frebold, 1963, p. 30, 31). Equivalents in the Twin Creek Limestone apparently include the Leeds Creek and Giraffe Creek Members. This correlation is indicated for the Leeds Creek Member by the presence throughout of *Gryphaea nebrascensis* Meek and Hayden, which is the most common fossil in those zones and does not occur lower. It is indicated also by the presence of a large globose ammonite, probably belonging to *Cadoceras*, obtained near the base of the Leeds Creek Member on Cabin Creek, Wyo. The Giraffe Creek Member probably corresponds to the *Kepplerites mclearni* zone which has been identified at the top of the Rierdon Formation in central Montana. This correlation is based on the fact that the Giraffe Creek Member occupies the same stratigraphic position as the Hulett Sandstone Member of the Sundance Formation and that the Hulett Sandstone Member passes northward in central Montana into oolitic limestone at the top of the Rierdon Formation.

COMPARISONS WITH OTHER FAUNAS

CENTRAL AND SOUTHERN UTAH

The molluscan fauna of the lower limy part of the Carmel Formation of central and southern Utah (Imlay, 1964a, p. C4) includes many of the same species that occur in the Twin Creek Limestone and some species that are characteristic of the Rich Member. The most noticeable difference is the absence in the Carmel Formation of the pelecypods *Gryphaea*, *Opis*, *Prorokia*, *Protocardia*, *Corbula*, and *Platymya*, a near absence of ammonites, and a much greater abundance of *Ostrea*. These differences suggest that the Jurassic sea in central and southern Utah was shallower and less favorable for the growth of a variety of mollusks than the sea farther north in which the Twin Creek Limestone was deposited. Shallowing of the Jurassic sea southward is shown by a marked southward increase in the relative abundance of *Ostrea* within the Twin Creek Limestone, by the complete absence of *Gryphaea* south of the Thistle area, Utah, and by an absence of ammonites south of Thistle and the northwest end of the San Rafael Swell. Apparently the southern part of the seaway was to shallow, or too agitated, or too saline for the survival of *Gryphaea*, of ammonites, and of some other organisms.

Most of the fossils found in the Twelvemile Canyon Member of the Arapien Shale in central Utah (Imlay, 1964a, p. C6) are likewise identical specifically with fossils that range through most of the Twin Creek Limestone. *Astarte* (*Coelastarte*) *livingstonensis* Imlay, however, from the lower part of the Twelvemile Canyon Member has been found in the Twin Creek Limestone only in the Sliderock, Rich, and Boundary Ridge Members. *Myopholas hardyi* Imlay from the upper 600 feet of the Twelvemile Canyon Member also occurs in the Watton Canyon Member of the Twin Creek Limestone.

MONTANA, WYOMING, AND SOUTH DAKOTA

The characteristic *Gryphaea* and ammonites present in the Sliderock Member have not been found elsewhere in the western interior region. In contrast the species characteristic of the Rich Member occur in the lower part of the Carmel Formation in Utah, in limestone beds in the middle of the Gypsum Spring Formation in Wyoming, in the middle limestone member of the Piper Formation in Montana, in the lower and middle parts of the Sawtooth Formation in southwestern Montana, and in the limestone member of the Sawtooth (Piper) Formation exposed in the Bearpaw Mountains and the Sweetgrass Hills in north-central Montana. This faunal distribution is so much greater than that of the older fauna of the Sliderock Member as to suggest an abrupt deepening and spreading of the sea at the beginning of deposition of the Rich Member.

The Rierdon Formation of Montana and the "Lower Sundance" Formation in Wyoming and South Dakota contain certain species in common with the Watton Canyon Member or the Leeds Creek Member of the Twin Creek Limestone. These species include *Myopholas hardyi* Imlay, *Platymya rockymontana* Imlay, n. sp., and *Gryphaea nebrascensis* Meek and Hayden. The lowest appearance of small striate Gryphaeas near the top of the Watton Canyon Member appears to coincide in time with the lowest apearance of *Gryphaea nebrascensis* at the top of the Canyon Springs Sandstone Member of the Sundance Formation. In addition the Leeds Creek Member near its base has furnished one globose ammonite that probably belongs to *Cadoceras*, a genus that is common in the Rierdon Formation and has not been found lower.

WESTERN INTERIOR OF CANADA

The described megafossils of Middle Jurassic age from the Fernie Formation in the western interior of Canada have very little in common with the megafossils from the Twin Creek Limestone (fig. 12). The pelecypods (Warren, 1932) and ammonites (McLearn, 1928, 1932b; Warren, 1947; Frebold, 1957) of Bajocian age belong to different species than occur in the Sliderock and Rich Members of the Twin Creek Limestone. The Canadian Bajocian fossils, however, are dated as middle Bajocian (Frebold, 1957, p. 13; 1964, p. 5), whereas the Sliderock Member of the Twin Creek Limestone contains the ammonites *Megasphaeroceras* and *Spiroceras* of late Bajocian age. So the faunal differences may reflect differences in age. Inasmuch as the late Bajocian faunas in the western interior of the United States must have entered from the west or from the north, the absence of any fossil evidence for the late Bajocian in Canada suggests that the faunas entered from the west via the northern part of the United States. This suggestion agrees very well with Frebold's (1957, p. 3, 39–41) arguments against a landmass extending northward from Nevada into British Columbia during Jurassic time, as had been suggested by Schuchert (1923, p. 226) and Crickmay (1931, p. 36, 84–89).

The Grey Beds in the upper part of the Fernie Formation (Frebold, 1957, p. 20; 1963, p. 1, 27) have furnished many pelecypods (McLearn, 1924) and ammonites (McLearn, 1928, 1929b; Frebold, 1957, 1963) that are identical with species in the upper part of the Sawtooth Formation and in the Rierdon Formation in Montana. Some of the pelecypod species are also identical with long-ranging species in the Twin Creek Limestone. These include in particular *Idonearca haguei* (Stanton) and *Cercomya punctata* (Stanton).

Most of the described pelecypods were obtained from the lower 103 feet of the Grey Beds exposed on Grassy Mountain near Blairmore, Alberta. At this place the basal 99 feet, called the *Corbula munda* beds (Freebold, 1957, p. 76; 1963, p. 4, 5), are lithologically similar to the upper siltstone member of the Sawtooth in northwestern Montana and in their upper 35 feet contain species of *Paracephalites* (Buckman, 1929, p. 10, 11; Frebold, 1963, p. 8–13) that are in part identical with species in the upper siltstone member of the Sawtooth Formation (Imlay, 1962a, p. C14, C15, C24, C25). If this correlation is valid, the *Corbula munda* beds on Grassy Mountain are equivalent approximately to the Boundary Ridge Member of the Twin Creek Limestone on the basis of regional stratigraphic correlations. The Boundary Ridge Member has furnished so few fossils, however, that a faunal correlation is not possible.

The *Corbula munda* beds on Grassy Mountain are overlain by 2 feet of sandstone and then by 1½ feet of a sandy coquina that together are called the *Gryphaea* bed (Frebold, 1957, p. 20, 21, 76; 1963, p. 5) because of the abundance of *Gryphaea impressimarginata* McLearn. This bed contains the same species of pelecypods as the underlying *Corbula munda* beds but includes such ammonites as *Warrenoceras* (=*Arcticoceras* of Imlay, 1953b. p. 19–22) and *Kepplerites* which in Montana occur in the Rierdon Formation. The association of these ammonites with *Gryphaea impressimarginata* McLearn is normal for the lower part of the Rierdon Formation, although in Montana that species of *Gryphaea* occurs also in the upper siltstone member of the Sawtooth Formation.

On the basis of the presence of *Warrenoceras*, the *Gryphaea* bed on Grassy Mountain may be correlated approximately with the Canyon Springs Sandstone Member of the Sundance Formation in central and eastern Wyoming (Imlay, 1947, p. 250), the basal bed of the Sundance Formation near Cody, Wyo. (Imlay, 1956b, p. 592), and unit 19 of the section described by Imlay (1956a, p. 70) at Lower Slide Lake in the Jackson Hole area, Wyoming. This unit is part of a sequence that is correlated on a stratigraphic basis with the Watton Canyon Member of the Twin Creek Limestone as exposed in the Jackson Hole area. It appears probable, therefore, that the bed containing *Gryphaea impressimarginata* McLearn near Blairmore, Alberta, correlates with some part of the Watton Canyon Member below the lowest occurrence of *Gryphaea* cf. *G. nebrascensis* Meek and Hayden.

The upper part of the Grey Beds in outcrops in Alberta and in the subsurface in Saskatchewan has furnished a few ammonites (Frebold, 1963, p. 4, 6, 7, 23–26, 30, 31) that are similar or identical with species of *Kosmoceras* and *Kepplerites* in the middle and upper parts of the Rierdon Formation of Montana. These parts of the Rierdon Formation are correlated with the Leeds Creek Member of the Twin Creek Limestone on the basis of stratigraphic position and the presence of *Gryphaea nebrascensis* Meek and Hayden. Strangely, this species has not been recorded from outcrops of the Grey Beds in Canada, although present in the subsurface (Frebold, 1957, p. 26) in beds of Callovian age. It has been recorded also from outcrops of the Green Beds which overlie the Grey Beds and which contain *Cardioceras* of early Oxfordian age (Frebold and others, 1959, p. 10).

COOK INLET REGION, ALASKA

The Jurassic megafossils from the Cook Inlet region, Alaska, have very little in common faunally with those from the Twin Creek Limestone of the western interior. The only significant faunal element in common is the ammonite *Megasphaeroceras* (fig. 12) which in both areas is associated with ammonites of early late Bajocian age. In Alaska (Imlay, 1962b, p. A2) it is associated with *Leptosphinctes*, *Sphaeroceras*, *Normannites* (=*Dettermanites*), and a questionable *Spiroceras*. In the Sliderock Member of the Twin Creek Limestone it is associated with *Spiroceras*, *Stephanoceras*, *Stemmatoceras*, and questionable *Normannites*. The fact that *Megasphaeroceras* has been found only in these two areas indicates that marine connections existed during late Bajocian time between the Pacific Ocean and the western interior sea.

GEOGRAPHIC DISTRIBUTION

The occurrences of Bajocian and Callovian mollusks from the Twin Creek Limestone described herein are shown by State and locality in tables 3–5 and 7–10 and in figures 16 and 17. The occurrences of the Bajocian ammonites from the Gypsum Spring Formation of Wyoming and from the Piper and Sawtooth Formations of Montana are shown in table 6 and figure 18. Detailed descriptions of all these fossil occurrences are given in the following table in which index numbers 1–97 in the left-hand column refer to localities in the Twin Creek Limestone, numbers 98–102 refer to the Sawtooth Formation, numbers 103–109 refer to the Piper Formation, and numbers 110 and 111 refer to the Gypsum Spring Formation. The Bajocian ammonite occurrences from the Carmel Formation of central Utah have been published previously (Imlay, 1964a, table 6 and fig. 1 under index numbers 45, 46, and 50).

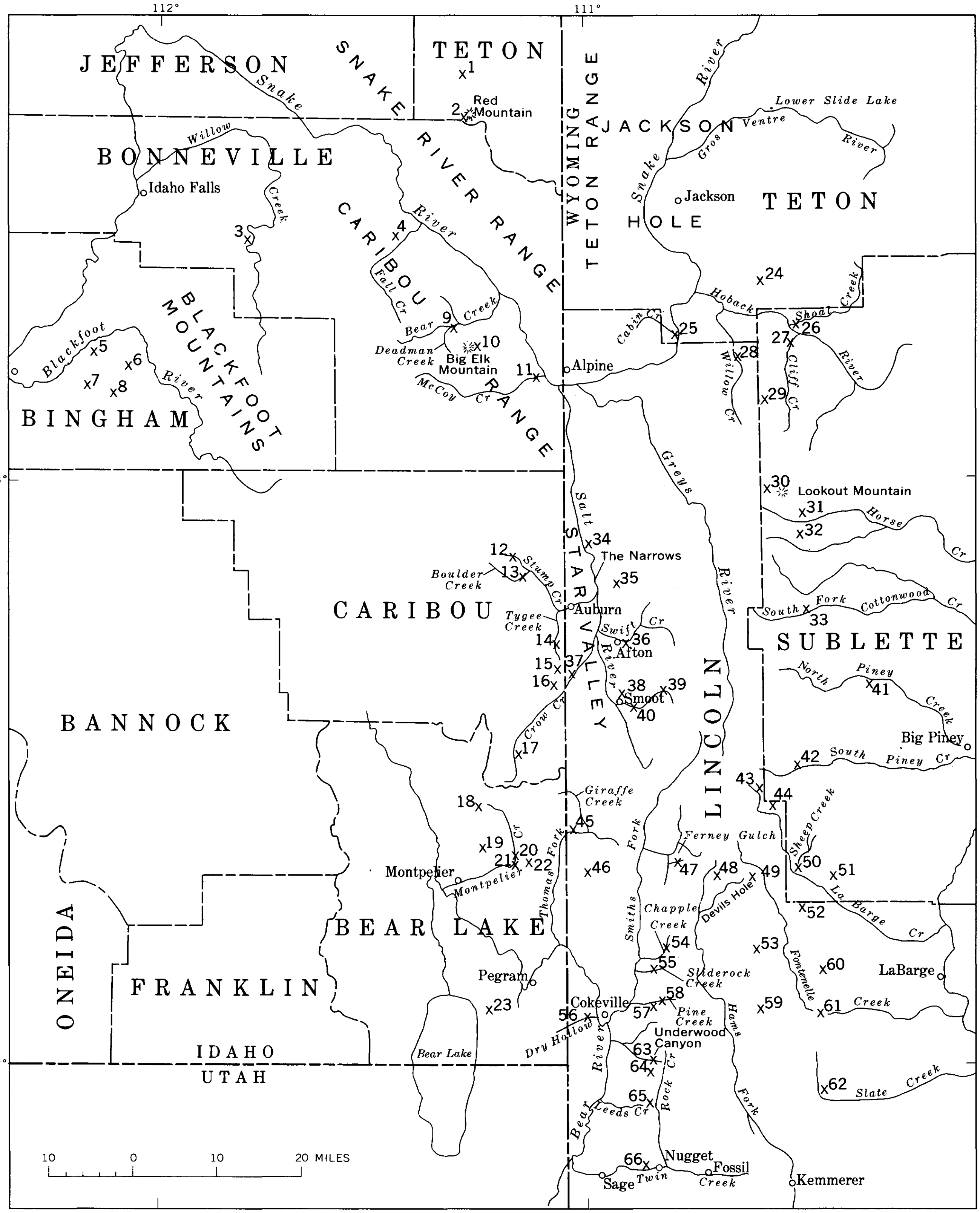

FIGURE 16.—Index map of Jurassic fossil localities in the Twin Creek Limestone in southeastern Idaho and western Wyoming. Numbers on map show approximate positions of fossil localities given in tables 3–5 and 7–10.

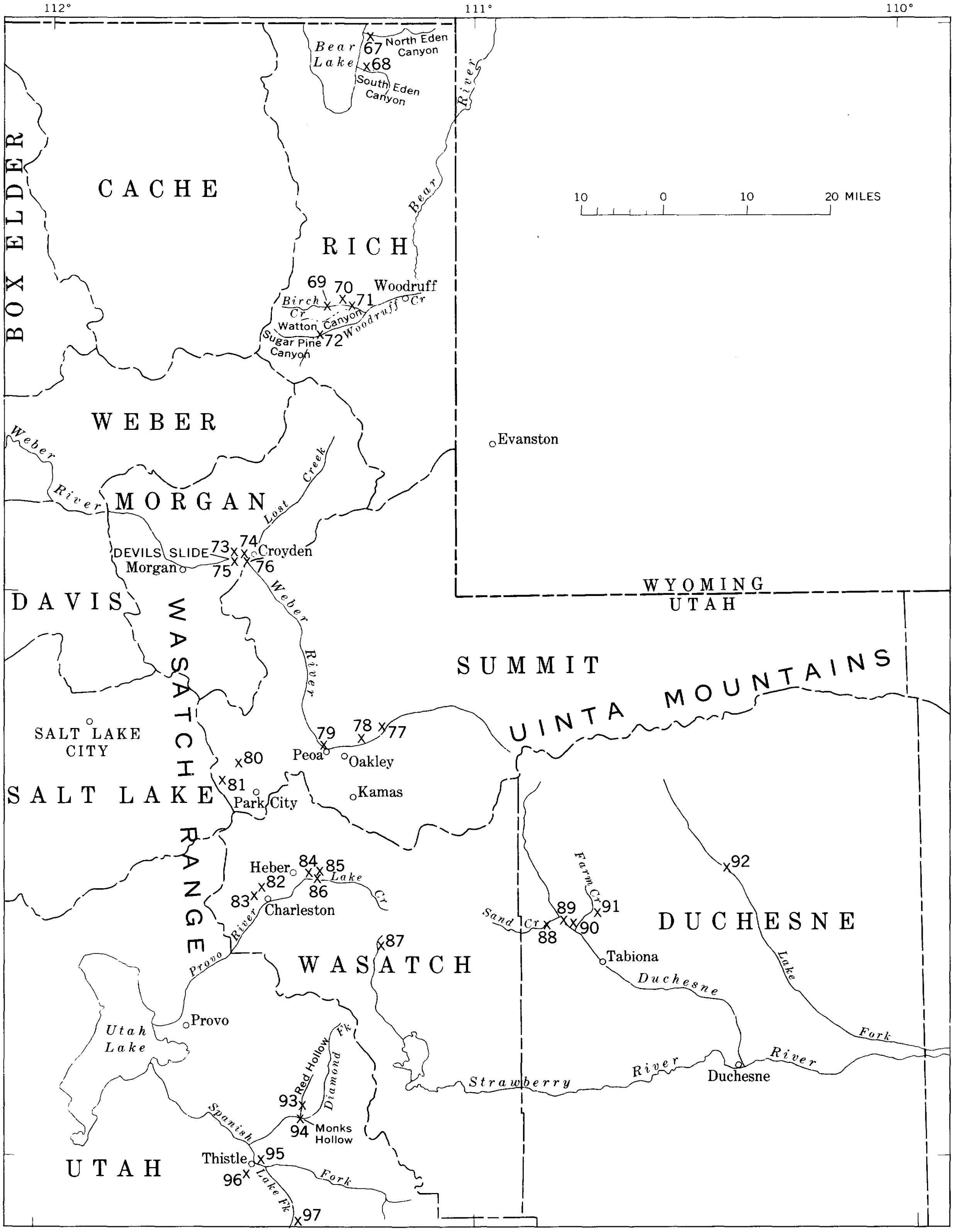

FIGURE 17.—Index map of Jurassic fossil localities in the Twin Creek Limestone in northern Utah. Numbers on map show approximate positions of fossil localities given in tables 3–5 and 7–10.

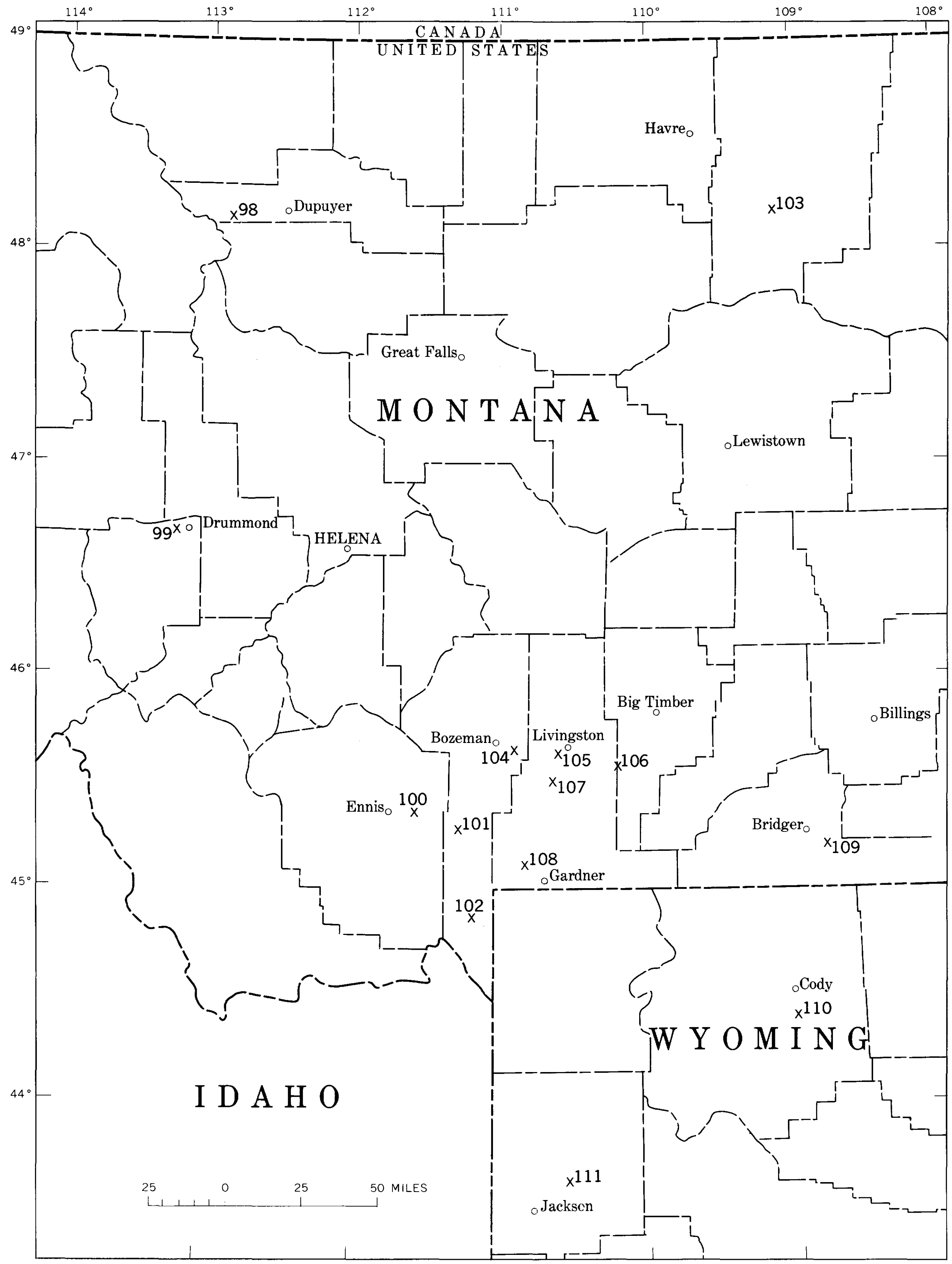

Figure 18.—Index map of certain Jurassic fossil localities in Montana and northern Wyoming outside the area of the Twin Creek Limestone. Numbers on map are fossil-collecting localities given in table 6.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
1	28584	HA-28-61	H. F. Albee, 1961. North-central part of SE¼ sec. 5, T. 4 N., R. 44 E., Garns Mountain 15-min quad., Teton County, Idaho. Twin Creek Limestone, Leeds Creek Member.
2	28585	MHS-89-61	M. H. Staatz, 1961. Sequence measured southwest from top of Red Mountain from NW¼ to SW¼ sec. 33, T. 4 N., R. 44 E., Garns Mountain 15-min quad., Teton County, Idaho. Twin Creek Limestone, near middle of Rich Member, about 186 ft above top of Nugget Sandstone.
	28586	MHS-90-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Sliderock Member, from 42 ft of fine-grained medium-gray limestone whose base is 39 ft above top of the Nugget Sandstone.
	28587	MHS-97-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Leeds Creek Member, about 145 ft above base of member.
	28588	MHS-98-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Leeds Creek Member, about 176 ft above base of member.
	28589	MHS-99-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Leeds Creek Member, about 240 ft above base of member.
	28590	MHS-100-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Leeds Creek Member, 295 ft above base of member.
	28591	MHS-101-61	M. H. Staatz, 1961. Same location as 28585. Twin Creek Limestone, Leeds Creek Member, 365 ft above base of member.
3	13491	M-323A, L-154	G. R. Mansfield and W. B. Lang, 1925. NE¼NE¼ sec. 19, T. 1 N., R. 40 E., Ammon 15-min quad., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, upper part.
	28500		R. W. Imlay and Yaacov Nir, 1961. North side of Willow Creek, NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, 53 ft below top of member and 15 ft below 4 ft of quartzitic sandstone.
	28501		Yaacov Nir, 1961. North side of Willow Creek. On west side of and about 6 ft above bed of small gulch, SE. cor. sec. 18, T. 1 N., R. 40 E., Ammon 15-min quad., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, float from nodular limestone at top of member.
	28502		Yaacov Nir, 1961. North side of Willow Creek, NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, from 4 ft of papery claystone 30 ft below top of member.
	28505		R. W. Imlay and Yaacov Nir, 1961. North side of Willow Creek, NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, from 6½ ft of soft fissile claystone 86 ft below top of member.
	28506		R. W. Imlay and Yaacov Nir, 1961. About ¼ mile north of road on north side of Willow Creek, NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, 79 ft below top of member.
	28507		R. W. Imlay and Yaacov Nir, 1961. About ¼ mile north of Willow Creek on east side of a southward-trending gulch, SW. cor. sec. 17, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Rich Member, from thin beds of nodular limestone near middle of member and about 170–190 ft above its base.
	28516		Yaacov Nir, 1961. Just west of bridge across Willow Creek in NE. cor. sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, float probably from Rich Member.
	28635	I-62-5-23A	R. W. Imlay, 1962. North side of Willow Creek, SE¼ sec. 18, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member from nodular gray limestone directly above soft papery claystone and 20–25 ft below top of member.
	28636	I-62-5-23C	R. W. Imlay, 1962. North side of Willow Creek, NE¼ sec. 19, T. 1 N., R. 40 E., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, from 7 ft of soft shaly limestone 79 ft below top of member.
4	21000	I-47-8-5	R. W. Imlay, 1947. West side of Fall Creek, in NW¼ sec. 18, T. 1 N., R. 43 E., Irwin 30-min quad., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member, from upper 13 ft.
5	8621	Mt. 169	J. W. Merritt for G. R. Mansfield, 1913. NW¼NW¼ sec. 26, T. 2 S., R. 37 E., Fort Hall 30-min quad., Indian Reservation, Bingham County, Idaho. Twin Creek Limestone, lower part.
6	8620	Mt. 167	J. W. Merritt for G. R. Mansfield, 1913. SE¼SW¼ sec. 36, T. 2 S., R. 37 E., Fort Hall 30-min quad., Indian Reservation, Bingham County, Idaho. Twin Creek Limestone, member unknown.
7	8622	Mt. 171	J. W. Merritt for G. R. Mansfield, 1913. SW¼SE¼ sec. 7, T. 3 S., R. 37 E., Fort Hall 30-min quad., Indian Reservation, Bingham County, Idaho. Twin Creek Limestone, member unknown.
8	8623	198	G. R. Mansfield and G. H. Girty, 1913. Northwest of Higham Peak, in east-central part of T. 3 S., R. 37 E., Fort Hall 30-min quad., Indian Reservation, Bingham County, Idaho. Twin Creek Limestone, lower part.
9	17892	9-37	W. W. Rubey, 1937. On hill just east of bench mark 7204, southeast junction of Deadman Creek and Bear Creek, SW¼ cor. sec. 4, T. 2 S., R. 44 E., Irwin 30-min quad., Bonneville County, Idaho. Twin Creek Limestone, Leeds Creek Member, near top.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
10	18181	39–F–18	L. S. Gardner, 1939. On Big Elk Mountain, sec. 23, T. 2 S., R. 44 E., Irwin 30-min quad., Bonneville County, Idaho. Twin Creek Limestone, Sliderock Member.
11	18182	39–F–19	L. S. Gardner, 1939. Near the mouth of McCoy Creek, SW¼ sec. 6, T. 3 S., R. 46 E., Irwin 30-min quad., Bonneville County, Idaho. Twin Creek Limestone, Leeds Creek Member.
12	16016	AW 101	W. W. Rubey, G. R. Mansfield, and J. S. Williams, 1931. On hillside west of North Fork of Stump Creek about ¼ mile north of its junction with Stump Creek. About half way between natural gate (cliff) across the North Fork and its mouth at Stump Creek, NW¼ sec. 27, T. 6 S., R. 45 E., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, Sliderock Member, upper part.
	21632	I–49–9–7A	R. W. Imlay and John McIntyre, 1949. Branch of Stump Creek in SE¼ sec. 28, T. 6 S., R. 45 E., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, about 110 ft below top of Sliderock Member, in yellow gray, sandy, shaly limestone about 8 ft above a 6-ft unit of white-weathering limestone.
	21633	I–49–9–7B	R. W. Imlay and John McIntyre, 1949. Branch of Stump Creek in SE¼ sec. 28, T. 6 S., R. 45 E., Freedom 15-min quad., Caribou County ,Idaho. Twin Creek Limestone, from upper 10 ft of Sliderock Member and lower 40 ft of Rich Member.
	22459	I–50–8–16	R. W. Imlay, 1950. About ½ mile above mouth of North Fork of Stump Creek, south-central part of sec. 22, T. 45 E., R. 6 S., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, 10 ft below top of Rich Member.
	22460	I–50–8–16	R. W. Imlay, 1950. About ½ mile above mouth of North Fork of Stump Creek, south-central part of sec. 22, T. 45 E., R. 6 S., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, 100 ft below top of Rich Member and 160 ft stratigraphically below cliff-forming Watton Canyon Member that is marked by a cataract.
	28795	I63–8–1A	R. W. Imlay, 1963. North side of Stump Creek about ½ mile east of the North Fork and just east of axis of an anticline, NE¼ sec. 27, T. 6 S., R. 45 E., Caribou County, Idaho. Twin Creek Limestone, Sliderock Member, 20–30 ft below top in medium- to thin-bedded limestone.
	28796	I63–8–1B	R. W. Imlay, 1963. About 200 ft east of Mesozoic loc. 28795 on north side of Stump Creek. Twin Creek Limestone, Rich Member, slightly above middle. Caribou County, Idaho.
13	9090	56	G. R. Mansfield, 1914. Boulder Creek Canyon, west-central part of sec. 1, T. 7 S., R. 45 E., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, Sliderock Member.
	28797	I–63–7–5	R. W. Imlay, 1963. Northwest side of Boulder Creek about 1 mile southwest of Stump Creek, west-central part sec. 1, T. 7 S., R. 45 E., Freedom 15-min quad., Caribou County, Idaho. Twin Creek Limestone, Rich Member, about 90–100 ft above base and a little below middle of member.
14	9309	M.29	G. R. Mansfield and P. V. Roundy, 1915. SE¼ sec. 15, T. 8 S., R. 46 E., 2 miles south of Draney Ranch, 1 mile east of Tygee Creek, Crow Creek 15-min quad., Caribou County, Idaho. Twin Creek Limestone, Giraffe Creek Member.
15	9096	JW.1	E. L. Jones, Jr., for G. R. Mansfield, 1914. SW¼SE¼ sec. 34, T. 8 S., R. 46 E., Crow Creek 15-min quad., Caribou County, Idaho. Twin Creek Limestone, lower part.
16	12116	BB	E. M. Parks and C. S. Lavington, 1923. West of center sec. 10, T. 9 S., R. 46 E., Crow Creek 15-min quad., Caribou County, Idaho. Twin Creek Limestone, Sliderock Member.
17	9315	Ry.134	P. V. Roundy for G. R. Mansfield, 1915. SE¼ sec. 23, T. 10 S., R. 45 E., 2¼ miles north of Half Way House, old stage route from Montpelier to Afton, Crow Creek 15-min quad., Caribou County, Idaho. Twin Creek Limestone, upper part, probably Giraffe Creek Member.
18	7430	R.8	R. W. Richards, 1911. Sec. 25, T. 11 S., R. 44 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, probably in Sliderock Member.
	7432	R. 17	R. W. Richards, 1911. Sec. 24, T. 11 S., R. 44 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Sliderock Member.
	7438	T.6	E. L. Troxell for R. W. Richards, 1911. Sec. 25, T. 11 S., R. 44 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, probably Sliderock Member.
19	6370	11	G. H. Girty, 1909. Near middle of sec. 17, T. 12 S., R. 45 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Sliderock Member.
20	4081	42	F. B. Weeks, 1906. About 1 mile north of Montpelier Canyon on east side of Star Valley road in NE. cor. sec. 27, T. 12 S., R. 45 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Sliderock Member.
21	28637	I–62–5–31A	R. W. Imlay, 1962. North side of U.S. Highway 89 in NW¼ sec. 35, T. 12 S., R. 45 E., Bear Lake County, Idaho. Twin Creek Limestone, Sliderock Member, shaly limestone in upper half.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
22	6359	131	C. L. Breger, 1909. NE¼ sec. 25, T. 12 S., R. 45 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Leeds Creek Member, in upper part of the formation about 100 ft above a red-bed unit.
	6360	133	C. L. Breger, 1909. SW¼ sec. 30, T. 12 S., R. 46 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Leeds Creek Member, in upper part of the formation, probably below a red-bed unit in white-weathering shaly limestone.
23	6638	1554	T. W. Stanton, 1910. North side of Indian Creek, NE. cor. sec. 30, T. 15 S., R. 45 E., Montpelier 30-min quad., Bear Lake County, Idaho. Twin Creek Limestone, Sliderock Member, lower 100 ft.
	6639	1555	T. W. Stanton, 1910. Same location as 6638. Twin Creek Limestone, near top of Sliderock Member and about 200 ft stratigraphically higher than Mesozoic loc. 6638.
24	3831		H. C. Schluter, 1906. 330 feet north of SE. cor. sec. 13, T. 39 N., R. 115 W., Jackson 15-min quad., Teton County, Wyo. Twin Creek Limestone, Leeds Creek Member.
25	27727		R. W. Imlay and N. F. Sohl, 1960. Cabin Creek, S½ sec. 17, T. 38 N., R. 116 W., Teton County, Wyo. Twin Creek Limestone, Leeds Creek Member, near base of unit 16 of published section (Imlay, 1953a, p. 62).
	27728		R. W. Imlay and N. F. Sohl, 1960. Cabin Creek, S½ sec. 17, T. 38 N., R. 116 W., Teton County, Wyo. Twin Creek Limestone, Leeds Creek Member, near middle of unit 16 (Imlay, 1953a, p. 62).
	28862		R. W. Imlay, 1964. Cabin Creek, same location as 27727. Twin Creek Limestone, Leeds Creek Member, about 70 ft above base.
26	7217	1103/C	Eliot Blackwelder, 1911. Foot of Shoal Creek Falls, south side Gros Ventre Mountains, T. 38 N., R. 114 W., Jackson 30-min quad., Sublette County, Wyo. Twin Creek Limestone, member unknown.
27	3848		E. E. Smith, 1906. West of Cliff Creek, 550 ft north of SW. cor. sec. 22, T. 38 N., R. 114 W., Jackson 30-min quad., Sublette County, Wyo. Twin Creek Limestone, member unknown.
28	3830		B. A. Iverson, 1906. North-central part of sec. 33, T. 38 N., R. 115 W., Jackson 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Leeds Creek Member.
	3834		E. E. Smith, 1906. 4,125 ft north of SE. cor. sec. 33, T. 38 N., R. 115 W., Jackson 15-min quad., Lincoln County, Wyo. Twins Creek Limestone, Leeds Creek Member.
29	3808		E. E. Smith, 1906. 1,200 ft east of NW. cor. sec. 31, T. 37 N., R. 114 W., Sublette County, Wyo. Twin Creek Limestone, probably Leeds Creek Member.
30	16031	AW.172	W. W. Rubey and J. S. Williams, 1931. On ridge about 1¼ miles northwest of peak of Lookout Mountain, in SE. cor. sec. 21, T. 35 N., R. 115 W., Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Leeds Creek Member.
31	16036	AW.180	W. W. Rubey and J. S. Williams, 1931. Hill about 3⅛ miles southeast of peak of Lookout Mountain. Elevation about 9,200 ft, in NE¼SW¼SW¼ sec. 6, T. 34 N., R. 114 W., Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, about 15–20 ft above red siltstone.
32	3839		E. E. Smith, 1906. 2,200 ft east and 1,100 ft north of NE. cor. sec. 24, T. 34 N., R. 115 W., in sec. 18, T. 34 N., R. 114 W., Sublette County, Wyo. Twin Creek Limestone, Leeds Creek Member.
33	3859		W. H. Longhurst, 1906. North side of South Fork of Cottonwood Creek, T. 32 N., R. 115 W., Sublette County, Wyo. Twin Creek Limestone.
34	9102	Ry. 62	G. R. Mansfield, 1914. East side of south end of The Narrows in Star Valley, SE¼ sec. 13, T. 33 N., R. 119 W., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member.
35	9101	Ry. 61	G. R. Mansfield, 1914. About 2½ miles east of The Narrows of Star Valley, SW¼ sec. 20, T. 33 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, lower part.
36	12018	N.E	E. M. Parks and C. S. Lavington, 1923; ⅘ mile up Swift Creek about 1½ miles east of Afton, Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, near base.
37	12034	T	E. M. Parks and C. S. Lavington, 1923. Near road along Crow Creek on west limb of anticline. Southwest of center of sec. 17, T. 31 N., R. 119 W., Crow Creek 15-min quad., Lincoln County, Wyo. Twin Creek Limestone, Giraffe Creek Member, within 50 ft of top.
38	12119	G.G	E. M. Parks and C. S. Lavington, 1923; ¾ mile northeast of Smoot, Star Valley, Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, 150 ft above base.
39	16058	AW 233	W. W. Rubey and J. S. Williams, 1931. Cottonwood Creek about ¼ mile west of Cottonwood Lake, about 5 miles northeast of Smoot, Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, lower part, vertical beds as much as 5 ft thick.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
40	12016	B	E. M. Parks and C. S. Lavington, 1923. Entrance to Cottonwood Canyon 2 miles southeast of Smoot, Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Leeds Creek Member, less than 500 ft stratigraphically below top of formation in well-bedded splintery blue shale containing thin lenses of limestone.
	12019	C	E. M. Parks and C. S. Lavington, 1923. Entrance of Cottonwood Canyon, 2 miles southeast of Smoot, Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, within 200 ft of base. Thick-bedded coarsely crystalline limestone containing pyrite and calcite veins.
41	3842		B. A. Iverson, 1906; 1,100 ft east of NE. cor. sec. 30, T. 31 N., R. 114 W., Sublette County, Wyo. Twin Creek Limestone, member unknown.
	3860		E. E. Smith and B. A. Iverson, 1906. North of North Piney Creek, east side of anticline, T. 31, N., R. 114 W., Sublette County, Wyo. Twin Creek Limestone.
42	17297	36–25	W. W. Rubey, 1936. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone, Rich Member, 118 ft above base.
	17298	36–26	W. W. Rubey, 1936. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone, Watton Canyon Member, 320 ft above base of formation.
	17299	36–27	W. W. Rubey, 1936. Gorge of Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone, basal part of Watton Canyon Member, 390 ft above base of formation.
	17319	36–49	W. W. Rubey, 1936. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone from 50 to 75 ft above loc. 17299 in Leeds Creek Member.
	20960	I–47–8–15A	R. W. Imlay, 1947. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Sublette County, Wyo. Twin Creek Limestone, Leeds Creek Member, from 65 to 88 ft above base of member.
	20980	I–47–8–15B	R. W. Imlay, 1947. South Piney Creek in sec. 11, T. 29 N., R. 115 W., Sublette County, Wyo. Twin Creek Limestone, upper part of Rich Member, about 200–240 ft above base of formation.
	28482		J. C. Wright and R. W. Imlay, 1961. South Piney Creek on north side of road, sec. 11, T. 29 N., R. 115 W., Sublette County, Wyo. Twin Creek Limestone, top of Watton Canyon Member.
	28485		J. C. Wright, Yaacov Nir, and R. W. Imlay, 1961. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone, lower half of Watton Canyon Member.
	28486		J. C. Wright, Yaacov Nir, and R. W. Imlay, 1961. South Piney Creek, sec. 11, T. 29 N., R. 115 W., Afton 30-min quad., Sublette County, Wyo. Twin Creek Limestone, top of Rich Member.
43	3817		B. A. Iverson, 1906. East of La Barge Creek, 180 ft north of NE. cor. sec. 24, T. 29 N., R. 116 W., Lincoln County, Wyo. Twin Creek Limestone, member unknown.
44	17294	36–22	W. W. Rubey, 1936. Sec. 2, T. 28 N., R. 116 W., Afton 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, lower part of Leeds Creek Member, about 500 ft above base of formation.
45	20971	I–47–8–21A	R. W. Imlay, 1947. Thomas Fork Canyon, north-central part of sec. 24, T. 28 N., R. 120 W., Montpelier 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from upper part of Sliderock Member.
	20988	I–47–8–21B	R. W. Imlay, 1947. North-central part of sec. 24, T. 28 N., R. 120 W., Montpelier 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from upper part of Sliderock Member.
	20990	I–47–8–22A	R. W. Imlay, 1947. North side of Thomas Fork Canyon in north-central part of sec. 19, T. 28 N., R. 119 W., Montpelier 30-min quad., Lincoln County, Wyo Twin Creek Limestone, middle part of Boundary Ridge Member, from unit 10 of published section (Imlay, 1950a, p. 44).
	27729		N. F. Sohl, 1960. Thomas Fork Canyon, N½ sec. 24, T. 28 N., R. 120 W., Montpelier 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member.
	28483		J. C. Wright, Yaacov Nir, and R. W. Imlay, 1961. Thomas Fork Canyon, N½ sec. 24, T. 28 N., R. 120 W., Montpelier 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
46	6364	228	G. H. Girty, 1909. West side of Sublette Range, NW¼ NE¼ sec 17, T. 27 N., R. 119 W., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member.
47	21628	I–49–9–2	R. W. Imlay and John McIntyre, 1949. Ferney Gulch, SW¼ sec. 1, T. 27 N., R. 117½ W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
48	20961	I–47–7–28C	R. W. Imlay, 1947. Head of Middle Fork of Devils Hole Creek in SE. cor. of sec. 15, T. 27 N., R. 117 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from upper 10 ft of Sliderock Member.
	20968	I–47–8–28B	R. W. Imlay, 1947. Head of North Fork of Devils Hole Creek in NE¼ sec. 15, T. 27 N., R. 117 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from upper 3 ft of Sliderock Member.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
	20972	I–47–7–28A	R. W. Imlay, 1947. Same location as 20968. Devils Hole Creek, Wyo. Twin Creek Limestone, from 18 ft of medium-bedded limestone 10 ft below top of Sliderock Member and 80 ft above base.
49	22017	C2–47	G. E. Lewis, 1947. South-central sec. 16, T. 27 N., R. 116 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, 25 ft above base of Sliderock Member.
50	20963	I–47–8–12A	R. W. Imlay, 1947. West side of Sheep Creek near La Barge Creek in NW¼ sec. 16, T. 27 N., R. 115 W., Cokeville 30-min quad., Sublette County, Wyo. Twin Creek Limestone, upper 30 ft of Rich Member, from 305 to 335 ft above base of formation.
	20983	I–47–8–12C	R. W. Imlay, 1947. North side La Barge Creek, NE¼ sec. 17, T. 27 N., R. 115 W., Cokeville 30-min quad., Sublette County, Wyo. Twin Creek Limestone, 158 ft below top of Leeds Creek Member, from upper part of unit 28 of published section (Imlay, 1950a, p. 42).
	20992	I–47–8–12B	R. W. Imlay, 1947. North side of La Barge Creek, NW¼ sec. 16, T. 27 N., R. 115 W., Sublette County, Wyo. Twin Creek Limestone, about 150 ft above base of Watton Canyon Member and 16 ft below top of unit 12 of published section (Imlay, 1950a, p. 42).
	28639	I–62–6–9a	R. W. Imlay, 1962. Sheep Creek about ½ mile north of La Barge Creek in NW¼ sec. 16, T. 27 N., R. 115 W., Cokeville 30-min quad., Sublette County, Wyo. Twin Creek Limestone, float from upper 40 ft of Rich Member.
51	22796	39–3	W. W. Rubey, 1939. SE¼ sec. 13, T. 27 N., R. 115 W., Cokeville 30-min quad., Sublette County, Wyo. Twin Creek Limestone, 300± ft above base near top of Rich Member.
52	3815		B. A. Iverson, 1906. About 600 ft east of NW. cor. sec. 4, T. 26 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member.
53	21629	I–49–9–5a	R. W. Imlay and John McIntyre, 1949. South Fork Fontenelle Creek, NW¼ sec. 33, T. 26 N., R. 116 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, about middle of Rich Member and about 100 ft below its top.
54	20979	I–47–7–13A	R. W. Imlay, 1947. Near head of Chapple Creek, NE¼SE¼ sec. 35, T. 26 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
	20985	I–47–7–26D	R. W. Imlay, 1947. NW. cor. sec. 36, T. 26 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
55	20344	I–46–9–14D	J. B. Reeside, Jr. and R. W. Imlay, 1946. North side of Sliderock Creek on center of line of secs. 10 and 11, T. 25 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member from 200 to 215 ft above base of formation.
	20346	I–46–9–14A	J. B. Reeside, Jr., 1946. Sliderock Creek, west half of sec. 10, T. 25 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from very top of Giraffe Creek Member.
	20347	I–46–9–14B	J. B. Reeside, Jr., 1946. Sliderock Creek, near center of sec. 10, T. 25 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, about middle of Leeds Creek Member.
	20348	I–46–9–14C	R. W. Imlay, 1946. Sliderock Creek, near center of sec. 10, T. 25 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, about middle of Leeds Creek Member, slightly below 20347.
	20970	I–47–8–3	R. W. Imlay, 1947. Same locality as 20344. Twin Creek Limestone, top of Sliderock Member.
	20973		R. W. Imlay, 1947. Same locality as 20344. Twin Creek Limestone, upper 15 ft of Sliderock Member.
	28484		J. C. Wright, Yaacov Nir, and R. W. Imlay, 1961. North side of Sliderock Creek on center of line of secs. 10 and 11, T. 25 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, about 30–40 ft below top.
	28481		Yaacov Nir, 1961. Sliderock Creek area, center of sec. 10, T. 25 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, near middle of Leeds Creek Member.
56	28794	I–63–7–4A	R. W. Imlay, 1963. North side of Dry Hollow, west of Cokeville, NW¼ sec. 12, T. 24 N., R. 120 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, middle and upper parts.
57	20978	I–47–7–13	R. W. Imlay, 1947. NW¼ sec. 5, T. 24 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, about 20 ft below top of Sliderock Member.
58	20345	I–46–9–15B	J. B. Reeside, Jr. and R. W. Imlay, 1946. North side of Pine Creek, SE¼SW¼ sec. 34, T. 25 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, from upper 30 ft of Sliderock Member.
59	25261	R2–54	W. W. Rubey, 1954. NE¼ sec. 5, T. 24 N., R. 116 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, top bed of Gypsum Spring Member.

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Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
60	3800		E. E. Smith, 1906. About 900 ft east and 600 ft north of NW. cor. sec. 13, T. 25 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, probably from Sliderock Member.
61	3822		A. R. Schultz, 1906. South bank of Fontenelle Creek, T. 24 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, lower part.
	28789	I–63–7–12A	R. W. Imlay, 1963. North side of Fontenelle Gap, about ¼ mile north of creek in north-central part of sec. 4, T. 24 N., R. 115 W., Fort Hill 7½-min quad., Lincoln County, Wyo. Twin Creek Limestone, near base of Rich Member.
	28790	I–63–7–13A	R. W. Imlay, 1963. North side of Fontenelle Gap, SW¼NE¼ sec. 5, T. 24 N., R. 115 W., Fort Hill 7½-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper 40 ft of Rich Member.
62	3821		A.R. Schultz, 1906. Slate Creek, halfway through canyon, T. 23 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member.
	17815		R. W. Brown and C. W. Mumm, 1938. About ⅓ way up north slope of Slate Creek Canyon about 12 miles northeast of Kemmerer, in sec. 21, T. 23 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member.
	28785	I–63–7–11	R. W. Imlay, 1963. North side of Slate Creek Canyon, near center of anticline in NE¼ sec. 28, T. 23 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member, from lower 50 of 130 ft of exposed part of member.
	28786	I–63–8–3A	R. W. Imlay, 1963. North side of Slate Creek Canyon in NW¼ sec. 27, T. 23 N., R. 115 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member, float from upper 30 ft.
	28787	I–63–8–3B	R. W. Imlay, 1963. Same location as 28786. Twin Creek Limestone, Rich Member, from ledge 65 ft below top.
	28788	I–63–8–3C	R. W. Imlay, 1963. Same location as 28786. Twin Creek Limestone, Rich Member, from lower 60 ft of 130 ft of exposed part of member.
63	20969	I–47–8–19A	R. W. Imlay, 1947. Head of Underwood Canyon, NE. cor. sec. 6, T. 23 N., R. 118 W., Cokeville 30-min quad., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
64	20984	I–47–7–12A	R. W. Imlay, 1947. SE¼SE¼ sec. 7, T. 23 N., R. 118 W., Lincoln County, Wyo Twin Creek Limestone, Sliderock Member.
65	20965	I–47–7–24B	R. W. Imlay, 1947. North side of Leeds Creek Canyon, center of S½ sec. 30, T. 23 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, 38–40 ft above base of Rich Member and 210 ft above base of formation.
	20966	I–47–7–24A	R. W. Imlay, 1947. Leeds Creek. Same locality as 20965. Twin Creek Limestone, Sliderock Member, upper 20 ft.
	20975	I–47–7–12C	R. W. Imlay, 1947. Near Leeds Creek, center S½ sec. 30, T. 23 N., R. 118 W. Lincoln County, Wyo. Twin Creek Limestone, from upper 20 ft of Sliderock Member.
	20977	I–47–7–12B	R. W. Imlay, 1947. Near Leeds Creek, west center of NE¼ sec. 30, T. 23 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, upper part of Sliderock Member.
	20981		R. W. Imlay, 1947. Head of Leeds Creek Canyon, S½ of sec. 30, T. 23 N., R. 118 W., Lincoln County, Wyo. Twin Creek Limestone, near top of Sliderock Member.
	20987	I–47–7–24B	R. W. Imlay, 1947. Same location as 20965. Twin Creek Limestone, 35–40 ft above base of Rich Member.
	20991	I–47–7–24C	R. W. Imlay, 1947. North side of Leeds Canyon, SW¼ sec. 30, T. 22 N., R. 119 W., Lincoln County, Wyo. Twin Creek Limestone, Leeds Creek Member, from 6 ft of silty limestone 97 ft above base of member.
	28798	I–63–7–4B	R. W. Imlay, 1963. Head of North Fork of Leeds Creek in west-central part SW¼SE¼ sec. 30, T. 23 N., R. 118 W., Sage 7½-min quad., Lincoln County, Wyo. Twin Creek Limestone, Sliderock Member, upper part.
66	3391		A. C. Veatch, 1905. 2 miles northwest of Nugget Station, Lincoln, County, Wyo. Near NW. cor. sec. 6, T. 21 N., R. 118 W. Twin Creek Limestone, Sliderock Member.
	3392		A. C. Veatch, 1905. About 9 miles west of Fossil, Lincoln County, Wyo. NE¼ sec. 1, T. 21 N., R. 119 W. Twin Creek Limestone, lower part.
	20350	I–46–9–13	J. B. Reeside, Jr. and R. W. Imlay, 1946. North side of road, about 4 miles east of Sage in north-central part of sec. 2, T. 21 N., R. 119 W., Lincoln County, Wyo. Twin Creek Limestone, Rich Member.
67	6373		C. L. Breger, 1909. North Eden Canyon, near Bear Lake, Rich County, Utah Twin Creek Limestone, lower part.
68	6363	188	C. L. Breger, 1909. SE¼ sec. 27, T. 14 N., R. 6 E., South Eden Canyon, 2 miles east of Bear Lake, Rich County, Utah. Twin Creek Limestone, Rich Member, in light-weathering softer shaly beds.
	8181	Ry. 133a	P. V. Roundy for G. B. Richardson, 1912. Near center sec. 27, T. 14 N., R. 6 E., north side South Eden Canyon about 2 miles from Bear Lake, Randolph 30-min quad., Rich County, Utah. Twin Creek Limestone, probably from Rich Member.
	21618	I–49–7–15	R. W. Imlay and John McIntyre, 1949. North side of road, South Eden Canyon, sec. 27, T. 14 N., R. 6 E., Randolph 30-min quad., Rich County, Utah. Twin Creek Limestone, from upper 30 ft of Sliderock Member.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
69	8177	Ry.77	P. V. Roundy for G. B. Richardson, 1912. About 12 miles west of Woodruff, probably NE¼ sec. 23, T. 9 N., R. 5 E., Randolph 30-min quad., Rich County, Utah. Twin Creek Limestone, Sliderock Member.
70	6362	167	C. L. Breger, 1909; 8 miles due west of Woodruff, 1 mile northeast of the reservoir on Birch Creek, probably sec. 18, T. 9 N., R. 6 E., Randolph 30-min quad., Rich County, Utah. Twin Creek Limestone, Rich Member, in the light-weathering shaly beds.
71	28644	I-62-5-16A	R. W. Imlay, 1962. Near top of hill just north of confluence of Birch Creek and Watton Canyon in NE¼NW¼ sec. 20, T. 9 N., R. 6 E., Randolph 30-min quad., Rich County, Utah. Twin Creek Limestone, Sliderock Member, upper part, from 62 ft of medium- to thin-bedded limestone.
	28645	I-62-5-16B	R. W. Imlay, 1962. About ¼ mile up Birch Creek from Watton Canyon confluence on north side of road just west of crest of ridge in NW¼NW¼ sec. 20, T. 9 N., R. 6 E., Rich County, Utah. Twin Creek Limestone, Sliderock Member, about 45 ft below top.
	28646	I-62-5-16C	R. W. Imlay, 1962. About ¼ mile west of loc. 28645, just north of road in NE¼ sec. 19, T. 9 N., R. 6 E., Rich County, Utah. Twin Creek Limestone, Sliderock Member, rubbly limestone in upper part.
	28647	I-62-5-17A	R. W. Imlay, 1962. Top of hill north of Birch Creek, in NW. cor. sec. 20, T. 9 N., R. 6 E., Rich County, Utah. Twin Creek Limestone, Sliderock Member. From top of rubbly linestone overlying 16 ft of ledge-forming sandstone and underlying 5 ft of shaly linestone. About 135 ft below top of member.
	28648	I-62-5-17C	R. W. Imlay, 1962. Same location as 28645 but a little higher stratigraphically. Twin Creek Limestone, Sliderock Member. Mostly from 32–37 ft above base of 62 ft of medium-bedded linestone forming upper part of member but partly from float directly below.
72	22638	I-51-7-3a	R. W. Imlay, 1951. On Woodruff Creek, about ⅔ mile below mouth of Sugar Pine Canyon and 10 miles southwest of Woodruff, SE¼ sec. 3, T. 8 N., R. 5 E., Rich County, Utah. Twin Creek Limestone, upper 6 ft of Sliderock Member.
73	28642		R. W. Imlay, 1962. North side of Weber River Canyon, north of Devils Slide, sec. 24, T. 4 N., R. 3 E., Morgan County, Utah. Twin Creek Limestone, Sliderock Member, from medium-bedded linestone 30–40 ft above basal oolitic limestone.
74	2906	901	T. W. Stanton, 1903. Low hills on north side of Weber Canyon, 1 mile above Croydon Station just below mouth of Lost Creek, Morgan County, Utah. Twin Creek Limestone, talus from upper part of Leeds Creek Member.
75	28478		R. W. Imlay, 1961. On south side of U.S. Highway 30S, sec. 24, T. 4 N., R. 3 E., Weber River Canyon, Morgan County, Utah. Twin Creek Limestone, near top of Rich Member. In shaly linestone about 40 ft below oolite forming the western ledge of Devils Slide.
	28641		R. W. Imlay, 1962. On south side of Weber River Canyon, a little west of Devils Slide, sec. 24, T. 4 N., R. 3 E., Morgan County, Utah. Twin Creek Limestone, Sliderock Member, float found 30 ft above basal oolitic limestone of member.
76	28643		R. W. Imlay and T. E. Mullens, 1962. In railroad cut east of railroad bridge across Weber River at town of Devils Slide, Morgan County, Utah. Twin Creek Limestone, Leeds Creek Member.
77	21619	I-49-8-25A	John McIntyre, 1949. NE¼ sec. 1, T. 1 S., R. 6 E., Weber Canyon, Summit County, Utah. Twin Creek Limestone, Sliderock Member, about 11 ft above thin bed of green tuff at top of Gypsum Spring Member.
78	6948	7	J. W. Boutwell, 1902. West end of Uinta Mountain uplift on nose of spur between White Creek and Whites Basin, north of Weber Canyon, SW¼ sec. 10, T. 1 S., R. 6 E., Summit County, Utah. Twin Creek Limestone.
79	985		T. W. Stanton, 1892; 1 mile north of Peoa, on east side of U.S. Highway 189 in NW¼ sec. 14, T. 1 S., R. 5 E., Summit County, Utah. Twin Creek Limestone, Rich Member. From 225 ft of shaly limestone forming lower exposures in the formation.
	28476		R. W. Imlay, 1961; 1 mile north of Peoa, on east side of U.S. 189, sec. 14, T. 1 S., R. 5 E., Summit County, Utah. Twin Creek Limestone, Rich Member, 15–35 ft above base of lowest exposed limestone.
80	28791	63 MC-28	M. D. Crittenden, Cal Bromfield, and R. W. Imlay, 1963. SW. cor. sec. 30, T. 1 S., R. 4 E., Park City West 7½-min quad., Summit County, Utah. Twin Creek Limestone, Boundary Ridge Member, about 15–20 ft below top.
81	3218	116	H. T. Boutwell and J. M. Boutwell, 1904. South side of ridge, NW¼SE¼SW¼ sec. 2, T. 2 S., R. 3 E., Park City West 7½-min quad., Summit County, Utah. First limestone above Nugget Sandstone. Twin Creek Limestone, Sliderock Member.
	3219	117	J. M. Boutwell and H. T. Boutwell, 1904. Same location as 3218 but on north side of divide. Twin Creek Limestone, Sliderock Member, 45 ft above Nugget Sandstone.
	3220	118	J. M. Boutwell and H. T. Boutwell, 1904. Same location as 3218. Twin Creek Limestone.
	3221	119	J. M. Boutwell and H. T. Boutwell, 1904. Same location as 3318. North side of divide, 200–225 ft above Nugget Sandstone in Twin Creek Limestone, lower part.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
82	17964	38–61	A. A. Baker, 1938. On east side of new railroad grade on north line of sec. 15, T. 4 S., R. 4 E., Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, Sliderock Member, about 10 ft above base.
83	17961	38–40	A. A. Baker, 1938. Near summit of hill about 1½ miles due west of Charleston in the SW¼ sec. 16, T. 4 S., R. 4 E., at west line of Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, Sliderock Member, about 60 ft above base.
84	17985	38–174	A. A. Baker, 1938. North of Lake Creek road in SE¼ sec. 33, T. 3 S., R. 5 E., Coalville 30-min quad., Wasatch County, Utah. Twin Creek Limestone, Sliderock Member, basal part.
85	17982	38–171	A. A. Baker, 1938. From ledges along Lake Creek road at northeast end of main outcrop, about 3 miles due east of center of town of Heber and ½ mile north of north boundary of Strawberry Valley 30-min quad., SW¼SW¼ sec. 35, T. 3 S., R. 5 E., Wasatch County, Utah. Twin Creek Limestone, lower part.
86	17983	38–172	A. A. Baker, 1938. In SE¼ sec. 3, T. 4 S., R. 5 E., north of Lake Creek road, Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, lower part.
	17984	38–173	A. A. Baker, 1938; 1,000 ft west of loc. 17983, on west end of knoll on north boundary of quadrangle, near center of sec. 3, T. 4 S., R. 5 E., Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, lower part.
87	17976	38–152	A. A. Baker, 1938. On top of ridge in NW¼ sec. 23, T. 1 S., R. 12 W., northwest of Right Fork of Strawberry River, Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, lower part.
	17977	38–153	A. A. Baker, 1938. On top of ridge in NW¼ sec. 23, T. 1 S., R. 12 W., Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, lower part.
	17978	38–154	A. A. Baker, 1938. An isolated outcrop on north end of ridge in SW¼ sec. 14, T. 1 S., R. 12 W., Strawberry Valley 30-min quad., Wasatch County, Utah. Twin Creek Limestone, lower part.
88	21623	I–49–8–27A	R. W. Imlay and John McIntyre, 1949. Northwest side of Sand Creek in north-central part of sec. 7, T. 1 S., R. 8 W., near north section line, Duchesne County, Utah. Twin Creek Limestone. From 4 ft of oolitic limestone about 44 ft below top of Watton Canyon Member.
	21624	I–49–8–27B	R. W. Imlay and John McIntyre, 1949. Northwest side of Sand Creek, in north-central part of sec. 7, T. 1 S., R. 8 W., Duchesne County, Utah. Twin Creek Limestone, Watton Canyon Member, 3 ft above base.
89	21620	I–49–8–26A	John McIntyre, 1949. Southwest side of Duchesne River, in SW¼ sec. 4, T. 1 S., R. 8 W., Duchesne County, Utah. Twin Creek Limestone, Rich Member, from shaly limestone in lower 40 ft of member.
	21621	I–49–8–26B	R. W. Imlay and John McIntyre, 1949. Near top of cliff on southwest side of Duchesne River at same locality as 21620, Duchesne County, Utah. Twin Creek Limestone, Boundary Ridge Member. From brown limestone 3–4 ft below massive oolitic limestone at base of Watton Canyon Member.
	21622	I–49–8–26C	R. W. Imlay, 1949. Near top of ridge on southwest side of Duchesne River at same locality as 21620, Duchesne County, Utah. Twin Creek Limestone, float from cliff-forming limestone in upper 44 ft of Watton Canyon Member.
90	17048		E. M. Spieker and J. B. Reeside, Jr., 1935. Gap of Duchesne River about 3 miles north of Tabiona on road from Duchesne to Kamas, SW. cor. sec. 3, T. 1 S., R. 8 W., Duchesne County, Utah. Twin Creek Limestone, about 60 ft above base of Rich Member and 100 ft above top of Nugget Sandstone.
	20349	I–46–9–12A	J. B. Reeside, 1946. North side of road in SW. cor. sec. 3, T. 1 S., R. 8 W., Duchesne County, Utah. Twin Creek Limestone, Rich Member, from shaly limestone below highest oolite unit.
	28793	I–63–8–12A	R. W. Imlay, 1963. North side of Ducheshe River in SW. cor. sec. 3, T. 1 S., R. 8 W., Duchesne County, Utah. Twin Creek Limestone, Rich Member, near middle in thin-bedded limestone.
91	28792	I–63–8–10	R. W. Imlay, 1963. East side of Farm Creek, south-central part of SE¼ sec. 31, T. 1 N., R. 7 W., Duchesne County, Utah. Twin Creek Limestone, Rich Member, near middle.
92	21468	1	J. W. Huddle, 1948. Lake Fork, east side of canyon in sec. 3, T. 1 N., R. 5 W., Duchesne County, Utah. Twin Creek Limestone. Float about 50 ft above the base of formation on lower part of the Rich Member.
93	17674	A9	A. A. Baker and M. N. Bramlette, 1937. East side of Red Hollow in NW¼ sec. 28, T. 8 S., R. 5 E., Strawberry Valley 30-min quad., Utah County, Utah. Twin Creek Limestone, Sliderock Member 50–75 ft above Navajo Sandstone.
94	17683	A27	A. A. Baker and M. N. Bramlette, 1937. East side of Monks Hollow near mouth in SE¼ sec. 32, T. 8 S., R. 5 E., Strawberry Valley 30-min quad., Utah County, Utah. Twin Creek Limestone, Leeds Creek Member, near base.
	17678	A14	A. A. Baker and M. N. Bramlette, 1937. Monks Hollow, sec. 5, T. 9 S., R. 5 E., Strawberry Valley 30-min quad., Utah County, Utah. Twin Creek Limestone, Giraffe Creek Member, about 75 ft below base of Preuss Sandstone.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
95	3548	R-5-50	G. B. Richardson, 1905. Thistle Junction, Utah County, Utah. Twin Creek Limestone.
	17064	F.19	E. M. Spieker and J. B. Reeside, Jr., 1935. Spanish Fork Canyon opposite mouth of Lake Fork Canyon, not far above Thistle, Utah County, Utah. Twin Creek Limestone, Leeds Creek Member.
	17673	A8	A. A. Baker and M. N. Bramlette, 1937. Top of high cliff northeast of Thistle on north side of Spanish Fork, Utah County, Utah. Twin Creek Limestone, Sliderock Member, about 75 ft above top of Navajo Sandstone.
	22657		Collector unknown, 1951(?). Cut south of railroad tracks. 50 yd east of automobile bridge at Thistle, Utah County, Utah. Twin Creek Limestone, from lower few hundred feet exposed in cut.
	27637		J. C. Wright and R. P. Snyder, 1960. From ridge north of highway just east of Thistle, sec. 28, R. 9 S., R. 4 E., Utah County, Utah. Twin Creek Limestone, Watton Canyon Member. From 15 ft of medium- to thin-bedded limestone about 42–57 ft above base of member.
96	28457		R. W. Imlay and N. F. Sohl, 1961. 2 miles southwest of Thistle, near mouth of Crab Creek Canyon, SW¼ sec. 5, T. 10 S., R. 4 E., Utah County, Utah. Twin Creek Limestone, float from top of Sliderock Member (unit 2 of Harris, 1954, p. 199).
	28458		R. W. Imlay and N. F. Sohl, 1961. Same location as 28457 except fossils obtained from outcrop at top of the Sliderock Member.
	28459		R. W. Imlay and N. F. Sohl, 1961. Same data as 28457 except from middle of Sliderock Member.
	28460		R. W. Imlay and N. F. Sohl, 1961. From Crab Creek, 2 miles southwest of Thistle, Utah County, Utah. Twin Creek Limestone, base of Watton Canyon Member (equals unit 7 of Harris, 1954, p. 198).
97	17019	S31F10	E. M. Spieker, 1931. On left fork of Lake Fork, near Smith's Reservoir, in northwest part of T. 11 S., R. 5 E., Utah County, Utah. Twin Creek Limestone.
98	19192		R. W. Imlay and H. C. Yingling, 1944. North side of Swift Reservoir in Birch Creek, sec. 27, T. 28 N., T. 10 W., Pondera County, Mont. Sawtooth Formation, about 20 ft above base in lower part of shale member (equals unit 6 of Cobban, 1945, p. 1295) directly above several inches of conglomerate.
	28825	FE27-61	H. W. Frebold, 1961. Swift Reservoir, NE¼ sec. 27, T. 28 N., R. 10 W., Pondera County, Mont. Sawtooth Formation. From conglomerate bed (equals unit 5 of Cobban, 1945, p. 1295) in lower part of shale member.
	28826	FE27a-61	H. W. Frebold, 1961. Same location as 28825 but 14 ft higher stratigraphically (equals unit 10 of Cobban, 1945, p. 1295) in the Sawtooth Formation.
99	27337	MK-58-T1-11	M. E. Kaufman, 1958. From gully southeast of Tigh Creek about 3 miles west of Drummond, east-central part of sec. 34, T. 11 N., R. 13 W., Drummond 30-min quad., Granite County, Mont. Sawtooth Formation, near middle of basal unit in brownish-gray siltstone.
100	21391	S-1157	R. W. Swanson, 1939. Madison Range, Jack Creek at road, NE¼SW¼ sec. 35, T. 5 S., R. 1 E., Madison County, Mont. Sawtooth Formation.
	22170	S-1109	R. W. Swanson, 1938. Madison Range, Jack Creek at road, NE¼SW¼ sec. 35, T. 5 S., R. 1 E., Madison County, Mont. Sawtooth Formation.
101	28758	S-1206	R. W. Swanson and W. H. Bucher, 1941. Madison Range. Crest of narrow spur halfway up south slope of main ridge at elevation of 7,150 ft, in SE¼SW¼ sec. 30, T. 6 S., R. 4 E., about 2 miles west of Gallatin River, Gallatin County, Mont. Sawtooth Formation.
102	28670	W9-406	I. J. Witkind, 1962. Near head of east fork of Red Canyon Creek, north-central part of NW¼ sec. 24, T. 11 S., R. 4 E., Tepee Creek 15-min quad., Gallatin County, Mont. Sawtooth Formation, near base.
	28800	I-63-7-30A	R. W. Imlay and I. J. Witkind, 1963. Same location as 28670. Sawtooth Formation, lower 20 ft.
103	8096	53	C. F. Bowen and Harvey Bassler, 1912. East end of Bearpaw Mountains, SW¼ SW¼ sec. 1, T. 28 N., R. 20 E., Blaine County, Mont. Piper Formation (in part).
04	19153	FE-2a	J. B. Reeside, Jr., W. A. Cobban, and R. W. Imlay, 1944. North side of Rocky Creek on north side of U.S. Highway 10 about 3.7 miles southeast of site of Fort Ellis in sec. 19, T. 2 S., R. 7 E., float from top of unit 8 of described section (Cobban, Imlay, and Reeside, 1945, p. 452). Piper Formation, from shale and shaly limestone about 59 ft below top of formation.
	19158	FE-1	J. B. Reeside, Jr., W. A. Cobban, and R. W. Imlay, 1944. Same location as 19153. From 14½ ft of shale and shaly limestone forming unit 6 of described section (Cobban, Imlay, Reeside, 1945, p. 452). Piper Formation, about 28 ft above base and 97 ft below top of formation.
105	15635		D. A. Andrews, 1930. Yellowstone Canyon, 2½ miles south of Livingston, Park County, Mont. Piper Formation, middle limestone member.
	19214		A. C. Peale, 1872. Near lower canyon of Yellowstone River, Mont. Piper Formation, middle limestone member.
	25866	Y-55-18	A. E. Roberts, 1955; 1,250 ft north and 2,150 ft east of SW. cor. sec. 35, T. 2 S., R. 9 E., Park County, Mont. Piper Formation, middle limestone member, from 59 ft of silty limestone.

Descriptions of some Jurassic localities in the Twin Creek Limestone and contemporary formations in Montana, Wyoming, Utah and southeastern Idaho—Continued

Locality on figs. 16–18	USGS Mesozoic locality	Collector's field No.	Collector, year of collection, description of locality, and stratigraphic assignment
105	27628		N. F. Sohl and R. W. Imlay, 1960. On west side of mouth of Canyon of Yellowstone River 2½ miles southwest of Livingston in secs. 26 and 35, T. 2 S., R. 9 E., Park County, Mont. Piper Formation, middle limestone member, from middle of 7 ft of light-gray massive limestone whose base is 136 ft above the Quadrant Quartzite. Collections from locs. 15625, 19214, and 25966 are either from this unit or from overlying 14 ft of limestone.
106	19630	I–45–7–5B	L. S. Gardner, C. P. Rogers, William Saalfrank, and R. W. Imlay, 1945. West side of Boulder River about 20 miles south of Big Timber in sec. 23, T. 3 S., R. 12 E., Sweet Grass County, Mont. Piper Formation, middle limestone member. From 6 to 9 ft of shaly limestone whose base is 23 ft above the top of the lower red bed.
	27624		N. F. Sohl, Grant Bartlett, Stanley Hashimoto, and R. W. Imlay, 1960. West side of Boulder River in sec. 23, T. 3 S., R. 12 E., Sweet Grass County, Mont. Piper Formation, middle limestone member. From 9 ft of dark-gray thin-bedded limestone whose base is 52 ft above the top of the lower red-bed member, 165 ft below top of formation, and 20 ft above loc. 19630.
107	27035	R–58–3	A. E. Roberts and R. W. Imlay, 1958. About ½ mile west of Yellowstone River in NE¼SE¼ sec. 7, T. 4 S., R. 9 E., Park County, Mont. Piper formation, middle limestone member, lower part.
108	5738	C23	W. R. Calvert, 1908; ½ mile northwest of Electric, Park County, Mont. Piper Formation.
	19621	I–45–7–6A	R. W. Imlay and William Saalfrank, 1945. Cinnabar Mountain, 6 miles northwest of Gardner, sec. 36, T. 8 N., R. 7 E., Park County, Mont. Piper Formation, from 11 ft of dark shaly limestone, 54 ft below main diabase sill near middle of formation.
109	17662	F–1	D. A. Andrews, 1937. West side of Pryor Mountains, south side of Red Dome, NW¼ sec. 28, T. 7 S., R. 24 E., Carbon County, Mont. Piper Formation, from upper 11 ft of middle limestone member just below upper red-bed member.
	20864		D. A. Andrews, 1937(?). Southeast part of Red Dome in NW¼ sec. 27, T. 7 S. R. 24 E., Carbon County, Mont. Piper Formation, middle limestone member, 6 ft above coral bed and just below base of upper red-bed member.
110	17096	A182	D. A. Andrews, 1935; 6 miles south of Cody, NE. cor. sec. 6, T. 51 N., R. 101 W., Park County, Wyo. Gypsum Spring Formation, from upper part of coquinitic limestone about 76 ft above a massive gypsum unit and 120 ft below top of highest red bed at top of formation.
	17105	A184	D. A. Andrews, 1935; 6 miles south of Cody in NE. cor. sec. 6, along line of sec. 5, T. 51 N., R. 101 W., Park County, Wyo. Gypsum Spring Formation, from limestone below upper red-bed member and probably from same unit as Mesozoic loc. 17096.
111	20962	I–47–8–28A	R. W. Imlay, 1947. North side of Lower Slide Lake on Gros Ventre River, sec. 4, T. 42 N., R. 114 W., Teton County, Wyo. "Lower Sundance" Formation, 20 ft above base of unit 10 of published section (Imlay, 1956a, p. 70).
	20967	I–47–8–28B	R. W. Imlay, 1947. Same location as 20962. From 12 to 13 ft above base of unit 10.
	22112	K8–F1	W. P. Keefer and L. L. Garrow, 1948. North side of Lower Slide Lake, N½NW¼ sec. 3, T. 42 N., R. 114 W., Teton County, Wyo. "Lower Sundance" Formation, from 20 to 30 ft above base.
	27724		N. F. Sohl, R. W. Imlay, and Grant Bartlett, 1960. Same location as 20962. From 10 to 12 ft above base of unit 10.

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA

Genus GRAMMATODON Meek and Hayden, 1860

Grammatodon haguei (Meek)

Plate 1, figures 2–6

Cucullaea haguei Meek, 1877, U.S. Geol. Explor. 40th Parallel (King), v. 4, pt. 1, p. 134, 135, pl. 12, figs. 1, 1a, 1b.

Cucullaea haguei Meek. Stanton, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 618, pl. 73, fig. 1.

Cucullaca haguei Meek. Veatch, 1907, U.S. Geol. Survey Prof. Paper 56, pl. 6, fig. 10.

Cucullaea haguei Meek. Butler, 1920, U.S. Geol. Survey Prof. Paper 111, pl. 10, figs. 12, 13.

This species is represented by 34 specimens from the Twin Creek Limestone.

The species is small, inflated, subrhomboidal in outline, and obliquely elongated. The hinge line is less than the greatest length of the valves. The umbones are prominent, incurved, and a little anterior to the center of the hinge. The postumbonal slope is subangular to carinate and delimits a concave posterior area. The ornamentation consists of fine, closely spaced, fairly regular concentric ribs, concentric undulations, and very fine radial striae. The striae on the anterior part of the shell are widely spaced, are curved anteriorly, and generally extend to the ventral margin. The striae on the remainder of the shell are closely spaced and on most specimens are confined to the umbones. On a few specimens the striae extend below the middle of the shell.

Narrow parallel, nearly horizontal teeth are present at both ends of the hinge plate. On several molds there are two teeth at the anterior end and four teeth at the posterior end. There is no evidence of short, transverse teeth in the center of the hinge plate, such as occur in the genus *Cucullaea*. The cardinal area, poorly exposed on one internal mold, is long and fairly narrow. Ligamental grooves are not preserved. The molds show no trace of a posterior adduction septum.

This species is assigned to *Grammatodon* rather than *Parallelodon* because of the mesial position of its umbones, the presence of a postumbonal ridge, and the lack of a sinus on the ventral margin. Its general appearance is similar to that of a small *Cucullaea*, but the characters of its hinge plate and its narrow cardinal area favor an assignment to *Grammatodon*. The presence of nearly horizontal teeth at the anterior end of the hinge line does not bar such an assignment (Cox, 1940, p. 40; Arkell, 1930, pl. 15, figs. 1a, 7b, 8b). Furthermore, as noted by Meek (1877, p. 135), *G. haguei* closely resembles species similar to *Cucullaea concinna* Phillips, which Arkell (1930, p. 303–306, pl. 15) and Cox (1940, p. 41–43) place in *Grammatodon*. In particular it resembles *G. bathonicus* Cox and Arkell (1948, p. 2; Morris and Lycett, 1853, p. 50, pl. 5, fig. 7) from the Great Oolite of England, but is distinguished by the presence of radiating striae on the umbonal region. In shape and ornamentation *G. haguei* is more similar to *G. jurianus* Cox (1940, p. 43, pl. 2, figs. 15–20) from India but has stronger radial striae. *G. concinnus* Phillips (Arkell, 1930, p. 431, pl. 15, figs. 2–4) from the Oxford Clay of England appears to lack radial striae on its umbonal region.

The only other described species of *Grammatodon* from the western interior region is *G. inornatus* Meek and Hayden (1858, p. 51; 1865, p. 90, pl. 3, figs. 9, 9a, 9b) which is distinguished from *G. haguei* (Meek) by having a nearly smooth surface and a much less prominent postumbonal ridge. *G. inornatus* occurs only in stratigraphically higher beds of early Oxfordian age, such as the Redwater Shale Member of the Sundance Formation. It was erroneously recorded by Arkell (1930, p. 341) as of Early Jurassic age.

Among Canadian species, one of the most similar is *Grammatodon sonninianus* Crickmay (1930, p. 47, pl. 3, figs. h, i) from beds of middle Bajocian age in British Columbia. It differs from *G. haguei* (Meek) by having weaker less extensive radial striae and probably a more rounded postumbonal ridge. The associated *G. seminornatus* Crickmay (1930, p. 46, pl. 3, fig. g) has more closely spaced radial striae on its anterior surface and none on its umbo.

Types: Holotype USNM 12546 (apparently lost); plesiotypes USNM 28955, 132717–132720.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3218, 3219, 21632, 28459, 28483, and 28645; probably from the Sliderock Member at Mesozoic locs. 3548 and 12019; Rich Member at Mesozoic locs. 20963, 20965, 20987, 21620, 28785, and 28788; Sliderock or Rich Member at Mesozoic loc. 17977. The holotype of the species was collected in Weber Canyon, Wasatch Range, Utah, presumably from the Twin Creek Limestone exposed near Devils Slide.

Grammatodon haguei (Meek) has been found also, at Lower Slide Lake, Teton County, Wyo., in units 10, 19, and 22 of the described section (Imlay, 1956a, p. 70). These units correlate with the Rich, Watton Canyon, and Leeds Creek Members of the Twin Creek Limestone. In Montana the species occurs in the Piper Formation south of Big Timber and Livingston, Mont., and in the Sawtooth Formation of western Montana. It has not been found in the Piper Formation in the Pryor Mountains, Mont., or in the Gypsum Spring and "Lower Sundance" Formations of north-central Wyoming. It occurs rarely in the Rierdon Formation in Montana, but most of the specimens of *Grammatodon* from that formation belong to a larger and smoother species.

Genus IDONEARCA Conrad, 1862

Idonearca haguei (Stanton)

Plate 1, figures 11–13, 15

Cypricardia? haguei Stanton, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 623, pl. 73, figs. 11–13.

?Cucullaea livingstonensis McLearn, 1924, Royal Soc. Canada Proc. and Trans., 3d ser., v. 18, sec. 4, p. 39, 40, pl. 2, fig. 7.

This species is represented by six specimens from the Twin Creek Limestone. Of these, five are from the upper part of the Sliderock Member and one is from the middle of the Rich Member. The generic identification was questioned by Stanton (1899, p. 623) because all the specimens available to him were internal molds that did not show the ornamentation or the hinge. He compared the species on the basis of form with *Cypricardia bathonica* d'Orbigny of Morris and Lycett (1853, p. 75, pl. 7, figs. 8, 8a–c) which is the genotype of *Pseudotrapezium* (Fisher 1887, p. 1075; Cox 1947, p. 144, 145, 175).

Most of the specimens now available are likewise internal molds, but one specimen from the Twin Creek Limestone (USGS Mesozoic loc. 28792) retains some shell material that bears both concentric marks and radial striae, such as occur on *Cucullaea* and *Idonearca* but not on *Pseudotrapezium*. Another specimen from the Piper Formation of Montana (USGS Mesozoic loc. 19613) shows that the hinge bears long, horizontal lateral teeth as in *Idonearca*.

The specimen illustrated by Stanton (1899, pl. 73, figs. 11, 12) is herein designated lectotype of *Idonearca haguei* (Stanton).

Types: Lectotype USNM 132721; syntype USNM 28941; plesiotype USNM 132722.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20344, 20345, and 28645; Rich Member at Mesozoic loc. 28792.

The species occurs also in the "Lower Sundance" Formation at Lower Slide Lake, Teton County, Wyo., in unit 10 (Imlay, 1956a, p. 70) which is correlated with the lower part of the Rich Member of the Twin Creek Limestone. It occurs in the upper siltstone member of the Sawtooth Formation in northwestern Montana (Imlay, 1962a, p. C21), at several places in the Piper Formation in south-central Montana, and in the Sawtooth Formation in southwestern Montana. On Cinnabar Mountain, Mont., just north of Yellowstone National Park, the species occurs (USGS Mesozoic loc. 19618) from 24 to 26 feet above the base of the Rierdon Formation in association with the ammonite *Warrenoceras* and about 30 feet below the lowest occurrence of *Gryphaea nebrascensis* Meek and Hayden. On Sykes Mountain in the Bighorn Basin, Wyo., the species occurs from 8 to 12 feet above the base of the "Lower Sundance" Formation, a few feet below the lowest occurrence of *Gryphaea nebrascensis* Meek and Hayden (Imlay, 1956b, p. 591).

Genus MODIOLUS Lamarck, 1799

Modiolus subimbricatus (Meek)

For synonymy, characterization, comparisons, and illustrations see Imlay, 1964a, p. C23, pl. 1, figs. 16–20.

Sixteen specimens of this species have been obtained from the Twin Creek Limestone. At lower Slide Lake, Teton County, Wyo., the species ranges from unit 10 to unit 22 of the "Lower Sundance" Formation (Imlay, 1956a, p. 70). In unit 10 it is associated with ammonites of Bajocian age. In units 19–22 it is associated with ammonites of early Callovian age.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20345, 28645, and 28794; Rich Member at Mesozoic loc. 17297, 28639; Watton Canyon Member at Mesozoic loc. 21642; Leeds Creek Member at Mesosoic loc. 17064.

Subgenus MUSCULUS Bolten, 1798

Modiolus (Musculus) sp.

Plate 1, figures 14, 19

One laterally crushed specimen from the Twin Creek Limestone is assigned to the subgenus *Musculus* because of the presence of fine radiating striae on the posterodorsal and posterior parts of the shell. It differs from *Modiolus formosus* (Meek and Hayden) (1865, p. 86, 87, figs. A and B on p. 87; Whitfield 1880, p. 361, pl. 5, fig. 15) from the Upper Jurassic of the Bighorn Mountains, Wyo., by having much finer radiating striae, coarser more irregular concentric ribs, and apparently a less elongate form. It differs from *M. (Musculus) pulchra Phillips* (Arkell, 1929, p. 58, pl. 3, fig. 1–3) from Callovian and Oxfordian beds in Europe by having finer radial striae that do not form a reticulate pattern with the concentric ribs.

Figured specimen: USNM 132723.

Occurrence: Twin Creek Limestone, Rich Member at USGS Mesozoic loc. 28788.

Genus MYTILUS Linné, 1758

Mytilus cf. M. whitei Whitfield

The genus *Mytilus* is represented in the Twin Creek Limestone by three smooth internal molds. Their smoothness contrasts with the rugose shells of *M. whitei* Whitfield (1877, p. 18, 1880, p. 360, pl. 5, figs. 9–12) from the Jurassic beds of the Black Hills, but resembles that of specimens of *Mytilus* from the Carmel Formation of southern Utah (Imlay, 1964a, p. C24, pl. 1, figs. 4–6).

Occurrence: Twin Creek Limestone, lower part, at USGS Mesozoic loc. 3392.

Genus GERVILLIA Defrance, 1820

Gervillia? montanaensis Meek

Plate 1, figures 1, 7–10

Gervillia montanaensis Meek, 1873, U.S. Geol. Survey Terr. (Hayden), 6th Ann. Rept., 1872, p. 472.

Gervillia sparsilirata Whitfield, 1876, *in* Ludlow, William, Report of a reconnaissance from Carroll, Montana Territory, * * * to the Yellowstone National Park, * * * p. 142, pl. 2, fig. 8.

Gervillia montanaensis Meek. White, 1880, U.S. Geol. Survey Terr. (Hayden) 12th Ann. Rept., 1878, p. 145, pl. 37, figs. 1a,b.

Gervillia montanaensis Meek. Stanton, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 617.

Gervillia montanaensis Meek. Imlay, 1964a, U.S. Geol. Survey Prof. Paper 483–C, p. C24, pl. 1, fig. 21.

This species is represented in the Twin Creek Limestone by three specimens.

The original description by Meek (1873, p. 472) is as follows:

> A medium-sized, very oblique species, with posterior ear flattened and of moderate size, angular at the extremity, and equaling on the hinge line about half the length of the valves; body portion of the valves rather slender, nearly straight, or a little arched, ranging at an angle of 28° to 30° below the hinge line, in the left valve convex, in the right flattened, or less convex than the other. Surface of both valves marked by fine concentric striae, and a few stronger furrows of growth, crossed on the body part of the left valve, by a few slender radiating costae, separated by wider spaces.

The original collection studied by Meek was collected by A. C. Peale from the west side of the Lower Canyon of the Yellowstone River about 2 miles south of Livingston, Mont. The type lot contains 11 specimens. Of these, two were illustrated by White (1880, p. 145, pl. 37, figs. 1a,b) who described the species in detail. The specimen illustrated by White on his plate 37, figure 1b is herein designated the lectotype of *Gervillia? montanaensis* Meek and is reillustrated.

Gervillia sparsilirata Whitfield (1876, p. 142, pl. 2, fig. 8) was obtained from 60 feet of blue compact limestone exposed near the south end of the east side of the

Bridger Range (Dana and Grinnell, 1876, p. 118–121). Inasmuch as the species was associated with *Gryphaea planoconvexa* Whitfield in compact limestone, it must have been obtained from the middle limestone member of the Piper Formation, which is well exposed at the south end of the range.

The holotype of *Gervillia sparsilirata* Whitfield is a small fragment of a left valve that shows parts of the body of the shell and of the posterior ear. Whitfield considered that the species differed from *G. montanaensis* Meek by having a larger hinge and a smaller angle between the body of the shell and the hinge line. These distinctions are clearly invalid, however, because the hinge line of the holotype is not well preserved and the parts of the shell that are preserved agree very well in shape and ornamentation with small specimens in the type lot of *G.? montanaensis* Meek, as illustrated herein.

Gervillia? montanaensis Meek is readily distinguished from other described species of *Gervillia* from the Jurassic of the western interior of North America by the presence of radial riblets that are generally conspicuous on the left valves and weak to faint on the right valves. This species was assigned by Hayami (1961, p. 315) to *Bakevellia*, presumably because of its *Pteria*-like shape. Until the hinge characters of the species are known, however, its generic position is questionable.

Types: Lectotype, USNM 132724; syntypes, USNM 7795, 132836–132838.

Occurrences: Twin Creek Limestone, upper part of Rich Member at USGS Mesozoic locs. 20980 and 28793; Sliderock or Rich Member at Mesozoic loc. 17977.

In the Sundance Formation at Lower Slide Lake, Teton County, Wyo., the species occurs in unit 10 (Imlay, 1956a, p. 70) which is correlated with the lower part of the Rich Member. In southern Montana the species is fairly common in the limestone member of the Piper Formation. It has not been found in the "Lower Sundance" Formation in north-central Wyoming or in the Rierdon Formation in Montana. It appears to be restricted to beds of Bajocian age.

Genus ISOGNOMON Solander, 1786

Isognomon cf. I. perplana (Whitfield)

Myalina (*Gervillia*) *perplana* Whitfield, 1876, in Ludlow, William, Report of a reconnaisance from Carroll, Montana Territory, * * * to the Yellowstone National Park, * * * p. 143, pl. 1, fig. 8.

The genus *Isognomon* is represented in the Twin Creek Limestone by five specimens of which one was erroneously assigned by White (1880, p. 147, pl. 37, fig. 9a) to *Mytilus whitei* Whitfield. All the specimens are poorly preserved but are similar in shape and ornamentation to *Isognomon perplana* (Whitfield), which species has been described and illustrated by Imlay (1964a, p. C24, pl. 1, figs. 32–34).

The holotype of *Isognomon perplana* (Whitfield) is from the limestone member of the Piper Formation exposed near the south end of the east side of the Bridger Range, northeast of Bozeman, Mont. The species is moderately common in the same member in southern Montana and in equivalent beds in northwestern Wyoming. It occurs also in the lower part of the "Lower Sundance" Formation in the Bighorn Basin (USGS Mesozoic locs. 17670, 19381).

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 21629, 28639, and 28790; undetermined position at Mesozoic loc. 17019; the specimen illustrated by White is labeled "near Fontenelle Canyon, west side Green River Basin, Wyoming." Presumably it was obtained near Fontenelle Gap north of Kemmerer, Wyo.

Genus PINNA Linné, 1758

Pinna kingi Meek

Plate 1, figures 20–22

For synonymy see Imlay, 1964a, p. C25.

This species is represented by 28 specimens from the Twin Creek Limestone. All are from the Sliderock and Rich Members. At Lower Slide Lake, Teton County, Wyo., the species ranges from units 10 to 19 of the described section (Imlay, 1956a, p. 70). These units are correlated with the Rich, Boundary Ridge, and Watton Canyon Members of the Twin Creek Limestone. In Montana, *Pinna kingi* Meek has been recorded from the upper siltstone member of the Sawtooth Formation (Imlay, 1962a, p. C21) and from the middle limestone member of the Piper Formation (Imlay, 1956b, p. 576). It is uncommon in the Rierdon Formation in Montana and in the "Lower Sundance" Formation in north-central Wyoming.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3219, 3391, 6364, 17964, 20345, 20977, 20984, 28459, 28483, 28645, and 28648; Rich Member at Mesozoic locs. 17297, 20963, 20965, 28785, 28788, and 28793; Sliderock or Rich Member at Mesozoic loc. 17977; member undetermined at Mesozoic locs. 3220 and 6948.

Genus CAMPTONECTES Meek, 1864

Camptonectes stygius White

For synonymy, description, and illustrations see Imlay, 1964a, p. C25, pl 2, figs. 1–10.

This species is represented in the Twin Creek Limestone by 41 specimens; it ranges from the upper part of the Sliderock Member to as high as the middle of the Leeds Creek Member.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic loc. 20345; Rich Member at Mesozoic loc. 3821; Watton Canyon Member at Mesozoic locs. 17299, 21624, and 28460; Leeds Creek Member at Mesozoic locs. 20348 and 28643; from undetermined member at Mesozoic locs. 3548 and 4798.

Camptonectes platessiformis White

Plate 2, figures 1, 2

For synoynmy, descriptions, and illustrations see Imlay, 1964a, p. C26, pl. 2, figs. 11–14.

This species is represented in the Twin Creek Limestone by 32 specimens, of which most are from the Sliderock and Rich Members. There is one specimen from the Boundary Ridge Member and one from near the top of the Leeds Creek Member. Elsewhere in the western interior region the same species occurs in the Piper, Sawtooth, and Rierdon Formations in Montana, in the "Lower Sundance" Formation in Wyoming, and in the lower limy unit of the Carmel Formation in Utah.

Types: Holotype, USNM 8179; plesiotypes, USNM 131939, 131940, 132725.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 16016, 17674, 17985, 20345, 20972, 21628, 28459, 28506, 28795; Rich Member at Mesozoic locs. 17297, 21468, 21629; Sliderock or Rich Member at Mesozoic loc. 17977; Boundary Ridge Member at Mesozoic loc. 20990; Leeds Creek Member at Mesozoic loc. 17892; lower part of formation at Mesozoic locs. 6373, 17983, 17984; undetermined position at Mesozoic loc. 3817.

Genus PLICATULA Lamarck, 1801

Plicatula sp.

Plate 1, figure 16

The genus *Plicatula* is represented by 16 specimens from the Twin Creek Limestone. These show considerable variation in fineness of ribbing and spinosity similar to that shown in specimens from the Carmel Formation of Utah (Imlay, 1964a, p. C26, pl. 1, figs. 13–15).

Figued specimen: USNM 132726.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 17674, 17985, and 20345; Rich Member at Mesozoic locs. 21620, 28785, 28786, and 28788; Leeds Creek Member at Mesozoic locs. 3830 and 20983.

Genus LIMA Bruguiere, 1797
Subgenus PLAGIOSTOMA, J. Sowerby, 1814

Lima (Plagiostoma) occidentalis Hall and Whitfield

For synonymy, description, and illustrations see Imlay, 1964a, p. C27, pl. 2, figs. 17–20.

This species is represented by 13 specimens from the Twin Creek Limestone. These are mostly from the Watton Canyon Member, but two are probably from the Sliderock Member. The species at Lower Slide Lake, Teton County, Wyo., has been found in unit 17 (Imlay, 1956a, p. 70). In Montana the species occurs in the middle limestone member of the Piper Formation (Imlay, 1956b, p. 576, 577) and rarely in the lower part of the Rierdon Formation.

Occurrences: Twin Creek Limestone, Watton Canyon Member at Mesozoic locs. 20992 and 21623; lower part of Twin Creek Limestone at Mesozoic locs. 3800, 7438, and 17982.

Genus CTENOSTREON Eichwald, 1862

Ctenostreon cf. C. gikshanensis McLearn

Plate 2, figures 4, 12, 13

Ctenostreon is represented in the Twin Creek Limestone by 10 fragmentary specimens. These resemble *C. gikshanensis* McLearn (1926, p. 91, pl. 19, figs. 3, 4) from the Bajocian of British Columbia in shape and in the presence of six to eight radiating ribs. They differ, however, by having appreciably wider ribs on their right valves. Wherever the shell is preserved, the ribs are about two-thirds as broad as the interspaces. This feature plus the small number of major ribs distinguishes the American species from the common European Jurassic species of *Ctenostreon* (Morris and Lycett, 1853, pl. 6, fig. 9; Lycett, 1863, pl. 39, fig. 1; Cox, 1930, p. 302; Arkell, 1932, p. 144–148, pl. 15, fig. 3).

The genus is not common in the western interior region but has been found in beds of late Bajocian to early Callovian age. Besides the occurrences in the Twin Creek Limestone, it has been found 12 feet above the base of the "Lower Sundance" Formation in the Bighorn Basin, Wyo. (USGS Mesozoic loc. 17651), 25 feet above the base of the Rierdon Formation in the Pryor Mountains, Mont. (USGS Mesozoic loc. 21636), above the middle of the limestone member of the Piper Formation near Livingston, Mont. (USGS Mesozoic loc. 19622), and at the top of the limestone member of the Piper Formation on Belt Creek, Mont. (USGS Mesozoic loc. 19159). All the specimens of *Ctenostreon* at these localities appear to belong to the same species as the specimens from the Twin Creek Limestone, but most of the specimens are so poorly preserved that specific identification is uncertain.

Figured specimen: USNM 132727.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20345, 20971, 20972, 20984, 22017, 28459, 28484, and 28648; probably from Sliderock Member at Mesozoic loc. 7430; Watton Canyon Member at Mesozoic loc. 20992; upper part of Leeds Creek Member at Mesozoic loc. 17892.

Genus OSTREA Linné, 1758
Subgenus LIOSTREA Douvillé, 1904

Ostrea (Liostrea) strigilecula White

For synonymy, descriptions, and illustration see Imlay, 1964a, p. C27, pl. 1, figs. 26–29.

About a hundred small nondescript oysters have been collected at about 30 localities from the Twin Creek Limestone throughout its area of distribution (tables 3–5 and 8–10). Most of the specimens are from the Sliderock, Rich, and Watton Canyon Members or from uncertain stratigraphic positions in the lower part of the formation. A few are from the Leeds Creek and Giraffe Creek Members. More than half of the specimens are from north-central Utah. This distribution suggests that bottom conditions were most favorable for the growth of oysters prior to the deposition of the Leeds Creek Member and were more favorable in Utah than farther north.

Genus GRYPHAEA Lamarck, 1801

Gryphaea planoconvexa Whitfield

Plate 3, figures 1–13

Gryphaea planoconvexa Whitfield, 1876, *in* Ludlow, William, Report of a reconnaissance from Carroll, Montana Territory, * * * to the Yellowstone National Park, * * * p. 142, pl. 1, figs. 9, 10, pl. 2, figs. 9, 10.

Gryphaea planoconvexa Whitfield. Stanton, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 611, pl. 72, figs. 9, 10.

Gryphaea planoconvexa Whitfield. Imlay, 1948, U.S. Geol. Survey Prof. Paper 214–B, p. 17, 18, pl. 5, fig. 6.

This species is of medium size for the genus. The right valve is subcircular in outline, concave, and marked only by concentric growth lines. The left valve is subcircular, longer than high, and depressed convex to moderately convex; it bears concentric growth lines, and its posterior side on many specimens bears a weak furrow that separates a triangular, winglike lobe from the remainder of the shell. The umbo of the left valve is narrow to pinched, low to moderately prominent, gently incurved, and is not deflected posteriorly. The beak is generally pointed, but on some specimens is terminated by an attachment scar.

The species, as typically developed, is readily distinguished from any other species of *Gryphaea* in the western interior region by its subcircular outline and its narrow, moderately incurved umbo. Some of the more inflated variants of *G. planoconvexa* Whitfield, however, are similar to the less inflated variants of *Gryphaea planoconvexa fraterna* Imlay, n. subsp., that occur in the Sliderock and Rich Members of the Twin Creek Limestone. The inflated variants of *G. planoconvexa* generally can be distinguished by their relatively greater length, a lack of radial ribs, and a less strongly incurved umbo that is not deflected posteriorly.

The species is widespread in the lower part of the Sawtooth Formation in southwestern Montana and in the middle limestone member of the Piper Formation in southern and central Montana (Imlay, 1948, p. 18) in association with the ammonites herein described as *Sohlites*, n. gen., and *Parachondroceras*, n. gen. It has been found, also, in the subsurface of north-central Montana in the Texas Co. Bowdoin Unit 1 (822) in the center SW¼SW¼ sec. 8, T. 32 N., R. 32 E., Phillips County, at the depth of 2,896–2,906 feet.

The holotype and paratype specimens of *Gryphaea planoconvexa* Whitfield were collected from about 60 feet of "firm, blue, compact limestone" exposed on the east side of the Bridger Range near its south end northeast of Bozeman, Mont. (Dana and Grinnell, 1876, p. 119–121). This limestone is now known as the middle limestone member of the Piper Formation.

The species has not been found in the Twin Creek Limestone in Utah or Wyoming. It has been found in Wyoming, however, in the lower 20 feet of unit 10 of the Sundance Formation exposed on the north side of Lower Slide Lake, Teton County (Imlay, 1956a, p. 70). This unit is correlated with the Rich Member of the Twin Creek Limestone on the basis of lithologic similarity, stratigraphic position, and the occurrence in common of the ammonite *Parachondroceras* as well as the typical form of *Gryphaea planoconvexa* Whitfield.

Types: Holotype, Yale University 6774; paratype, Yale University 6778; plesiotypes, USNM 12369, 28931, 104138, 132728–132730.

Occurrences: Twin Creek Limestone, middle and upper parts of the Rich Member at USGS Mesozoic locs. 28507, 28585, and 28796. These localities are all in southeastern Idaho toward the northern part of the Twin Creek Limestone outcrops.

Gryphaea planoconvexa fraterna Imlay, n. subsp.

Plate 4, figures 1–17

This subspecies is represented in collections from the Twin Creek Limestone by about 430 specimens; it ranges from a little below the middle of the Sliderock Member to near the middle of the Rich Member. Most of the specimens are from the upper part of the Sliderock Member.

The subspecies typically differs from *Gryphaea planoconvexa* Whitfield (1876, p. 142, pl. 2, figs. 9, 10), which succeeds it stratigraphically, by having a much more convex left valve, a subovate to subtrigonal instead of a subcircular outline, a higher more strongly incurved umbo, and a posteriorly directed beak, and by weak radial riblets on some specimens.

The lowest known stratigraphic occurrence of the subspecies is on Birch Creek about 9 miles west of Woodruff, Utah, at USGS Mesozoic locality 28647, which is about the top of the lower two-fifths of the Sliderock Member. On specimens from this locality (pl. 4, figs. 1–3, 6, 10, 13) the right valve is concave and subovate in outline. The left valve is moderate in size for the genus, is strongly convex, subtrigonal in outline, and higher than long. Its basal margin is extended posteriorly, or anteriorly, or in both directions. Its umbo is strongly incurved. Its beak is slender and deflected strongly posteriorly. Its posterior side bears a sulcus that varies in strength from faint to deeply impressed. Its surface is marked mainly by weak growth lamellae, but a few specimens bear faint radial riblets on the beak.

Most specimens of the subspecies from the upper part of the Sliderock Member and from the lower part of the Rich Member are identical in appearance with those just described except for averaging larger in size (pl. 4, figs. 7, 9, 12, 14, 15–17). They are associated, however, and are connected gradationally with other specimens whose left valves are much less convex, are subovate instead of subtrigonal in outline, are about as long as high, and have less strongly incurved umbones (pl. 4, figs. 8, 11). In addition, about one-third of the specimens, regardless of their shape, bear weak radial riblets on the umbonal part of the shell (pl. 4, figs. 4, 5, 8, 11, 16) and broad ribs and furrows toward the ventral margin (pl. 4, figs. 4, 5, 11, 16).

The subspecies *fraterna* bears resemblances to several species of *Gryphaea* in the western interior of North America. Specimens that are highly convex, are subtrigonal in outline, and bear radial riblets are similar in appearance to *Gryphaea cadominensis* Warren (1932, p. 17, pl. 3, figs. 1–4) from beds of middle Bajocian age in Alberta. They differ by having much weaker radial ribs and by lacking broad radiating furrows on the postumbonal slope. Such ribbed specimens also resemble *G. impressimarginata* McLearn (1924, p. 44, pl. 4, figs. 1–5; Imlay 1948, p. 18, pl. 5, figs. 9–11) from beds of Bathonian to Callovian age in Montana and Alberta, but differ by having a less robust shape, a narrower umbo, and much weaker ribbing.

Specimens of the subspecies that are moderately convex, subovate in outline, and lack distinct radial ribs or furrows greatly resemble the more convex variants of *Gryphaea planoconvexa* Whitfield, as discussed under the description of that species. For example, the specimen shown on plate 4, figure 11, differs from the convex variant of *G. planoconvexa* Whitfield only by having faint broad ribs near its ventral margin. It was obtained (USGS Mesozoic loc. 21618), however, in the upper part of the Sliderock Member in association with many Gryphaeas showing the characteristics of the subspecies. Similarly some Gryphaeas obtained near the middle of the Rich Member on the North Fork of Stump Creek, Idaho (USGS Mesozoic loc. 22460), resemble the convex variant of *G. planoconvexa* Whitfield, except that they have posteriorly curved beaks as in the subspecies *fraterna*.

Such associations of variable gryphaeas plus the fact that typical specimens of *Gryphaea planoconvexa* Whitfield occur in the middle and upper parts of the Rich Member indicate that all the Gryphaeas in the Sliderock and Rich Members belong to a single gradational series. Recognition of the subspecies *fraterna* is useful stratigraphically, however, because it has been found only in the lower part of the Twin Creek Limestone, whereas the typical depressed subcircular form of *G. planoconvexa* has a much wider geographic distribution in northern Wyoming and in Montana at a slightly higher stratigraphic position.

Type: Holotype, USNM 132731; paratypes, USNM 132732–132741.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3219, 6364, 7432, 8177, 9102, 12116, 13491, 16016, 18181, 20344, 20345, 20961, 20966, 20968, 20970–20973, 20975, 20977, 20988, 21000, 21618, 21633, 22638, 27729, 28483, 28484, 28502, 28505, 28635–28637, 28644, 28645, 28647, 28648, 28795; Rich Member at Mesozoic locs. 22460 and 28797.

Gryphaea nebrascensis Meek and Hayden

For synonymy and diagnosis see Imlay, 1948, p. 18, 19.

This species is represented by 135 specimens from the Leeds Creek Member of the Twin Creek Limestone. It has been found in westernmost Wyoming from South Piney Creek northward to the Jackson Hole area and in easternmost Idaho in the mountains bordering the Snake River. It ranges throughout the Leeds Creek Member but is most common at or a little below the middle of the member.

In addition, small striate Gryphaeas that are probably immature specimens of *Gryphaea nebrascensis* Meek and Hayden have been found in the uppermost part of the Watton Canyon Member of the Twin Creek Limestone at Sliderock Creek northeast of Cokeville and in Cottonwood Creek east of Smoot, Wyo. Similar immature specimens that probably represent *G. nebrascensis* occur in unit 19 of the Jurassic section at Lower Slide Lake, Teton County, Wyo. (Imlay, 1956a, p. 70). This unit is considered to be equivalent of the upper part of the Watton Canyon Member. Such occurrences of *Gryphaea* sp. juv. cf. *G. nebrascensis* Meek and Hayden in the Watton Canyon Member or equivalent beds are probably at about the same stratigraphic position as the lowest occurrences of the species at the top of the basal member of the "Lower Sundance" Formation in north-central Wyoming (Imlay, 1956b, p. 591).

Occurrences: Twin Creek Limestone, Leeds Creek Member at USGS Mesozoic locs. 3808, 3830, 3831, 3834, 16031, 18182, 27727, 27728, 28584 and 28587–28590.

Genus TRIGONIA Bruguière, 1789

Trigonia americana Meek

For synonymy, descriptions, and illustrations see Imlay, 1964a, p. C28, pl. 3, figs. 8–13.

This species is represented by 18 specimens in the Twin Creek Limestone and ranges from the Sliderock to the Leeds Creek Member. In the section on the north side of Lower Slide Lake, Teton County, Wyo. (Imlay, 1956a, p. 70), it ranges from units 10 to 20.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 16036, 17674 and 28798; lower part of formation at Mesozoic loc. 3392; Rich Member at Mesozoic locs. 21620, 28785, 28788 and 28793; Leeds Creek Member at Mesozoic loc. 3830; stratigraphic position unknown at Mesozoic loc. 6948.

Trigonia elegantissima Meek

For synonymy, description, and illustrations see Imlay, 1964a, p. C29, pl. 3, figs. 1–7.

This species is represented by 19 specimens from the Twin Creek Limestone, ranging from the Rich to the Leeds Creek Member. At Lower Slide Lake, Teton County, Wyo., it occurs in units 10 and 19 (Imlay, 1956a, p. 70), which are correlated with the Rich, Boundary Ridge, and Watton Canyon Members of the Twin Creek Limestone. In Montana the species occurs in the middle limestone member of the Piper Formation and in the lower part of the Rierdon Formation (Imlay, 1956b, p. 576, 577, 588). In north-central Wyoming it occurs in equivalent beds (1956b, p. 583, 591) in the Gypsum Spring and Sundance Formations.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 20963, 20965, 28639, 28785, and 28788; Sliderock or Rich Members at Mesozoic loc. 3822; Boundary Ridge Member at Mesozoic loc. 21621; Watton Canyon Member at Mesozoic loc. 21624; Leeds Creek Member at Mesozoic loc. 28643.

Genus VAUGONIA Crickmay, 1930

Vaugonia conradi (Meek and Hayden)

For synonymy, description, and illustrations see Imlay, 1964a, p. C30, pl. 3, figs. 14–21.

This species is represented by 33 specimens from the Twin Creek Limestone in Wyoming and north-central Utah. It is fairly common in the Rich and Watton Canyon Members and uncommon in the lower part of the Leeds Creek Member. At Lower Slide Lake, Teton County, Wyo., it ranges from the lower part of unit 10 (USGS Mesozoic loc. 20967) to near the top of unit 19 (Imlay, 1956a, p. 70). These units correspond to the Rich and Watton Canyon Members of the Twin Creek Limestone.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 3821, 17297, 20349, 22796, and 28793; Watton Canyon Member at Mesozoic locs. 17298, 21623, and 21624; Leeds Creek Member at Mesozoic loc. 20960; member unknown at Mesozoic locs. 3292, 3820, 3842, 3860.

Genus MYOPHORELLA Bayle, 1878

Subgenus PROMYOPHORELLA Kobayashi and Tamura, 1955

Myophorella (Promyophorella) montanaensis (Meek)

For synonymy, descriptions, and illustrations see Imlay, 1964a, p. C31, pl. 3, figs. 33–36, 38–41.

This species is represented by 21 specimens from the Twin Creek Limestone and ranges from the middle of the Sliderock Member to near the top of the Watton Canyon Member. In Montana the species occurs in the middle limestone member of the Piper Formation (Imlay, 1956b, p. 577), in the middle and upper members of the Sawtooth Formation (Imlay, 1962a, p. C21), and in the lower part of the Rierdon Formation (Cobban, 1945, p. 1281).

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20344, 20973, 28483, 28644, 28645, 28648, and 28798; Rich Member at Mesozoic locs. 17815, 20350, 20963, 21468, and 28792; Watton Canyon Member at Mesozoic locs. 21622 and 21624; unknown member at Mesozoic locs. 3548.

Subgenus HAIDAIA Crickmay, 1930

Myophorella (Haidaia) yellowstonensis Imlay

For synonymy, descriptions, and illustrations see Imlay 1964a, p. C33, pl. 3, figs. 27–32.

This species is represented by three specimens from the Twin Creek Limestone in Wyoming. Two specimens (USGS Mesozoic locs. 17815 and 20963) are from the upper part of the Rich Member and one (USGS Mesozoic loc. 3822) is either from the Sliderock or the Rich Member. Elsewhere in Wyoming the species has been found on the north side of Lower Slide Lake, Teton County (USGS Mesozoic loc. 20967) in unit 10 of the described section (Imlay, 1956a, p. 70). In southern Montana on the Boulder River the species has been found (USGS Mesozoic loc. 27624) near the middle of the limestone member of the Piper Formation in association with the ammonites *Sohlites* and *Parachondroceras*, which in the Twin Creek Limestone have been found only in the Rich Member. In southwestern Montana it has been found (USGS Mesozoic loc. 21385) in the Sawtooth Formation in association with *Gryphaea planoconvexa* Whitfield, which species in the Twin Creek Limestone has been found only in the Rich Member. The species has not been found in the Rierdon Formation in Montana or in equivalent beds of Callovian age in Wyoming. It appears, therefore, to have a narrow stratigraphic range in a sequence of Bajocian age.

Genus ASTARTE Sowerby, 1816

Astarte meeki Stanton

Plate 5, figures 1–6

Astarte meeki Stanton, 1899, U.S. Geol. Survey Mon. 32, pt. 2, p. 620, pl. 73, figs. 3–5.

This species is characterized by its subcircular outline, moderate convexity, medium size, and fine regular dense concentric ribs. The beaks are situated from ⅓ to ⅖ of the length of the shell from the anterior end. The shells are slightly longer than high, and some are relatively more elongate than others. The concentric ribs are coarsest on the umbones, become finer and denser ventrally, and in some specimens become faint near the ventral margins. The density of ribbing varies considerably from one specimen to another. The specimen illustrated by Stanton on his plate 73, figure 3, has about 42 ribs in a distance of 15 mm (millimeters) from the umbo. Others have as few as 30–35 ribs in about the same distance.

Astarte meeki Stanton in shape and ribbing resembles *Astarte depressa* Blake and Huddleston (Arkell, 1934, p. 235, pl. 33, figs. 1–9) from the Oxfordian of England, but probably has even finer and denser ribbing. Among described American species the most similar is *Astarte packardi* White (1880, p. 149, pl. 37, fig. 6). It differs from *A. meeki* Stanton by being smaller and more convex and by having much coarser and sparser ribbing.

The specimen figured by Stanton (1899) on his plate 73, figure 3, is herein selected as lectotype of *Astarte meeki* Stanton.

The species is represented by 40 specimens in collections from the Twin Creek Limestone. Most of these are from the Sliderock and Rich Members, but three are from the Watton Canyon Member and two are from the Leeds Creek Member. At Lower Slide Lake, Teton County, Wyo., the species ranges from unit 10 to unit 22 (Imlay, 1956a, p. 70). In Montana the species is fairly common in the middle limestone member of the Piper Formation, in the middle and upper parts of the Sawtooth Formation, and occurs rarely in the Rierdon Formation.

Types: Lectotype, USNM 28936; syntype, USNM 132742; plesiotypes, USNM 132743–132746.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3218, 3219, 3391, 13491, 18181, 20984, 21618 and 28648; Rich Member at Mesozoic locs. 3815, 20963, 20965, 21620, 21629, 28507, 28785, and 28793; Sliderock or Rich Member at Mesozoic loc. 17977; Boundary Ridge Member at Mesozoic loc. 21621; Watton Canyon Member at Mesozoic loc. 21624; Leeds Creek Member at Mesozoic locs. 12016 and 28591.

Subgenus COELASTARTE Boehm, 1893

Astarte (Coelastarte) livingstonensis Imlay

For synonymy, descriptions and illustrations see Imlay, 1964a, p. C 33, pl. 4, figs. 1–4.

Fifteen specimens of this species have been found in the Twin Creek Limestone. These are mostly from various parts of the Sliderock and Rich Members, but two speciments were obtained from the upper part of the Boundary Ridge Member.

The species occurs in unit 10 of the section at Lower Slide Lake, Teton County, Wyo. (Imlay, 1956a, p. 70). It is fairly common in beds of Bajocian age in the western interior region and has not been found in beds of Callovian age.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20344, 21619, and 28645; Rich Member at Mesozoic locs. 17297, 20963, 20987; Boundary Ridge Member at Mesozoic loc. 21621.

Genus OPIS Defrance, 1825
Subgenus TRIGONOPIS (Munier-Chalmas) Fischer, 1887

Opis (Trigonopis) sp.

Plate 2, figure 3

One large internal mold from the Twin Creek Limestone is assigned to *Opis* on the basis of its triangular shape and its extremely prominent narrow incurved umbones. A weak ridge extends from the posterior side of the umbo to the postero-ventral angle. The ornamentation is not preserved.

The genus *Opis* is probably represented also by a small specimen described by Meek (1877, p. 133, 134, pl. 12, figs. 3, 3a) questionably as *Myophoria lineata* (Münster). The specimen, now lost, is reported to have been obtained above the "quarry rock" in Weber Canyon, Wasatch Range, Utah. Presumably it was collected from the Twin Creek Limestone near Devils Slide. Meek's description and illustration indicate that the specimen resembles *Opis* (*Trigonopis*) *corallina* Damon (Arkell, 1934, p. 259, pl. 34, figs. 7–9) from England but has less prominent umbones and a more quadrate outline.

Elsewhere in the western interior region, *Opis* (*Trigonopis*) has been found in limestone in the upper part of the Gypsum Spring Formation near Mill Creek, Fremont County, Wyo. (USGS Mesozoic locs. 18939 and 19357). The species present is identical in lateral view with the specimen described by Meek from Weber Canyon, Utah, except that the concentric ribs are fairly strong dorsal to the postumbonal ridge instead of terminating or passing into fine growth lines.

Figured specimen. USNM 132747.

Occurrence: Twin Creek Limestone, Sliderock Member at USGS Mesozoic loc. 20344; unknown position near Devils Slide. Weber Canyon, Utah.

Genus PROROKIA Boehm, 1883

Prorokia fontenellensis Imlay, n. sp.

Plate 5, figures 9–13

This species is represented in the Twin Creek Limestone by 12 molds, of which several retain some shelly material. The shell is small, moderately convex, oblong, longer than high. The umbones are small, depressed, and anterior to the middle of the shell. The ventral margin is gently curved and makes nearly a right angle with the posterior margin. The anterior margin is evenly rounded. The posterior margin is nearly straight in its lower part and gently convex in its upper part. A low ridge trends obliquely from the umbo to the posteroventral angle. The surface is covered with fine concentric ribs of variable strength and spacing. The internal border of the shell is denticulate. The hinge characters are unknown.

This species is assigned to *Prorokia* rather than *Astarte* because of its oblong shape, its depressed beaks, and the presence of a weak postumbonal ridge. *Coelastarte* Boehm is flatter, more inequilateral, and more quadrate in outline. Among foreign species, *Prorokia rustica* Lycett (1863, p. 76, pl. 35, fig. 5, pl. 40, figs. 8, 8a; Cox and Arkell, 1948, p. 28) from the Bathonian of England is nearly identical with American species described herein in shape, size, and ornamentation, but it's beaks are less prominent and are located more anteriorly.

Prorokia fontenellensis Imlay, n. sp., has been found in the Twin Creek Limestone only in the Sliderock and Rich Members. In Montana it has been found in the middle limestone member of the Piper Formation south of Livingston, Mont., (USGS Mesozoic locs. 25866 and 27035).

Types: Holotype, USNM 132748; paratypes, USNM 132749–132752.

Occurrences: Twin Creek Limestone. Sliderock Member at USGS Mesozoic loc. 21619; Rich Member at Mesozoic locs. 17297, 28788, and 28790.

Genus PRONOELLA Fischer, 1887

Pronoella spp.

The collections from the Twin Creek Limestone contain 105 specimens that belong to *Pronella*, or to similar appearing genera of the family Cyprinidae. Most of the specimens are internal molds. Silicified specimens showing the ornamentation and shape of the shell occur only at two localities (USGS Mesozoic locs. 16058, 28791). Inasmuch as the hinge of a right valve is preserved on only one specimen (USGS Mesozoic loc. 16058), the generic identification is based mostly on resemblances to described species of *Pronoella* from Jurassic beds elsewhere in the western interior region. These include *Pronoella cinnabarensis* (Stanton) (1899, p. 621, 622, pl. 72, figs. 7, 8; Imlay, 1964a, p. C34, pl. 4, figs. 27–30); *P. uintahensis* Imlay (1964a, p. C34, pl. 4, figs. 15–23), and *P.?iddingsi* (Stanton) (1899, p. 622, pl. 73, fig. 9; Imlay, 1964a, pl. 4, figs. 24, 25). Of these species, *P. cinnabarensis* (Stanton) is identified from the Twin Creek Limestone at USGS Mesozoic localities 20971 and 28790, *P. uintahensis* Imlay at Mesozoic localities 3221, 3392, 17064, 17961, 28648, and 28791, and *P.?* cf. *P.? iddingsi* (Stanton) at Mesozoic localities 16058, and 20977. Specimens of *Pronella* that are too poorly preserved for identification with any described species occur at many other localities. The known stratigraphic range of *P. cinnabarensis* (Stanton) and *P. uintahensis* Imlay is from the middle of the Sliderock Member to the middle of the Leeds Creek Member. External molds of *Pronoella?* sp. have been found in the Giraffe Creek Member at Mesozoic locality 12034.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3391, 16036, 17673, 17961, 17964, 18182, 20344, 20345, 20970, 20971, 20973, 20977, 20984, 28459, 28483, 28644, 28648; lower part, probably Sliderock Member at Mesozoic locs. 3392 and 16058; Rich Member at Mesozoic locs. 3221, 17297, 20963, 20980, 22796, 28507, 28785, 28787, 28788, and 28790; Boundary Ridge Member at Mesozoic locs. 20990, 21621, and 28791; Watton Canyon Member at Mesozoic loc. 21624; Leeds Creek Member at Mesozoic locs. 2906, 12016, 17064, 18182, 20983, 28591, 28643, and questionably at Mesozoic loc. 12034.

Genus MACTROMYA Agassiz, 1842

Mactromya? sp.

Plate 1, figure 18

Twelve internal molds from the Twin Creek Limestone are tentatively assigned to *Mactromya*. They are ovate, inflated, and generally a little longer than high. The umbones are swollen, incurved, and slightly anterior to the middle of the mold. The ornamentation consists only of fine dense concentric growth limes.

Figured specimen: USNM 132753.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3219, 20966 and 20977; Rich Member at Mesozoic loc. 28789 and 28793; Sliderock or Rich Member at Mesozoic loc. 17977; member unknown at Mesozoic loc. 3220.

Genus QUENSTEDTIA Morris and Lycett, 1854

Quenstedtia sublevis (Meek and Hayden)

Plate 5, figures 7, 8, 14, 15

Thracia? sublevis Meek and Hayden, 1860, Acad. Nat. Sci., Philadelphia Proc., v. 12, p. 182.

Thracia? sublevis Meek and Hayden, 1685, Smithsonian Contr. Knowledge, v. 14, no. 172, p. 102, pl. 4, figs. 4a, 4b.

?Thracia? sublevis Meek and Hayden. Whitfield, 1880, U.S. Geog. and Geol. Survey Rocky Mtn. Region (Powell), p. 375, pl. 5, fig. 34.

Quenstedtia sublevis (Meek and Hayden), Imlay, 1947, Am. Assoc. Peteroleum Geologists Bull., v. 31, p. 253.

?Thracia canadensis McLearn, 1924, Royal Soc. Canada Proc. and Trans., 3d ser., sec. 4, v. 18, p. 56, pl. 9, figs. 8, 9.

This species is represented by seven specimens in the Twin Creek Limestone. The original description (Meek and Hayden, 1860, p. 182) is as follows:

> Shell elongate, or narrow oblong-oval, rather compressed. Anterior end narrowly rounded; base nearly straight along the middle, rounding up toward the ends; posterior side longer than the other, rounded, or slightly truncate, and apparently gaping a little at the extremity; dorsal border straight or concave in outline, and nearly horizontal behind the beaks, declining more abruptly in front. Beaks moderately elevated, the right one being usually a little higher than the other; located in advance of the middle; posterior umbonal slopes prominently rounded. Surface concentrically striate.
>
> Length, 1.19 inch; height 0.63 inch; breadth, about 0.32 inch.

The two specimens illustrated by Meek are from a collection of five internal molds obtained from the southwest base of the Black Hills. Four of these are preserved in a fine-grained sandstone and one is preserved in a calcareous matrix. All can be matched with specimens in the Geological Survey collections from the Stockade Beaver Shale Member of the Sundance Formation. The specimens preserved in a sandy matrix, however, could have been obtained from the Hulett Sandstone Member or the Canyon Springs Sandstone Member of the Sundance Formation. The specimen illustrated by Meek and Hayden (1865, pl. 4, fig. 4a) is herein selected as lectotype cf. *Quenstedtia sublevis* (Meek and Hayden).

The specimen described by Whitfield (1880, p. 375, pl. 5, fig. 34) as *Thracia? sublevis* Meek and Hayden differs from the type specimens of that species by having a faint posterior umbonal ridge and a slightly concave ventral margin. These are the features that are reported to distinguish *Quenstedtia arcuata* (Meek and Hayden) (1860, p. 182; 1865, pl. 102, pl. 4, fig. 8) from *Q. sublevis* (Meek and Hayden). *Quenstedtia canadensis* (McLearn) (1924, p. 56, pl. 9, figs. 8, 9) from beds of early Callovian age near Blairmore, Alberta, is reported to differ from *Q. sublevis* (Meek and Hayden) by having its beaks nearer the center of the shell.

Types: Lectotype, USNM 132754; syntypes, USNM 197, 132841; plesiotype, USNM 132755.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 17297 and 28787; Leeds Creek Member at Mesozoic locs. 18182 and 20983; Sliderock or Rich Member at Mesozoic loc. 3822.

Genus PROTOCARDIA Beyrich, 1845

Protocardia cf. P. schucherti McLearn

This genus is represented by six poorly preserved internal molds from the Twin Creek Limestone. These molds are small and ovate, have an angular postumbonal slope, from 9 to 12 radiating ribs on the posterior surface, and fine lines of growth elsewhere on the surface. They differ from *Protocardia schucherti* McLearn (1924, p. 57, pl. 9, figs. 4, 10) by being less stout and by having fewer radiating ribs on the postumbonal slope. Similar internal molds from the Yellowstone Park area were assigned by Stanton (1899, p. 621) to *P. shumardi* (Meek and Hayden) (1860, p. 98, 99), but the ornamentation on the type specimens of that species is not preserved sufficiently for positive identification of the species outside of the type locality.

The types of *Protocardia shumardi* (Meek and Hayden) were obtained from the southwestern part of the Black Hills in association with species that are characteristic of the Redwater Shale Member of the Sundance Formation. That member contains the ammonite *Cardioceras* of late Oxfordian age. The types of *P. schucherti* McLearn were obtained from Grassy Mountain near Blairmore, Alberta (Frebold, 1957, p. 21, 76; 1963, p. 4, 5), in beds that are dated as early Callovian and possibly also late Bathonian (Frebold, 1963, p. 28–30). *Protocardia* in the Twin Creek Limestone has been found only in the Rich and Leeds Creek Members of Bajocian and early Callovian ages.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 20963 and 28507; Leeds Creek Member at Mesozoic locs. 18182 and 28591.

Genus PLEUROMYA Agassiz, 1843

Pleuromya subcompressa (Meek)

Plate 5, figures 16–21

For synonymy and discussion of this species see Imlay, 1964a, p. C 35.

Pleuromya subcompressa (Meek) is represented by about 135 specimens from the Twin Creek Limestone. These were collected from the middle and upper parts of the Sliderock Member and from all parts of the Rich Member. The species possibly includes *P. weberensis* (Meek) (1877, p. 137, pl. 12, figs. 11, 11a) (pl. 5, figs. 22, 23) which was obtained with *P. subcompressa* (Meek) from the Twin Creek Limestone in Weber Canyon, Wasatch Range, Utah. Similar-appearing specimens of *Pleuromya* have since been obtained (USGS Mesozoic loc. 28642) at about the same place from 30 to 40 feet above the basal oolitic limestone of the Sliderock Member. The species is common elsewhere in the western interior in beds of Bajocian to early Callovian age. For example, in the Jurassic sequence on the north side of Lower Slide Lake, Teton County, Wyo., the species ranges from the upper part of unit 10 to about 40 feet above the base of unit 22 (Imlay, 1956a, p. 70–71). The associated ammonites are of Bajocian age in unit 10 and of Callovian age in units 19 and 22.

Types: Lectotype, USNM 132756; syntypes, USNM 8061, 132839, 132840; plesiotypes, USNM 8180, 28958–28961, 132757.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 3218, 3219, 3391, 6364, 8177, 17961, 20344, 20345, 20966, 20968, 20969, 20970, 20975, 20977, 20984, 20988, 21618, 21619, 21632, 27729, 28459, 28483, 28484, 28635, 28642, 28644, 28645, 28648 and 28798; Rich Member at Mesozoic locs. 985, 6362, 6363, 17297, 20963, 20965, 21468, 21620, 21629, 28639, 28785, 28788, 28792 and 28793; from Sliderock or Rich Member at Mesozoic locs. 3822, 9101, and 17977.

Genus CORBULA Bruguière, 1797

Corbula cf. C. munda McLearn

Plate 2, figures 5–11

c.f. *Corbula munda* McLearn, 1924, Royal Soc. Canada Proc. and Trans., 3d ser., sec. 4, v. 18, p. 58, pl. 9, figs. 1, 2, 5.

Many molds of *Corbula* have been obtained from the Twin Creek Limestone between Labarge Creek and Slate Creek in western Wyoming. These molds are similar in size, shape, and in fineness of concentric ribbing to *Corbula munda* McLearn (1924, p. 58, pl. 9, figs. 1, 2, 5) from beds of late Bathonian or early Callovian age on Grassy Mountain near Blairmore, Canada (Frebold, 1963, p. 5, 29). *C. munda* McLearn has been obtained elsewhere in the lower 38 feet of the Rierdon Formation (USGS Mesozoic loc. 18716) in northwestern Montana (Cobban, 1945, p. 1280, 1281; Imlay, 1945, p. 1024). That part is considered to be of earliest Callovian age on the basis of the occurrence of the ammonites *Cadoceras* and *Kepplerites*. The specimens of *Corbula* in the Twin Creek Limestone occur in beds that are of Bajocian age.

Figured specimens: USNM 132758–132760.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 20963, 21629, 28786–28788.

Genus **PHOLADOMYA** G. B. Sowerby, 1823

Pholadomya kingi Meek

Plate 5, figures 36–38, 42

For synonymy see Imlay, 1964a, p. C460.

This species bears from 8 to 14 strong radial ribs that occur on the middle and most of the anterior parts of the shell.

It is represented in the Twin Creek Limestone by five specimens from the Sliderock Member, by one from the Rich Member, and by one fragment probably from the Rich Member. Elsewhere in the western interior region the species is moderately common in shale and shaly limestone of Bajocian and early Callovian age.

Types: Holotype, USNM 7815; plesiotypes USNM 28957, 132003.

Occurrences: Twin Creek Limestone; Sliderock Member at USGS Mesozoic locs. 20344, 20972, 20988, 21619, and 28645; Rich Member at Mesozoic locs. 28785 and 21620.

Pholadomya inaequiplicata Stanton

Plate 5, figures 24–26

Pholadomya inaequiplicata Stanton, 1899, U.S. Geol. Survey Mon. 32, p. 625, pl. 74, fig. 4.

Pholadomya inaequiplicata Stanton. Imlay, 1964a, U.S. Geol. Survey Prof. Paper 384-C, p. C36, pl. 4, figs. 37, 38.

This species is characterized by having about 20 radiating ribs that cover most of the shell. It differs from *Pholadomya kingi* Meek by being smaller, thicker, and shorter and by having more radiating ribs.

It is represented by four specimens from the Twin Creek Limestone.

Types: Holotype, USNM 28956; paratypes, USNM 30668; plesiotypes, USNM 132004, 132005.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 17985 and 28635; Sliderock or Rich Member at Mesozoic locs. 3822 and 17977.

Genus **GONIOMYA** Agassiz, 1842

Goniomya montanaensis Meek

Plate 1, figure 17

For synonymy and description see Imlay, 1964a, p. C36, pl. 4, figs. 34, 35.

This species is represented by seven specimens from the Twin Creek Limestone; it ranges from the upper part of the Sliderock Member to the upper part of the Rich Member.

Types: Holotype, USNM 7814; plesiotype, USNM 132761.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 20971, 20977, and 28798; Rich Member at Mesozoic locs. 20963 and 28785; Sliderock or Rich Member at Mesozoic loc. 17977.

Genus **MYOPHOLAS** H. Douville, 1907

Myopholas hardyi Imlay

Plate 5, figures 27–35

Myopholas hardyi Imlay, 964a, U.S. Geol. Survey Prof. Paper 483-C, C37, pl. 4, figs. 12–14.

In addition to the primary types, this species is now represented by one specimen from the Watton Canyon Member of the Twin Creek Limestone in Utah, five specimens from the Rierdon Formation in central Montana, and 17 specimens from the "Lower Sundance" Formation in the Bighorn Basin, Wyo. On the basis of these specimens, the species may be redescribed as follows:

The shell is rather large for the genus, elongate ovate, nearly twice as long as high, highly convex, and inequivalve. The umbones are broad, strongly incoiled, inclined forward, and are at about one-third of the length of the shell from the anterior end. The anterior margin is evenly rounded. The ventral margin is gently convex. The posterior margin is narrowly rounded and gaping. Most of the gape is in the right valve.

The ornamentation consists of strong radial ribs, slightly weaker widely spaced concentric ribs, and a radial sulcus that extends steeply backward from the posterior side of the umbo to the ventral margin. The anterior part of the shell bears from five to seven strong sharp widely spaced radial ribs that curve anteriorly as they approach the ventral margin. The medial part of the shell bears from six to eight less sharp closely spaced radial ribs. These are bounded posteriorly by a sulcus that is much more pronounced on the right valve than on the left and that marks the beginning of the gape and of an abrupt change in the curvature of the shell. Posterior to the sulcus follow six or seven rather fine radial ribs, the most posterior of which is stronger than the others and marks another change in the curvature of the shell. Posterior to these ribs the surface is marked by concentric ribs and by a weak sulcus near the dorsal margin. This sulcus on the right valve extends farther anteriorly than on the left valve, contains small pits, and apparently marks the position of the external ligament. The intersection of the concentric ribs with the radial ribs produces a reticulate appearance that is most pronounced posterior to the sulcus.

This species greatly resembles *Myopholas nana* H. Douvillé (1907, p. 110, pl. 2, fig. 1; Lissajous, 1932, p. 198, pl. 32, figs. 8, 8a) from beds of Bathonian age in Europe but differs by having somewhat finer radial ribs on the medial and posterior parts of the shell and by attaining a much larger size. Compared with *M. acuticostata* (Sowerby) (1829, pl. 546, fig. 1; Arkell, 1935, p. 349, pl. 45, figs. 14–16), it has a broader and deeper radial sulcus, a broader posterior margin, and stronger concentric ribbing. The genus *Myopholas* is possibly represented by *Neaera longirostra* Whitfield (1880, p. 376, pl. 5, fig. 35) from the Jurassic of the Black Hills, but the type specimen is a poorly preserved mold that retains mere traces of ornamentation.

All occurrences of *Myopholas hardyi* Imlay are in beds of Callovian age as indicated by associated ammonites or by high stratigraphic position. In central Utah the species occurs within the upper 500–600 feet of the Twelvemile Canyon Member of the Arapien Shale (USGS Mesozoic locs. 21448 and 21449). In northeastern Utah near Hanna it occurs a little above the middle of Watton Canyon Member of the Twin Creek Limestone (USGS Mesozoic loc. 21623). In central Montana near Lewistown it occurs in the lower 15 feet of the Rierdon Formation (USGS Mesozoic loc. 19170) associated with *Cadoceras* and *Gryphaea nebrascensis* Meek and Hayden. In north-central Montana in the Little Rocky Mountains it occurs near the top of the Rierdon Formation (USGS Mesozoic locs. 18750 and 18754) associated with *Kepplerites* and *Gryphaea nebrascensis* Meek and Hayden.

In north-central Wyoming, *Myopholas hardyi* Imlay occurs in the lower part of the "Lower Sundance" Formation just below the lowest occurrence of *Gryphaea nebrascensis* Meek and Hayden. At one locality near Cody (USGS Mesozoic loc. 19633) it was found with *Arcticoceras codyense* Imlay (now referred to *Warrenoceras* by Frebold, 1963, p. 13) in a bed 7 feet above the base of the formation. At another locality in the Mavericks Springs area (USGS Mesozoic loc. 26032) north of Lander it was found with *Cadoceras* from 28 to 35 feet above the top of red beds. At these localities in Wyoming it occurs in oolitic beds that pass eastward into the Canyon Springs Sandstone Member of the Sundance Formation and westward into the Watton Canyon Member of the Twin Creek Limestone (Imlay, 1950a, p. 40; 1953a, p. 56).

Types: Holotype, USNM 132007; paratype, USNM 132008; plesiotypes, USNM 132762–132766.

Occurrence: Twin Creek Limestone, Watton Canyon Member at USGS Mesozoic loc. 21623.

Genus CERCOMYA Agassiz, 1843

Cercompa punctata Stanton

Plate 5, figures 39–41

For synonymy and discussion see Imlay, 1964a, p. C37, pl 4, fig. 31.

This species is represented by four specimens from the Twin Creek Limestone. All were collected from the soft shaly limestone of the Rich Member in the easternmost occurrences of the formation. In the "Lower Sundance" Formation exposed north of the Lower Slide Lake, Teton County, Wyo., the species ranges from the lower part of unit 10 into unit 19 (Imlay, 1956a, p. 70). Of these, unit 10 is correlated with the lower part of the Rich Member and unit 19 with the Watton Canyon Member of the Twin Creek Limestone. In northwestern Montana it has been found in the upper siltstone member of the Sawtooth Formation (Imlay, 1962a, p. C21) as well as near the top of the Rierdon Formation USGS Mesozoic loc. 10729).

Types: Holotype, USNM 28945; paratype, USNM 30593; plesiotypes, USNM 132009, 132767, and 132768.

Occurrences: Twin Creek Limestone, Rich Member at USGS Mesozoic locs. 3815, 20963, and 28788.

Genus PLATYMYA Agassiz, 1838

Platymya rockymontana Imlay, n. sp.

Plate 5, figures 43–49

This species is represented in the Geological Survey collections by 14 specimens of which 1 is from the Twin Creek Limestone.

The shell is moderate in size for the genus, elongate, oblong, moderately inflated and gaping posteriorly. The umbones are wide, depressed, contiguous, directed slightly backward, rising ⅕–⅙ of the height of the shell above the hinge line, and are about ⅖ of the length of the shell from the anterior end. The anterior end is evenly rounded. The posterior end is subquadrate in outline and becomes narrower during growth. The hinge is long and straight. The ventral margin is subparallel to the hingeline and concave posterior to its center. The post-umbonal slope is marked by a broadly rounded carina that trends from the umbones to the posteroventral angle. On most specimens this carina is followed dorsally by a shallow sulcus which is followed in turn by a sharp narrow carina bordering the escutcheon. In addition the shell bears a nearly vertical sulcus that trends from the umbo to the ventral margin a little anterior to the center of the shell and produces an emargination of the ventral margin.

The ornamentation consists of coarse widely spaced concentric growth lines on which are superimposed fine dense concentric growth lines. The coarse growth lines are strongest on the anterior part of the shell, are fairly strong on the postumbonal ridge, and are weakest on the posterior part of the shell ventral to the postumbonal ridge. Radial rows of fine punctae are preserved on several specimens. On one specimen they are visible on most of the ventral half of the shell anterior to the postumbonal ridge. The hinge line is not exposed. None of the specimens are preserved well enough for accurate measurements.

This species is referred to *Platymya* rather than *Cercomya* because its posterior margin is subquadrate, and its posterior part is not extended as a long, narrow rostrum. *Platymya* was once considered by Arkell (1936, p. 351) to be a synonym of *Cercomya* but later was recognized by Cox and Arkell (1950, p. 96) as a distinct genus. This conforms with the views of Gillet (1924, p. 154).

The species shows considerable resemblance to "*Plectomya*" *rugosa* (Roemer) as figured by de Loriol and others (1872, p. 193, 194, pl. 12, figs. 6, 7) from the Portlandian of Europe, but its beaks are more anterior, its ventral margin is concave, and it has a distinct median sulcus. *Platymya scarburgensis* (Morris and Lycett) (1855, p. 138, pl. 15, fig. 13) from the Inferior Oolite of England is similar in shape and concentric ribbing but lacks a median sulcus. "*Anatina*" *agassizi* d'Orbigny (1845, pl. 369, figs. 3, 4) from the Neocomian of Europe differs from *Platymya rockymontana* Imlay, n. sp., by having a broader truncated posterior margin. "*Anatina*" *astieriana* d'Orbigny (1845, pl. 370, figs. 4, 5) of Neocomian age has a less distinct sulcus and smaller less elevated umbones.

Another similar species is "*Pleuromya*" *postculminata* McLearn (1924, p. 55, pl. 9, fig. 6) from the *Corbula munda* beds on Grassy Mountain near Blairmore, Alberta, (McLearn, 1929c, p. 86; Frebold, 1957, p. 76; 1963, p. 5, 29). It differs from *Platymya rockymontana* Imlay, n. sp., by having more prominent umbones that are situated more anteriorly; and its anterior dorsal margin is concave.

Platymya rockymontana Imlay, n. sp., has been found in the Twin Creek Limestone only in the Leeds Creek Member. This member is considered to be of Callovian age because its eastern and northern marginal parts contain the pelecypod *Gryphaea nebrascensis* Meek and Hayden, which elsewhere in the western interior is associated with ammonites of Callovian age and has not been found in older beds. Furthermore, within the Jackson Hole area in northwestern Wyoming, the Leeds Creek Member passes into shaly beds that contain the Callovian ammonites *Cadoceras* and *Xenocephalites* (Imlay, 1956a, p. 70).

Other occurrences of *Platymya rockymontana* Imlay, n. sp., outside of the Twin Creek Limestone are all from beds that contain *Gryphaea nebrascensis* Meek and Hayden and that generally contain Callovian ammonites. For example, at Lower Slide Lake, Teton County, Wyo., the species occurs (USGS Mesozoic loc. 20974) in unit 19 (Imlay, 1956a, p. 70) in association with *Cadoceras*. In the Big Snowy Mountains, Mont., it occurs (USGS Mesozoic loc. 19170) in the basal 15 feet of the Rierdon Formation associated with *Cadoceras*. In the Little Rocky Mountains, Mont., it occurs (USGS Mesozoic locs. 9834, 18735, 19583) near the top of the Rierdon Formation associated with *Kepplerites*. In Park County, Mont., about 8 miles west southwest of Livingston, it is associated with *Warrenoceras* (USGS Mesozoic loc. 25868). These occurrences are evidence that the species is a good indicator for a Callovian age.

Types: Holotype, USNM 132769; paratypes, USNM 132770–132773.

Occurrences: Twin Creek Limestone, Leeds Creek Member at USGS Mesozoic loc. 12016; Rierdon Formation at Mesozoic locs. 9834, 10729, 18735, 18750, 19170, 19583 and 25868; "Lower Sundance" Formation at Mesozoic loc. 20974.

Genus THRACIA Leach, 1823

Thracia weedi Stanton

For synonymy, description, and illustrations see Imlay, 1964a, p. C38, pl. 4, figs. 32, 33.

Thracia weedi Stanton is represented by 14 specimens from the Rich Member and one from the upper part of the Sliderock Member of the Twin Creek Limestone in Wyoming and Utah. The species is fairly common in shaly limestone of Bajocian age near Yellowstone National Park. For example, it occurs from 8 to 20 feet above the base of unit 10 of the section on the north side of Lower Slide Lake, Teton County, Wyo. (Imlay, 1956a, p. 70.) It is common in the middle limestone member of the Piper Formation in southern Montana.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic loc. 20977; Rich Member at USGS Mesozoic locs. 17297, 20963, 21468, 21629, 28785, 28788, and 28793.

Class CEPHALOPODA
Genus SPIROCERAS Quenstedt, 1858

Spiroceras cf. S. orbignyi Baugier and Sauze

Plate 6, figures 4–6, 9, 11

cf. *Toxoceras orbignyi* Baugier and Sauze. d'Orbigny, 1850, Paléontologie française: Terrains jurassiques, v. 1, Céphalopodes, p. 593, pl. 231, pl. 232, figs. 1, 2.

cf. *Patoceras orbignyi* (Baugier and Sauze). Fallot and Blanchet, 1923, Inst. Catalana Hist. Nat., Trabajos, v. 1921–22, pt. 11, p. 131, pl. 3, figs. 8, 9.

cf. *Spiroceras orbignyi* Baugier and Sauze. Potonie, 1929, Preuss. geol. Landesanstalt Jahrb., v. 50, p. 247, pl. 18, figs. 29–32.

cf. *Spiroceras orbignyi* Baugier and Sauze. Roman and Petourand, 1927, Lyon Univ., Lab. Géologie Travaux Mem. 9, pt. 11, p. 36, pl. 4, figs. 14, 14a,b,c.

The genus *Spiroceras* is represented by two molds. One is a small external mold that shows the ventral region, and one is a large internal mold that is part of a slightly curved shaft. The internal mold is subovate in section and higher than wide. The ornamentation consists of two rows of tubercles on each side of the venter and of simple, low, broad, gently curved ribs. The most ventral row of tubercles is the stronger. The ribs incline slightly forward on the upper part of the flanks, cross the venter transversely, and are somewhat weakened along the midline of the venter. The ribs on the lower part of the flanks curve toward the aperture, weaken dorsally, and are not apparent on the dorsum. Neither mold shows any trace of the suture line.

These specimens compare closely in size, shape, and ornamentation with the illustrations of *Spiroceras orbignyi* Baugier and Sauze, as given above and could be within the range of variation of that species. The specimen showing the closest resemblance is that illustrated by Potonie (1929, pl. 18, figs. 29, 30). The large specimen from the Twin Creek Limestone differs apparently only by having a straighter shaft. The fact that the shaft is only slightly curved does not preclude its assignment to *Spiroceras* whose shaft in places and in some specimens may be straight (compare d'Orbigny, 1950, pl. 226, fig. 1, pl. 228, fig. 1; Potonie, 1929, pl. 17, fig. 24, pl. 18, fig. 30).

Figured specimens: USNM 132774, 132775.

Occurrences: Twin Creek Limestone, upper part of Sliderock Member at USGS Mesozoic locs. 20969 and 20985.

Genus STEPHANOCERAS Waagen, 1869

Stephanoceras cf. S. skidegatensis (Whiteaves)

Plate 6, figure 10

cf. *Stephanoceras* cf. *skidegatensis* (Whiteaves). Warren, 1947, Research Council Alberta Rept. 49, p. 72, pl. 5, fig. 2, pl. 7, fig. 1.

cf. *Stephanoceras* ex. gr. *skidegatensis* (Whiteaves). Frebold, 1957, Canada Geol. Survey Mem. 287, p. 49, pl. 21, fig. 1.

One crushed body whorl bears about 38 weak primary ribs that curve forward gently on the lower part of the flanks. At the adapical end of the whorl the ribs terminate in weak tubercles. On most of the whorl the primary ribs are nontuberculate and pass indistinctly into weaker secondary ribs that outnumber the primary ribs about three to one. The body chamber occupies about two-thirds of a whorl and is probably nearly complete. The specimen has considerably weaker ribbing than the holotype of *Stephanoceras skidegatensis* (Whiteaves) (1876, p. 34, pl. 3, figs. 8, 9; McLearn, 1932a, p. 54, pl. 1, fig. 2, pl. 2, fig. 3, pl. 3, figs. 8, 9) from the Queen Charlotte Islands and shows more resemblance to the specimens of *Stephanoceras* from the Rock Creek Member of the Fernie Formation as illustrated by Warren (1947, pl. 5, fig. 2, pl. 7, fig. 1) and Frebold (1957, pl. 21, fig. 1).

Figured specimen: USNM 132776.

Occurrence: Twin Creek Limestone, about 110 feet below the top and 17 feet above the base of the Sliderock Member at USGS Mesozoic loc. 21632.

Stephanoceras aff. S. nodosum (Quenstedt)

Plate 7, figures 4, 5

The species is represented by one distorted internal mold that shows the umbilicus, part of the penultimate whorl, and most of the adult body whorl. The shell is compressed and evolute. The septate whorls embrace the preceding whorls about one-half. The body whorl embraces the penultimate whorl less than one-third. The whorls are ovate in section and a little wider than high. The flanks, venter, and umbilical wall round evenly into each other. The umbilicus is fairly wide and shallow. The umbilical wall is steeply inclined on the inner whorls, but becomes gently inclined on the outer whorls. The body chamber occupies about three-fourths of a whorl. The aperture on the internal mold is marked by a forwardly inclined constriction that is followed by a collar.

The whorls exposed in the umbilical wall bear rather weak moderately spaced primary ribs that incline slightly forward and terminate in acute tubercles near the middle of the flanks. Adorally, the primary ribs gradually become widely spaced and weaker and are barely visible on the body chamber. The tubercles remain acute and persist a little below the middle of the flanks to within 50 mm of the aperture. The body whorl bears 15 tubercles. Secondary ribs, exposed on the adapical end of the penultimate whorl, are fine and closely spaced and outnumber the tubercles about six or seven to one. On the body whorl the secondary ribs are broader and outnumber the tubercles four or five to one.

The specimen at a maximum diameter of 140 mm, has a whorl height of 38 mm, a whorl thickness of 41 mm, and an umbilical width of 70 mm. The suture line cannot be traced.

This species is characterized by the presence of widely spaced acute tubercles on its body whorl, by marked weakening of its primary ribs adorally, and by the presence of fine closely spaced secondary ribs on the penultimate whorl. It resembles *Stephanoceras nodosum* (Quenstedt) (1887, p. 532, pl. 65, fig. 17; Weisert, 1932, p. 136–138, pl. 15, figs. 1, 2) in tuberculation, involution, and whorl shape, but its body whorl has sparser and weaker primary ribs, and its septate whorls have finer and denser secondary ribs. It shows a closer resemblance in these respects to a fragmentary specimen described by Maubeuge (1951, p. 59, pl. 6, fig. 6) as *S.* aff. *S. nodosum* (Quenstedt).

Figured specimen: USNM 132777.

Occurrence: Twin Creek Limestone, upper 30 feet of Sliderock Member in Utah at USGS Mesozoic loc. 21618.

Genus STEMMATOCERAS Mascke, 1907

Stemmatoceras arcicostum Imlay, n. sp.

Plate 8, figures 1, 2; plate 9, figures 1–11

The species is represented by eight fragmentary specimens from one locality on Birch Creek in north-central Utah and seven specimens from Tigh Creek near Drummond, Mont.

The shell is a stout serpenticone. The whorls are subovate in section, a little wider than high, and embrace the preceding whorls about one-half. The flanks round evenly into the broadly rounded venter and into the steeply inclined umbilical wall. The umbilicus is fairly wide and does not appear to widen on the adult whorl. The adult body chamber occupies about three-fifths of a whorl. The aperture, preserved only in part on the holotype, is slightly contracted. The curvature of growth lines near the adoral end of the holotype show that the aperture was prolonged ventrally.

The small septate whorls are marked by fairly sharp moderately spaced primary ribs that arise near the umbilical seam, curve slightly forward on the flanks, and terminate in small acute tubercles just below the middle of the flanks. From the tubercles pass bundles of three to four sharp secondary ribs that arch gently forward on the venter. Other ribs arise freely at or above the zone of tuberculation, resulting in about five secondary ribs for each primary rib.

On the larger septate whorls the primary ribs become broader and more widely spaced; tuberculation becomes less distinct, and the secondary ribs arch forward more strongly on the venter.

On the adult body chamber the primary ribs are broad and low and terminate weakly at about one-third of the whorl height without forming tubercles. The upper part of the flanks and the venter are marked by weak secondary ribs that arch forward strongly on the venter, outnumber the primary ribs nearly six to one, and are mostly indistinctly connected with the primary ribs. Adorally, on the body chamber, the primary ribs become broader and fainter and are replaced near the aperture by forwardly curved striae. The secondary ribbing persists on the venter almost to the aperture. The body whorl bears 23 primary ribs.

The suture line has broad saddles that descend evenly to the unbilical seam. The first lateral lobe is trifid, moderately wide, and is shorter than the ventral lobe. The first auxiliary lobe is inclined obliquely.

The holotype, measured near its aperture, has a maximum diameter of 205 mm, has a whorl height of 68 mm, a whorl thickness of 89 mm, and an unbilical width of 85 mm. One-half whorl adapical from the aperture the same dimensions are 170, 55, 78, and 69 mm, respectively.

This species is assigned to *Stemmatoceras* rather than *Teloceras because* of its weak tuberculation. It is much stouter and more involute than *Stephanoceras*. It is characterized by its fine, closely spaced secondary ribs, by the forward arching of those ribs, and by its early loss of tuberculation.

The septate whorls of this species resembles the septate holotype of *Stemmatoceras palliseri* McLearn (1932b, p. 114, pl. 2, pl. 5, fig. 1) from Canada in whorl shape and umbilical width. They differ by having weaker tubercles and ribs and by their secondary ribs being closer spaced and arching forward on the venter instead of crossing the venter transversely. The adult body whorl of *S. palliseri McLearn*, as illustrated by Warren (1947, p. 68, pl. 3, fig. 1), differs from the adult body whorl of *S. arcicostum* Imlay, n. sp., by becoming higher than wide adorally and by contracting considerably from the penultimate whorl. *S. mclearni* Warren (1947, p. 68, 69, pl. 1, fig. 1, pl. 4, fig. 1) differs from *S. arcicostum* Imlay, n. sp., by developing a higher whorl, by being more evolute, and by having only about three secondary ribs for each primary rib. *Teloceras allani* Warren (1947, p. 70, pl. 2) is more evolute, has sparser secondary ribs, and appears to have coarser primary ribs on its septate whorls. All the various described species of *Stemmatoceras* from central Europe (Weisert, 1932) have sparser and coarser secondary ribbing.

Types: Plastoholotype, USNM 132778; paratypes, USNM 132779–132783.

Occurrences: Twin Creek Limestone, about 45 feet below top of Sliderock Member at USGS Mesozoic loc. 28645. Sawtooth Formation near Tigh Creek 3 miles west of Drummond, Mont., at USGS Mesozoic loc. 27337 (equals Marvin Kauffman's locs. MK–58–T–3 and 4, MK–60–TC, and MK–61–TC). The holotype is the property of J. M. Rufus at Drummond, Mont., and was obtained by him at, or near, the same locality as the specimens collected by Marvin Kauffman. Three fragments of *Stemmatoceras* resembling *S. arcicostum* Imlay, n. sp., were collected by Hans Frebold from Swift Reservoir west of Dupuyer, Mont. Two of these fragments (USGS Mesozoic loc. 28825) are from a conglomeratic bed near the base of the shale member of the Sawtooth Formation (unit 5 of Cobban, 1945, p. 1295) and one (USGS Mesozoic loc. 28826) is from 14 feet higher (unit 10 of Cobban, 1945, p. 1295).

Stemmatoceras, n. sp. aff. S. albertense McLearn

Plate 10, figures 1–8; plate 16, figures 5–7

cf. *Stemmatoceras albertense* McLearn, 1928, Canada Natl. Mus. Bull. 49, Geol. ser., no. 48, p. 20, pl. 5–7.
cf. *Stemmatoceras albertense* McLearn. Warren 1947, Alberta Research Council Rept. 49, p. 67, 68, pl. 5, fig. 1.
cf. *Stemmatoceras albertense* McLearn. Frebold, 1957, Canada Geol. Survey Mem. 287, p. 50, 51, pl. 21, figs. 2a, b, pl. 23, figs. 1a–c.

Forty-six fragmentary ammonites, herein compared with *Stemmatoceras albertense* McLearn, are characterized by having a depressed whorl section that is much wider than high. On the inner whorls the primary ribs are sharp, fairly closely spaced, curved forward, and terminate ventrally in acute tubercles just below the middle of the flanks. Adorally the primary ribs become stronger and more widely spaced and the tubercles become more pronounced. Secondary ribs arise by two's and three's on the inner whorls and by three's and four's on the outer whorls. The secondary ribs are fairly sharp, are separated by much wider interspaces, incline forward on the upper parts of the flanks, and cross the venter almost transversely. One large, mostly nonseptate, internal mold, probably representing part of the adult body whorl, bears strong widely spaced primary ribs and much weaker secondary ribs that arch forward slightly on the venter. The ventral ends of the primary ribs bear blunt tubercles.

The specimen shown on plate 10, figures 1 and 3, at an estimated diameter of 98 mm, has a whorl height of 35 mm, a whorl thickness of 45 mm, and an umbilical width of 43 mm. The next outer whorl of the same specimen (pl. 10, figs. 4, 7) at a whorl height of 50 mm has a whorl thickness of 62 mm. The largest figured fragment (pl. 10, fig. 5) at a whorl height of about 67 mm has a whorl thickness of 104 mm. Evidently, the whorl section becomes lower during growth.

These fragmentary ammonites differ from the holotype of *Stemmatoceras albertense* McLearn by having a slightly higher whorl section, more widely spaced primary ribs on their outer whorls, more closely spaced primary ribs on their inner whorls, and somewhat stronger secondary ribs. Their secondary ribs are no stronger, however, than those on the specimen of *S. albertense* McLearn illustrated by Warren (1947, pl. 5, fig. 1). Their whorl height and the spacing of their primary ribs is similar to that on *Stemmatoceras mclearni* Warren (1947, p. 68, 69, pl. 1, fig. 1, pl. 4, fig. 1), but that species, as illustrated, has much weaker primary ribs and tubercles.

Figured specimens: USNM 132784–132786, 132940, 132941.

Occurrences: Twin Creek Limestone, upper part of Sliderock Member at USGS Mesozoic locs. 16016, 20344, 20345, 20988, 21618, 22638, 28644–28646, 28483, 28794, and 28795. The species is questionably represented by one specimen from the Sawtooth Formation on Tigh Creek west of Drummond, Mont. (loc. MK-61–TC).

Stemmatoceras cf. S. palliseri McLearn

Plate 7, figures 1–3

Four fragmentary internal molds from Tigh Creek near Drummond, Mont., resemble *Stemmatoceras palliseri McLearn* (1932b, p. 114, pl. 2, pl. 5, fig. 1) in whorl shape and ribbing. One of the fragments includes part of a septate whorl and part of the body chamber. The septate whorl bears four secondary ribs for each primary rib. The body chamber bears broad low widely spaced forwardly inclined primary ribs that fade out near the middle of the flanks. The venter and the upper parts of the flanks are smooth. These specimens differ from those herein assigned to *S. arcicostum* Imlay, n. sp., by having coarser and sparser ribbing on the septate whorl and by the secondary ribs fading on the body chamber. The adult body chamber of *S. palliseri* McLearn, as illustrated by Warren (1947, pl. 3), shows similar weakening of the ribbing adorally.

Figured specimen: USNM 132787.

Occurrences: Sawtooth Formation on Tigh Creek, 3 miles west of Drummond, Mont. at USGS Mesozoic loc. 27337 (locs. MK–58–T1, MK–58–T2, MK–60–TC and MK–61–TC of Marvin Kauffman).

Genus SOHLITES Imlay, n. gen.

This genus is characterized by fairly involute coiling, by a moderately compressed whorl section, by prominent umbilical tubercles that during growth change from conical to radially elongate and from a position a little below the middle of the flanks to near the umbilicus, by many sharp forwardly inclined ribs that arise from the tubercles or from the zone of tuberculation and are strongest on the venter, and by simple suture lines that have nonretracted suspensive lobes.

The type species of *Sohlites* is *S. spinosus* Imlay, n. sp. The genus is named in honor of Norman F. Sohl of the U.S. Geological Survey.

The ornamentation of *Sohlites* resembles that of *Reineckeia* Bayle, 1878 (see Arkell and others, 1957, p. L312), *Zemistephanus* McLearn (1927, p. 72; 1929a, p. 18), and *Ermoceras* H. Douvillé (1916, p. 17; Arkell, 1952, p. 272–277). *Sohlites* differs from any described genus of the Reineckiidae, however, by being much more involute, by lacking a ventral band or sulcus, and by having a much simpler suture line. From *Reineckeia*, in addition, it differs also by its tubercles being nearer the umbilicus after an early growth stage. In this respect it shows more resemblance to *Zemistephanus* and particularly to small specimens of *Z. carlottensis* (Whiteaves) (Imlay, 1964b, p. B52, pl. 28, figs. 1, 2). It is easily distinguished from *Zemistephanus* by greater involution and a much simpler suture line that has a straight instead of a retracted suspensive lobe. It also shows some resemblance to *Ermoceras* but differs by lacking a ventral sulcus, by having a *Reineckeia*-like arrangement of tubercles and ribs on its inner whorls, and by having a slightly simpler suture line.

The systematic position of *Sohlites* is uncertain, but it is tentatively assigned to the family Stephanoceratidae. On the basis of its resemblance to *Ermoceras*, however, it might be assigned to the family Thamboceratidae Westermann (1964, p. 409).

Sohlites spinosus Imlay, n. sp.

Plate 11, figures 1–26; plate 14, figures 7, 8

This genus is represented by 86 molds from the western interior region. Of these, 37 were obtained in southern Montana south of Big Timber, Livingston, and Bozeman; 30 were obtained near Cody, Wyo.; 1 was obtained from the northwest end of the San Rafael Swell in central Utah; and one was obtained from the Duchesne River near Hanna in northeastern Utah. All are fragmentary and most are crushed or distorted. All appear to belong to a single species.

The innermost whorls to a diameter of about 6½ mm are smooth and evolute. The succeeding septate whorls are strongly ornamented and fairly involute, are ovate in section, and embrace each other about three-fifths. The body whorl is unknown.

The ornamentation appears abruptly after the initial smooth stage. It consists of prominent umbilical tubercles and rather sharp forwardly inclined ribs that arch forwardly gently on the venter and are strongest on the venter. On the smallest ornamented whorls the tubercles are round, very high and very widely spaced, and arise at about two-fifths of the height of the whorl. From them pass from three to four high thin ribs that incline gently forward. In addition, from one to two similar ribs arise freely a little above the zone of tuberculation.

During subsequent growth to a diameter of about 50 mm the tubercles become radially elongate, somewhat less prominent, and extend from the very edge of the umbilicus to about one-fourth of the height of the flanks. From the tubercles arise bundles of four to five ribs that are faint near the tubercles, are sharp and forwardly inclined on the flanks, and that cross the venter with a gentle forward arching. In addition, from one to two ribs arise freely on the flanks and result in a total of six to seven ribs for each tubercle. All ribs are highest and broadest on the venter.

At diameters greater than 50 mm the tubercles become lower and more elongate radially and the ribs become fewer relative to the number of tubercles. On the largest specimens, from two to three ribs arise from each tubercle and from one to two ribs arise freely on the flanks; thus, there are about four ribs for each tubercle. On these specimens the ribs become fairly broad ventrally and arch forward moderately on the venter. Some specimens show faint traces of fine radial striation parallel to the ribs.

The specimens available are too poorly preserved for accurate measurements, but the whorl section appears to be higher than wide.

The suture line is simple and varies appreciably in shape from one specimen to another. The lobes are shallow, wide, and irregular in shape. The ventral lobe is about as long as the first lateral lobe. The first lateral lobe varies from irregularly trifid to almost bifid. The second lateral lobe is irregularly bifid in some specimens, and in others merges with the suspensive lobe which trends nearly straight to the umbilical seam. The first lateral saddle is very broad and irregular in shape. The second lateral saddle, where recognizable, is much narrower than the first lateral saddle.

In summary, *Sohlites spinosus* Imlay, n. sp., is characterized by an early evolute smooth stage that is followed at a small size by a fairly involute coronate strongly tuberculate stage. At first the tubercles are high and conical and are at about two-fifths of the height of the flanks where they give rise to bundles of ribs as in the Callovian genus *Reineckeia*. Later, the tubercles become radially elongate and occupy a position near the umbilicus as in the Bajocian genera *Zemistephanus* and *Ermoceras*. The secondary ribs at all growth stages incline forward on the upper part of the flanks, become higher and broader ventrally, and arch forward on the venter without reduction in strength along the midline.

The larger specimens of *Sohlites spinosus* Imlay, n. sp., show considerable resemblance in ornamentation to the intermediate size whorls of *Zemistephanus carlottensis* (Whiteaves) (1876, p. 38, pl. 6; Imlay, 1964a, p. B52, pl. 24, fig. 6; pl. 28, figs. 1–3), but their umbilical tubercles are more elongate radially and their secondary ribs are sparser and stronger. The small whorls of *S. spinosus* Imlay, n. sp., differ from the smallest whorls of *Z. carlottensis* (Whiteaves) by being more involute and by having from five to seven ribs per tubercle instead of three to five.

Within the genus *Ermoceras*, the type species *E. mogharense* Douvillé (1916, p. 19, 20, pl. 2, figs. 5–9) is probably most similar to *Sohlites spinosus* Imlay, n. sp., but differs by having a distinct ventral sulcus, by lacking *Reineckeia*-like ornamentation on its immature whorls, by its ribs bending forward more strongly on the venter, and by having numerous fine radial striations parallel to the major ribs.

Types: Holotype, USNM 132788; paratypes, USNM 132789–132806.

Occurrences: Carmel Formation in central Utah at USGS Mesozoic loc. 12555; Twin Creek Limestone, Rich Member in Utah at Mesozoic loc. 17048; Gypsum Spring Formation in north central Wyoming at Mesozoic locs. 17096 and 17105; Piper Formation in Montana at Mesozoic locs. 5738, 19621, 19214, 25866, 27035, and 27624; Sawtooth Formation in Montana at Mesozoic loc. 21391 and 28758. Fragments assigned questionably to *Sohlites* were obtained from the Carmel Formation in central Utah at Mesozoic locs. 20351 and 25678 (pl. 11, figs. 19, 22, 23).

The occurrences of *Sohlites* in the western interior of the United States indicate that it is restricted to the upper part of a marine sequence of Bajocian age. In central Utah, it has been found from 6 to 12 feet above the base of the Carmel Formation exposed at the northwest end of the San Rafael Swell. In northeast Utah it has been found 100 feet above the base of the Twin Creek Limestone in the upper part of the Rich Member exposed along the Duchesne River near Hanna. In north-central Wyoming, it has been found about 6 miles south of Cody in shaly beds at or just above the middle of the middle limestone member of the Gypsum Spring Formation (Imlay, 1956b, p. 582, 583). In southern Montana, it has been found mostly in the middle and upper parts of the middle limestone member of the Piper Formation south of Big Timber and Livingston. The fossils at USGS Mesozoic loc. 27035, however, appear to be from the lower part of the limestone member. It has not been found in the Sliderock Member of the Twin Creek Limestone.

Sohlites has been found with *Parachondroceras* only in Montana and only at USGS Mesozoic locs. 19214, 25866, 27035, and 27624. At locality 27624 it was collected from the same bed. At the other localities, collections were made from an interval of at least 20 feet. It may be significant ecologically that *Sohlites* has been found with *Parachondroceras* at only four localities; its total occurrences are far fewer than those of *Parachondroceras*, but it has been collected in much greater numbers.

Genus NORMANNITES Munier-Chalmas, 1892

Normannites? cf. N. crickmayi (McLearn)

Plate 12, figures 1–4

cf. *Kanastephanus crickmayi* McLearn, 1927, Royal Soc. Canada Proc. and Trans., 3d ser., v. 21, sec. 4, p. 73, pl. 1, figs. 5, 6.
cf. *Kanastephanus crickmayi* McLearn, 1929a, Canada Natl. Mus. Bull. 54, p. 22, pl. 16, figs. 7, 8.

The genus *Normannites* is probably represented by five fragments from the western interior region. One fragment obtained from the Sawtooth Formation in western Montana, represents part of the body chamber but does not retain the lateral lappet. The other four fragments, obtained from four localities in the Twin Creek Limestone, are all septate but probably represent part of the penultimate whorl. The specimens all have a depressed whorl section, a wide umbilicus, and coarse widely spaced ribs. There are two secondary ribs for each primary rib. All the specimens are considerably corroded, but one is well enough preserved to show the presence of acute tubercles at the ventral ends of the primary ribs at about one-third of the height of the flanks.

Figured specimens: USNM 132809, 132810.

Occurrences: Twin Creek Limestone, upper part of Sliderock Member at USGS Mesozoic locs. 9090, 20978, 28645, and 28794; Sawtooth Formation at Mesozoic loc. 27337.

Genus CHONDROCERAS Mascke, 1907

Chondroceras cf. C. allani (McLearn)

Plate 6, figures 1–3, 7, 8

Defonticeras oblatum (Whiteaves). Imlay, 1948, U.S. Geol. Survey Prof. Paper 214–B, p. 19, pl. 5, figs. 1–5.
cf. *Saxitoniceras allani* McLearn, 1928, Canada Geol. Survey Bull. 49, p. 21, 22, pl. 8, figs. 1, 2.
cf. *Chondroceras* (*Saxitoniceras*) *allani* McLearn. Westermann, 1956, Geol. Jahrb. Beihefte, no. 24, p. 107–108, pl. 12, fig. 3a–c, text fig. 64.
cf. *Chondroceras allani* McLearn. Frebold, 1957, Canada Geol. Survey Mem. 287, p. 53, pl. 27, figs. 2a, b.

One partly crushed ammonite from northwestern Montana was formerly assigned to *Chondroceras oblatum* (Whiteaves) (Imlay, 1948, p. 19) because of its very simple suture line, an abrupt coarsening of ribbing at the adapical end of the body chamber, and a fairly broad depressed whorl section on the body chamber. The fineness of the ribbing on its outermost septate whorl, however, resembles that on *C. allani* (McLearn) (1928, pl. 8, figs. 1, 2; Frebold, 1957, pl. 27, fig. 2a,b) more than that on *C. oblatum* (Whiteaves) (1876, pl. 4, figs. 2a, b; McLearn, 1929a, pl. 15, fig. 1). The available collections of *C. allani* (McLearn) from Canada (USGS Mesozoic locs. 14630 and 27642) include a few specimens that have a fairly broad whorl section and that show a fairly abrupt coarsening of ribbing on the body chamber.

One difficulty in identifying the Montana specimen is that published descriptions of most of the Canadian species are based on single specimens and consequently the range of variation within the species is unknown. For example, *Chondroceras oblatum* (Whiteaves) is based on a single corroded specimen. It possibly includes other described species as suggested by Westermann (1956, p. 102), but such has not yet been demonstrated.

The Montana specimen is of considerable interest because it is the only specimen of *Chondroceras* definitely identified in the western interior region of the United

States. All other specimens from that region, previously assigned by the writer to *Chondroceras*, are now included in the new genera *Parachondroceras* and *Eocephalites*.

Figured specimen: USNM 104134.

Occurrence: Sawtooth Formation in Montana at USGS Mesozoic loc. 19192. The specimen was collected from the spillway at Swift Reservoir about 21 feet above the base of the Sawtooth Formation. This occurrence is 2 feet above a thin conglomerate bed (unit 5 of Cobban, 1945, p. 1295) that has furnished *Stemmatoceras* and 12 feet below a shale bed (unit 10 of Cobban, 1945, p. 1295) that has also furnished *Stemmatoceras.*

Genus **PARACHONDROCERAS**, n. gen.

This genus is characterized by highly involute coiling on the septate whorls, by markedly eccentric coiling on the body chamber, by a high compressed whorl section, by a narrowly rounded to subacute venter, by fairly sharp ribbing on septate whorls, by disappearance of primary ribs on the body chamber, and by a rather simple suture line that has broad shallow lobes and saddles and a bifid second lateral lobe.

The ribbing of the septate whorls resembles that of *Chondroceras Mascke* (see illustrations in Westermann, 1956, pls. 1–12), but differs by the thickening of the secondary ribs slightly ventrally and their arching forward on the venter. The suture line, also, is similar to that of *Chondroceras*, although simpler. The genus differs from *Chondroceras* mainly by being discoidal instead of spherical, by having a vertical instead of a rounded umbilical wall, and by fading of its primary ribs on the body chamber. There is no evidence of a pronounced terminal constriction and collar as in *Chondroceras*. The fading of ribs on the body chamber is similar to that on *Labyrinthoceras* Buckman (1919, pl. 134).

Parachondroceras resembles the Bathonian to Callovian family Tulitidae in its eccentric coiling and suture line, but has a much different whorl shape and on its septate whorls has much sharper ribbing. Overall, it shows more resemblance to such genera as *Chondroceras* and *Labyrinthoceras* of the Otoitidae.

The type species of *Parachondroceras* is *P. andrewsi* Imlay, n. sp.

Parachondroceras andrewsi Imlay, n. sp.

Plate 12, figures 5–18

This species is represented definitely by 11 specimens and probably also by 10 fragmentary immature specimens. All the specimens except the holotype have been somewhat crushed.

On the holotype the shell is compressed and involute. The venter is nearly acute on the penultimate whorl and is narrowly rounded on the body chamber. The whorl section is much higher than wide. The flanks are flattened and convergent. The umbilicus is very narrow on the septate whorl but widens abruptly on the adoral half of the body chamber. The umbilical wall is low and vertical, and rounds abruptly into the flanks. The body chamber is not completely preserved but occupies nearly three-fifths of a whorl and probably was not much longer. This probability is indicated by marked contraction of the adoral half of the body chamber and by the presence of a weak constriction at the adoral end of the body chamber.

The immature whorls of this species are all somewhat crushed but appear to have had a high elliptical whorl section, a narrowly rounded venter, flat flanks, and a narrow umbilicus.

The immature whorls bear sharp moderately spaced primary ribs that are nearly radial, or that incline forward slightly on the lower two-fifths of the flanks. From the primary ribs arise two slightly weaker secondary ribs that become broader ventrally and arch forward gently on the venter. Most pairs of forked ribs are separated by single ribs that arise freely a little above the furcation zone.

During further growth the primary ribs become broader and stronger relative to the secondary ribs. The secondary ribs become more common and more strongly arched forward. On largest septate whorls there are from three to four secondary ribs for each primary rib.

On the body whorl the ribbing fades rather abruptly on the lower part of the flanks and is replaced by forwardly inclined striae. In contrast, the venter of the body whorl bears strong forwardly arched secondary ribs.

The holotype at a diameter of 64 mm has a whorl height of 32 mm, a whorl thickness of 23 mm, and an umbilical width of 11.5 mm. At the diameter of 80 mm the same dimensions are 40, 30, and 15 mm, respectively. At the maximum diameter of 90 mm the same dimensions are 90, 41, 29, and 18 mm. respectively.

The suture line, well preserved on the holotype, is characterized by broad, shallow lobes and saddles and particularly by the presence of a bifid second lateral lobe. It is similar in plan to that of *Chondroceras* (Westermann, 1956, p. 53, 59, 71, 75, 81, 90, 101, 105, 107) but is less frilled.

The ribbing on the larger septate whorls of this species greatly resembles that on some species of *Chrondroceras*, such as figured by McLearn (1928, pl. 8, figs. 1–4; 1929a, pl. 12, figs. 1–3, pl. 13, figs. 4, 5), and was the basis for some identifications of that genus in previous reports (Imlay, 1945, p. 1021; 1948, p. 14 in part; 1950a, p. 39; 1956b, p. 577).

These identifications were supported by such features as the suture line and the small umbilicus. The species, however, is clearly differentiated from any species of *Chondroceras* by having a high compressed whorl section instead of a rounded whorl section and by the fading out of the primary ribs on the body chamber. Small crushed fragments of the species may possibly be distinguished from similar fragments of *Chondroceras* by the thickening ventrally and arching forward on the venter of the secondary ribs.

The species is named in honor of David A. Andrews who collected the holotype specimen.

Types: Holotype, USNM 132811; paratypes, USNM 12221, 132812–132814.

Occurrences: Piper Formation, middle limestone member in Montana at USGS Mesozoic locs. 17662, 19153, 19214, 20864, 27035, and 27628. Twin Creek Limestone, Rich Member in Wyoming at Mesozoic loc. 21629; Twin Creek Limestone, probably from the Rich Member, in Utah at Mesozoic loc. 8181; "Lower Sundance" Formation in Wyoming at Mesozoic locs. 20967, and 27724. Small fragmentary specimens of *Parachondroceras*, probably belonging to *P. andrewsi* Imlay, n. sp., occur in the Sawtooth Formation in Montana, at Mesozoic locs. 22170 and 28670.

This species in Montana occurs in the upper part of the middle limestone member of the Piper Formation (USGS Mesozoic locs. 19214, 208464, and 27628). In west-central Wyoming it occurs (USGS Mesozoic loc. 21629) near the middle of the Rich Member of the Twin Creek Limestone exposed on the South Fork of Fontenelle Creek. In northwestern Wyoming it occurs (USGS Mesozoic locs. 20967 and 27724) from 10 to 13 feet above the base of unit 10 of the described section of the "Lower Sundance" Formation north of Lower Slide Lake on the Gros Ventre River. This occurrence is in shaly limestone that is considered to be equivalent to the Rich Member of the Twin Creek Limestone of nearby areas. In north-central Utah it occurs in the lower part of the Twin Creek Limestone (USGS Mesozoic loc. 8181). If the location given is correct it should be from the Rich Member rather than from the Sliderock Member. It is associated with *Sohlites*, n. gen., in the Piper Formation at USGS Mesozoic loc. 19214. *Parachondroceras* cf. *P. andrewsi* Imlay was obtained from the lower 20 feet of the Sawtooth Formation at USGS Mesozoic loc. 28670 and from the top of unit 8 (USGS Mesozoic loc. 19153) in the type section of the Ellis Group (Cobban and others, 1945, p. 452).

Parachondroceras filicostatum Imlay, n. sp.

Plate 13, figures 11–14, 16–25

This species is represented by 16 specimens of which most are fragmentary and have been crushed laterally.

The shell is compressed and involute. The whorl section is much higher than wide. The venter is narrowly rounded on the inner whorls, subacute on the largest septate whorl, and narrowly arched on the body chamber. The flanks are flattened, subparallel in immature specimens, and convergent on adult specimens. The umbilicus is very narrow on the septate whorls but widens abruptly on the adoral half of the body chamber. The umbilical wall is low and vertical and rounds abruptly into the flanks. The body chamber is incompletely preserved but occupies at least half a whorl.

The ribbing on the immature whorls consist of fairly sharp moderately closely spaced primary ribs and very fine densely spaced secondary ribs. The primary ribs begin low on the umbilical wall and incline forward slightly on the lower two-fifths of the flanks. From the primary ribs arise two or three secondary ribs that are very weak near the zone of furcation but become a little stronger ventrally. In addition, from one to two secondary ribs arise freely between successive forked ribs near the middle of the flanks. All secondary ribs are of equal strength ventrally, incline slightly forward on the flanks, and arch gently forward on the venter.

During subsequent growth the fine dense forwardly inclined secondary ribs persist on the venter as far as the adapical end of the body chamber. The primary ribs gradually become broader and fainter and eventually fade out on the largest septate whorl. Most of the body chamber is smooth.

The holotype at a diameter of 64 mm has a whorl height of 34 mm, a whorl thickness of 20 mm, and an umbilical width of 9.5 mm. At a diameter of 81 mm, the same dimensions are 40, 27, and 11 mm, respectively. At the maximum diameter of 90 mm, the same dimensions are 43, 30, and 16 mm, respectively.

The suture line has broad, shallow saddles and lobes. The first lateral lobe is irregularly trifid. The second lateral lobe is bifid.

This species differs from *Parachondroceras andrewsi* Imlay, n. sp., mainly by its much finer and denser ribbing that disappears at a much earlier growth stage. Because it is associated with *P. andrewsi* at several localities, it might be considered to be a finely ribbed variant of that species. This possibility is unlikely, however, because the collections do not contain any specimens having ribbing intermediate in coarseness. The available specimens are either finely ribbed or fairly coarsely ribbed.

Types: Holotype, USNM 132815; paratypes, USNM 132816–132819.

Occurrences: Piper Formation, middle limestone member, in Montana at USGS Mesozoic locs. 15635, 19158, 19214, 19630, 20864, 25866, 27624, and 27628; Sawtooth Formation, lower part, in Montana at Mesozoic loc. 28800; unit 10 of "Lower Sundance" Formation at Lower Slide Lake in northwest Wyoming (Imlay, 1956a, p. 70) at Mesozoic locs. 20962 and 22112; Twin Creek

Limestone, Rich Member in Wyoming at Mesozoic loc. 20963. Fragments questionably assigned to this species have been found in the Piper Formation at Mesozoic loc. 17662 and in the lower part of the Twin Creek Limestone in Utah at Mesozoic loc. 21468.

This species in central and southern Montana ranges throughout most of the middle limestone member of the Piper Formation and through the lower part of the Sawtooth Formation. In west-central Wyoming it was found in the upper 30 feet of the Rich Member of the Twin Creek Limestone. In northwestern Wyoming on the north side of Lower Slide Lake it was found from 10 to 20 feet above the base of unit 10 of the published section (Imlay, 1956a, p. 70). This occurrence is near the middle of a shaly sequence that is considered equivalent to the Rich Member of the Twin Creek Limestone in nearby areas.

Genus MEGASPHAEROCERAS Imlay, 1961

Megasphaeroceras cf. M. rotundum Imlay

Plate 14, figures 1–6, 9–16; plate 16, figures 1–4

Twenty-two internal molds from the Twin Creek Limestone closely resemble *Megasphaeroceras rotundum* Imlay (1962b, p. A10, pl. 3, figs. 1, 4–12) from the Cook Inlet region, Alaska, in their stout to globose form, tiny umbilicus, and fine ribbing, and they are probably within the range of variation of that species. The body chamber, preserved on three specimens, occupies about three-fourths of a whorl and is slightly contracted at the aperture. The aperture curves forward and on the internal mold is marked by a broad constriction that is followed by a weak swelling.

The small septate whorls bear fine sharp flexuous ribbing that curves forward on the flanks and arches gently forward on the venter. Some primary ribs remain simple, but most of them bifurcate at about the top of the lower fourth of the flanks. From one to two secondary ribs arise freely near the zone of furcation between adjoining primary ribs. The secondary ribs are nearly as sharp and strong as the primary ribs on the flanks and become stronger ventrally. On the body whorl of internal molds the ribbing fades out toward the aperture. Fading of the ribs occurs first on the lower part of the flanks and finally on the ventral region.

Figured specimens: USNM 132820–132822, 132939.

Occurrences: Twin Creek Limestone, upper part of Sliderock Member at USGS Mesozoic locs. 12019, 20344, 21618, 28483, 28644, 28645, 28648 and 28794.

Megasphaeroceras aff. M. rotundum Imlay

Plate 13, figures 6–10

Six internal molds differ from *Megasphaeroceras rotundum* Imlay (Imlay, 1962b, p. A10, pl. 3, fig. 1, 4–12) and from closely similar specimens herein compared with that species by having somewhat coarser ribbing that persists onto the adult body chamber. The umbilicus appears to be a little wider, also, on two specimens but on the others is very small. This apparent difference in the umbilicus is probably due to deformation and defective preservation. The adoral end of the adult body whorl is slightly contracted from the preceding whorl.

The suture line (pl. 13, fig. 10) greatly resembles that of the compressed variant of *Megasphaeroceras rotundum* Imlay herein illustrated (pl. 13, fig. 15). Both have a broader first lateral saddle than present on the holotype of that species (Imlay, 1962b, pl. 3, fig. 9).

Figured specimens: USNM 132823, 132824.

Occurrences: Twin Creek Limestone, Sliderock Member at USGS Mesozoic locs. 16016, 20978, 28483, and 28635.

All collections, except possibly those from Mesozoic loc. 16016, were obtained near the top of the member.

Megasphaeroceras sp. undet.

Plate 13, figures 4, 5

One internal mold of a body chamber probably represents an adult as indicated by weakening of the ribbing at the adoral end of the body chamber and by the shape of the umbilicus. The specimen differs from those in the Twin Creek Limestone that are herein compared with *M. rotundum* Imlay by having a compressed subquadrate whorl section, a much wider umbilicus, and fairly strong ribbing on the internal mold of the body chamber. The shape of the umbilicus suggests that the body chamber is more contracted.

This specimen probably represents a new species; however, the upper Bajocian collections of *Megasphaeroceras* from Alaska contain three similarly compressed specimens that also bear ribs on the internal molds of the adult body chamber (USGS Mesozoic locs. 20001, 21314, and 21318). These are associated with the typical stout to globose variant of *M. rotundum* Imlay (1962b, p. A10, pl. 3, figs. 1, 4–12) as well as with others that are less stout. One of these compressed specimens, herein illustrated for comparative purposes (pl. 13, figs. 1–3, 15), has a wider umbilicus than the typical variant of *M. rotundum* Imlay, but is less wide than the compressed specimen from the Twin Creek Limestone. It bears a resemblance to some small specimens of *Cranocephalites* from Greenland (Callomon, 1959, pl. 17, figs. 3, 4; pl. 18, figs. 1, 2) but has weaker primary ribs and less eccentric coiling.

Figured specimens: USNM 132825.

Occurrence: Twin Creek Limestone, upper 20 feet of the Sliderock Member at USGS Mesozoic loc. 20975.

Genus EOCEPHALITES, n. gen.

This genus is characterized by fairly involute coiling; by the development of slightly eccentric coiling near the adult aperture; by a stout whorl section; by fairly sharp ribbing that inclines forward on the flanks, arches gently forward on the venter, and does not weaken on the adult body chamber except slightly on internal molds; by the simple termination of the aperture; and by the suture line having broad saddles, trifid lobes, and a long ventral lobe.

The type species of *Eocephalites* is *E. primus* Imlay, n. sp.

This genus differs from *Megasphaeroceras* Imlay (1961, p. 470; 1962b, p. A9–A10, pl. 3, figs. 1–12), with which it is associated in the Twin Creek Limestone, by having a wider and deeper umbilicus, coarser ribbing that does not weaken appreciably on the molds of adult body chambers, and by the much broader saddles of the suture line. It differs from *Chondroceras* by not becoming scaphitoid, by its aperture terminating simply instead of bearing a marked constriction and flare, and by its second lateral lobe being trifid instead of bifid. It differs from *Paracephalites* (Buckman, 1929, p. 8; Frebold, 1963, p. 8, 9) by having a narrower adult umbilicus, by its ribbing remaining fairly strong on the adult body chamber instead of fading, and by its suture line having much broader saddles. It differs from *Cranocephalites* (Spath, 1932, p. 14–16) by not developing a scaphitoid body chamber and by having wider saddles (Spath, 1932, pl. 1, figs. 4a, b; pl. 3, fig. 5), although some specimens of *Cranocephalites* have fairly wide saddles (Spath, 1932, p. 22, pl. 1, fig. 6; pl. 4, fig. 8). It differs from *Arctocephalites* (Spath, 1932, p. 32–34) by not developing a smooth, or nearly smooth, body chamber and by having much broader saddles.

Among these genera, *Eocephalites* probably shows the greatest resemblance to the small- and intermediate-sized whorls of *Paracephalites*, such as *P. sawthoothensis* (Imlay) (1962a, pl. 3, fig. 1–5, 7, 8; pl. 4, fig. 2). Inasmuch as it occurs in the same faunal province as *Paracephalites* and in only slightly older beds, it could be the ancestor of that genus.

The overall characteristics of *Eocephalites* suggest that it is in the same family as *Paracephalites*, *Cranocephalites*, and *Arctocephalites* which Spath (1932, p. 9) placed in the family Macrocephalitidae and which Arkell and others (1957, p. L–301) placed in the family Cardioceratidae and in the subfamily Cadoceratinae. Callomon (1959, p. 507–511) stated that *Cranocephalites* is characteristic of beds of Bathonian age in East Greenland, that the oldest occurrences of the genus are in beds of possible late Bajocian age, that it bears close resemblances to *Chondroceras* of middle Bajocian age, and that it is the earliest of the Cadoceratinae. The resemblance of *Eocephalites* to *Cranocephalites* suggests that the Cadoceratinae began in late Bajocian time.

Eocephalites primus Imlay, n. sp.

Plate 15, figures 3–5, 9–13, 16–20; plate 16, figures 8–14

This species is represented by 43 specimens of which most are fragmentary and distorted internal molds.

The septate whorls are fairly stout, wider than high, and are widest at about one-fourth of the height of the flanks. The venter is fairly broad and rounds evenly into the flanks. The flanks round rather abruptly into a low steeply inclined umbilical wall that becomes vertical near its base. The umbilicus is narrow but not occluded. The adult body whorl is less stout, is a little wider than high, and becomes slightly contracted from the septate whorls. The body chamber occupies about three-fifths of a whorl. The aperture on the internal mold is marked by a forwardly inclined weak constriction that is followed by a weak swelling.

The ribbing on the inner septate whorls is fairly sharp. The primary ribs begin low on the unbilical wall and curve forward on the lower third of the flanks where most of them pass into two slightly weaker secondary ribs. A few primary ribs remain unbranched, and a few ribs arise freely along the zone of furcation. The secondary ribs incline forward on the flanks and venter.

The ribbing on the larger septate whorls gradually becomes stronger and more widely spaced during growth. The primary ribs become stronger relative to the secondary ribs and develop a pronounced forward curve. The secondary ribs arise in pairs, incline considerably forward on the flanks, and arch gently forward on the venter. A few ribs arise freely at or above the zone of furcation resulting in the presence of about three secondary ribs for each primary rib.

The ribbing on the body whorl gradually becomes sparser adorally and on internal molds weakens considerably as compared with the ribbing on the septate whorls. On body whorls that are represented by external molds or that retain some shell material, however, the ribbing is fairly strong.

The suture line, partly preserved on three specimens, is characterized by broad saddles, a trifid second lateral lobe, and a long ventral lobe.

One paratype (pl. 15, figs. 3–5) at a diameter of 48 mm has a whorl height of 25 mm, a whorl thickness of 32 mm, and an umbilical width of 8.5 mm. It has been slightly distorted at the adapical end. On the holotype at a diameter of 76 mm, the same dimensions are 36, 41, and 17 mm, respectively.

This species differs from *Megasphaeroceras rotundum* Imlay, 1962b, p. A10, pl. 3, figs. 1, 4–12) from beds of late Bajocian age in Alaska by having a little wider umbilicus and much stronger and sparser ribbing, by the persistence of ribs on the body chambers of external molds, and by the much broader saddles of its suture lines.

The ribbing on the septate whorls of *Eocephalites primus* Imlay, n. sp., is similar to that on some species of *Cranocephalites* from Greenland (Spath, 1932, pl. 1, figs. 3a, b; pl. 2, figs. 3a, b; pl. 4, figs. 3a, b; pl. 5, figs. 2a, b, 7) except for having a much more pronounced forward curvature. The adult of *Cranocephalites* is distinguished by developing a scaphitoid body chamber whereas the adult body chamber of *E. primus* is contracted only slightly near the aperture.

Eocephalites primus Imlay, n. sp., shows even more resemblance in ribbing to species of *Paracephalites* (Frebold, 1963, p. 8–13, pl. 1, 2, 4; Imlay, 1962a, pl. 3–5) from Alberta, British Columbia, and Montana, but its ribs do not fade out nearly as much on the body chamber, its suture line has much broader saddles, its adult umbilicus is narrower and shallower, its umbilical wall is more gently inclined, and its ribs arch gently forward on the venter instead of crossing the venter transversely. The small septate whorls of *Paracephalites sawthoothensis* Imlay (1962a, pl. 3, figs. 1–5, 7, 8) greatly resemble the small whorls of *Eocephalites primus* Imaly, n. sp., in shape and ribbing, but are distinguished by much sharper ribbing that curves backward slightly on the flanks.

Types: Holotype, USNM 132826; paratypes, USNM 132827–132832, 132938, 132942.

Occurrences: Twin Creek Limestone, upper part the Sliderock Member at USGS Mesozoic locs. 20344, 20345, 20961, 20966, 20968, 20970, 20973, 20988, 21618, 21628, 22638, 27729, 28483, 28484, 28644, 28645, and 28648. Most occurrences are in the upper third of the member, ranging from the top to within 35 feet of the top.

Eocephalites? sp. undet. A

Plate 15, figures 6–8

One small specimen from the Twin Creek Limestone represents an adult as shown by the presence of an apertural constriction and by contraction of the body chamber near the aperture.

The shell is stout. The whorl section is depressed, subcircular, and wider than high. The flanks and venter are evenly rounded. The umbilicus is narrow but widens considerably near the aperture. The umbilical wall is low and steep and rounds evenly into the flanks. The body chamber occupies about three-fifths of a whorl. The aperture is imperfectly preserved, but its lower part inclines strongly forward and is constricted.

The ribbing is high and sharp. The primary ribs begin low on the umbilical wall, incline forward on the lower two-fifths of the flanks, and generally divide into two slightly weaker secondary ribs. A few secondary ribs arise freely below the middle of the flanks. All secondary ribs incline gently forward on the flanks and venter.

The specimen at a diameter of 45 mm has a whorl height of 22 mm, a whorl thickness of 29 mm, and an umbilical width of 6.5 mm. The suture line cannot be traced.

This species differs from *Eocephalites primus* Imlay, n. sp., by having much sharper and sparser ribbing, a more depressed whorl section, and by being much smaller at adult size.

Figured specimen: USNM 132833.

Occurrence: Twin Creek Limestone, Sliderock Member, upper 25–30 feet, at USGS Mesozoic loc. 28648.

Eocephalites? sp. undet. B

Plate 15, figures 14, 15

Ten fragmentary distorted ammonites from the Twin Creek Limestone differ from *Eocephalites primus* Imlay, n. sp., by having a stouter form and much coarser ribbing. The whorl section is subcircular and is wider than high. The flanks and venter are evenly rounded. The umbilicus, preserved only on one large specimen, is narrow and fairly deep. The umbilical wall is low and vertical and rounds evenly into the flanks. The adult body chamber consists of about five-sixths of a whorl and is scaphitoid near its adoral end. The aperture is not preserved.

The ribbing is coarse and sparse. The primary ribs incline slightly forward on the lower fourth or third of the flanks where most of them pass into pairs of slightly weaker secondary ribs. A few primary ribs remain simple, and a few secondary ribs arise freely near the zone of furcation. The secondary ribs incline forward gently on the flanks and venter.

The suture line cannot be traced.

Figured specimen: USNM 132834.

Occurrences: Twin Creek Limestone, upper part of the Sliderock Member at USGS Mesozoic locs. 20979, 21618, 28644, and 28648. Most of the fossils are from the upper 30 feet of the member.

Eocephalites? sp. undet. C

Plate 15, figures 1, 2

One fragmentary specimen is possibly an immature form of the species herein described as *Eocephalites?* sp. undet. B, but it appears to have much stronger primary ribs and a more depressed whorl section. Near the apical end of the specimen, one set of ribs is cut off obliquely by another set of ribs. This change corresponds roughly with the beginning of the body chamber. Aside from this feature, the character of the ribbing is similar to that on *Chondroceras* (*Praetulites*) *kruizingai* Westermann (1956, p. 108–111, pl. 13 and text figs. 65, 66; Kruizinga, 1926, p. 52, pl. 12, fig. 4, pl. 14, figs. 2, 3) from the Sula Islands in Indonesia. The holotype of

Westermann's species was once considered by Arkell (in Arkell and Playford, 1954, p. 583) to belong to *Chondroceras* and later (Arkell, 1956, p. 440) was given as "* * * a Sphaeroceratid at least closely related to Chondroceras * * *."

Figured specimen: USNM 132835.

Occurrence: Twin Creek Limestone, upper part of the Sliderock Member at USGS Mesozoic loc. 28644.

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[Italic page numbers indicate major references or fossil descriptions]

PLATE 1

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FIGURES 1, 7–10. *Gervillia? montanaensis* Meek (p. 77).

1. Syntype USNM 132837.
7. Syntype USNM 7795.
8. Syntype USNM 132838.
9. Syntype USNM 132836.
10. Lectotype USNM 132724. All specimens shown are from the Piper Formation at USGS Mesozoic loc. 19214, at mouth of lower canyon of the Yellowstone River.

2–6. *Grammatodon haguei* (Meek) (p. 75).

2. Internal mold of left valve of plesiotype USNM 28955 (× 2) from USGS Mesozoic loc. 1181, Piper Formation, near Sentinel Butte, Yellowstone National Park.
3. Concave composite mold of left valve showing external radial ribs and internal dentition. Plesiotype USNM 132720 (× 2) from USGS Mesozoic loc. 20987, Twin Creek Limestone, Rich Member.
4. Internal mold of left valve of plesiotype USNM 132718 (× 2) from USGS Mesozoic loc. 20974. "Lower Sundance" Formation, unit 19 of published section (Imlay, 1956a, p. 70).
5. Internal mold of left valve of plesiotype USNM 132719 (× 2) from USGS Mesozoic loc. 20987, Twin Creek Limestone, Rich Member.
6. Internal mold of left valve of plesiotype USNM 132717 (× 2) from USGS Mesozoic loc. 20964. "Lower Sundance" Formation, unit 22 of published section (Imlay, 1956a, p. 70).

11–13, 15. *Idonearca haguei* (Stanton) (p. 76).

11. Internal mold of left valve of syntype USNM 28941 from USGS Mesozoic loc. 28941 from Piper Formation at head of Fawn Creek, Yellowstone National Park.

12, 13. Internal mold of lectotype USNM 132721 from USGS Mesozoic loc. 28941.

15. Internal mold showing hinge, plesiotype USNM 132722 from USGS Mesozoic loc. 19613. Lower 5 ft of limestone member of Piper Formation on Five Mile Creek, sec. 36, T. 5 S., R. 24 E., Carbon County, Mont.

14, 19. *Modiolus* (*Musculus*) sp. (p. 77).

Left valve (× 2 and × 3) of figured specimen USNM 132723 from USGS Mesozoic loc. 28788. Note fine radiating striae shown in fig. 19. Twin Creek Limestone, Rich Member.

16. *Plicatula* sp. (p. 79).

Figured specimen USNM 132726 from USGS Mesozoic loc. 17985, Twin Creek Limestone, Sliderock Member.

17. *Goniomya montanaensis* Meek (p. 86).

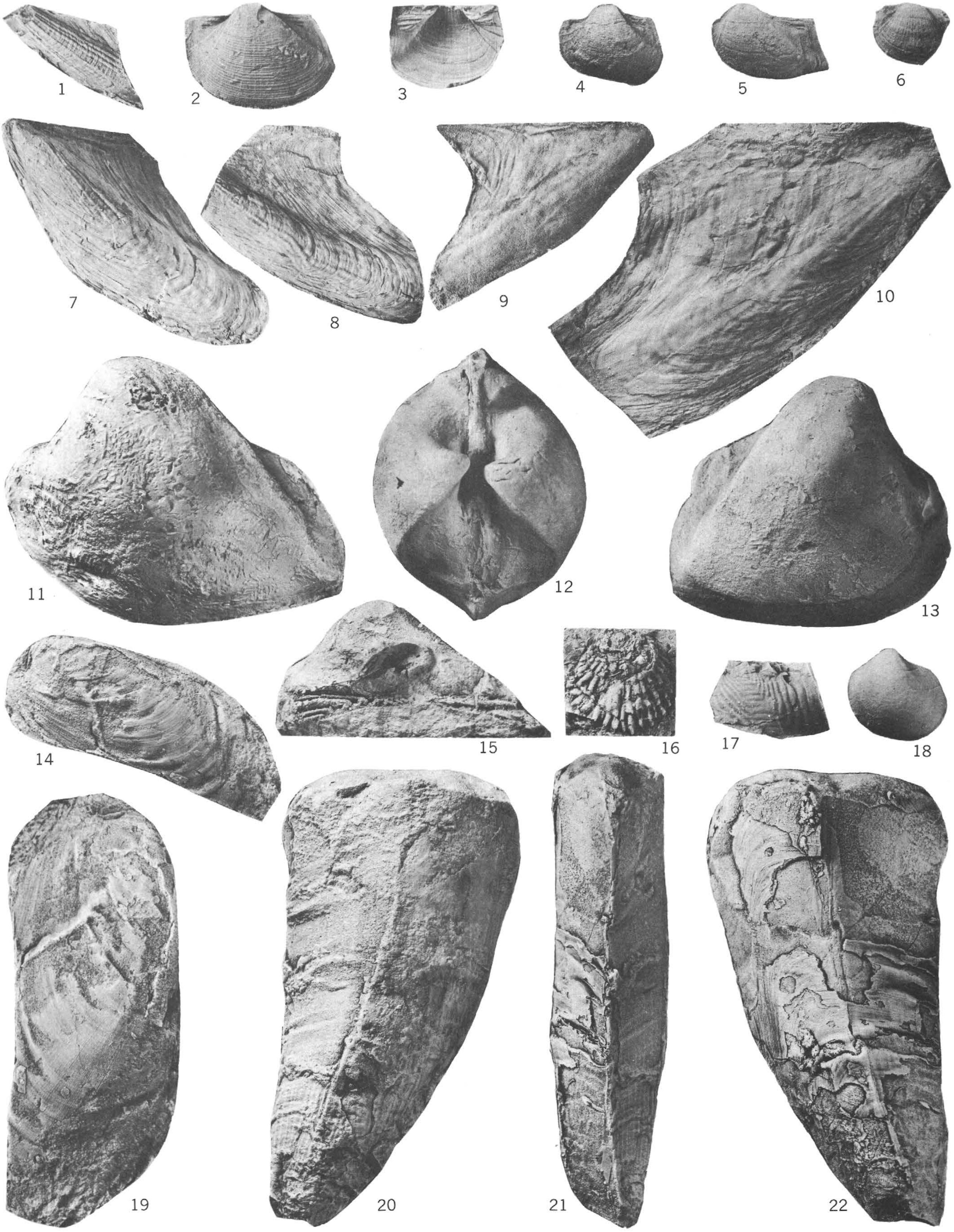
Plesiotype USNM 132761 from USGS Mesozoic loc. 20963, Twin Creek Limestone, Rich Member.

18. *Mactromya?* sp. (p. 84).

Figured specimen USNM 132753 from USGS Mesozoic loc. 20977, Twin Creek Limestone, Sliderock Member.

20–22. *Pinna kingi* Meek (p. 78).

Holotype USNM 20221 from Weber Canyon, Watatch Range, Utah. Presumably collected near Devils Slide from the Twin Creek Limestone.



GERVILLIA?, *GRAMMATODON*, *IDONEARCA*, *MODIOLUS* (*MUSCULUS*)
PLICATULA, *GONIOMYA*, *MACTROMYA*?, AND *PINNA*

PLATE 2

[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Camptonectes platessiformis* White (p. 79).

Left and right valves of plesiotype USNM 132725 from USGS Mesozoic loc. 19170. Rierdon Formation, lower 15 ft, from one-half mile west of Bear Gulch, sec. 15, T. 14 N., R. 21 E., Fergus County, Mont.

3. *Opis* (*Trigonopis*) sp. (p. 83).

Internal mold of left valve of figured specimen USNM 132747 from USGS Mesozoic loc. 20344, Twin Creek Limestone, Sliderock Member.

4, 12, 13. *Ctenostreon* cf. *C. gikshanensis* McLearn (p. 79).

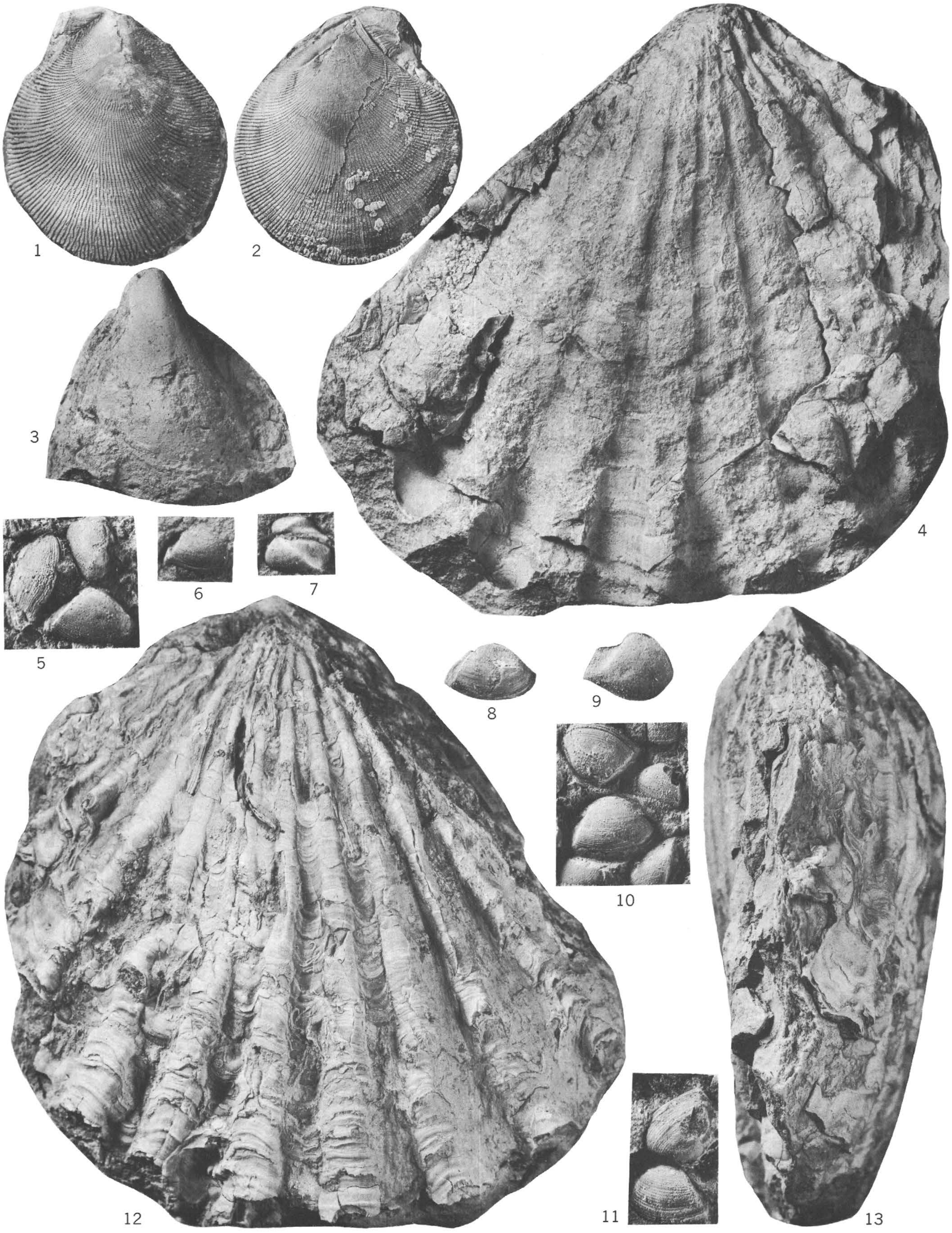
Left valve (mostly an internal mold), right valve retaining shell material, and anterior view of specimen USNM 132727 from USGS Mesozoic loc. 21636. Rierdon Formation, 25 ft above base, on divide one-half mile west of Five Mile Creek, sec. 36, T. 5 S., R. 24 E., Carbon County, Mont.

5–11. *Corbula* cf. *C. munda* McLearn (p. 85).

5, 8, 10, 11. Figured specimens USNM 132758 (× 3) from USGS Mesozoic loc. 28787, Twin Creek Limestone, Rich Member.

6. Figured specimen USNM 132760 (× 3) from USGS Mesozoic loc. 18716. Rierdon Formation, lower 38 ft, head of Rierdon Gulch, sec. 23, T. 24 N., R. 9 W., Teton County, Mont.

7, 9. Figured specimens, USNM 132759 (× 3) from USGS Mesozoic loc. 28788, Twin Creek Limestone, Rich Member.



CAMPTONECTES, OPIS (TRIGONOPIS), CTENOSTREON, AND *CORBULA*

PLATE 3

[All figures natural size]

FIGURES 1–13. *Gryphaea planoconvexa* Whitfield (p. 80).

1, 4. Lateral and dorsal views of left valve of holotype, Yale University 6774. Piper Formation on east side of south end of Bridger Range, Mont.

2. Left valve of plesiotype USNM 104138 from USGS Mesozoic loc. 19619. Sawtooth Formation in Madison Range, sec. 20, T. 8 S., R. 2 E., Madison County, Mont.

3. Left valve of plesiotype USNM 132729 from USGS Mesozoic loc. 19158. Piper Formation on north side of Rocky Creek, sec. 19, T. 2 S., R. 7 E., Gallatin County, Mont.

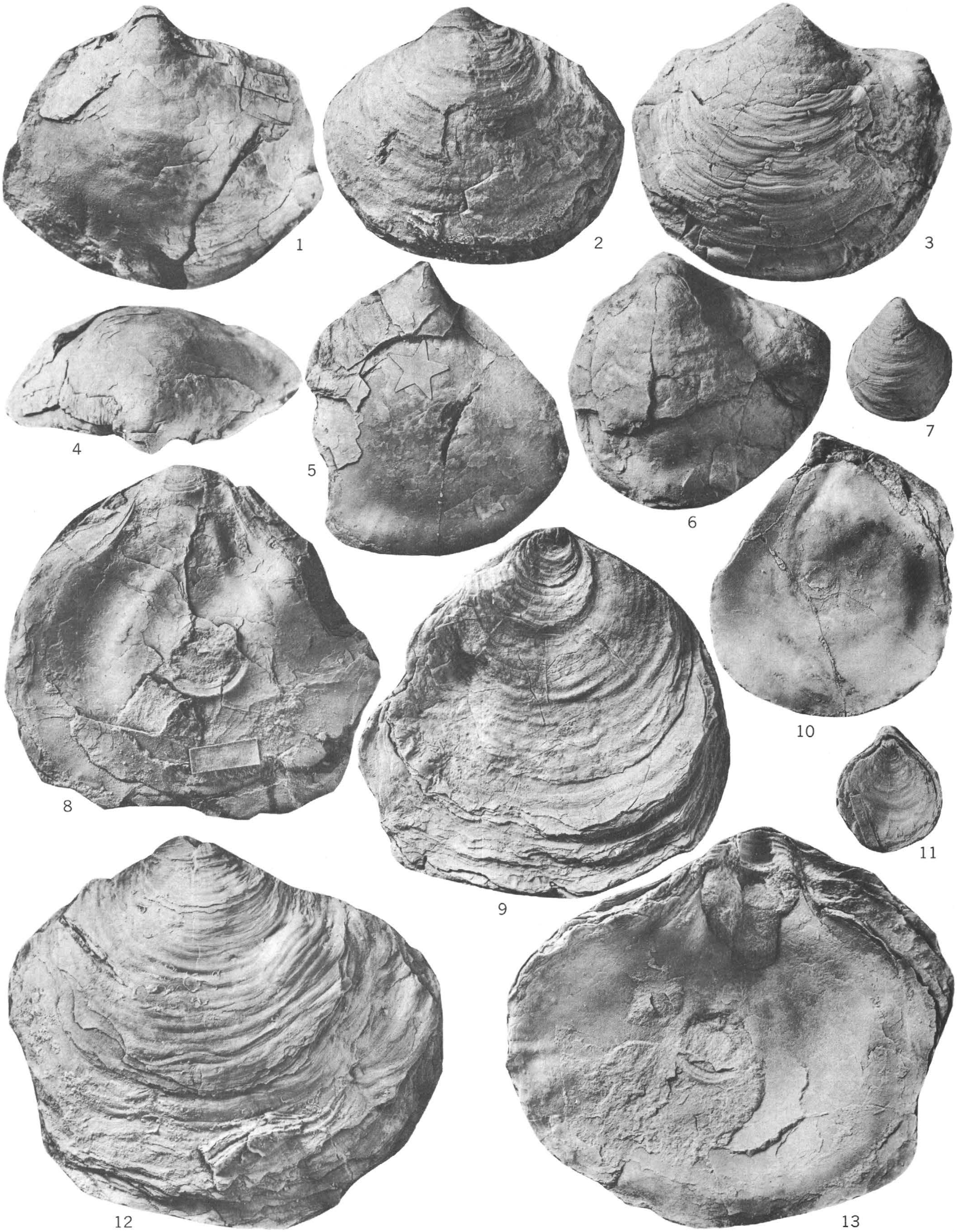
5, 10. Right valve of paratype, Yale University 6778 from same locality as holotype.

6. Left valve of plesiotype USNM 12369 from USGS Mesozoic loc. 19214, Piper Formation in lower canyon of Yellowstone River.

7, 11. Left and right valves of an immature specimen. Plesiotype USNM 132730 from USGS Mesozoic loc. 28800. Sawtooth Formation, head of Red Canyon sec. 24, T. 11 S., R. 4 E., Gallatin County, Mont.

8, 9. Interior and exterior of right valve of plesiotype USNM 132728 from USGS Mesozoic loc. 20989. "Lower Sundance" Formation, 8–20 ft above base of unit 10 (Imlay, 1956a, p. 70).

12, 13. Exterior and interior of left valve of same specimen represented by right valve shown in figs. 8 and 9.



GRYPHAEA

PLATE 4

[All figures are natural size]

FIGURES 1–17. *Gryphaea planoconvexa fraterna* Imlay (p. 80).

1–3. Posterior, dorsal, and lateral views of left valve of paratype USNM 132732 from USGS Mesozoic loc. 28647.

4. Paratype USNM 132738 from USGS Mesozoic loc. 20344. Note radial riblets.

5. Paratype USNM 132739 from USGS Mesozoic loc. 20344. Note radial riblets.

6, 10. Laterial and posterior views of paratype USNM 132734 from USGS Mesozoic loc. 28647.

7, 9. Right and left valves of paratype USNM 132736 from USGS Mesozoic loc. 21618.

8. Paratype USNM 132737 from USGS Mesozoic loc. 21618.

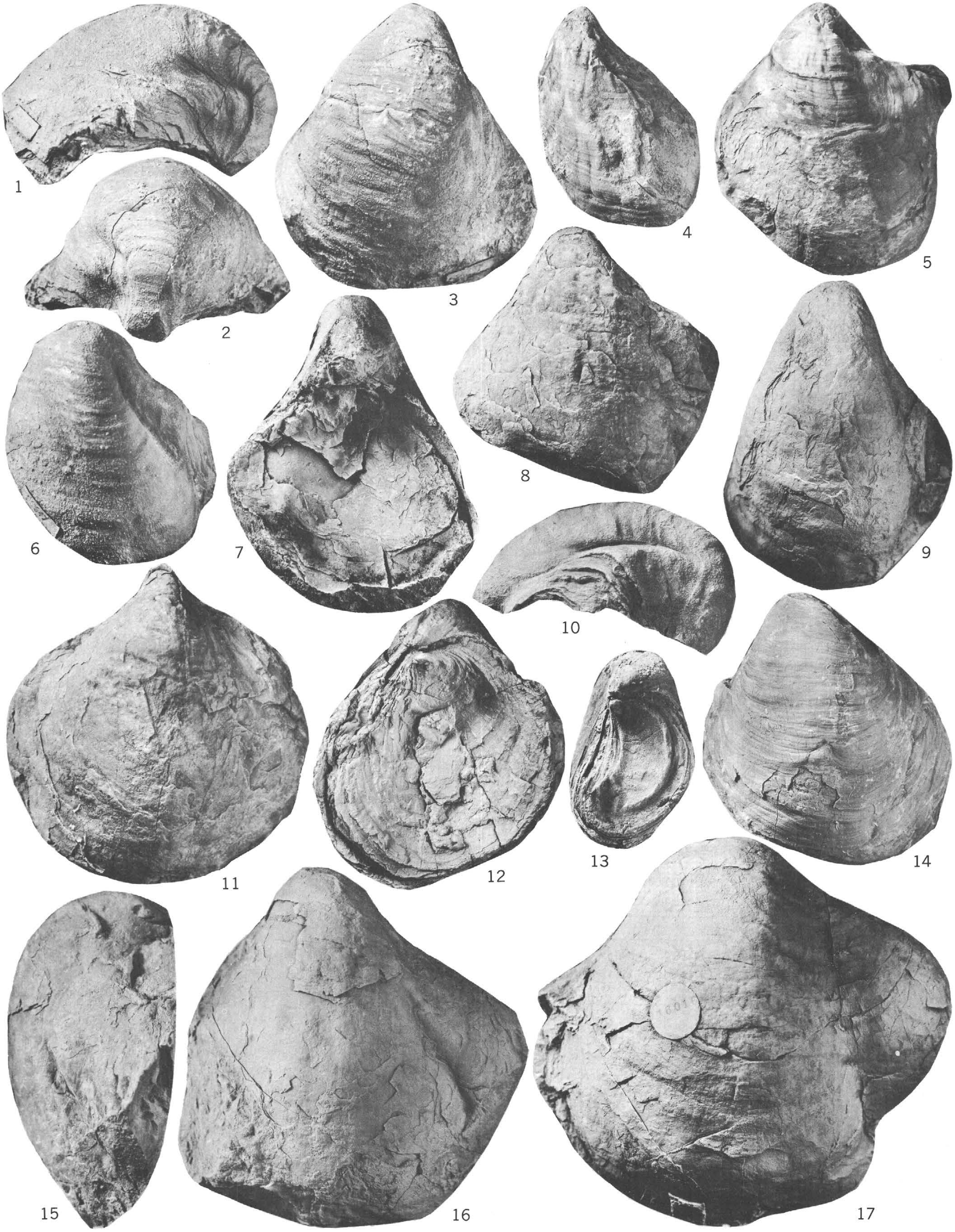
11. Paratype USNM 132735 from USGS Mesozoic loc. 21618. This specimen resembles *Gryphaea planoconvexa* Whitfield in its pinched beak and nearly circular outline, but it bears radial furrows ventrally and is associated with the specimens shown in figs. 7–9 which are typical of the variety *fraterna*.

12, 14. Right and left valves of paratype USNM 132740 from USGS Mesozoic loc. 28483. Shows only a trace of a posterior sulcus.

13. Right valve of paratype USNM 132733 from USGS Mesozoic loc. 28647.

15, 16. Posterior and lateral views of holotype USNM 132731 from USGS Mesozoic loc. 28795. Note radial furrows and posterior sulcus.

17. Paratype USNM 132741 from USGS Mesozoic loc. 16016. Shows pronounced posterior sulcus and broad, strongly incurved umbo. All specimens shown on this plate are from the Sliderock Member of the Twin Creek Limestone.



GRYPHAEA

PLATE 5

[Figures natural size unless otherwise indicated]

FIGURES 1–6. *Astarte meeki* Stanton (p. 82).

1. Plesiotype USNM 132743 from USGS Mesozoic loc. 25866. Piper Formation, west side of lower canyon of Yellowstone River, Park County, Mont.
2. Plesiotype USNM 132744 from same locality as fig. 1.
3. Lectotype USNM 28936 from USGS Mesozoic loc. 1164, Piper Formation on Cinnabar Mountain, Park County, Mont.
4. Syntype USNM 28937 from USGS Mesozoic loc. 1153. Ridge west of head of Gardner River, Yellowstone National Park.
5. Plesiotype USNM 132746 from USGS Mesozoic loc. 28507. Twin Creek Limestone, Rich Member.
6. Plesiotype USNM 132745 from USGS Mesozoic loc. 21621. Twin Creek Limestone, Boundary Ridge Member.

9–13. *Prorokia fontenellensis* Imlay, n. sp. (p. 83).

9. Right valve of paratype USNM 132749 (× 2) from USGS Mesozoic loc. 25866. Piper Formation.
10. Left valve of holotype USNM 132748 (× 2) from USGS Mesozoic loc. 25866. Piper Formation.
11. Right valve of paratype USNM 132750 (× 2) from USGS Mesozoic loc. 28788. Twin Creek Limestone, Rich Member.
12. Right valve of paratype USNM 132751 (× 2) from USGS Mesozoic loc. 21619. Twin Creek Limestone, Sliderock Member.
13. Rubber cast of external mold of paratype USNM 132752 from USGS Mesozoic loc. 28788. Twin Creek Limestone, Rich Member.

7, 8, 14, 15. *Quenstedtia sublevis* (Meek and Hayden) (p. 84).

7. Plesiotype USNM 132755 from USGS Mesozoic loc. 3822. Twin Creek Limestone, lower part.
8. Lectotype USNM 132754 from southwest base of the Black Hills, Wyo. Probably from Stockade Beaver Shale Member of the Sundance Formation.
14. Syntype USNM 132841 from southwest base of the Black Hills, Wyo., Sundance Formation, lower part.
15. Syntype USNM 197 from southwest base of the Black Hills, Wyo., Sundance Formation, lower part.

16–21. *Pleuromya subcompressa* (Meek) (p. 85).

16, 17. Lectotype USNM 132756 from USGS Mesozoic loc. 19214. Piper Formation.

18. Syntype USNM 132839 from USGS Mesozoic loc. 19214. Piper Formation.
19. Syntype USNM 8061 from USGS Mesozoic loc. 19214.
20. Plesiotype USNM 132757 from USGS Mesozoic loc. 20344, Twin Creek Limestone, Sliderock Member.
21. Syntype 132840 from USGS Mesozoic loc. 19214. Piper Formation.

22, 23. *Pleuromya weberensis* (Meek) (p. 85).

Lateral and anterior view of holotype USNM 13386 from Twin Creek Limestone, Weber, Canyon, Wasatch Range, Utah. Posterior end missing. Possibly a finely ribbed variant cf. *P. subcompressa* (Meek) with which it is associated.

24–26. *Pholadomya inaequiplicata* Stanton (p. 86).

Posterior, anterior, and right valve of holotype USNM 28956 of USGS Mesozoic loc. 1130. Rierdon Formation, basal part.

27–35. *Myopholas hardyi* Imlay (p. 86).

27. Posterior part of right valve of plesiotype USNM 132766 from USGS Mesozoic loc. 21623, Twin Creek Limestone, Watton Canyon Member.

28, 29. Posterior end of left and right valves of plesiotype USNM 132763 from USGS Mesozoic loc. 18750, Rierdon Formation near top, Little Rocky Mountains, middle S½ sec. 5, T. 24 N., R. 26 E., Phillips County, Mont.

30–32. Right valve, dorsal view, and left valve of plesiotype USNM 132764 from USGS Mesozoic loc. 18754. Rierdon Formation, top bed, NE¼ sec. 11, T. 26 N., R. 24 E., Blaine County, Mont.

33. Posterior end of right valve of plesiotype USNM 132765 from USGS Mesozoic loc. 19170. Rierdon Formation, lower 15 ft, near center of sec. 15, T. 14 N., R. 21 E., Fergus County, Mont.

34, 35. Left valve and dorsal view (anterior end to right) of plesiotype USNM 132762 from USGS Mesozoic loc. 18750. Rierdon Formation, near top, S½ sec. 5, T. 24 N., R. 26 E., Phillips County, Mont.

PLATE 5—Continued

FIGURES 36–38, 42. *Pholadomya kingi* Meek (p. 86).

Dorsal view, right valve, anterior end, and posterior end of holotype USNM 7815 from USGS Mesozoic loc. 19214, Piper Formation, middle limestone member.

39–41. *Cercomya punctata* (Stanton) (p. 87).

39. Right valve of plesiotype USNM 132767 (× 2) from USGS Mesozoic loc. 3815. Twin Creek Limestone, Rich Member. Shows fine radiating striae posterior to the sulcus near the middle of the valve.

40. Right valve of plesiotype USNM 132768 (× 2) from USGS Mesozoic loc. 20963. Twin Creek Limestone, Rich Member.

41. Left valve of holotype USNM 28945 from USGS Mesozoic loc. 1131, south slope of ridge south of Gray Mountain, Yellowstone National Park. Probably from Piper Formation.

43–49. *Platymya rockymontana* Imlay, n. sp. (p. 87).

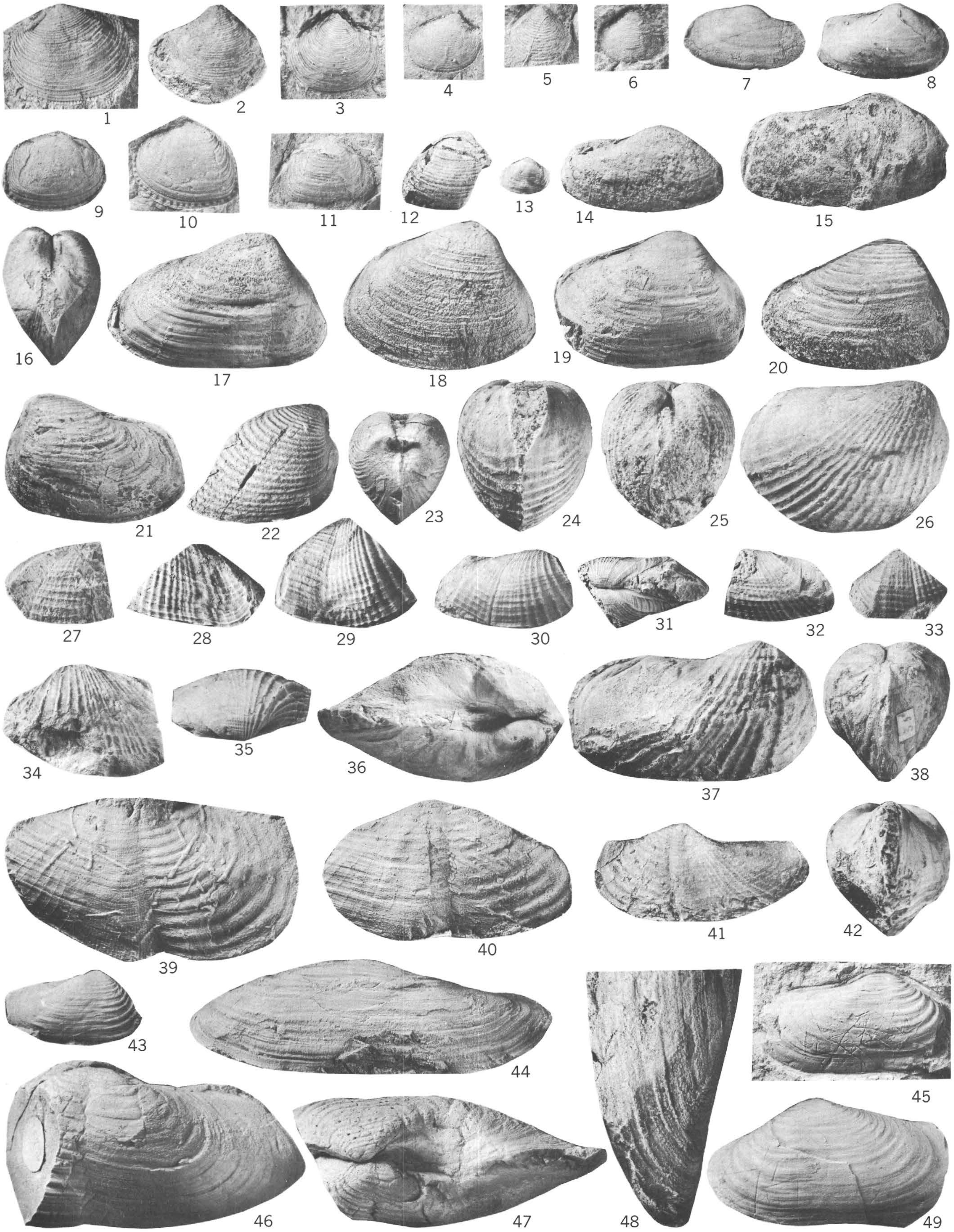
43. Right valve of paratype USNM 132773 from USGS Mesozoic loc. 12016, Twin Creek Limestone, Leeds Creek Member.

44, 48. Left valve of paratype USNM 132772 (× 2, × 3) from USGS Mesozoic loc. 20974. "Lower Sundance" Formation, 8 ft above base of unit 19 (Imlay, 1956a, p. 70). Oriented to show ventral margin (fig. 44) and radial striae (fig. 48).

45. Right valve of paratype USNM 132770 from USGS Mesozoic loc. 10729, Rierdon Formation, upper part, 1 mile east-northeast of St. Paul Mission at northwest end of Little Rocky Mountains, Blaine County, Mont.

46, 47. Left valve and dorsal view of holotype USNM 132769 from USGS Mesozoic loc. 18735, Rierdon Formation, upper part, SE¼ sec. 12, T. 25 N., R. 25 E., Phillips County, Mont.

49. Left valve of paratype USNM 132771 from USGS Mesozoic loc. 18750, Rierdon Formation, upper part, S½ sec. 5, T. 24 N., R. 26 E., Phillips County, Mont.



ASTARTE, PROROKIA, QUENSTEDTIA, PLEUROMYA, PHOLADOMYA, MYOPHOLAS, CERCOMYA, AND *PLATYMYA*

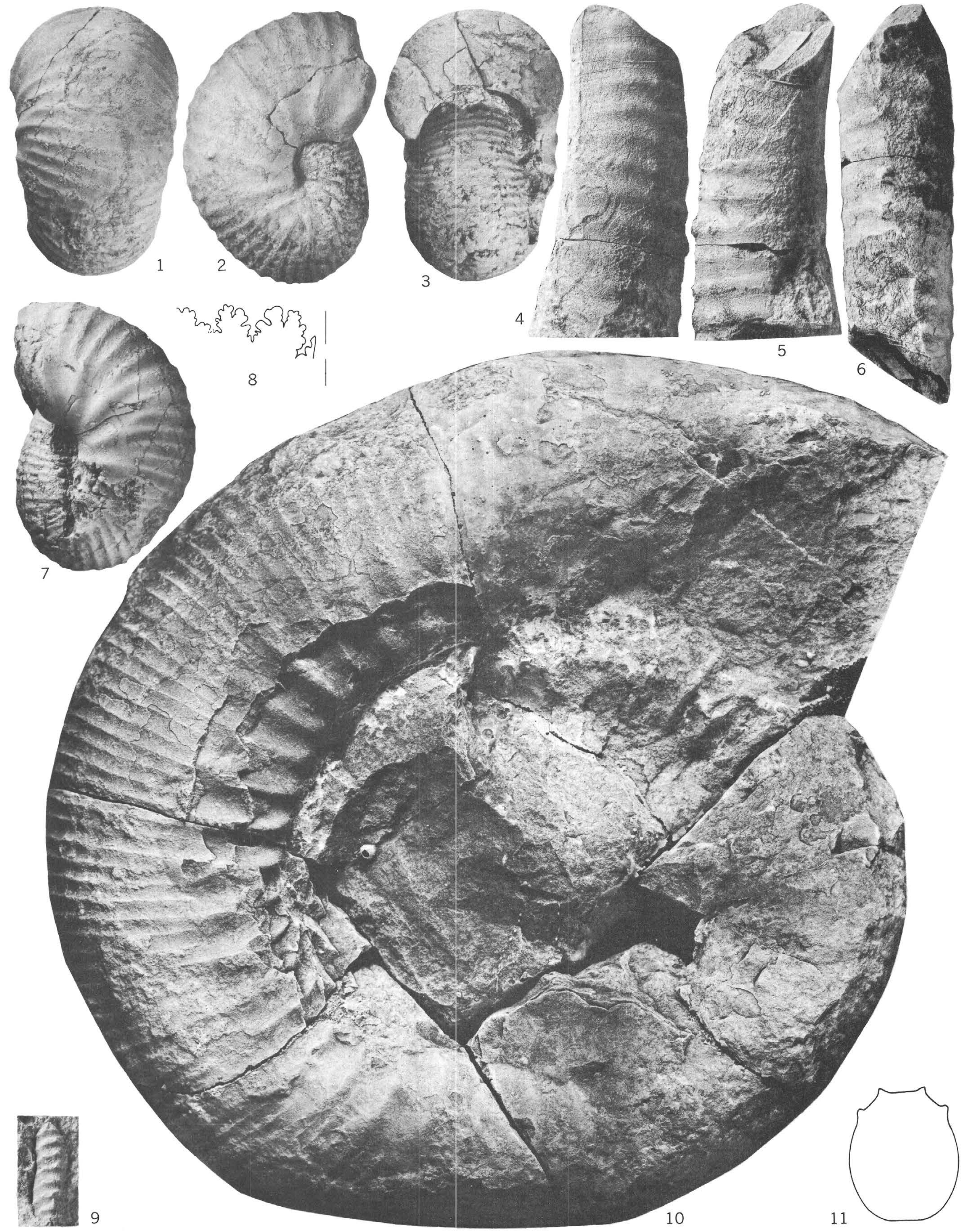
PLATE 6

[All figures are natural size]

FIGURES 1–3, 7, 8. *Chondroceras* cf. *C. allani* (McLearn) (p. 93).
Ventral, lateral, and apertural views and last suture line of specimen USNM 104134 from USGS Mesozoic loc. 19192. Sawtooth Formation.

4–6, 9, 11. *Spiroceras* cf. *S. orbignyi* Baugier and Sauze (p. 88).
4–6, 11. Lateral and ventral views and cross section of internal mold USNM 132774 from USGS Mesozoic loc. 20985. Twin Creek Limestone, Sliderock Member. Adoral end is pointed downward on figs. 4 and 5.
9. Ventral view of external mold USNM 132775 from USGS Mesozoic loc. 20969. Twin Creek Limestone, Sliderock Member.

10. *Stephanoceras* cf. *S. skidegatensis* (Whiteaves) (p. 89).
Laterally crushed internal mold of nearly complete body chamber. USNM 132776 from USGS Mesozoic loc. 21632, Twin Creek Limestone, Sliderock Member.



CHONDROCERAS, SPIROCERAS, AND *STEPHANOCERAS*

PLATE 7

[All figures natural size]

FIGURES 1–3. *Stemmatoceras* cf. *S. palliseri* McLearn (p. 91).

1, 2. Ventral and lateral views of part of last septate whorl of specimen USNM 132787 from USGS Mesozoic loc. 27337. Basal part of Sawtooth Formation near Tigh Creek west of Drummond, Granite Count, Mont. In fig. 1 the adoral end is pointed downward.

3. Lateral view of part of body chamber of same specimen as shown in figs. 1 and 2.

4, 5. *Stephanoceras* aff. *S. nodosum* (Quenstedt) (p. 89).

Lateral and ventral view of adult body whorl of specimen USNM 132777 from USGS Mesozoic loc. 21618. Twin Creek Limestone, Sliderock Member.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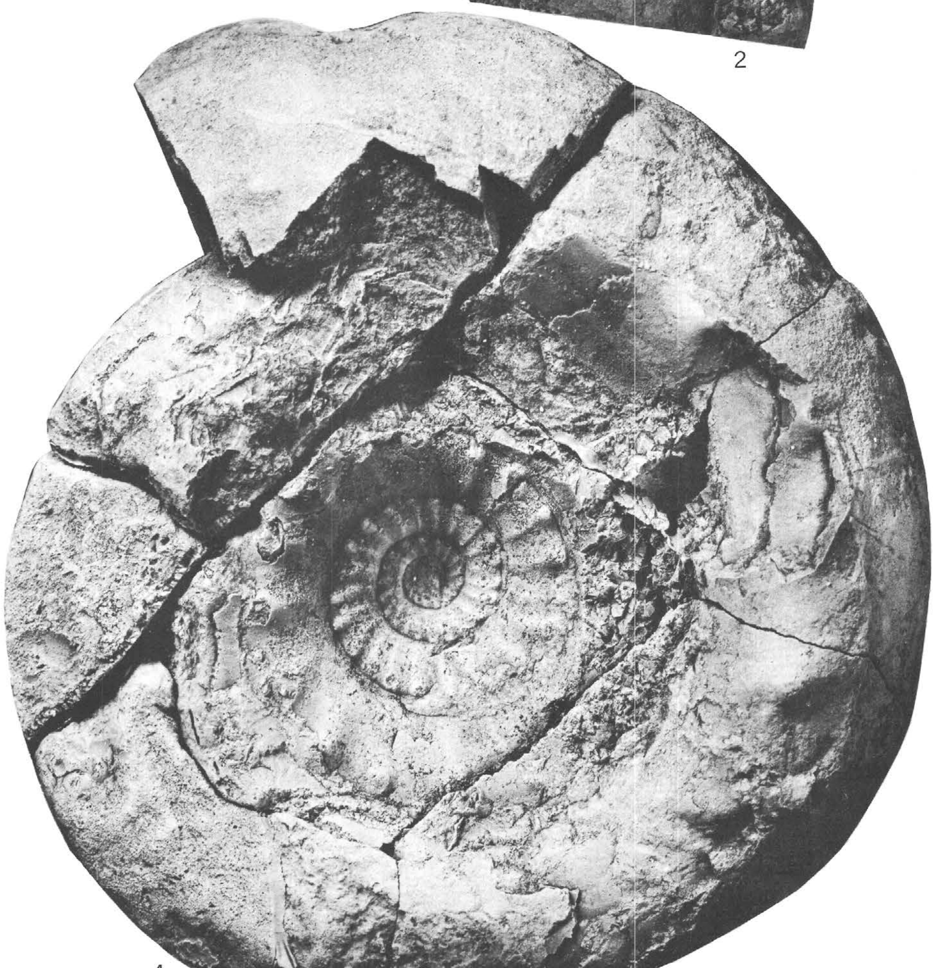
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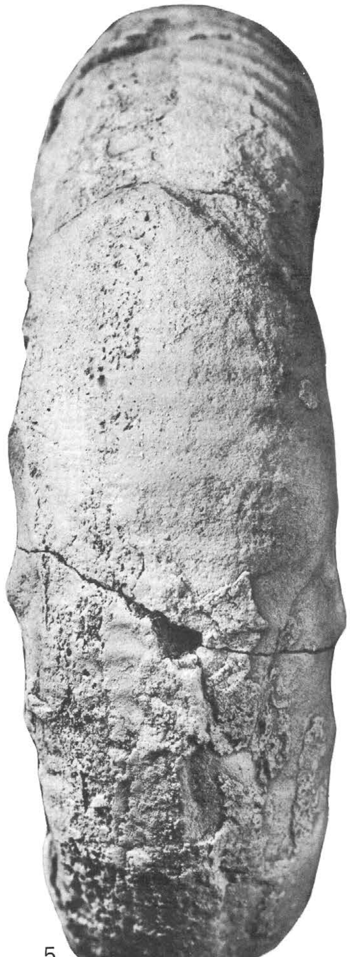
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STEMMATOCERAS AND *STEPHANOCERAS*

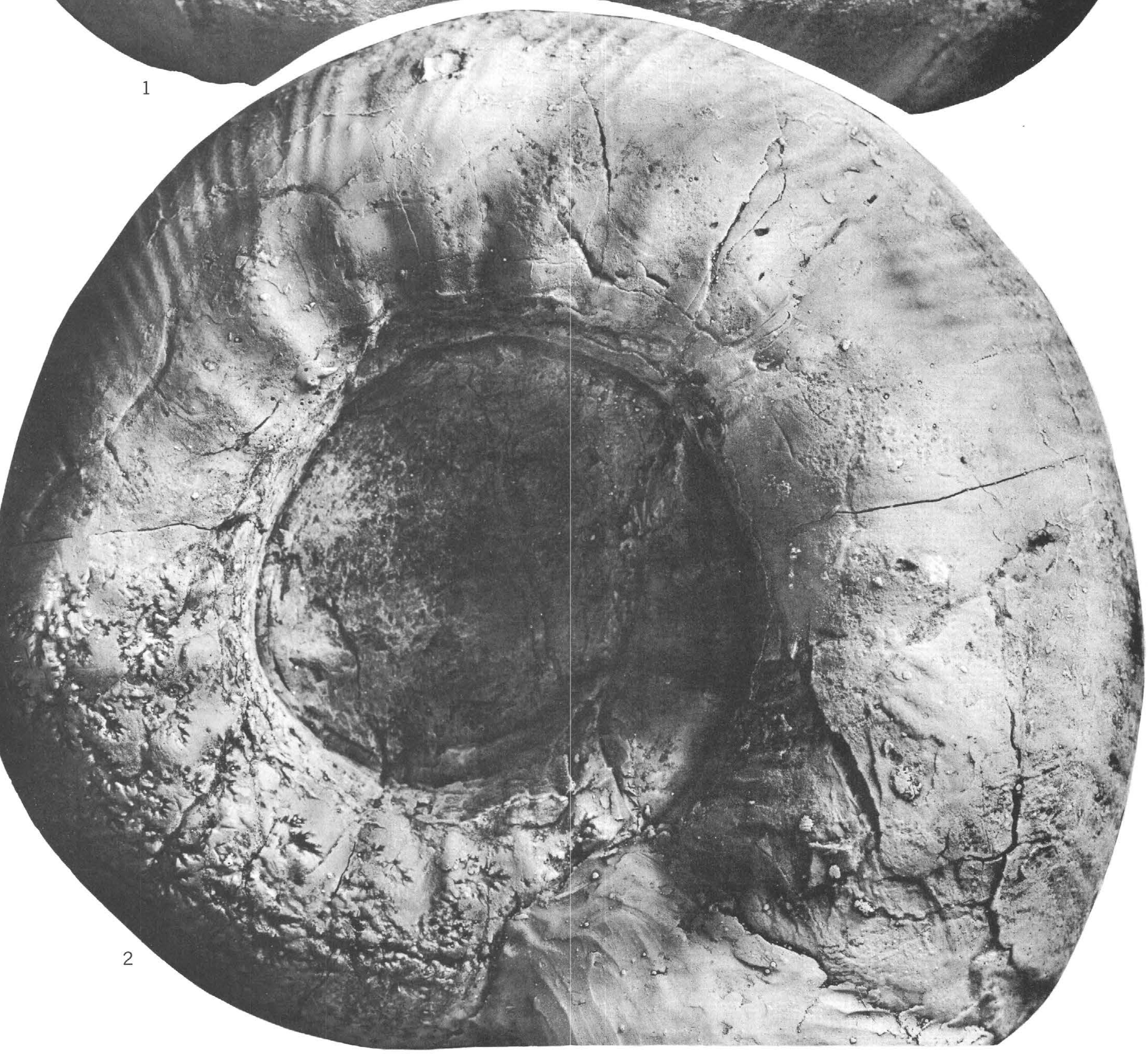
PLATE 8

[Figures slightly reduced]

FIGURES 1, 2. *Stemmatoceras arcicostum* Imlay, n. sp. (p. 90).

Ventral and lateral views of plastoholotype USNM 132778. Sawtooth Formation, basal part, near Tigh Creek, 3 miles west of Drummond in Granite County, Mont. Shows complete body chamber except for a ventral prolongation.

1



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STEMMATOCERAS

PLATE 9

[All figures are natural size]

FIGURES 1–11. *Stemmatoceras arcicostum* Imlay, n. sp. (p. 90).

1. Parts of three internal whorls and suture line of paratype USNM 132780 from USGS Mesozoic loc. 27337. Sawtooth Formation.

2, 9. Lateral and ventral views of internal whorls of paratype USNM 132783 from USGS Mesozoic loc. 28645. Twin Creek Limestone, Sliderock Member. In fig. 9 the adoral end is pointed downward.

3, 10. Lateral and ventral views of septate whorl of paratype USNM 132782 from USGS Mesozoic loc. 28645. Twin Creek Limestone, Sliderock Member.

4. Cross section of holotype shown on pl. 8 measured about one-sixth of a whorl adapical from the aperture at whorl height of 68 mm.

5, 6. Ventral and lateral views of paratype USNM 132781 from USGS Mesozoic loc. 27337. Sawtooth Formation, basal part.

7, 8, 11. Suture line, cross section, and lateral view of paratype USNM 132779 from USGS Mesozoic loc. 27337. Sawtooth Formation, basal part.

STEMMATOCERAS

PLATE 10

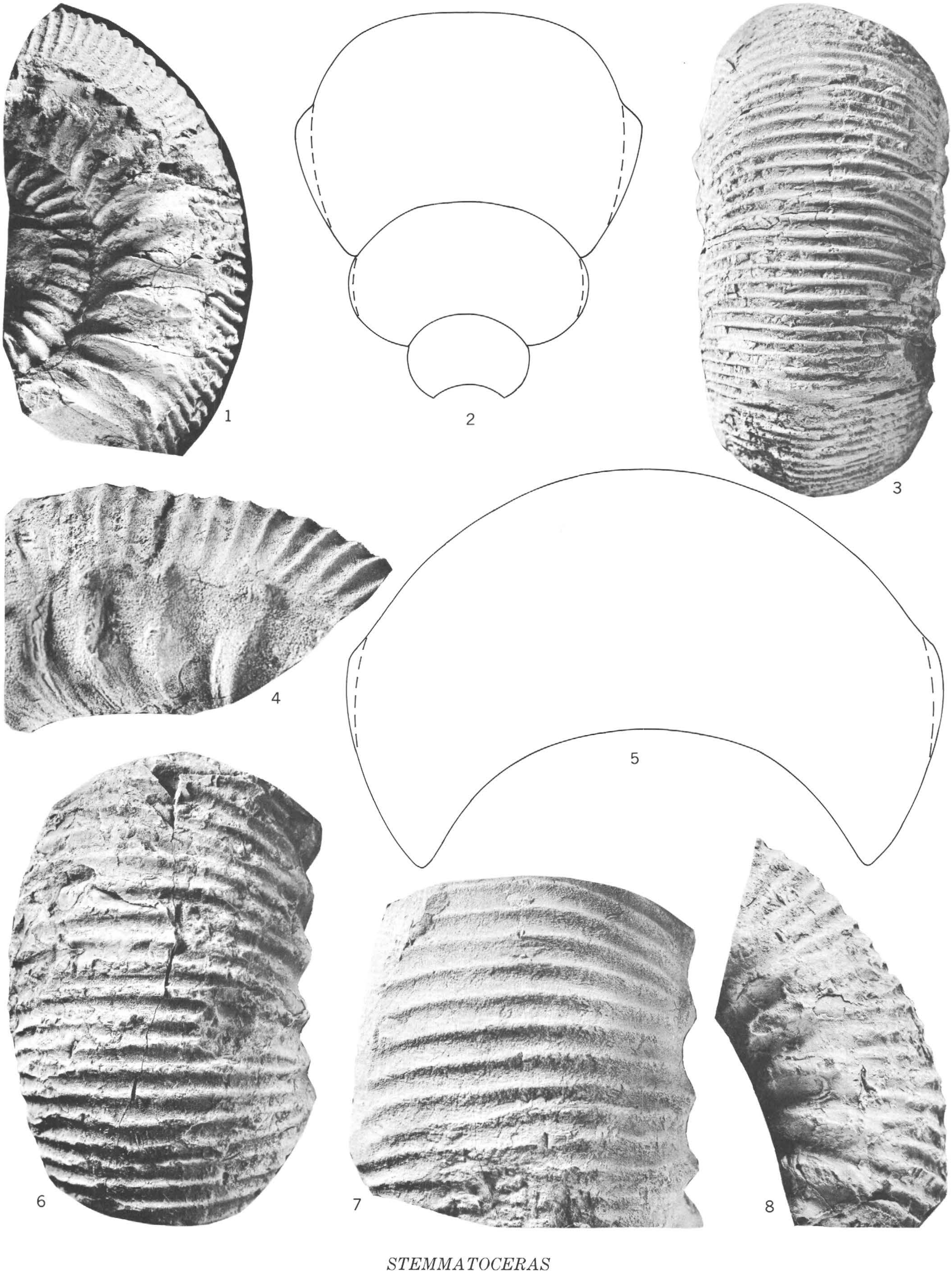
[All figures are natural size]

FIGURES 1–8. *Stemmatoceras* n. sp. aff. *S. albertense* McLearn (p. 91).

1–4, 7. Lateral and ventral views and cross section of specimen USNM 132786 from USGS Mesozoic loc. 28646. Twin Creek Limestone, Sliderock Member. Figs. 4 and 7 are an outer whorl of the same specimen shown in figs. 1 and 3.

5. Cross section of a large fragment measured at the adapical end of the body chamber, USNM 132785 from USGS Mesozoic loc. 28645. Twin Creek Limestone, Sliderock Member.

6, 8. Ventral and lateral views of a septate fragment, USNM 132784 from USGS Mesozoic loc. 28644. Twin Creek Limestone, Sliderock Member. In fig. 8 the adoral end is pointed downward.



STEMMATOCERAS

PLATE 11

[Figures natural size unless otherwise indicated]

FIGURES 1–18, 21, 24–26. *Sohlites spinosus* Imlay, n. sp. (p. 92).

1. Paratype USNM 132794 from USGS Mesozoic loc. 27624. Piper Formation.
2. Paratype USNM 132795 from USGS Mesozoic loc. 27624. Piper Formation. Note smooth nucleus.
3. Paratype USNM 132803 from USGS Mesozoic loc. 19214. Piper Formation.
4. Rubber cast of an external mold, paratype USNM 132797 from USGS Mesozoic loc. 27035. Piper Formation.

5, 6. Suture lines (× 2) and lateral view of crushed paratype USNM 132790 from USGS Mesozoic loc. 27624. Piper Formation. Suture line drawn at whorl height of about 18 mm.

7. Rubber cast of an external mold of paratype USNM 132796 from USGS Mesozoic loc. 27035. Piper Formation. Specimen does not appear to be crushed.

8, 9. Suture lines (× 2) and lateral view of paratype USNM 132802 from USGS Mesozoic loc. 25866. Piper Formation.

10. Ventral view of paratype USNM 132793 from USGS Mesozoic loc. 27624. Piper Formation.

11, 12. Suture lines (× 2) and lateral view of paratype USNM 132801 from USGS Mesozoic loc. 25866. Piper Formation.

13, 14. Suture lines (× 2) and lateral view of paratype USNM 132800 from USGS Mesozoic loc. 27035. Piper Formation.

15. Ventral view of paratype USNM 132792 from USGS Mesozoic loc. 27624. Piper Formation.

16. Lateral view of paratype USNM 132791 from USGS Mesozoic loc. 27624. Piper Formation. Smoothness of adoral third of specimen is due to corrosion.

17, 20. Suture lines (× 2) and lateral view of holotype USNM 132788 from USGS Mesozoic loc. 27624. Piper Formation. Specimen has been crushed laterally.

18. Lateral view of laterally crushed paratype USNM 132789 from USGS Mesozoic loc. 27624. Piper Formation.

21, 25. Lateral and ventral views of paratype USNM 132805 from USGS Mesozoic loc. 17096. Gypsum Spring Formation. In fig. 25 the adoral end of specimen is pointed downward.

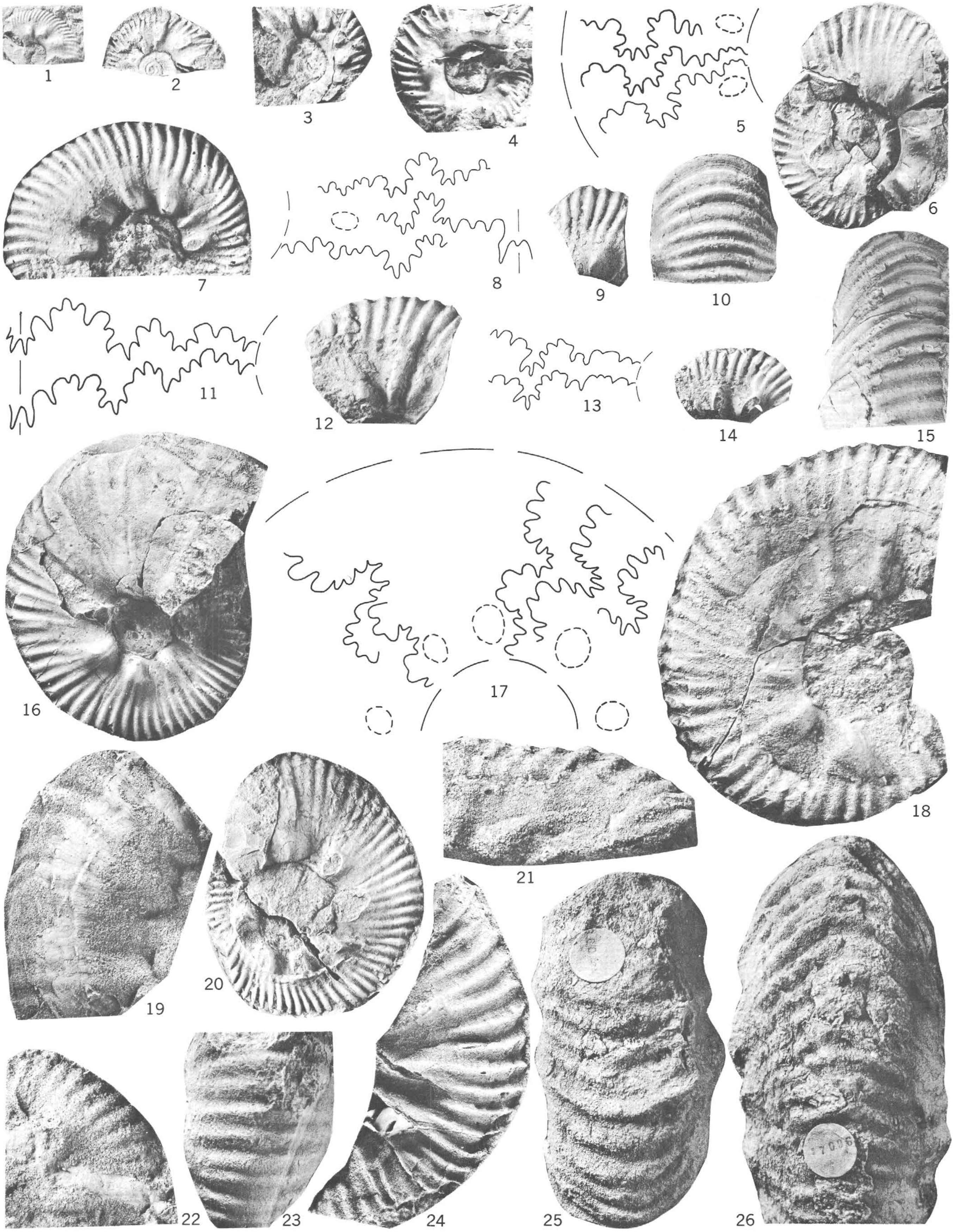
24. Lateral view of rubber cast of external mold of paratype USNM 132804 from USGS Mesozoic loc. 12555 on wedge about 2 miles south of Fullers Bottom along San Rafael River, Emery County, Utah. Carmel Formation, 6–12 ft above base.

26. Ventral view of paratype USNM 132806 from USGS Mesozoic loc. 17096. Gypsum Spring Formation.

19, 22, 23. *Sohlites*? sp. (p. 93).

19, 22. Lateral views of rubber casts of two external molds of specimens USNM 132807 from USGS Mesozoic loc. 20351. Head of Buckhorn Wash, sec. 13, T. 19 S., R. 10 E., Emery County, Utah. Carmel Formation, about 25 ft above base.

23. Ventral view of internal mold of specimen USNM 132808 from USGS Mesozoic loc. 25678. From NE¼ sec. 18, T. 19 S., R. 11 E., Emery County, Utah. Carmel Formation, about 40 ft above base.



SOHLITES

PLATE 12

[All figures are natural size]

FIGURES 1–4. *Normannites*? cf. *N. crickmayi* (McLearn) (p. 93).

1, 2. Ventral and lateral views of specimen USNM 132809 from USGS Mesozoic loc. 27337. Sawtooth Formation, basal part. Adoral end is pointed downward.

3, 4. Lateral and ventral views of specimen USNM 132810 from USGS Mesozoic loc. 28645. Twin Creek Limestone, Sliderock Member.

5–18. *Parachondroceras andrewsi* Imlay, n. sp. (p. 94).

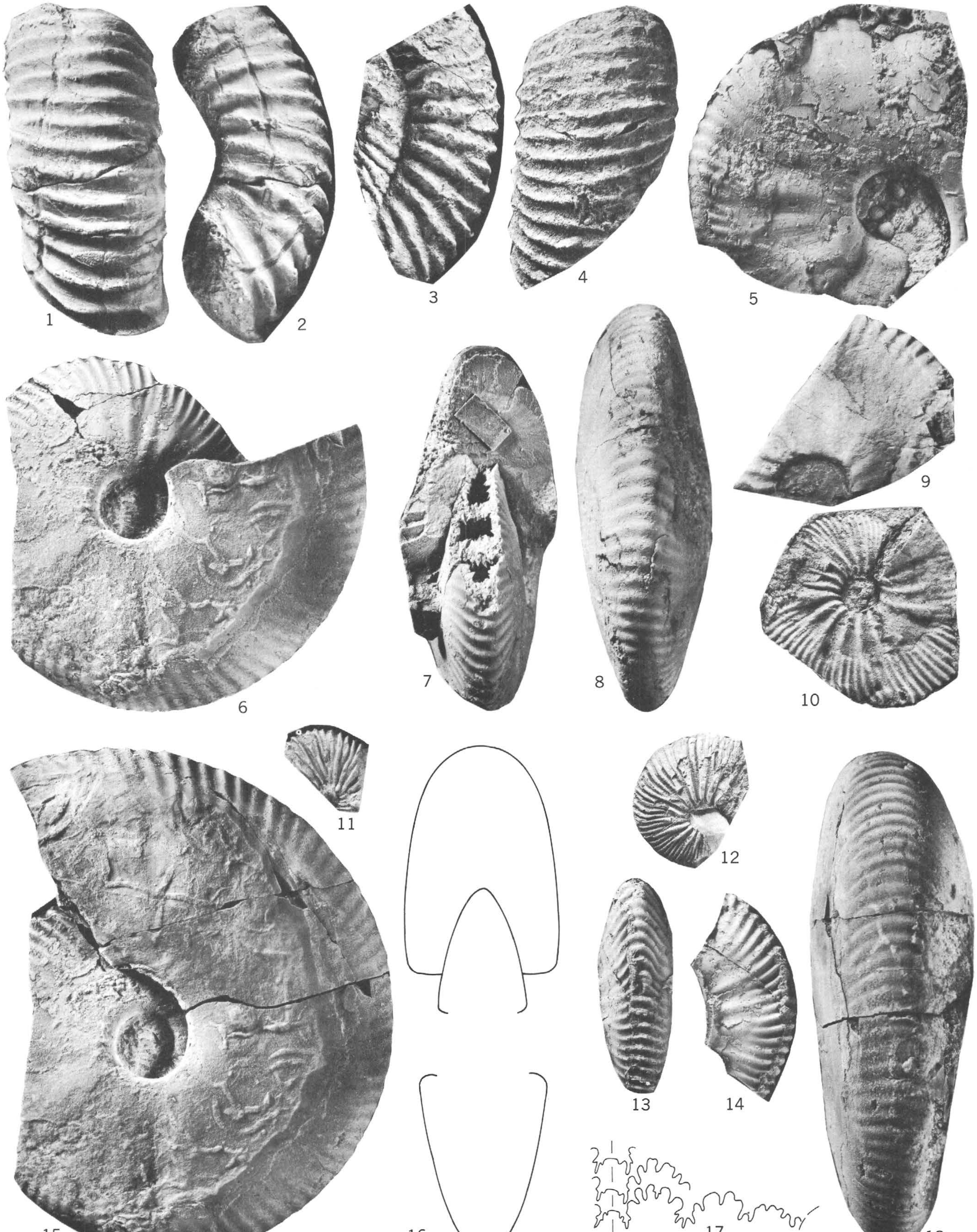
5–8, 13–18. Lateral, apertural, and ventral views, cross section, and suture lines of holotype USNM 132811 from USGS Mesozoic loc. 20864. Piper Formation. Fig. 5 is from a rubber cast of an external mold and corresponds to the lowest part of fig. 15. It shows forwardly inclined striae. In figs. 6–8, part of the body whorl has been removed in order to show the changes in ornamentation and whorl shape. Figs. 13 and 14 are from a rubber cast of an external mold and correspond with the innermost part of the septate whorl shown in fig. 6. Figs 15–18 show the nearly complete body chamber. The suture line was drawn at a whorl height of 31 mm near the adapical end of the last septate whorl.

9. Internal mold of paratype USNM 132813 from USGS Mesozoic loc. 21629. Twin Creek Limestone, Rich Member.

10. From rubber cast of external mold of paratype USNM 12221 from USGS Mesozoic loc. 19214. Piper Formation.

11. Laterally crushed internal mold of paratype USNM 132812 from USGS Mesozoic loc. 19214. Piper Formation.

12. Laterally crushed internal mold of paratype USNM 132814 from USGS Mesozoic loc. 8181. Twin Creek Limestone, probably from Rich Member.



NORMANNITES? AND *PARACHONDROCERAS*

PLATE 13

[Figures natural size unless otherwise indicated]

FIGURES 1–3, 15. *Megasphaeroceras rotundum* Imlay, var. (p. 96).

Apertural, ventral, and lateral views and suture line of plesiotype USNM 132824 from USGS Mesozoic loc. 20001, Cook Inlet region, Alaska. Twist Creek Siltstone (Detterman 1963, p. C31–C33; Imlay, 1962b, p. A5). This specimen is considered to be a compressed variant of *M. rotundum* Imlay.

4, 5. *Megasphaeroceras* sp. undet. (p. 96).

Ventral and lateral views of specimen USNM 132825 from USGS Mesozoic loc. 20975. Twin Creek Limestone, Sliderock Member. Note resemblance to specimen shown in figs. 1–3.

6–10. *Megasphaeroceras* aff. *M. rotundum* Imlay (p. 96).

6, 7, 9, 10. Ventral, apertural, and lateral views and suture line of specimen USNM 132823 from USGS Mesozoic loc. 20978, Twin Creek Limestone, Sliderock Member. Suture line drawn at diameter of 54 mm.

8. Lateral view of specimen USNM 132824 from USGS Mesozoic loc. 28635. Twin Creek Limestone, Sliderock Member. About three-fifths of specimen represents body chamber. Note slight contraction of whorl at adoral end.

11–14, 16–25. *Parachondroceras filicostatum* Imlay, n. sp. (p. 95).

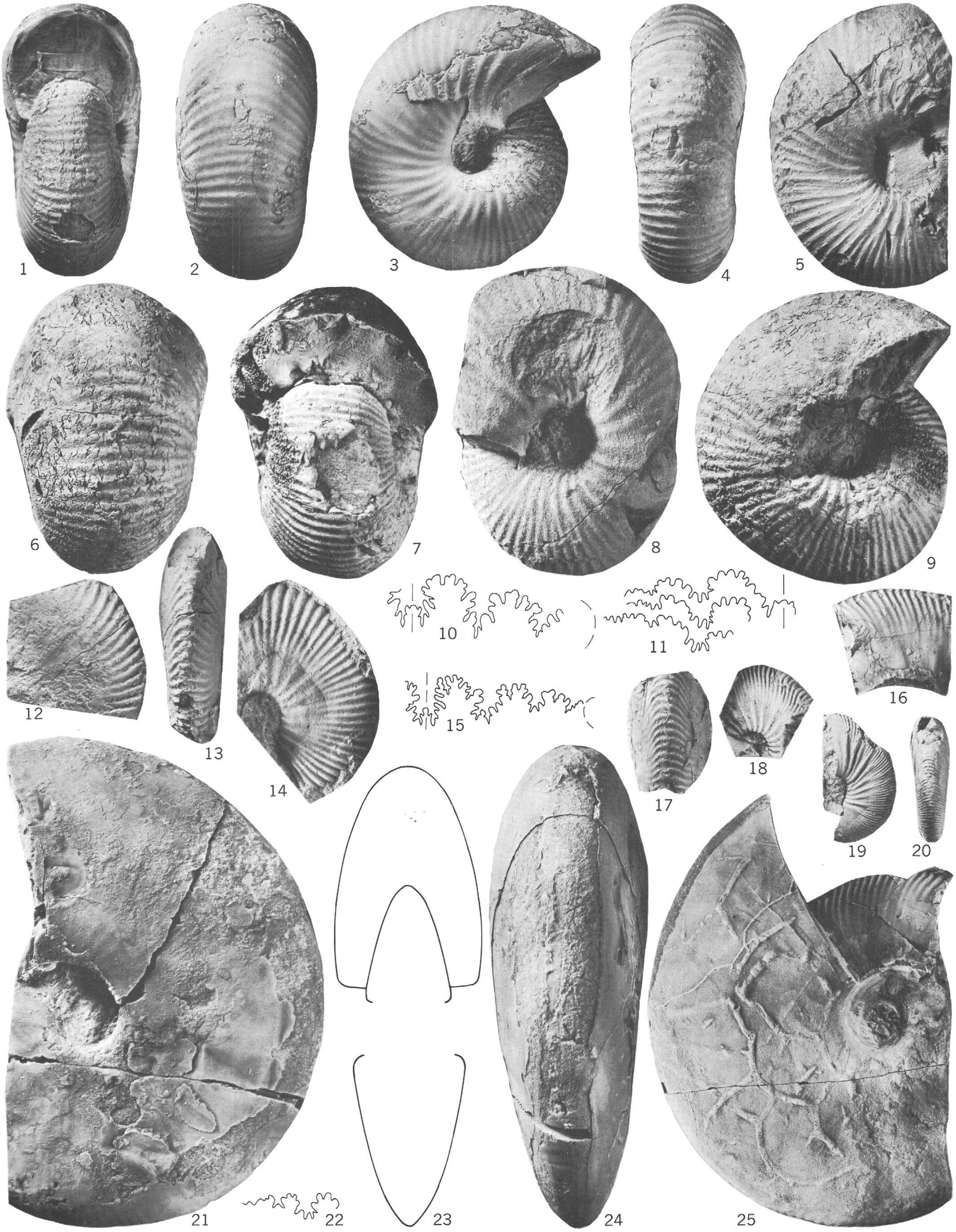
11, 16, 17, 21, 23–25. Suture line, inner whorls, lateral, and ventral views and cross section of holotype USNM 132815 from USGS Mesozoic loc. 20864. Piper Formation. Suture line drawn near adoral end of last septate whorl at whorl height of 34 mm. Figs. 16 and 17 are from a rubber cast of an external mold of the septate whorl corresponding to the ribbed part of the internal mold shown in fig. 25. On this figure, part of the body chamber has been removed.

12, 13, 22. Lateral and ventral views and suture line of internal mold of paratype USNM 132818 from USGS Mesozoic loc. 20962. "Lower Sundance" Formation, 20 ft above base of unit 10 (Imlay, 1956a, p. 70) of section at Lower Slide Lake, Teton County, Wyo.

14. Rubber cast of an external mold of paratype USNM 132816 from USGS Mesozoic loc. 19214. Piper Formation.

18. Internal mold of paratype USNM 132817 from USGS Mesozoic loc. 15635. Piper Formation.

19, 20. Small undeformed internal mold of inner whorls of paratype USNM 132819 from USGS Mesozoic loc. 28800. Sawtooth Formation, near base.



MEGASPHAEROCERAS AND *PARACHONDROCERAS*

PLATE 14

[All figures are natural size]

FIGURES 1–6, 9–16. *Megasphaeroceras* cf. *M. rotundum* Imlay (p. 96).

1, 2. Ventral and lateral views of internal mold USNM 132821a from USGS Mesozoic loc. 28483.

3, 4. Ventral and lateral views of USNM 132821b from USGS Mesozoic loc. 28483. Note apertural constriction.

5, 6. Apertural and lateral views of internal mold of USNM 132820a from USGS Mesozoic loc. 28648. Note sharp ribbing similar to that on Alaskan species (Imlay, 1962b, pl. 3).

9, 13. Lateral and ventral views of internal mold USNM 132820b from USGS Mesozoic loc. 28648. In fig. 9 the adoral end is pointed downward. Note fading of ribs on lower part of flanks.

10–12. Apertural, lateral, and ventral views of adult specimen USNM 132820c from USGS Mesozoic loc. 28648. Fig. 10 shows strong ribbing on shell material preserved at the adoral end of the last septate whorl. The body chamber does not bear any shell material and is almost smooth. Note the apertural constriction and terminal swelling and the slight contraction of the body chamber near the aperture.

14–16. Apertural and lateral views of adult specimen USNM 132822 from USGS Mesozoic loc. 28794. Note fading of ribs adorally on the body chamber. All specimens of *Megasphaeroceras* are from the Sliderock Member of the Twin Creek Limestone.

7, 8. *Sohlites spinosus* Imlay, n. sp. (p. 92).

7. Rubber cast of an external mold, paratype USNM 132798 from USGS Mesozoic loc. 27035. Piper Formation.

8. Rubber cast of an external mold, paratype USNM 132799 from USGS Mesozoic loc. 27035. Piper Formation.

MEGASPHAEROCERAS AND *SOHLITES*

PLATE 15

[All figures are natural size. All specimens from the Sliderock member of the Twin Creek Limestone.]

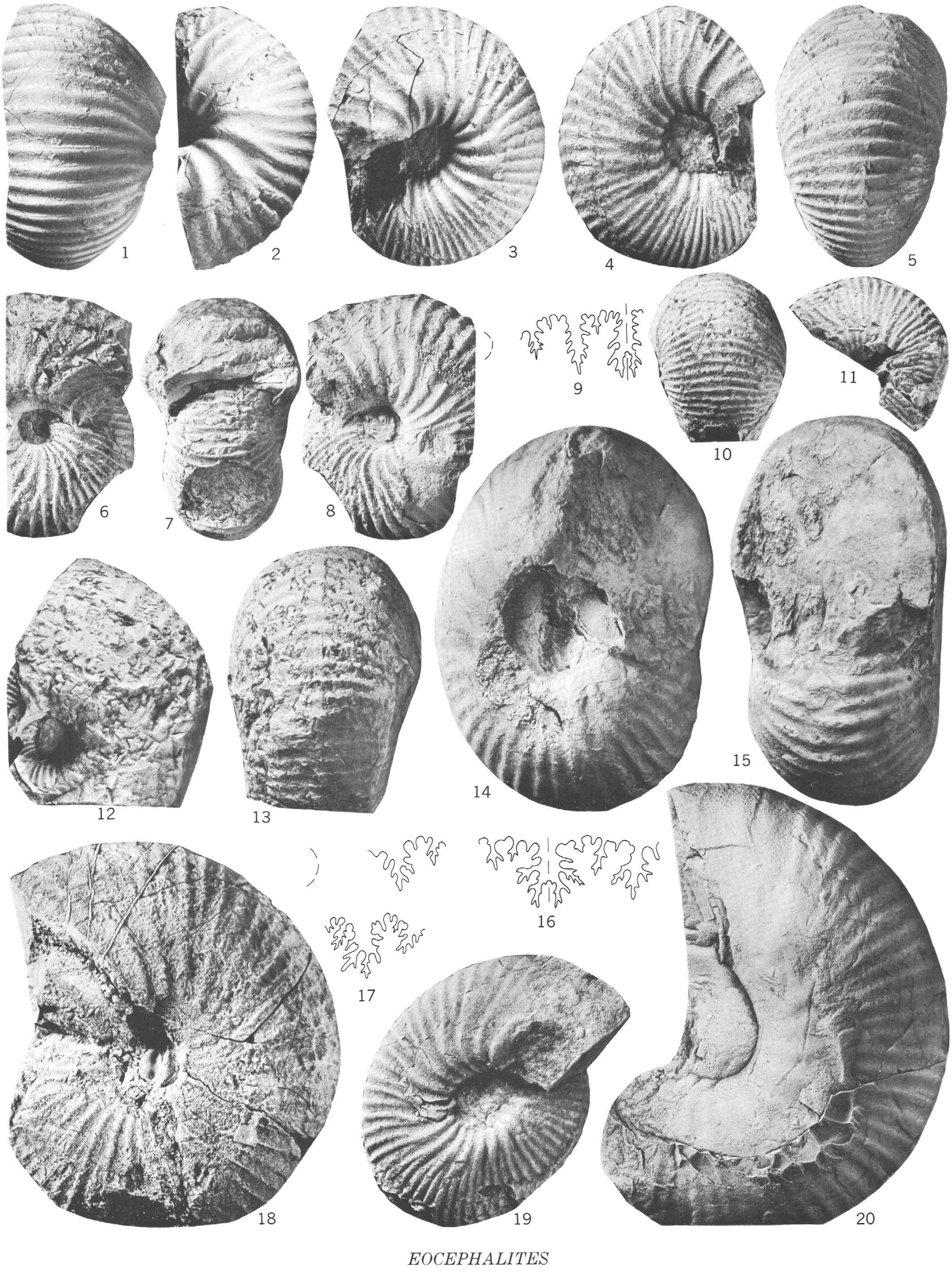
FIGURES

1, 2. *Eocephalites*? sp. undet. C (p. 98).
Ventral and lateral view of internal mold USNM 132835 from USGS Mesozoic loc. 28644. In fig. 2 the adoral end is pointed downward.

3–5, 9–13, 16–20. *Eocephalites primus* Imlay, n. sp. (p. 97).
3–5. Lateral and ventral views of paratype USNM 132828 from USGS Mesozoic loc. 22638.
9–11. Suture line, ventral, and lateral views of inner whorls of a larger specimen. Paratype USNM 132831 from USGS Mesozoic loc. 28483. Suture line drawn at diameter of 32 mm.
12, 13, 16. Lateral and ventral views and suture line of internal mold. Paratype USNM 132829 from USGS Mesozoic loc. 21618.
17. Partial suture line showing first and second lateral lobe. Paratype USNM 132832 from USGS Mesozoic loc. 20973.
18. Paratype USNM 132942 from USGS Mesozoic loc. 20961. Shows nearly complete body chamber whose adapical end is marked by a small fault. Note presence of part of an apertural constriction. The body chamber is an internal mold and has been corroded. The septate part of the outer whorl bears some shell material and has fairly sharp ribbing.
19. Internal mold of paratype USNM 132830 from USGS Mesozoic loc. 21618.
20. Internal mold of laterally crushed adult body chamber of paratype USNM 132827 from USGS Mesozoic loc. 27729.

6–8. *Eocephalites*? sp. undet. A (p. 98).
Lateral and apertural views of specimen USNM 132833 from USGS Mesozoic loc. 28648. This specimen retains some shell material.

14, 15. *Eocephalites*? sp. undet. B. (p. 98).
Lateral and apertural views of internal mold of specimen USNM 132834 from USGS Mesozoic loc. 20979.



EOCEPHALITES

PLATE 16

[All figures are natural size. All specimens from the Sliderock Member of the Twin Creek Limestone].

FIGURES 1–4. *Megasphaeroceras* cf. *M. rotundum* Imlay (p. 96).

Lateral, apertural, and ventral views of septate internal mold USNM 132939 fromUSGS Mesozoic loc. 28645.

5–7. *Stemmatoceras* n. sp. cf. *S. albertense* McLearn (p. 91).

5, 7. Ventral and lateral views of immature specimen, USNM 132940 from USGS Mesozoic loc. 28645. Shows ribbing on internal whorls.

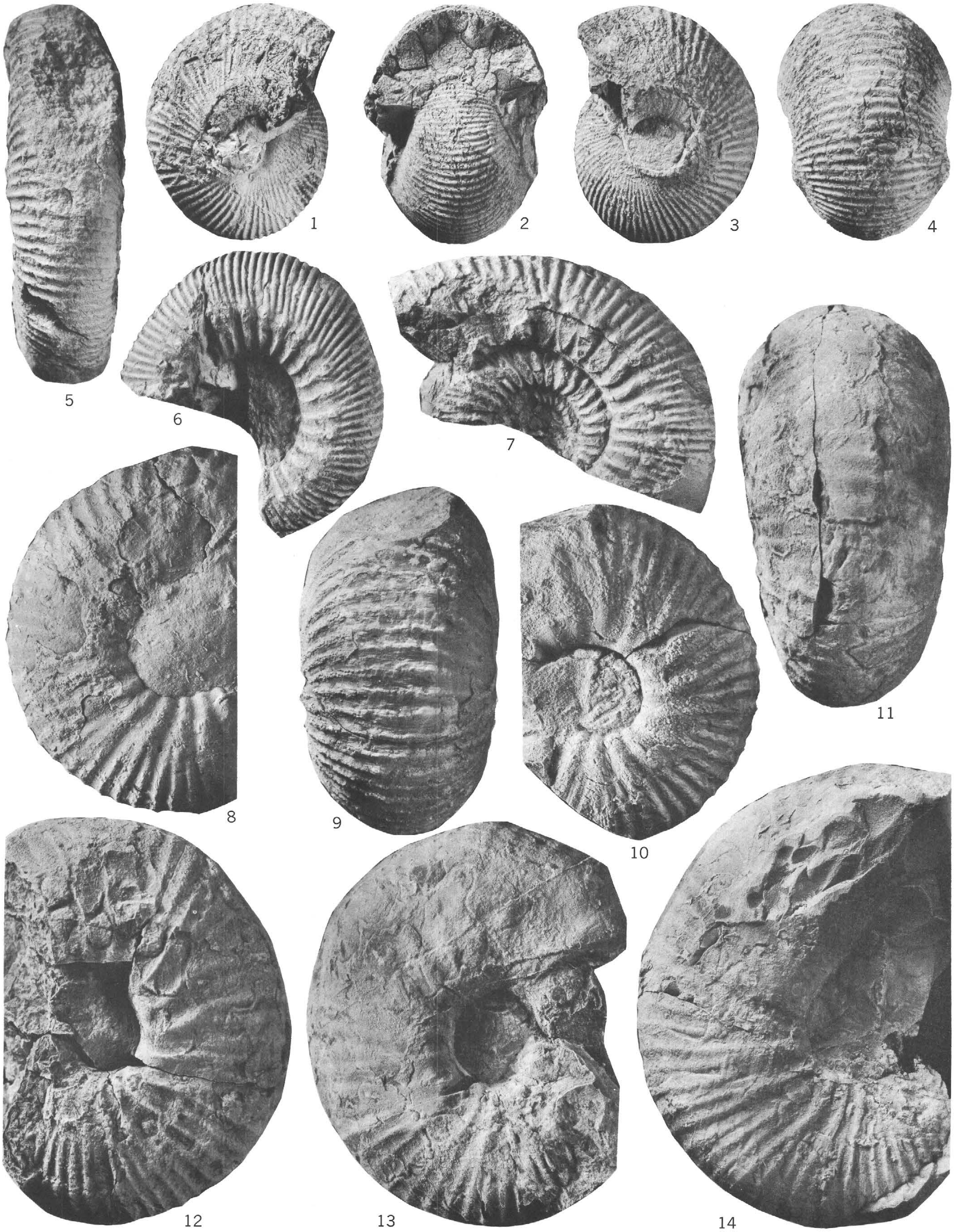
6. Immature specimen USNM 132941 from USGS Mesozoic loc. 28645.

8–14. *Eocephalites primus* Imlay, n. sp. (p. 97).

8–10. Lateral and ventral views of paratype USNM 132938 from USGS Mesozoic loc. 20345. Shows ribbing on adult body chamber.

11–13. Ventral and lateral views of holotype USNM 132826 from USGS Mesozoic loc. 20345. Shows ribbing on internal mold of adult body chamber and abrupt truncation at aperture.

14. Lateral view of internal mold of paratype 132827 from USGS Mesozoic loc. 27729. See view of same specimen on pl. 15, fig. 20.



MEGASPHAEROCERAS, STEMMATOCERAS, AND *EOCEPHALITES*