Stratigraphy and Ammonite Fauna of the Graneros Shale and Greenhorn Limestone Near Pueblo, Colorado

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By WILLIAM A. COBBAN *and* GLENN R. SCOTT

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A description of the rocks and a comprehensive study of the ammonites

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STRATIGRAPHY AND AMMONITE FAUNA OF THE GRANEROS SHALE AND GREENHORN LIMESTONE NEAR PUEBLO, COLORADO

By WILLIAM A. COBBAN and GLENN R. SCOTT

ABSTRACT

The Upper Cretaceous Graneros Shale and Greenhorn Limestone crop out at many places in southeastern Colorado, but they are especially well exposed near Pueblo where many of their beds are fossiliferous. Type localities of both formations are within 30 miles of Pueblo. The Graneros Shale is underlain by the Dakota Sandstone, and the Greenhorn Limestone is overlain by the Carlile Shale.

In 1896, G. K. Gilbert gave the name Greenhorn Limestone to a ledge-forming unit of alternating thin beds of limestone and calcareous shale. He named the underlying slope-forming unit the Graneros Shale and noted the presence of a few beds of limestone in the upper part. Although not recorded as such by Gilbert, the shale in the upper part of his Graneros is calcareous. In the mid-1920's, W. W. Rubey and N. W. Bass included in the Greenhorn Limestone of Kansas the equivalent of this calcareous shale as well as the main ledge-forming beds equivalent to Gilbert's Greenhorn Limestone. This enlarged scope of the Greenhorn was later also applied to the west flank of the Black Hills in northeastern Wyoming and southeastern Montana, along the Front Range in north-central Colorado as well as in the subsurface farther east in the Denver basin, and in parts of southeastern Colorado. In the present report, the Graneros and Greenhorn in their type localities are redefined to conform to usage along the nearby Front Range and the Denver basin areas. Sections measured on the Rock Canyon anticline a few miles west of Pueblo are presented here as the principal reference sections for the Graneros and Greenhorn, and supplemental reference sections of these formations are given for other localities in southeastern Colorado and southwestern Kansas.

The Graneros Shale, 114 feet thick on the Rock Canyon anticline, is chiefly dark-gray noncalcareous shale that conformably overlies the Dakota Sandstone. The contact with the Greenhorn is drawn at the base of the so-called marker bentonite bed which lies at or very close to the change from noncalcareous shale below to calcareous shale above. The Thatcher Limestone Member, about a foot thick, lies a little above the middle of the Graneros Shale and separates a lower unit devoid of molluscan fossils from an upper fossiliferous unit. The lower barren unit contains some resistant gray siltstone layers, many thin layers of bentonite from ¼–4 inches thick, and several beds of brown-weathering chamosite ironstone concretions. The upper fossiliferous unit also contains brown-weathering chamosite ironstone concretions and thin layers of bentonite, but the concretions are commonly fossiliferous. Limestone concretions are present near the base and top of the unit, and small phosphatic nodules and pyritic nodules are found in the lower part.

The Greenhorn Limestone, 153 feet thick on the Rock Canyon anticline, consists of three members: in ascending order, the Lincoln Limestone, Hartland Shale, and Bridge Creek Limestone, all originally named for exposures in Kansas. The Lincoln Limestone Member is chiefly calcareous shale that contains thin layers of resistant calcarenite. It is 37 feet thick near Pueblo and crops out as a steep slope having small ledges. Limestone concretions and bentonite beds are present in the lower part. The base is marked by the marker bentonite bed, 10 inches to 2 feet thick. The Hartland Shale Member, 59 feet thick near Pueblo, consists of calcareous shale interbedded with a few very thin inconspicuous layers of calcarenite and many thin layers of bentonite. The Bridge Creek Limestone Member is made of many thin beds of limestone and calcareous shale and a few thin beds of bentonite. It is 57 feet thick near Pueblo where it forms a conspicuous tree-covered escarpment. The member represents the entire Greenhorn Limestone of Gilbert.

Ammonites are moderately common in most of the Graneros Shale and Greenhorn Limestone, and 30 genera and 54 species were recognized. Almost all specimens occur as internal molds, and many are somewhat distorted.

Ammonites from the Thatcher Limestone Member of the Graneros Shale are assigned to four genera. *Conlinoceras* is described as a new subgenus of *Calycoceras*, and *Calycoceras (Conlinoceras) gilberti* n. sp. is named as the type.

Ammonites in the upper fossiliferous unit of the Graneros Shale are arranged in four zones, and there is some overlap in the vertical range of the species. In ascending order these zones are *Calycoceras (Conlinoceras) gilberti*, *Acanthoceras granerosense* n. sp., *A. muldoonense* n. sp., and *A. amphibolum* Morrow. The unit also contains species of *Stomohamites*, *Anisoceras*, *Idiohamites*, *Desmoceras (Pseudouhligella)*, *Euomphaloceras*, *Tarrantoceras*, *Epengonoceras*, *Borissiakoceras*, and the new subspecies *Turrilites (Turrilites) acutus* Passy subsp. *americanus*.

Only four genera of ammonites *(Turrilites, Acanthoceras, Calycoceras*? and *Metoicoceras)* were found in the Lincoln Limestone Member of the Greenhorn Limestone. The Zone of *Acanthoceras amphibolum* ranges upward into the basal part of the member, and the Zone of *Calycoceras*? *canitaurinum* characterizes the upper part.

The thin calcarenite beds in the Hartland Shale Member contain bits of ammonites which represent at least four genera (*Stomohamites, Calycoceras*?, *Tarrantoceras*?, and *Metoicoceras*). *Metoicoceras* seems to be the commonest genus. Fresh exposures of the shale reveal small impressions of juvenile ammonites that may represent an undescribed genus related to *Tarrantoceras.*

Ammonites of the Bridge Creek Limestone Member can be assigned to four zones—from oldest to youngest—*Sciponoceras gracile, Watinoceras coloradoense, Mammites nodosoides,* and *Collignoniceras woollgari;* some overlapping occurs in the upper two zones. At least 23 genera are present. *Puebloites* is described as a new genus whose type is *P. corrugatus* (Stanton); *Greenhornoceras* is described as a new subgenus of *Vascoceras,* and *Vascoceras (Greenhornoceras) birchbyi* n. sp. is the type. Other new species described from the Bridge Creek Limestone Member are *Hemiptychoceras reesidei, Ampakabites collignoni,* and *Kanabiceras puebloense.*

In terms of the standard stages of the Cretaceous, a late Cenomanian age is assigned to the upper part of the Graneros Shale and to the Lincoln Limestone Member and Hartland Shale Member of the Greenhorn Limestone. The basal part *(Sciponoceras gracile* Zone) of the Bridge Creek Limestone Member, formerly assigned to the lower Turonian, is herein considered of latest Cenomanian age. The rest of the member is of early Turonian age.

INTRODUCTION

The purposes of this report are to redefine the Graneros Shale and Greenhorn Limestone near their type localities and to describe their stratigraphy and ammonite fauna. These formations were named more than 70 years ago near Pueblo, Colo. (fig. 1). Forty years ago the Greenhorn Limestone in Kansas (enlarged by the addition of the upper part of the Graneros) was subdivided into members. Within a few years these member names had been applied near the type locality in Colorado as subdivisions of the Graneros and Greenhorn. However, no one, until now, has redefined the type Graneros and Greenhorn by lowering the basal boundary of the Greenhorn to include the calcareous beds in the upper part of the Graneros. The redefinition applied here will formalize a terminology that has been used for the last 40 years.

The stratigraphy of the two formations near Pueblo is described and shown in columnar sections in considerable detail so that the positions of the fossil zones can be accurately plotted. Because Gilbert (1896) did not publish type sections, we have measured and are designating a reference section near Pueblo (fig. 2). The Graneros, especially in the type locality near Pueblo, has been studied so little that only two ammonite zones were known when we started this study. For the Greenhorn, also, much information has been collected concerning the ammonites that characterize two principal faunal zones of the Bridge Creek Limestone Member. The stratigraphic positions of all the fossils are shown as accurately as possible. To ascertain the relationship of the Bridge Creek Member at Pueblo to the type Bridge Creek Member in Hamilton County, Kans., we remeasured and recollected the type section. All these investigations resulted in larger

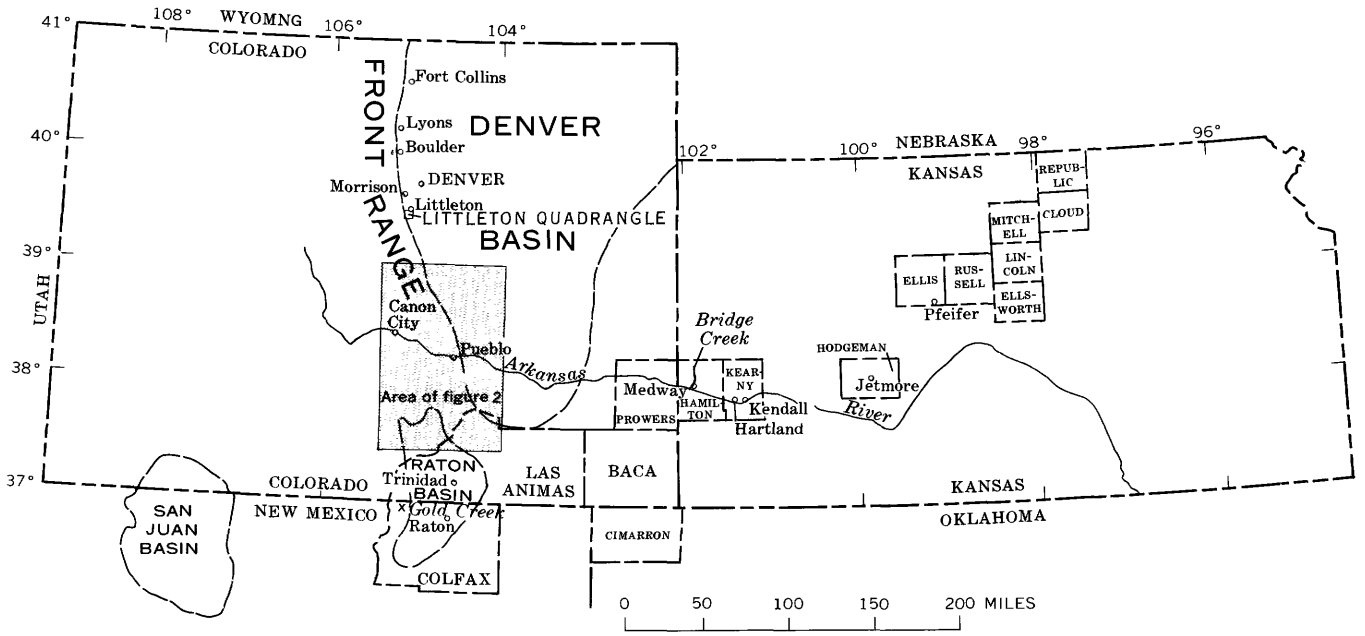

FIGURE 1.—Map of Colorado and parts of adjoining States showing places of outcrop of the Greenhorn Limestone and Graneros Shale discussed in report.

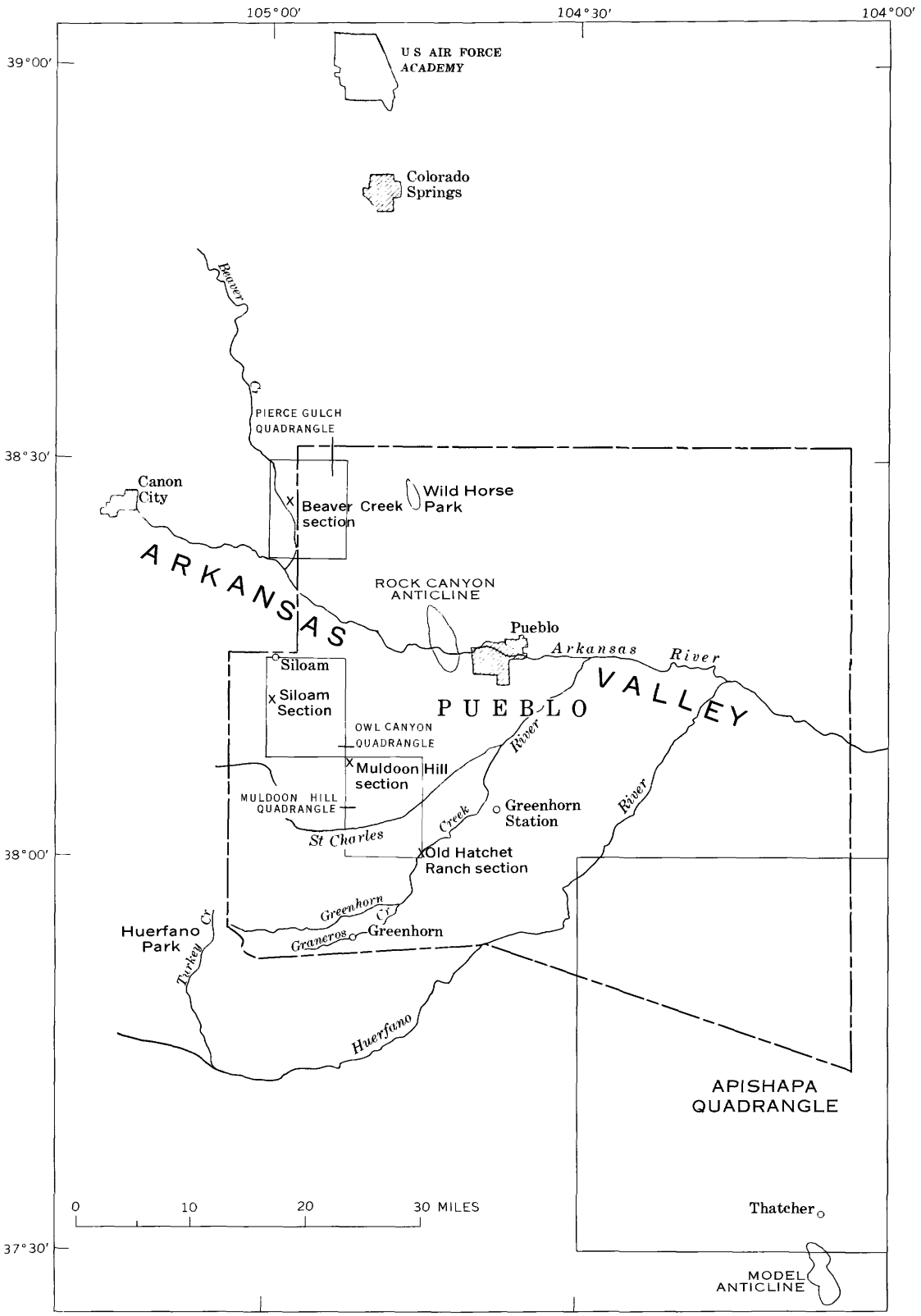

FIGURE 2.—Map of part of southeastern Colorado showing Pueblo and locations of stratigraphic sections and other features mentioned in report.

collections and a realization of a greater number of ammonite range zones than known previously and enabled a more accurate correlation than heretofore of the Graneros and Greenhorn with contemporaneous rocks elsewhere in the world.

This study was begun in 1957 as a part-time project, and in most years only a few days were devoted to it. In 1961 and 1962, the Graneros and Greenhorn near Pueblo were mapped in connection with an engineering geology study of Pueblo (Scott, 1969a, b). After publication of the Pueblo maps in 1964 and an engineering geology report (Scott, 1969a), some changes in the positions of contacts and in thicknesses were made; the corrected contacts and thicknesses are shown in this report. In 1957 and 1961, a stratigraphic section was measured at Rock Canyon anticline just west of Pueblo. In 1965 and 1966, the fieldwork was accelerated with the hope of early completion of the project; stratigraphic sections of the Graneros Shale were measured at several places near Pueblo, and fossils were collected at strategic localities in southeastern Colorado. The original objective was a redefinition of the two formations, but as larger collections were made, it became desirable to expand the objectives to include the publication of much new biostratigraphic information.

ACKNOWLEDGMENTS

We are grateful to the many people who aided us in this study. Many of the ammonites were collected by Mr. William H. Birchby, Pueblo, Colo., who devoted numerous days to bed-by-bed collecting from the Greenhorn Limestone for us. The loan by Mr. James P. Conlin, Fort Worth, Tex., of many ammonites from Texas greatly facilitated the ammonite study. Dr. Peter U. Rodda kindly loaned us type specimens belonging to the Texas Bureau of Economic Geology. Général Maurice Collignon, Moirans, France, also loaned us related ammonites from Madagascar and gave us helpful advice on some of the generic determinations. The study of the fossils was also aided by plaster casts of ammonites supplied by Dr. Leo G. Hertlein, California Academy of Sciences, San Francisco; Prof. Keith Young, University of Texas, Austin; Dr. M. K. Howarth, British Museum (Natural History), London; Mr. C. W. Wright, London; Dr. Jost Wiedmann, Institut und Museum für Geologie und Paläontologie der Universität, Tübingen, West Germany; Mme. Suzanne Taxy-Fabre, Faculté des Sciences de Marseille, France; Prof. M. A. Avnimelech and Mr. S. Rothmann, Hebrew University of Jerusalem, Israel; Prof. Tatsuro Matsumoto, Kyushu University, Fukuoka, Japan; and Dr. Ikuwo Obata, National Science Museum, Tokyo.

The sketches, cross sections, and suture patterns of the ammonites were prepared by Charles C. Capraro, of the U.S. Geological Survey. Robert E. Burkholder, also of the U.S. Geological Survey, prepared the fossils and photographed them. All ammonites illustrated are in the U.S. National Museum in Washington, D.C., and plaster casts of most are in the Federal Center in Denver, Colo.

PREVIOUS WORK

Work on the Graneros Shale and Greenhorn Limestone began in Kansas and Nebraska before 1856. Table 1 shows the history of the nomenclature of the Graneros Shale and Greenhorn Limestone and their members between 1856 and 1947. The names in the last column of table 1 are the approved names in use today in southeastern Colorado and along the east flank of the Front Range.

The earliest definitive study of the rocks between the Dakota Sandstone and the Niobrara Formation in southeastern Colorado was by Gilbert (1896). He divided these rocks into a lower thick noncalcareous and calcareous clayey shale, called Graneros Shale, a middle thin limestone and shale, called Greenhorn Limestone, and an upper thick calcareous shale, noncalcareous shale, and sandstone, called Carlile Shale. He also was the first to describe the thin limestone bed that was later named the Thatcher Limestone Member of the Graneros Shale. In Kansas, Rubey and Bass (1925) and Bass (1926a, b) applied names to members of a calcareous unit that they assigned to the Greenhorn Limestone. Their Greenhorn was later found to be equivalent to both the type Greenhorn Limestone and the upper part of the type Graneros Shale (Dane and others, 1937, p. 213). Dane, Pierce, and Reeside (1937, p. 211) were the first to demonstrate that the nomenclature of members in Kansas was also applicable in southeastern Colorado and that the lower members of the Greenhorn in Kansas merge westward into the upper part of the type Graneros Shale.

Because the Graneros Shale is nearly monolithologic, only one member and one bed have ever been named. A limestone layer below the middle of the formation at the Model anticline was named the Thatcher Limestone Member by Bass, Straub, and Woodbury (1947). In addition, a widespread, thicker than usual bentonite bed near the top of the Graneros Shale has received many names, but ac-

TABLE 1.—*Evolution of nomenclature of the Graneros Shale and Greenhorn Limestone and their members*

Hall and Meek (1856) Nebraska Territory		Meek and Hayden (1862) Nebraska Territory		Cragin (1896) Kansas			Gilbert (1896) Arkansas Valley, Colorado		Rubey and Bass (1925) Russell County, Kansas		Bass (1926a) Ellis County, Kansas		Bass (1926b) Hamilton County, Kansas		Bass, Straub, and Woodbury (1947) Model anticline, Colorado		This paper Pueblo, Colorado	
Cretaceous formation (part)	No. 2 bed	Lower series (part)	Fort Benton group (Formation No. 2)	Benton group (part)	Russell formation (part)	Downs or fence-post *limestone*	Benton group (part)	Greenhorn Limestone	Greenhorn Limestone	Upper member	Greenhorn Limestone	Pfeifer Shale Member	Greenhorn Limestone	Bridge Creek Limestone Member	Greenhorn Limestone	Bridge Creek Limestone Member	Greenhorn Limestone	Bridge Creek Limestone Member
										Jetmore Chalk Member		Jetmore Chalk Member						
										Unnamed member		Hartland Shale Member		Hartland Shale Member		Hartland Shale Member		Hartland Shale Member
						"Lincoln marble"				Lincoln Limestone Member		Lincoln Limestone Member		Lincoln Limestone Member		Lincoln Limestone Member		Lincoln Limestone Member
								Graneros Shale	Graneros Shale		Graneros Shale		Graneros Shale	Marker bentonite bed	Graneros Shale	Oyster-bearing limestone	Graneros Shale	*Ostrea beloiti* bed
																		Upper fossiliferous unit
																Thatcher Limestone Member		Thatcher Limestone Member
																		Lower barren unit

cording to Hattin (1965a, p. 38) it apparently is a single continuous bed and should be designated by a single name. It was named the gray-red bentonite by M. N. Bramlette and W. W. Rubey (in Moore, 1949, fig. 18, p. 27), the Soap Creek Bentonite Bed of Frontier Formation by Richards and Rogers (1951) in southern Montana, the "X" or "marker bentonite" by Jensen and Sharkey (1954, p. 62), and bed F by Knechtel and Patterson (1956, p. 18). The name marker bentonite bed is used in this report.

In addition to the previously mentioned work concerning nomenclature, many reports discussed the fossils that characterize the Graneros and Greenhorn in southeastern Colorado. Most of these reports simply referred to the presence of the fossils, but in two reports an echinoid and an aberrant ammonite were described for the first time. In addition, two species and one subspecies of Foraminifera were first collected and named from the Graneros Shale at localities in southeastern Colorado (Eicher, 1965).

The earliest detailed discussion of fossils from southeastern Colorado was by Stanton (1893). In 1897 Gilbert reported three fossil horizons in the Graneros and Greenhorn near Pueblo and observed that the shale of the Greenhorn [Bridge Creek] contained the same fossils as the interlayered limestone. Hills (1899), Stose (1912), Reeside (1927, 1957), Morrow (1935), Dane, Pierce, and Reeside (1937), Bass, Straub, and Woodbury (1947), Cooke (1953), McLaughlin (1954), Cobban (1956b), Varnes and Scott (1967), and Scott (1969a) all listed fossils collected at various places in southeastern Colorado.

In 1930, Johnson listed and showed the range of all the fossils then known from the Graneros and Greenhorn of eastern Colorado and Kansas. There were 21 species from the Graneros (of Gilbert) and 34 from the Greenhorn [Bridge Creek].

In 1952, Cobban and Reeside published charts showing the correlation of all Cretaceous rocks in the western interior of the conterminous United States. Seven zonal indices or fossil zones—six based on ammonites—were shown within the time of deposition of the Graneros and Greenhorn. These zones were, in ascending order, (1) *Calyoceras* Hyatt, (2) *Acanthoceras? amphibolum* Morrow, (3) *Acanthoceras*? sp. A, (4) *Dunveganoceras pondi* Haas, (5) *Dunveganoceras* aff. *D. albertense* (Warren), (6) *Sciponoceras gracile* (Shumard), and (7) *Inoceramus labiatus* (Schlotheim). Only the index fossils of zones 1, 2, 4, 6, and 7 have been found at Pueblo.

In 1961, in a description of the ammonite family Binneyitidae Reeside, Cobban stated: "* * * the oldest unquestioned Cenomanian megafossil zone in the Western Interior region is the level of the

Thatcher limestone member of the Graneros shale of southeastern Colorado." Scott (1964) showed several zones of fossils identified by Cobban from the Graneros and Greenhorn at Rock Canyon anticline west of Pueblo, Colo. The lowest zone contains *Calycoceras* sp. (in the Thatcher Limestone Member), the upper part of the Graneros contains *Acanthoceras amphibolum* and *Inoceramus rutherfordi,* and the top of the Lincoln contains *Calycoceras canitaurinum. Inoceramus pictus* appears throughout the Hartland, *Sciponoceras gracile* occupies a little less than the lower half of the Bridge Creek, and *Inoceramus labiatus* occupies the upper part and extends up into the Fairport Chalky Shale Member of the Carlile Shale.

In an excellent report about the Graneros of Kansas, Hattin (1965a) also gave some information about the Graneros of southeastern Colorado, chiefly supplied by Dr. Erle G. Kauffman of the U.S. National Museum. Kauffman stated that *Ostrea beloiti* ranges from the middle part of the Graneros into the Lincoln Limestone Member in Colorado and that he had collected early forms of *Inoceramus rutherfordi* from below the zone of *Acanthoceras amphibolum* in Colorado. Kauffman further stated that fossils in the lower part of the Graneros in southeastern Colorado apparently represent a zone that is older than any part of the Graneros in central Kansas. From this information, Hattin inferred that the shoreline migrated progressively eastward or northeastward as Graneros sediments were deposited.

Recently, Eicher (1965) studied the Foraminifera and biostratigraphy of the Graneros Shale and its equivalents in the western interior. As a result, he divided the Graneros at Rock Canyon anticline west of Pueblo into two fossil zones, a *Trochammina rutherfordi mellariolum* Zone below and a *Trochamminoides apricarius* Zonule above (fig. 15). Seven different species of Foraminifera are restricted to each of the two zones, and 12 species are common to both zones. The boundary between the two zones was drawn about 30 feet below the Thatcher Limestone Member. Eicher found that the Graneros at Pueblo represented more time than the Graneros in Kansas but less time than the Graneros near Morrison, Colo. The *Trochamminoides apricarius* Zonule near Pueblo was found to be equivalent to the entire Graneros in Kansas, and beds in the Dakota Sandstone below the Graneros at Pueblo were found to be equivalent to both the Mowry Shale and an overlying pre-*mellariolum* interval at Morrison.

In 1967 Kauffman interpreted the cycles of deposition of the Cenomanian and Turonian rocks in the western interior and attempted to establish the broad relationships between lithology, fauna, and paleoenvironment. Kauffman, Powell, and Hattin (1969) described the Cenomanian and Turonian rocks at Huerfano Park and Model anticline in Colorado and in Cimarron County, Okla. They then inferred the paleoenvironments and facies changes that took place between these three places. Detailed study of fossils allowed them to construct a refined local biostratigraphic zonation. In addition they have now lowered the upper boundary of the Graneros Shale and extended the names of the members of the Greenhorn Limestone from Kansas as far west as Huerfano Park, Colo.

STRATIGRAPHY

The Graneros Shale and Greenhorn Limestone of Late Cretaceous age constitute about the lower two-thirds of the rocks between the Dakota Sandstone and the Niobrara Formation at Pueblo, Colo. The upper one-third, the Carlile Shale, is not described here. The boundary established by Gilbert (1896, p. 564) between the Graneros and Greenhorn was nearly 100 feet higher than the currently used boundary. In the upper part of the type Graneros, Gilbert included calcareous shale and calcarenite beds that now are assigned to the Lincoln Limestone and Hartland Shale Members of the Greenhorn Limestone. In the type Greenhorn, Gilbert included only the thin hard beds of limestone now called the Bridge Creek Limestone Member. We are here redefining the Greenhorn so that it includes all the calcareous beds of the Lincoln, Hartland, and Bridge Creek. We are further redefining the Graneros so that it contains only the generally noncalcareous beds below the marker bentonite bed.

The lower boundary of the Graneros and the upper boundary of the Greenhorn are conformable; however, the boundary between the Graneros and Greenhorn is not everywhere conformable. In southwestern Kansas, for example, Hattin (1965a, p. 11) found evidence of an erosional unconformity at this contact. The contact used at Pueblo is several feet lower than in Kansas or southeasternmost Colorado. The basal calcarenite of the Greenhorn in Kansas apparently is represented at Pueblo by calcareous shale, and no unconformity has been found; therefore, we have placed the contact at the base of the calcareous shale and beneath the marker bentonite bed. For the same lithologic reason, a contact beneath the bentonite bed has been used for several

years in both the surface and the subsurface of the Denver basin (Scott, 1963, p. 95; Haun, 1959, p. 2).

GRANEROS SHALE

The Graneros Shale, of Cenomanian age, is a nonresistant unit, 114 feet thick, composed chiefly of dark-gray shale. It crops out only rarely in cutbanks along modern streams and where upland arroyos have cut into the gentle slope between the Lincoln Limestone Member and the Dakota Sandstone. Because the shale is nearly black, the outcrops show as gray spots on aerial photographs. The only persistent ledge-forming bed is the Thatcher Limestone Member; it becomes thickest, hardest, and most resistant and forms a prominent ledge in the east end of Las Animas County and the west end of Baca County, Colo.

The Graneros Shale was named by Gilbert (1896, p. 570) for exposures along Graneros Creek in Pueblo County, about 24 miles south of Pueblo. The exposures at the type locality show only part of the formation, and no type section was published by Gilbert.

The only complete stratigraphic section of the Graneros Shale is designated the principal reference section at Rock Canyon anticline a few miles west of Pueblo (pl. 40). No other complete section was seen, and partial sections probably are well exposed at not more than a dozen other places.

Rock Canyon section

[Principal reference section of Graneros Shale in the SW¼ sec. 30, T. 20 S., R. 65 W., and the NW¼NE¼ sec. 36, T. 20 S., R. 66 W., Pueblo County, Colo.]

		Ft	in
Graneros Shale:			
70.	Shale, dark-gray, calcareous	1	0
69.	Limestone, dark-gray; weathers gray; contains minute white specks; lenticular, in places as much as 1 ft thick and in places absent. Commonly has a coquina of oysters at base or top. Usually shaly		6
	USGS 22887:		
	Inoceramus rutherfordi Warren		
	Ostrea beloiti Logan		
	Turrilites acutus americanus Cobban and Scott		
	Desmoceras (*Pseudouhligella*) sp.		
	Tarrantoceras rotatile Stephenson		
	Acanthoceras amphibolum Morrow		
	Borissiakoceras sp.		
68.	Shale, dark-gray, slightly calcareous	6	4
67.	Bentonite, gray		½
66.	Shale, dark-gray		7
65.	Bentonite		½
64.	Shale, dark-gray, noncalcareous; contains a few gypsiferous limonitic casts of ammonites in the lower foot	3	9
	USGS D5153:		
	Ostrea sp.		
	Acanthoceras amphibolum Morrow?		
63.	Bentonite, gray		1
62.	Shale, dark-gray, noncalcareous; rarely contains a gypsiferous limonitic cast of an ammonite in lower half	8	5
61.	Bentonite		1
60.	Shale; rarely contains a chamosite ironstone concretion	1	7
	USGS D5152, from concretion at base:		
	Acanthoceras muldoonense Cobban and Scott		
59.	Bentonite		¼
58.	Shale, dark-gray; contains an occasional gypsiferous limonitic cast of an ammonite	3	4
57.	Chamosite ironstone concretions, dark-gray; weather grayish red and brown, iron stained; some are crowded with crushed ammonites		4
	USGS D1306:		
	Arrhoges modesta (Stephenson)?		
	Acanthoceras muldoonense Cobban and Scott		
	USGS D3965:		
	Ostrea sp.		
	Acanthoceras muldoonense Cobban and Scott		
	Fish scales		
56.	Bentonite, gray		1
55.	Shale, dark-gray; contains iron-stained chamosite ironstone concretions, pyrite nodules, phosphatic nodules, and limonitic masses of gypsum	17	0
	USGS D5294, from 3-in.-thick concretion 8 in. below top:		
	Acanthoceras muldoonense Cobban and Scott		
	USGS D5729, limonitic-gypsiferous ammonites 3—4½ ft below top:		
	Acanthoceras muldoonense Cobban and Scott		
	USGS D3963, from a concretion 5½ ft below top:		
	Ostrea sp.		
	Arrhoges modesta (Stephenson)?		
	Stomohamites sp.		
	Acanthoceras muldoonense Cobban and Scott		
	Epengonoceras dumbli (Cragin)?		
	Fish scales		
	USGS D5151, from 6½–10 ft below top:		
	Acanthoceras muldoonense Cobban and Scott		
	A. granerosense Cobban and Scott		
	USGS D5728, from 4½–5 ft above base:		
	Calycoceras (*Conlinoceras*) *gilberti* Cobban and Scott		

Graneros Shale—Continued

		Ft	in
	USGS D3964, from dark-greenish-gray phosphatic nodules 1½ ft above base: *Inoceramus* sp. *Ostrea* sp. *Arrhoges modesta* (Stephenson)? *Stomohamites* cf. *S. simplex* (d'Orbigny) *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott Fish scales and bones		
	USGS D3970 and D1305, crushed phosphatic ammonites covered by shell material, 6 in. above base: *Stomohamites* cf. *S. simplex* (d'Orbigny) *Anisoceras* cf. *A. plicatile* (J. Sowerby) *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott		
54.	Limestone, dark-gray, hard, dense, concretionary, silty; weathers pale yellowish orange and grayish red; cone-in-cone structure at top and bottom. Contains crushed fossils at top. Thatcher Limestone Member	1	0
	USGS D4445 and D5150: *Inoceramus eulessanus* Stephenson *Ostrea* sp. *Camptonectes* sp. *Plicatula arenaria* Meek *Anomia* sp. *Arrhoges modesta* (Stephenson)? *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott *Borissiakoceras compressum* Cobban		
53.	Shale		8
52.	Bentonite		4
51.	Shale, dark-gray, noncalcareous	8	6
50.	Bentonite		4
49.	Shale		3
48.	Siltstone; in hard layers up to 1½ in. thick; shows burrows on bottom surface and some fish bones and cross-bedding		5
47.	Shale, dark-gray; contains sparse widely spaced large concretions that are tan to medium-brown and have cone-in-cone structure, and contains fish bones and wood	3	7
46.	Bentonite, gray		1
45.	Shale	1	1
44.	Bentonite, gray		½
43.	Shale; contains closely spaced yellowish-tan to reddish-brown concretions as much as 15 in. thick and 5 ft long lying 20 in. below top. Cone-in-cone structure present in concretions as well as in calcite in the shale	4	8

Graneros Shale—Continued

		Ft	in
42.	Bentonite, gray		2
41.	Shale		6
40.	Bentonite, gray		1½
39.	Shale		1
38.	Bentonite, gray		2
37.	Shale	1	9
36.	Bentonite, limonitic		1
35.	Shale	2	10
34.	Bentonite		1
33.	Shale	4	9
32.	Bentonite		1
31.	Shale, dark-gray, noncalcareous	1	10
30.	Bentonite		1
29.	Shale, dark-gray, noncalcareous; in upper part contains sparse thin lenses of tan calcite having cone-in-cone structure	2	8
28.	Siltstone, gray, hard, thin-layered, buttress-forming; weathers brown; interlayered with dark-gray shale		9
27.	Bentonite		1
26.	Siltstone, gray, hard, thin-layered, lenticular, buttress-forming; weathers brown; interlayered with dark-gray shale; contains worm trails and burrows near base	1	6
25.	Shale, dark-gray; in lower part contains thin hard layers of brown-weathering gray siltstone containing worm burrows; in upper part contains sparse tan concretions having cone-in-cone structure	4	4
24.	Bentonite		½
23.	Shale; contains a few thin layers of siltstone	1	6
22.	Bentonite and jarosite		½
21.	Shale, dark-gray; contains streaks of siltstone and concretionary lenses of brown-weathering dark-gray calcareous siltstone as much as 1 ft thick and 8 ft long; cone-in-cone structure is developed on top and bottom of upper lens; lenses contain abundant fish scales and bones (USGS D3971)	4	9
20.	Bentonite		¼
19.	Shale		5
18.	Bentonite		1½
17.	Shale, dark-gray, medium-hard, fissile, noncalcareous; contains thin hard siltstone layers in upper 1½ ft	3	5
16.	Shale, dark-gray; contains layers of bentonite at base, middle, and top one-quarter in. thick	1	4
15.	Shale, dark-gray, medium-hard, fissile, noncalcareous	1	5
14.	Bentonite		½
13.	Shale		1
12.	Bentonite, light-olive-gray, soft, plastic		½
11.	Shale, dark-gray, medium-hard, silty, noncalcareous, platy	1	4
10.	Jarosite		⅛

Graneros Shale—Continued

		Ft	in
9.	Shale, dark-gray, medium-hard silty, noncalcareous, platy	3	2
8.	Bentonite, grayish-orange-pink, soft, plastic		2
7.	Shale, dark-gray, medium-hard, blocky	1	3
6.	Bentonite, light-gray, well-stratified, slightly hard, plastic		4
5.	Shale	2	0
4.	Bentonite, light-gray; contains selenite crystals		1
3.	Shale, dark-gray, fissile	3	0
2.	Bentonite, yellow and light-gray, soft, plastic		1
1.	Shale, dark-gray, fissile, medium-hard	3	0
	Total Graneros Shale (rounded)	114	0

Dakota Sandstone (not measured).

The contact between the Graneros and the underlying Dakota Sandstone is sharp and easily mappable. The upper part of the Dakota contains resistant platy sandstone beds about 2–4 inches thick separated by sandy shale. In these beds at Beaver Creek, 22 miles northwest of Pueblo, Eicher (1965, p. 883) found a marine foraminifer that is characteristic of the lower part of the Graneros Shale farther north near Morrison, Colo. Therefore, at least the upper part of the Dakota at Pueblo is marine in origin and Cenomanian in age.

The contact between the Graneros and the overlying Lincoln Limestone Member is sharp but not easily mappable. The lower beds of the Lincoln are calcareous nonledge-forming shale overlying a basal bentonite, the marker bentonite bed. Limestone concretions, about 1 foot below the bentonite bed, stand out conspicuously at most places and form a satisfactory mapping horizon.

The upper contact of the Graneros in southwestern Kansas and at the Model anticline in southeastern Colorado lies at the base of a hard finely banded thin-bedded limestone composed of sand-sized calcareous grains, that is 10–13 feet above the marker bentonite bed. The hard limestone bed, or calcarenite, is absent from the Pueblo area, and there is no way to tell where it might lie within the thick section of calcareous shale between the marker bentonite bed and the topmost, and only thick, calcarenite bed in the Lincoln Limestone Member. The most logical position for an upper contact of the Graneros Shale in southeastern Colorado is at a prominent lithologic change that is nearest to the contact as picked in Kansas. The contact that is chosen lies between chiefly noncalcareous beds below and chiefly calcareous beds above and is marked by the marker bentonite bed above and gray limestone concretions and an oyster coquina below.

For convenience of description, the Graneros is divided into three parts: a lower barren unit 70 feet thick, the Thatcher Limestone Member 1 foot thick, and an upper fossiliferous unit 43 feet thick. The terms "barren" and "fossiliferous" pertain only to megafossils, for the lower barren unit does contain microfossils. The chief difference between the lower and upper units is in the contained concretions, and to a lesser extent, in the shale itself.

LOWER BARREN UNIT

The lower barren unit is chiefly dark-gray medium hard noncalcareous shale. Most of the shale is fissile, but some beds show no stratification and are blocky. In the lower part, the shale is silty, platy, and contains yellowish- or reddish-brown ferruginous layers. Hydrometer and sieve analyses show that the lower part of the lower barren unit contains 64 percent clay and 36 percent silt-sized particles. X-ray analysis indicates that 70 percent is clay minerals, 30 percent is quartz, and a trace is potassium feldspar. Of the clay minerals, mixed-layer clay (consisting of illite and montmorillonite) is more abundant than illite, which is about equal in abundance to kaolinite. The shale weathers readily to a depth of more than 5 feet to soft brownish-gray or light-olive-gray clay.

Siltstone in thin layers and concretions makes up a small part of the lower barren unit. The siltstone is gray or dark gray, hard, and more resistant to erosion than the shale. Most layers are thinner than 1½ inches, some are cross-stratified, and most are lenticular. Harder layers form thin ribs or resistant buttresses along arroyo walls. Two layers of siltstone concretions, each about 1 foot thick and 8 feet long, lie 22 feet above the base of the unit near Pueblo and form the only resistant bench between the Dakota and the Thatcher Limestone Member. The siltstone generally weathers brown and shaly; ferruginous layers near the base weather reddish orange. The only sandstone bed is a nonpersistent light-olive-gray soft shaly glauconitic layer near the base.

Bentonite beds, ¼–4 inches thick, are common, 25 beds having been observed near Pueblo. The bentonite, or volcanic ash altered to clay, is light gray, gray, light olive gray, pale yellow, or grayish orange pink, depending on the amount of contained iron. Some of it is limonitic, and some of its beds are accompanied by layers of jarosite, a hydrous sulfate of iron and potassium. Also, jarosite forms other nearly pure discrete layers. The bentonite generally

is a soft, extremely plastic, amorphous clay, but some layers show well-developed stratification. The thickness of a single bentonite layer varies between an exposed face and a deeply buried bed, owing to the clay swelling where exposed to moisture. The bentonite beds in the stratigraphic sections were measured at the bottoms of trenches several inches deep.

Concretions in the lower barren unit are composed of dark-gray nonfossiliferous amorphous limestone and pale-brown calcite having cone-in-cone structure (fig. 3). The concretions are more resistant than the containing shale and, after erosion, remain as yellowish-brown knobs perched on shale prominences. Cones from the cone-in-cone calcite litter the slope below the knobs.

The only fossils observed, other than foraminifers, were bones and wood in siltstone concretions and layers and fish scales. Trails and burrows of worms or crustaceans are on the lower surfaces of some siltstone layers.

THATCHER LIMESTONE MEMBER

The Thatcher Limestone Member (Bass and others, 1947) is a dark-gray extremely hard, brittle dense limestone that fractures conchoidally. The Thatcher forms the most persistent and conspicuous ledge between the Dakota and Lincoln. The Thatcher Limestone Member was named by Bass, Straub, and Woodbury (1947) for dense dark-gray limestone in an exposure along U.S. Highway 350 at Thatcher, Colo. Bass, Straub, and Woodbury originally included in their Thatcher Limestone Member two beds of limestone separated by shale. We find that the lower bed is best described as siltstone and that only the upper limestone bed is persistent away from the type locality. Therefore, we here redefine the Thatcher Limestone Member to in-

FIGURE 3.—Yellowish-tan concretion 15 inches thick and 5 feet long showing cone-in-cone structure in unit 43 of the Graneros Shale principal reference section at Rock Canyon anticline in the SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo.

clude only the upper limestone bed. The following section measured at the type locality shows the positions and thicknesses of the Thatcher Limestone Member and the underlying siltstone bed. The limestone is nearly continuous, yet it is concretionary in that it swells to 15 inches and pinches to 6 inches in thickness and commonly thins laterally to zero between large concretionary masses (fig. 4). As a result of the thinning, the base is irregular but sharp on the shale. Many of the largest masses have cone-in-cone structure at their tops and bottoms. Generally, the limestone is silty and unbedded, but along Greenhorn Creek (figs 5, 6) some concretions are banded with alternating laminae of dark-gray shale and gray siltstone. Wherever the Thatcher occurs, it is stained by iron minerals or is ferruginous throughout. It weathers to many shades of brown, orange, and red. Near Pueblo, the characteristic colors are grayish red or pale yellowish orange; near Thatcher, the color is ordinarily dark yellowish orange. Burrows of worms or crustaceans were seen on both the top and the bottom of the limestone. Other fossils are common on the top of the limestone (fig. 7).

Section of a small part of the Graneros Shale, including the Thatcher Limestone Member, at the type locality of the Thatcher Member in the N½ sec. 10, T. 29 S., R. 60 W., Las Animas County, Colo.

		Ft	in
Graneros Shale (part):			
11.	Shale, dark-gray; contains impressions of fossils ----------	>2	0
	USGS D5733:		
	Inoceramus sp.		
	Ostrea sp.		
	Calycoceras (*Conlinoceras*) *gilberti* Cobban and Scott		
	Borissiakoceras compressum Cobban		

FIGURE 4.—Bench made by the Thatcher Limestone Member of the Graneros Shale at the type locality near Thatcher in the N½ sec. 10, T. 29 S., R. 60 W., Las Animas County, Colo.

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FIGURE 5.—Bench made by the Thatcher Limestone Member of the Graneros Shale in the channel of Greenhorn Creek at Old Hatchet Ranch near the center of sec. 35, T. 23 S., R. 66 W., Pueblo County, Colo.

Graneros Shale (part)—Continued

		Ft	in
10.	Limestone, dark-gray; weathers dark yellowish brown to dark yellowish orange, silty, ferruginous, very hard, unbedded, concretionary. Forms conspicuous ledge. Contains a few oysters and ammonites. Some burrows on top surface. Thatcher Limestone Member -----		3–18
	USGS D5732:		
	Ostrea cf. *O. beloiti* Logan		
	Calycoceras (*Conlinoceras*) *gilberti* Cobban and Scott		
9.	Bentonite, pale-yellow ----------		3
8.	Shale, brownish-gray; contains some fish scales and bones. Thickness approximate ----------	5	6
7.	Bentonite, pale-yellow ----------		2½
6.	Siltstone, brown, ferruginous, hard, thin-bedded. Forms ledge. Rather poorly bedded. Contains small burrows on surfaces ----------		6
5.	Shale, dark-gray and brownish-gray. Contains some laminae of medium-gray hard siltstone ----------	3	6
4.	Bentonite, gray ----------		¾
3.	Shale ----------		6
2.	Bentonite, light-gray ----------		3
1.	Shale, dark-gray; not measured.		

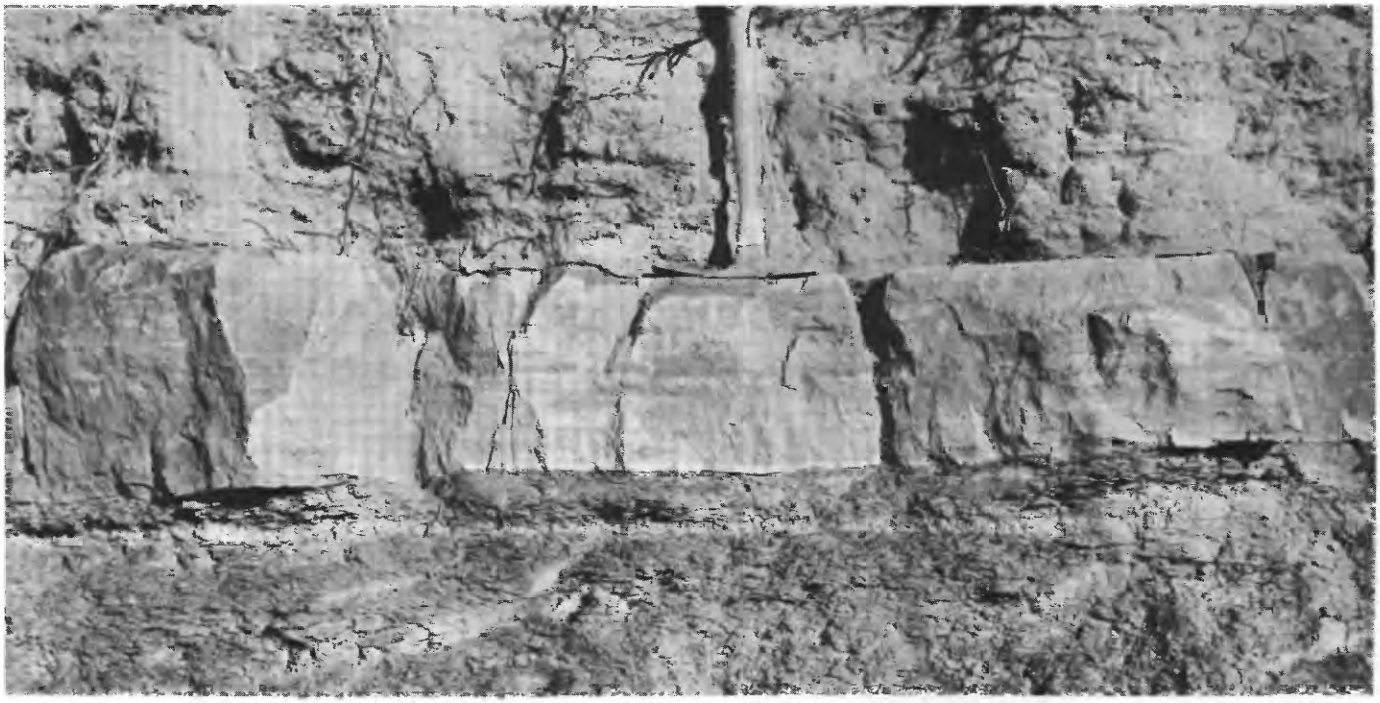

FIGURE 6.—Thatcher Limestone Member of the Graneros Shale and thin persistent underlying bentonite bed (bed 3 of section) at Old Hatchet Ranch near the center of sec. 35, T. 23 S., R. 66 W., Pueblo County, Colo.

UPPER FOSSILIFEROUS UNIT

The upper fossiliferous unit of the Graneros Shale is chiefly dark-gray gypsiferous blocky noncalcareous silty shale. Gypsum occurs both disseminated in the shale and as crystals of selenite. Shale in the upper 2–10 feet of the unit is calcareous. Yellow stains in the shale probably are jarosite. The shale weathers to gray or brownish-gray fissile chips and, after continued weathering, to soft residual clay. Limonitic gypsum casts of ammonites are abundant, but few can be identified because of poor preservation. Near Pueblo they were found between 11 and 37 feet above the base, but most are in the lower part.

Siltstone layers were found in the lower part and calcareous siltstone concretions in the middle part of the upper unit. A gray very hard slightly laminated lenticular layer that extends for about 50 feet along a streambank is 3 feet above the base. A similar dark-gray hard layer 2 inches thick lies 12½ feet above the base. Dark-gray hard siltstone concretions, which weather light olive gray, brown, or grayish red owing to iron oxide, lie in several persistent layers between 16 and 24 feet above the base. The concretions are about 4 inches thick by

FIGURE 7.—Accumulation of more than 25 individuals of *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott, n. sp., in the upper part of the Thatcher Limestone Member of the Graneros Shale at Old Hatchet Ranch near the center of sec. 35, T. 23 S., R. 66 W., Pueblo County, Colo.

1–2 feet in diameter and are so widely spaced that more than one seldom is seen at an outcrop. The concretions contain many crushed ammonites and pelecypods, but the shale layers are less fossiliferous.

Gray bentonite beds ranging from ¼–3½ inches thick are abundant in the upper fossiliferous unit. Only the lowermost 17–26 feet and the uppermost 3–8 feet contain no bentonite beds, and as a general rule there is no calcareous shale below the uppermost bentonite. Several of the bentonite beds contain limonite and other unidentified impurities. The bentonite weathers to light-gray or pale-yellowish-gray puffy clay.

Phosphatic nodules and pyrite nodules are found on freshly exposed outcrops. Dark-greenish-gray phosphatic nodules lie 1½–12 feet above the base and range from a fraction of an inch to several inches in diameter, and most are replacements of ammonites. Pyrite nodules ½–4 inches in diameter lie about 5 feet above the base; a few of them are formed around ammonites.

Limestone concretions lie near the base and the top of the unit. A lens of calcarenite one-half inch thick containing inocerams and oysters lies 1½ feet above the base at one locality; at another, pale-brown 2-inch-thick small fossiliferous limestone concretions lie 3 feet above the base. Large limestone concretions, the principal source of *Acanthoceras amphibolum*, lie at, or 3½ feet below, the top of the unit. At other localities, similar concretions lie above the marker bentonite rather than below. The concretions are dark gray, hard, platy, about 1 foot thick, 5–10 feet long and are spaced about every 10 feet along the outcrop. They contain minute white specks that possibly are aggregates of coccospheres. The limestone weathers moderate yellowish brown or gray and shaly or to small rectangular blocks. A coquina composed almost entirely of the shells of *Ostrea beloiti* lies at the same position as the limestone concretions but is more widespread. The coquina is medium brownish gray, hard, variable in thickness—but generally 2 inches thick—and weathers light yellowish gray. This bed is resistant to erosion and fragments pave slopes below its outcrop.

REGIONAL VARIATION OF THICKNESS

The Graneros Shale varies considerably in thickness in southeastern Colorado and even more outside this area. The thicknesses used are for the interval between the Dakota Sandstone and the marker bentonite bed. The trend of thickening of the shale is from nearly 20 feet in east-central Kansas to more than 100 feet near Pueblo; southward from Pueblo the shale thickens slightly; northward from Pueblo it thickens greatly. In Cloud County, Kans., the Graneros is 19½ feet thick (Buck and others, 1951, p. 9); it thickens westward to 50 feet in Hamilton County (Bass, 1926b, p. 72). In Baca County, Colo., the Graneros is 81 feet thick (McLaughlin, 1954, p. 112), in Prowers County it is about 90 feet thick (Voegeli and Hershey, 1965, p. 66), at Model anticline it is 92 feet thick (Bass and others, 1947), at Pueblo it is 114 feet thick, and at Huerfano Park it is 120 feet thick (Kauffman and others, 1969). In New Mexico, the Graneros ranges in thickness from 120 to 130 feet in the northern part of the San Juan Basin (Dane, 1960, p. 69) to 112 feet at Gold Creek, Colfax County, west of Raton (Charles L. Pillmore, written commun., 1966). Northward from Pueblo, the thickness increases to 145 feet (exclusive of the Mowry Shale equivalent) in the Littleton quadrangle (Scott, 1962, p. L11). Farther north the correlative Belle Fourche Shale of Crook County, Wyo., attains a thickness of 565 feet (Cobban, 1952, p. 86).

GREENHORN LIMESTONE

The Greenhorn Limestone, of Cenomanian and Turonian age, contains three members—in ascending order, the Lincoln Limestone, Hartland Shale, and Bridge Creek Limestone—all originally named for exposures in Kansas. Together, these make up a unit 153 feet thick, which consists of a lower calcareous shale containing calcarenite beds, a middle calcareous shale, and an upper limestone and shale. The Greenhorn was named by Gilbert (1896, p. 570) for exposures near Greenhorn Station, which is 28 miles south of Pueblo, and along Greenhorn Creek. The name originally was applied only to the 57-foot-thick Bridge Creek Limestone Member, but as used here, includes all three members. Because no type section was published by Gilbert, we measured a section at Rock Canyon anticline where the entire Greenhorn is well exposed and here designate it the principal reference section.

LINCOLN LIMESTONE MEMBER

The Lincoln Limestone Member (Cragin, 1896; Logan, 1897, p. 216; Rubey and Bass, 1925, p. 47), of Cenomanian age, is principally calcareous shale 37 feet thick containing one or more thick hard beds of calcarenite (fig. 8, pl. 41). It crops out as the lower part of a steep slope formed by the

FIGURE 8.—Platy gray ledge-forming calcarenite beds composed of fragments of fossil shells at top of the Lincoln Limestone Member of the Greenhorn Limestone (beds 10, 11, and 12 of the principal reference section) in the NE¼SE¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Slabs in foreground show fossils and flow casts.

Greenhorn Limestone. Resistant calcarenite beds form minor benches on the slope. The most persistent ledge-forming bed lies near the top of the member. In southern Prowers County, one of the calcarenite beds becomes a yellow chalky limestone and forms a prominent ledge. The Lincoln generally is poorly exposed owing to an overlying accumulation of slopewash from the higher parts of the Greenhorn.

The Lincoln Limestone Member, a part of the Russell Formation of Cragin, was named "Lincoln marble" by Cragin (1896, p. 49–50) for crystalline limestone quarried in Lincoln County, Kans. Logan (1897, p. 215–216) described the "Lincoln Marble horizon" but changed the nomenclature of the enclosing beds from Russell Formation to lower or limestone group of the Benton Formation. In 1925, Rubey and Bass (p. 47) applied the name Lincoln Limestone Member of the Greenhorn Limestone but did not designate a reference locality in Kansas. We measured a section at Rock Canyon anticline where the entire section is well exposed (pl. 41) and here designate it the reference section for Colorado.

The contact between the Lincoln and the overlying Hartland Shale Member is drawn at the top of the highest thick persistent calcarenite bed in the Lincoln. The bench formed by the calcarenite bed is prominent (fig. 9). This contact is easier to map than the basal contact of the Lincoln.

Rock Canyon section

[Reference section of Lincoln Limestone Member measured on Rock Canyon anticline in the SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo.]

		Ft	in
Lincoln Limestone Member:			
12.	Calcarenite and shale, in very thin layers		11
11.	Calcarenite, light-gray; in several layers, has crude columnar structure. Basal 1 in. limonitic		5
10.	Calcarenite, gray; weathers buff. Unit consists of shaly layers of calcarenite ⅛–2 in. thick separated by soft gray calcareous shale. Calcarenite is composed chiefly of pelagic foraminifers and prisms of *Inoceramus* shells	1	8
	USGS D3967: *Inoceramus* cf. *I. pictus* Sowerby *Calycoceras*? *canitaurinum* (Haas) *Metoicoceras* sp.		
9.	Shale, dark-gray, calcareous; contains a few layers of shaly calcarenite 1/16–1 in. thick	5	0
8.	Calcarenite, gray, shaly, foraminiferal		4
7.	Shale, dark-gray, calcareous; contains a few very thin layers of gray shaly limestone	3	0
6.	Shale, dark-gray		11
5.	Bentonite		1
4.	Shale, dark-gray		3
3.	Bentonite		2

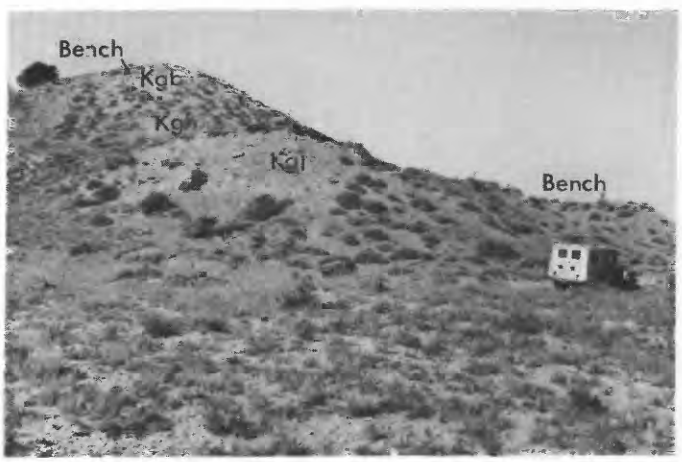

FIGURE 9.—Benches made by the Bridge Creek Limestone (Kgb) and Lincoln Limestone (Kgl) Members of the Greenhorn Limestone in the SW¼NE¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Kgh, Hartland Shale Member.

Lincoln Limestone Member—Continued	Ft	in
2. Shale, dark-gray, soft, calcareous. Contains scattered thin layers or lenses of limonitic calcarenite; one layer, 1 in. thick about 5 ft above base, contains acanthoceratid horns and ray teeth	22	3
1. Bentonite, white, stained by limonite. Marker bentonite bed	1	8
Total Lincoln Limestone Member (rounded	37	0

The Lincoln Limestone Member is chiefly dark-gray calcareous platy or fissile shale. It weathers to gray, light-gray, or yellowish-gray soft shale chips, then to clayey calcareous silt. Sixty-three percent of an average sample of shale in the Lincoln is insoluble in dilute hydrochloric acid. The texture of the insoluble part, as determined by hydrometer and sieve analysis, is sandy silty clay containing 57 percent clay-sized, 37 percent silt-sized, and 6 percent sand-sized particles. X-ray analysis shows that the shale contains 55 percent clay minerals, 15 percent quartz, 5 percent feldspar (plagioclase equals potassium feldspar in abundance), 20 percent calcite, and 5 percent dolomite. Of the clay, illite is equal in abundance to kaolinite, which is more abundant than mixed-layer clay (consisting of illite and montmorillonite). Most of the coarse grains, which are not recorded in the sieve analysis because they were dissolved by acid, are foraminifers and fragments of the prisms of *Inoceramus* shells. Dark-gray fossiliferous stratified calcarenite layers are the main feature of the Lincoln Limestone Member. They too are composed of prisms of *Inoceramus* shells, foraminifers, and teeth of the ray, *Ptychodus*. Most of the beds are lenticular and only $\frac{1}{16}$–2 inches thick; a few thicker layers range in thickness from 4 inches to nearly 3 feet. The layers commonly show swash marks and fossil impressions. The calcarenite weathers gray or light gray and shaly; some limonitic layers are stained yellowish brown or yellowish orange. A crude columnar structure has developed in one 5-inch-thick bed apparently as a result of weathering. Dark-gray fossiliferous limestone concretions that are finer grained than the calcarenite lie as much as $7\frac{1}{2}$ feet above the base of the member. The concretions are about 6 inches thick and 5 feet in diameter. They weather light olive gray, light yellowish gray, or medium brown. These concretions are absent from some outcrops, and replacing them in one outcrop is a brown coquina composed of *Ostrea beloiti*. The limestone concretions contain the upper part of the zone of *Acanthoceras amphibolum*, which is divided by the marker bentonite bed. The Lincoln contains several white or yellowish-gray bentonite beds ranging in thickness from 1 inch to 2 feet. Because of limonite and other impurities, the bentonite weathers brownish gray or orange. The most prominent and important bed is the marker bentonite bed, 10 inches to 2 feet thick (fig. 10). It lies at the base of the Lincoln (or in the upper part of the Graneros in Kansas) and has been traced in the surface and subsurface for hundreds of miles.

The Lincoln Limestone Member varies somewhat in thickness but not nearly so much as the Graneros. The thicknesses used are for the Lincoln above the base of the marker bentonite bed. The member thickens from central Kansas to western Kansas, then thins toward Pueblo, but thickens again both to the north and the south. In Cloud County, Kans., the member is about 23 feet thick (Buck and others, 1951, p. 12); it thickens to 31 feet in Ellis County (Bass, 1926a, p. 33), then to 45 feet in Hamilton County, Kans. (Bass. 1926b, p. 70), and to 44 feet in Prowers County, Colo. (Voegeli and Hershey, 1965, p. 68). From a low of 20 feet in Cimarron County, Okla. (Kauffman and others, 1969), it increases to 29 feet in Baca County, Colo. (McLaughlin, 1954, p. 115), 32 feet at the Model anticline (Bass and others, 1947), and 37 feet at Pueblo. At Gold Creek, Colfax County, N. Mex., the member is 62 feet thick (C. L. Pillmore, written commun., 1966). At Littleton, Colo. (Scott, 1962), the Lincoln is 105 feet thick.

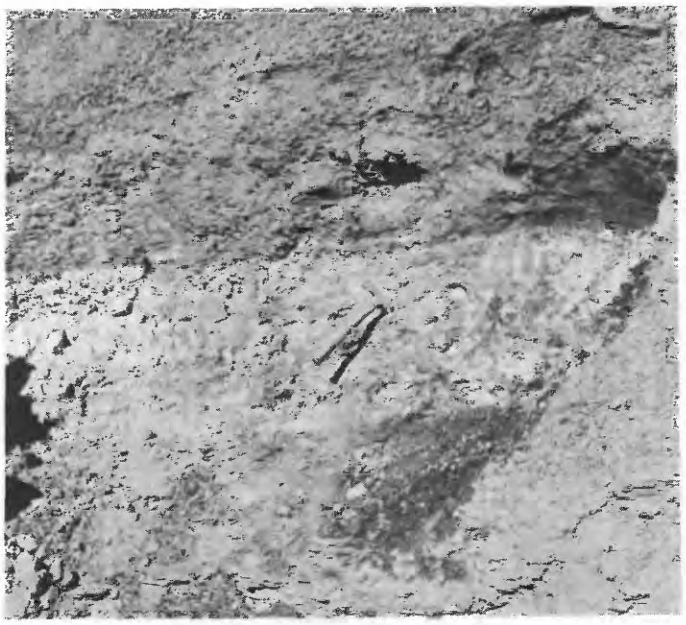

FIGURE 10.—Marker bentonite bed of the Lincoln Limestone Member in the SE¼NW¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo.

HARTLAND SHALE MEMBER

The Hartland Shale Member (Bass, 1926a, p. 33), of Cenomanian age, is mostly calcareous shale 59 feet thick which contains thin lentils of calcarenite. The member forms the middle of a steep slope composed of Greenhorn Limestone. Where the slope is freshly cut, as at Rock Canyon, it lies at angles of 30° or more and the shale is completely exposed (fig. 11); where the slope is old, it is gentler and is covered by slopewash. No ledge-forming beds were observed in the Hartland.

The Hartland Shale Member was named by Bass (1926b, p. 66, 69–70) for exposures of calcareous shale near Hartland in Kearny County, Kans. The member was said to be well exposed in western Kearny County between Hartland and Kendall, but a type locality was not designated and a type section was not measured. In Colorado a well-exposed section was measured at Rock Canyon anticline (fig. 9) and is here designated the reference section. The bed numbers are continued from those of the reference section of the Lincoln Limestone Member (p. 15).

The contact between the Hartland Shale Member and the overlying Bridge Creek Limestone Member is drawn at the base of the lowest hard gray dense limestone bed of the Bridge Creek. The basal bed is fairly easy to trace on aerial photographs and makes a satisfactory mapping horizon.

FIGURE 11.—Bridge Creek Limestone and Hartland Shale Members of the Greenhorn Limestone in railroad cut in the NE¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Thick limestone bed at cut bench lies at base of Bridge Creek Member.

Rock Canyon section

[Reference section of Hartland Shale Member measured on Rock Canyon anticline in the SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo.]

		Ft	in
Hartland Shale Member:			
62.	Shale, gray, soft, calcareous	2	7
61.	Limonite		1
60.	Shale, gray, soft, calcareous; contains some very thin gray shaly foraminiferal limestone beds. Contains impressions of small ammonites USGS D3968: *Stomohamites*? sp. *Tarrantoceras*? sp.	3	4
59.	Bentonite, limonitic		2
58.	Shale, gray, soft, calcareous		8
57.	Bentonite, limonitic		½
56.	Shale, gray, soft, calcareous; contains some very thin limestone layers	1	5
55.	Limestone; weathers buff; hard, foraminiferal		1
54.	Shale, gray, soft, calcareous; contains a few thin shaly layers of limestone in upper part	6	6
53.	Bentonite		½
52.	Shale	1	0
51.	Bentonite		1
50.	Shale		5
49.	Bentonite		1
48.	Shale		2
47.	Limestone, medium-gray, hard; weathers buff USGS D1307: *Inoceramus* sp. *Calycoceras*? sp.		1
46.	Shale, gray, calcareous	2	11
45.	Bentonite, gray and orange-brown		2
44.	Shale		3
43.	Bentonite		1
42.	Shale, gray, calcareous; contains a few thin shaly layers of limestone in lower part	4	9
41.	Bentonite, gray and orange-brown		3
40.	Shale	1	0
39.	Bentonite		1
38.	Limestone and shale; in thin layers; contains fragments of fossil mollusks USGS D6488: *Inoceramus* sp. *Metoicoceras* cf. *M. defordi* Young	1	0
37.	Shale, gray, calcareous; contains a very thin bentonite layer, at top		4
36.	Bentonite, light-gray		6
35.	Shale, gray, calcareous	3	5
34.	Shale, dark-gray, calcareous; contains light-gray chalky limestone concretions		8
33.	Bentonite, light-gray		6
32.	Shale, dark-gray, calcareous; contains soft light-gray chalky limestone concretions as much as 3 ft long and 6 in. thick at base	1	3

Hartland Shale Member—Continued

		Ft	in
31.	Bentonite, gray and orange-brown		3
30.	Shale, dark-gray, calcareous	3	6
29.	Bentonite		¼
28.	Shale		3
27.	Bentonite		¼
26.	Shale		3
25.	Bentonite, gray and orange-brown		3
24.	Shale, dark-gray, calcareous; contains a thin layer of bentonite about 6 in. above base	1	9
23.	Bentonite		1
22.	Shale, dark-gray, calcareous; contains some small limonitic nodules and rarely a very thin shaly layer of limestone	9	10
21.	Bentonite		1
20.	Shale	2	7
19.	Bentonite		½
18.	Shale		5
17.	Bentonite		2
16.	Shale	1	8
15.	Bentonite		¼
14.	Shale		9
13.	Shale, dark-gray, calcareous; contains several very thin shaly layers of gray calcarenite and, in lower part, two very thin layers of bentonite	2	6
	Total Hartland Shale Member (rounded)	59	0

The Hartland Shale Member is mostly olive-black or dark-gray petroliferous calcareous shale that is speckled, brittle, platy, or fissile. It weathers to gray soft flakes, then to a soft calcareous, silty clay soil. Forty-six percent of the shale is insoluble in dilute hydrochloric acid. As with the Lincoln Limestone Member, the texture of the insoluble particles, as determined by hydrometer and sieve analysis, is silty clay, 69 percent being clay-sized particles and 31 percent being silt-sized. X-ray analysis of the shale shows 50 percent clay minerals, 10 percent quartz, 10 percent gypsum, 25 percent calcite, and 5 percent dolomite. Of the clay, illite is equal in abundance to kaolinite, which is more abundant than mixed-layer clay (composed of illite and montmorillonite). Coarse particles, which are soluble in acid, are foraminifers and fragments of the prisms of *Inoceramus* shells. Hard dark-gray calcarenite layers and lentils are abundant in the Hartland, but few are thick enough to warrant description in the stratigraphic section. Most are paper thin or less than half an inch thick. They are composed of sand-sized particles and weather gray or light gray, soft, chalky, or shaly. Some beds are concretionary and as much as 3 feet long and 6 inches thick. Yellowish-orange limonite layers and nodules, as much as 6 inches long, are found throughout the shale. Twenty-four light-gray, gray, or yellowish-orange bentonite beds ranging in thickness from ¼ inch to 6 inches were measured.

The thickness of the Hartland Shale Member more than doubles between Kearny County, Kans., and Rock Canyon and nearly triples northward near Denver. Thicknesses of the Hartland in central Kansas are not comparable to the Hartland in Colorado because the Hartland in Kansas includes beds that compose the lower part of the Bridge Creek in Colorado. The Hartland below the zone of *Scipionoceras gracile* in Russell County, Kans. (Hattin, 1965b, p. 51), is only 9 feet thick. This same part of the section constitutes the entire Hartland in Kearny County (Bass, 1926b, p. 69) and is 23 feet thick. It increases in thickness to 29 feet at Model anticline (Bass and others, 1947) and to about 59 feet near Pueblo. At Gold Creek, Colfax County, N. Mex. (C. L. Pillmore, written commun., 1966), the thickness decreases to about 52 feet; northward in the Littleton quadrangle (Scott, 1962) the thickness is 65 feet. A section has not been published for the area north of Littleton that shows the thickness of the Hartland Shale Member. Supposedly, it thickens to the north, but in northernmost Colorado or southern Wyoming the Bridge Creek Limestone Member becomes entirely shale, so that the top of the Hartland Shale Member cannot be recognized there.

BRIDGE CREEK LIMESTONE MEMBER

The Bridge Creek Limestone Member (Bass, 1926b, p. 66), of Cenomanian and Turonian age, consists of many thin beds of limestone separated by thick beds of calcareous shale. The limestone forms the lower of two prominent persistent tree-covered escarpments (fig. 9) that can be traced across a wide belt of broken land from Canon City southeastward to the New Mexico line and eastward to the Kansas line. The member is well exposed at many places along these lines of outcrop. Freshly cut slopes, as at Rock Canyon anticline, lie at angles of 35° to vertical (fig. 11). Weathered slopes stand at about 20°, and generally the ledge-forming limestone layers are masked by weathered chips of limestone in a matrix of calcareous silt. The member is 57 feet thick at Rock Canyon anticline; a complete section was measured there and is here designated a reference section.

The Bridge Creek Limestone Member was named by Bass (1926b, p. 66–69) for a series of thin limestone beds at the top of the Greenhorn Limestone on Bridge Creek near Medway, Hamilton County,

Kans. The upper part of the beds constituting the Bridge Creek had been called (table 1) the Jetmore Chalk Member (Rubey and Bass, 1925, p. 51), composed of alternating thin beds of chalk and chalky shale near Jetmore, Hodgeman County, Kans., and the Pfeifer Shale Member (Bass, 1926a, p. 32), composed of alternating layers of chalky shale and chalky limestone near Pfeifer, Ellis County, Kans. Bass (1926b, p. 69) concluded that these two members were exactly equivalent to the Bridge Creek. A type section of the Bridge Creek was published by Bass (1926b, fig. 21); in addition we remeasured the type section and collected fossils on October 9–12, 1964. Figures 12 and 13 show the meander scars along Bridge Creek in Hamilton County, Kans., where different parts of the member were measured and where fossils were collected.

A principal reference section of the Bridge Creek measured at Rock Canyon anticline is 18 feet thinner than the type locality but seems to embrace the same amount of geologic time. Other differences in the two sections are a greater amount of shale in the upper part of the reference section but a greater abundance of concretionary limestone in the type locality (pl. 41). The bed numbers are continued from those of the Hartland Member (p. 17).

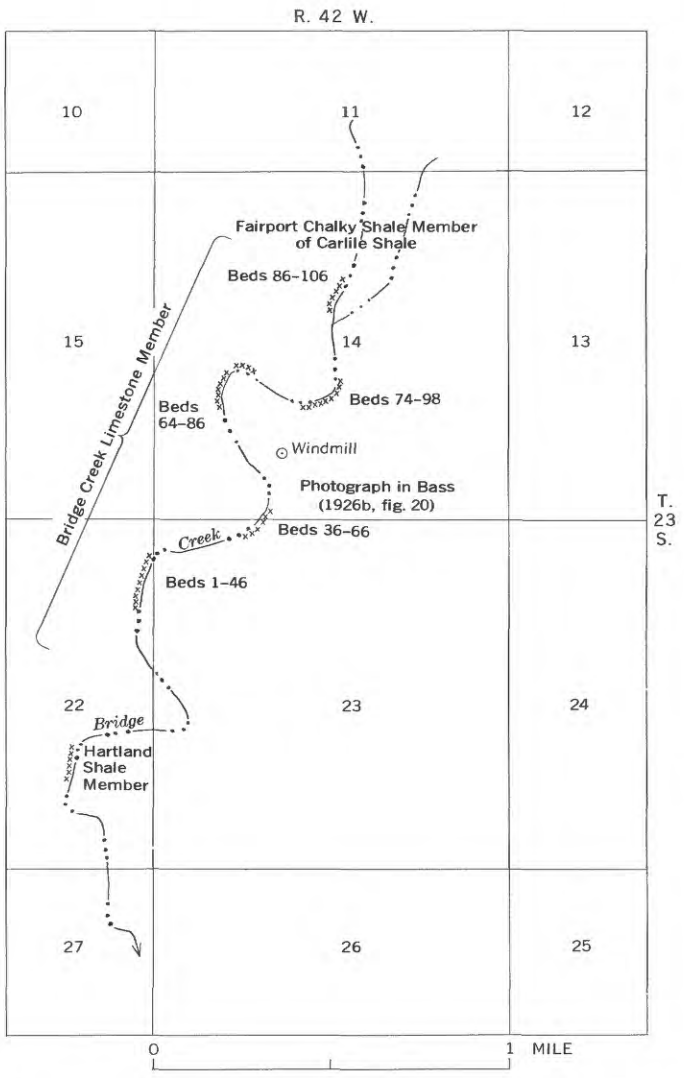

FIGURE 12.—Type locality of the Bridge Creek Limestone Member (beds 1–98) of the Greenhorn Limestone on the Mel Hinkle Ranch along Bridge Creek, Hamilton County, Kans. The X's mark the good outcrops of bedrock.

Hinkle Ranch section

[Bridge Creek Limestone Member of the Greenhorn Limestone at the type locality on the Mel Hinkle Ranch along Bridge Creek in secs. 14, 22, and 23, T. 23 S., R. 42 W., Hamilton County, Kans. Measured with tape by W. A. Cobban and G. R. Scott. Fossil collections prefixed by letter "D" were made by Cobban and Scott; all other collections were made by N. W. Bass.]

		Ft	in
Fairport Chalky Shale Member of the Carlile Shale (part):			
106.	Limestone, yellowish-gray		4
	USGS D4900:		
	Inoceramus labiatus var. *subhercynica* Seitz		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Collignoniceras sp.		
105.	Shale, yellowish-gray	1	5
104.	Limestone, yellowish-gray		3
	USGS D4899:		
	Inoceramus labiatus var. *subhercynica* Seitz		
	Collignoniceras woollgari (Mantell)		
103.	Shale, yellowish-gray	1	6
102.	Limestone, gray; weathers light tan		3
	USGS D4898:		
	Inoceramus labiatus (Schlotheim)		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Collignoniceras woollgari (Mantell)		
101.	Shale, yellowish-gray	3	10
100.	Limestone; forms lens-shaped bodies		3
99.	Shale, calcareous	5	4
Bridge Creek Limestone Member of the Greenhorn Limestone:			
98.	Limestone; weathers tan; contains two beds nearly equal in thickness. Fence Post limestone bed		6
	USGS D4897:		
	Inoceramus labiatus (Schlotheim)		
	Baculites calamus Morrow		
	Collignoniceras woollgari (Mantell)		
97.	Shale	2	7
96.	Bentonite, limonitic		2
95.	Shale	1	0
94.	Limestone, chalky. Fossils very sparse		4
	USGS D4896:		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Collignoniceras woollgari (Mantell)		

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued	Ft	in
93. Shale		1
92. Bentonite; stained by limonite		1
91. Shale; contains sparse broad limestone concretions in lower part		9
90. Limestone		1½
USGS D4895: *Inoceramus labiatus* (Schlotheim)		
89. Shale	2	8
88. Limestone concretions		6
USGS D4894: *Inoceramus labiatus* (Schlotheim)		
87. Shale; contains lenses in middle up to 1 in. thick of "inoceramite"	1	2
86. Limestone; in places concretionary nodules have developed beneath the bed		4
USGS D4893, from bed: *Inoceramus labiatus* (Schlotheim) *Ostrea* sp. *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu		
USGS D4892, from nodules beneath bed: *Inoceramus labiatus* (Schlotheim)		
85. Shale	1	5
84. Limestone, concretionary. Commonly has smaller concretions beneath main bed		7
USGS D4891: *Inoceramus labiatus* (Schlotheim) *Ostrea* sp.		

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued	Ft	in
83. Shale		4
82. Bentonite		⅛
81. Shale	1	2½
80. Limestone; base is irregular		2
USGS D4890: *Inoceramus labiatus* (Schlotheim)		
79. Shale	1	5
78. Limestone concretions; also some limonitic nodules		4
USGS D4889: *Inoceramus labiatus* (Schlotheim)		
77. Shale	1	1
76. Limestone		5
USGS D4888: *Inoceramus labiatus* (Schlotheim) *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu *Stomohamites* cf. *S. simplex* (d'Orbigny)		
75. Shale	1	4
74. Limestone; in very widely spaced lenses. Forms lowest bed in cut just south of center of sec. 14		2
USGS D4887: *Inoceramus labiatus* (Schlotheim) *Anisomyon* sp. *Puebloites* sp. *Collignoniceras*? sp.		
73. Shale	1	2
72. Limestone; contains limonitic nodules		3
USGS D4886: *Inoceramus labiatus* (Schlotheim)		
71. Shale	5	5

FIGURE 13.—Exposure of the Bridge Creek Limestone Member of the Greenhorn Limestone on the west side of Bridge Creek in the SW¼ sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Thickest shale layer is bed 71 and is 5½ feet thick.

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
70.	Limestone; lower half is shaly	1	4
	USGS D4885:		
	Inoceramus labiatus (Schlotheim)		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
69.	Shale	2	1
68.	Limestone concretions, closely spaced; contain many limonite nodules probably altered from pyrite nodules		4
	USGS D4884:		
	Inoceramus labiatus (Schlotheim)		
67.	Shale		10
66.	Limestone, somewhat concretionary; locally thins to 3 in		6
	USGS D4883:		
	Inoceramus labiatus (Schlotheim)		
65.	Shale	1	3
64.	Limestone		6
	USGS D4882:		
	Inoceramus labiatus (Schlotheim)		
63.	Shale		2
62.	Bentonite		¼
61.	Shale	1	0
60.	Bentonite, rust-stained		1
	USGS D4881:		
	Inoceramus labiatus (Schlotheim)		
	Tragodesmoceras bassi Morrow		
59.	Limestone		6
58.	Shale	1	3
57.	Limestone; irregular along outcrop. In places is only 2–3 in. thick and shaly		5
	USGS D4880:		
	Inoceramus labiatus (Schlotheim)		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Tragodesmoceras bassi Morrow		
56.	Shale	1	3
55.	Limestone, shaly, soft; contains *Inoceramus labiatus*		4
54.	Shale	1	3
53.	Limestone; contains pyrite nodules and abundant borings filled with dark-calcareous mud. Locally swells to 20 in. or pinches to 8 in		10
	USGS 12768:		
	Inoceramus labiatus (Schlotheim)		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Tragodesmoceras bassi Morrow		
52.	Shale	3	2
51.	Limestone; contains pyrite nodules		5
	USGS D4879:		
	Inoceramus sp.		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
	Mammites nodosoides wingi Morrow		
50.	Shale	1	2
49.	Limestone		4
48.	Shale		10
47.	Limestone, shaly; softer than most beds		2

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
46.	Limestone; contains some pyrite		6
	USGS D4878:		
	Inoceramus labiatus (Schlotheim)		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
45.	Shale	1	4
44.	Limestone		7
43.	Shale	1	3
42.	Limestone; contains oysters		4
	USGS D4877:		
	Inoceramus labiatus (Schlotheim)		
	Ostrea sp.		
	Baculites cf. *B. yokoyamai* Tokunaga and Shimizu		
41.	Shale	1	3
40.	Limestone, hard; weathers buff		5
	USGS D4876:		
	Inoceramus labiatus (Schlotheim)		
	Watinoceras coloradoense (Henderson)		
	Vascoceras (*Greenhornoceras*) *birchbyi* Cobban and Scott		
	Neoptychites cf. *N. cephalotus* (Courtiller)		
39.	Shale		1
38.	Bentonite		½
37.	Shale		10
36.	Limestone, shaly, soft		2
35.	Shale	1	1
34.	Limestone		5
33.	Shale		9
32.	Limestone, shaly, soft		4
31.	Shale		5
30.	Bentonite, yellow-stained		1
29.	Shale		4
28.	Limestone		7
	USGS D4875:		
	Inoceramus labiatus (Schlotheim)		
27.	Shale	2	1
26.	Limestone; contains a few fossils		7
	USGS D4874:		
	Inoceramus cf. *I. pictus* Sowerby		
25.	Shale	1	10
24.	Limestone, fossiliferous		7
	USGS D4873:		
	Inoceramus sp.		
	Puebloites sp.		
	Watinoceras reesidei Warren?		
23.	Shale	1	3
22.	Limestone; contains no fossils		6
21.	Shale	1	0
20.	Limestone, soft chalky; contains no fossils		3
19.	Shale; contains a 2-in. chalky shale 6 in. above base and occasional limonitic nodules in middle	1	6
18.	Bentonite, white; has limonitic stains		3
17.	Limestone; massive tabular bed		6
	USGS D4872:		
	Inoceramus pictus Sowerby		
16.	Shale; contains some very thin lenses of limestone in upper part	1	10

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
15.	Limestone; massive layer but locally decreases in thickness to 4 in ------ USGS D4871: *Inoceramus pictus* (Sowerby) *Pteria* sp. *Sciponoceras* sp. *Worthoceras vermiculum* (Shumard) *Kanabiceras septemseriatum* (Cragin)		6
14.	Shale ----------		5
13.	Shale, chalky; harder and lighter than contiguous beds ----------		4
12.	Shale; contains a thin limonitic layer -		9
11.	Limestone, silty, concretionary; occurs in closely spaced concretions generally 4 by 12 in ---------- USGS D4870: *Inoceramus pictus* Sowerby *Sciponoceras* sp. *Puebloites* sp. *Worthoceras gibbosum* Moreman *vermiculum* (Shumard) *Scaphites* sp. *Calycoceras* cf. *C. naviculare* (Mantell) *Kanabiceras septemseriatum* (Cragin)		4
10.	Shale, calcareous; contains abundant rusty layers and lenses of limestone up to 2 in. thick near top ----------		10
9.	Limestone, hard; weathers to smooth-surfaced slabs. Locally decreases to 3 in. in thickness ---------- USGS D4869: *Inoceramus pictus* Sowerby *Cerithiopsis* sp. *Worthoceras vermiculum* (Shumard) *Pseudocalycoceras dentonense* (Moreman) *Kanabiceras septemseriatum* (Cragin)		4
8.	Shale ----------		4
7.	Limestone, soft; swells into concretions about 4 by 12 in ---------- USGS D4868: *Inoceramus pictus* Sowerby		1
6.	Shale, calcareous ----------		8
5.	Bentonite, white, rust-stained -------		6
4.	Shale ----------		6
3.	Limestone, chalky ---------- USGS D4867: *Inoceramus pictus* Sowerby *Sciponoceras gracile* (Shumard)		4
2.	Shale, very calcareous ----------		6
1.	Limestone, chalky ----------		4
	Total Bridge Creek Limestone Member (rounded) ----------	75	0

Rock Canyon section

[Principal reference section of Bridge Creek Limestone Member of the Greenhorn Limestone measured on Rock Canyon anticline in the NW¼NE¼ sec. 31, T. 20 S., R. 65 W., and in the SW¼ and NW¼NW¼ sec. 30, T. 20 S., R. 65 W. Pueblo County, Colo.]

		Ft	in
	Bridge Creek Limestone Member of the Greenhorn Limestone:		
150.	Calcarenite, shaly to platy; contains some fragments of *Inoceramus* and *Collignoniceras woollgari* ----------		4
149.	Shale, calcareous, soft ----------		5
148.	Bentonite ----------		½
147.	Shale, calcareous, soft ----------		3
146.	Shale, calcareous; contains numerous hard thin partings of calcarenite. Contains some fragments of *Inoceramus* ----------	1	3
145.	Shale, calcareous, soft; contains a few thin partings of calcarenite --------		5½
144.	Bentonite ----------		½
143.	Shale, calcareous, hard ----------		4
142.	Bentonite, orange-brown, limonitic ----		2
141.	Shale, calcareous, hard and soft ------		3
140.	Bentonite, yellowish-orange; contains selenite crystals ----------		1½
139.	Shale, calcareous, hard, platy --------		5
138.	Shale, calcareous, soft ----------		11
137.	Limestone, shaly; contains fragments of *Ostrea* and *Inoceramus* ---------		2
136.	Shale, calcareous, soft ----------		4
135.	Limestone, light-gray, shaly ---------- USGS D3985 and D3986: *Inoceramus labiatus* (Schlotheim) *Collignoniceras woollgari* (Mantell)		5
134.	Shale, gray, calcareous ----------		6
133.	Limestone, gray, shaly; top has worm burrows. Contains *Inoceramus labiatus*		5
132.	Shale, gray, calcareous; contains three hard beds ----------	3	7
131.	Shale; medium gray where fresh, orange brown where weathered, soft, calcareous; contains very thin partings of harder shale and calcarenite ---- USGS D3983 at top: *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu *Collignoniceras woollgari* (Mantell)	5	0
130.	Bentonite, orange-brown ----------		2
129.	Shale, calcareous, soft ----------	1	5
128.	Bentonite ----------		½
127.	Shale, calcareous, soft ----------		7½
126.	Shale, calcareous; contains thin hard partings of calcarenite and hard shale	2	11
125.	Bentonite ----------		½
124.	Shale, calcareous, soft ----------		3½
123.	Calcarenite, shaly; contains fragments of *Inoceramus* ----------		7
122.	Limestone, light-gray, massive, chalky		3½
121.	Shale, calcareous, soft ----------	1	2
120.	Limestone, gray, hard, irregularly bedded. Forms top of bluff locally -- USGS D3982: *Inoceramus labiatus* (Schlotheim) *Mammites nodosoides wingi* Morrow		5

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
119.	Shale, gray, calcareous		8
118.	Limestone, gray, hard, irregularly bedded. Commonly forms top of bluff USGS D3981: *Inoceramus labiatus* (Schlotheim) *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu *Mammites nodosoides wingi* Morrow		8
117.	Shale, gray, calcareous		9
116.	Limestone, gray, hard, irregularly bedded. Contains *Inoceramus labiatus* (Schlotheim)		7
115.	Shale, gray, calcareous		10
114.	Bentonite, yellowish-orange		3
113.	Limestone, gray, hard, irregularly bedded. Contains well-preserved fossils USGS D3980: *Inoceramus labiatus* (Schlotheim) *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu		4
112.	Shale, gray, calcareous		9
111.	Bentonite		1
110.	Shale, gray, calcareous	1	1
109.	Limestone, gray, shaly. Contains *Inoceramus labiatus* (Schlotheim)		3
108.	Shale, gray, calcareous		5
107.	Limestone, gray, shaly		2½
106.	Shale, gray, calcareous	1	7
105.	Limestone, gray, hard, massive to shaly. Fragments of *Puebloites* rather common USGS D3979: *Inoceramus labiatus* (Schlotheim) *Puebloites greenhornensis* Cobban and Scott *Tragodesmoceras bassi* Morrow sp. *Kanabiceras puebloense* Cobban and Scott *Mammites nodosoides wingi* Morrow *Choffaticeras pavillieri* (Pervinquière)		6
104.	Shale, gray, calcareous		9
103.	Limestone, gray, shaly, platy; contains baculites		6
102.	Shale, gray, calcareous; middle is harder and in part a shaly limestone that contains abundant pelagic Foraminifera and some flattened baculites USGS D6134: *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu	1	5
101.	Limestone, gray, hard, somewhat shaly; contains pyrite in places USGS D3978: *Inoceramus labiatus* (Schlotheim) *Watinoceras coloradoense* Henderson? *Mammites* sp. *Choffaticeras*? sp.		6

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
100.	Shale, gray, calcareous		8
99.	Limestone, gray, shaly		2
98.	Shale, gray, calcareous		10
97.	Limestone, gray, hard, irregularly bedded; contains horizontal burrows and here and there grayish-green patches and films of montmorillonitic clay that contains small amounts of quartz and pyrite (L. G. Schultz, oral commun., July 1968) USGS D3977: *Inoceramus labiatus* (Schlotheim) *Ostrea* sp. *Puebloites spiralis* Cobban and Scott *Watinoceras coloradoense* (Henderson) *reesidei* Warren? *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott *Fagesia* sp.		6
96.	Shale, gray, calcareous		9
95.	Limestone, gray, shaly		3
94.	Shale, gray, calcareous		2
93.	Limestone, gray, shaly		2
92.	Shale, gray, calcareous		2
91.	Bentonite		½
90.	Limestone, gray, hard, massive; weathers yellowish gray; contains numerous horizontal burrows filled with limonitic marl that give rock a mottled appearance USGS D3976: *Inoceramus* sp. *Ostrea* sp. *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu *Puebloites* sp.		5
89.	Shale, gray, calcareous		10
88.	Bentonite		½
87.	Shale, gray, calcareous	1	8
86.	Limestone, gray, hard; largely massive but upper few inches shaly; contains abundant pelagic Foraminifera and some mollusks USGS D3975: *Inoceramus labiatus* (Schlotheim) *Puebloites*? sp. *Kanabiceras* sp. *Anisoceras* sp.		11
85.	Shale, gray, calcareous	2	1
84.	Limestone, gray, hard, massive; contains small pyritic spots and abundant pelagic Foraminifera		9
83.	Shale, gray, calcareous	1	8
82.	Bentonite, rusty		1
81.	Shale, gray, calcareous		3
80.	Bentonite, orange-gray		6
79.	Limestone, gray, hard, massive. Contains a few *Inoceramus pictus*		6
78.	Shale, gray, calcareous	2	0

Bridge Creek Limestone Member of the Greenhorn Limestone—Continued

		Ft	in
77.	Limestone, gray, nodular, hard, extremely irregular in thickness (3–6 in.); weathers light tan. Fossils sparse		6
	USGS D3974:		
	Sciponoceras sp.		
	Kanabiceras septemseriatum (Cragin)		
	Worthoceras gibbosum Moreman		
76.	Shale, gray, calcareous		3
75.	Limestone, gray, hard, nodular, concretionary (commonly lensing out); may be as thick as 2 in		1
74.	Shale, gray, calcareous		7
73.	Limestone, gray, nodular, rather soft and unbedded; contains burrows as much as 1 in. in diameter. Thickness ranges from 3 to 6 in		5
	USGS D4444:		
	Echinoid		
	Inoceramus pictus Sowerby		
	Sciponoceras gracile (Shumard)		
	Camptonectes sp.		
	Pseudocalycoceras sp.		
	Kanabiceras septemseriatum (Cragin)		
72.	Shale, gray, calcerous		4
71.	Bentonite		1
70.	Shale, gray, calcareous		2
69.	Bentonite, yellowish-orange, limonitic		7
68.	Shale, gray, calcareous		9
67.	Limestone, gray, hard, nodular, concretionary		6
	USGS D3973 and D6472:		
	Holaster feralis Cooke		
	Inoceramus pictus Sowerby		
	Camptonectes sp.		
	Gastropods (sparse)		
	Hemiptychoceras reesidei Cobban and Scott, n. sp.		
	Sciponoceras gracile (Shumard)		
	Allocrioceras annulatum (Shumard)		
	Puebloites corrugatus (Stanton)		
	Pseudocalycoceras dentonense (Moreman)		
	Kanabiceras septemseriatum (Cragin)		
	Metoicoceras whitei Hyatt		
66.	Shale, gray, calcareous		6
65.	Limestone, gray		2
64.	Shale, gray, calcareous		3
63.	Limestone, gray, hard, massive; weathers light gray and forms conspicuous ledge	1	6
	USGS D3972 and D6473:		
	Inoceramus pictus Sowerby		
	Calycoceras cf. *C. naviculare* (Mantell)		
	Metoicoceras sp.		
	Total Bridge Creek Limestone Member (rounded)	57	0

The contact between the Bridge Creek and the overlying Fairport Chalky Shale Member of the Carlile Shale is somewhat gradational between the dense hard gray limestone of the Bridge Creek and the granular yellowish-gray fossiliferous limestone of the Fairport. An upper contact is easy to map because of the escarpment made by the uppermost beds of the Bridge Creek, but its exact placement is not easy to agree upon in a stratigraphic section. The upper contact that we originally picked for our stratigraphic section was at the top of bed 135, the uppermost bed of a rather continuous series of limestone beds. Later, at the suggestion of Miss Paula Worstell, Scripps Institution of Oceanography, we raised the top of the member 5½ feet to the top of a thick calcarenite bed. The suggested change was based chiefly on the similarity of the Foraminifera in this calcarenite to those in the upper part of the Bridge Creek at the type locality in Hamilton County, Kans. We could be charged with selecting the boundary by the use of fossils rather than by lithology; however, either boundary could logically have been selected on the basis of lithology alone.

The Bridge Creek Limestone Member in southeastern Colorado is composed of dark-gray massive nodular or concretionary thin beds of hard dense or soft chalky limestone separated by thick beds of dark-gray fissile to platy hard or soft calcareous shale (fig. 14). Some beds of shaly to platy calcarenite lie in the upper part of the member. Shale beds contain thin hard partings of calcarenite and harder shale. Limestone beds range in thickness from 1 inch to 1½ feet and average about 5½ inches; shale beds range in thickness from 2 inches to 8 feet and average about 1 foot. Most limestone layers are crudely stratified or irregularly bedded. Worm burrows were observed at the top of one limestone layer. Where weathered, the limestone becomes yellowish gray or light gray and shaly, platy, or nodular. Most of the beds weather to irregularly conchoidal chips that armor the slopes. The shale weathers to a light-gray soft clayey calcareous silt. Several beds of limestone in the lower part of the member are traversed by joints; when weathered, the joints split through fossils; therefore, well-preserved fossils can be collected only from relatively unweathered unsplit pieces of limestone. Yellowish-brown limonite nodules in the limestone apparently are weathered inclusions of pyrite. Some unaltered masses of pyrite several inches in diameter were seen.

FIGURE 14.—Bridge Creek Limestone Member of the Greenhorn Limestone showing thin resistant layers of limestone separated by thicker layers of shale north of the Arkansas River in the SW¼NE¼ sec. 31, T. 20 S., R. 65 W., Pueblo County, Colo. The top of limestone bed 86 of the reference section is at top of 5-foot Jacob staff.

According to petrographic examination by the U.S. Bureau of Reclamation (written commun., 1950), the limestone is composed predominantly of calcareous oolite, calcite, some pyrite, illitic clay, quartz, chalcedony, feldspar, and magnetite in a fine-grained clayey calcareous matrix. Thin continuous calcite veinlets form a network in the limestone. Acid-insoluble constituents make up about 6 percent.

Eleven orange-brown, yellowish-orange, or orange-gray plastic bentonite beds ranging in thickness from ½ inch to 7 inches are intercalated in the shale. Many of the beds are rusty or limonitic, and some beds contain crystals of selenite.

The Bridge Creek Limestone Member nearly triples in thickness between central northern Kansas and central Colorado east of the Front Range. In Cloud County, Kans. (Buck and others, 1951), and Republic County, Kans. (Byrne and others, 1950), the Pfeifer Shale Member, Jetmore Chalk Member, and upper part of the Hartland Shale Member down to the base of beds containing *Sciponoceras gracile* (Shumard) total about 45 feet in thickness. The same beds are 60½ feet thick in Russell County, Kans. (Hattin, 1965b, p. 50–51), and 43 feet thick in Cimarron County, Okla. (Kauffman and others, 1969). In Hamilton County, Kans. (Bass, 1926b), the Bridge Creek at its type locality increases to 74 feet. Southwestward it decreases to 62 feet in Baca County (McLaughlin, 1954) and 30 feet at Model anticline, Colo. (Bass and others, 1947). To the west at Pueblo, it also decreases to 57 feet and to only 34 feet at Huerfano Park (Kauffman and others, 1969). At Gold Creek, Colfax County, N. Mex. (C. L. Pillmore, written commun., 1966), the Bridge Creek is only 16½ feet thick. Northward from Pueblo the Bridge Creek increases greatly to 130 feet near Littleton, Colo. (Scott, 1962). The thickness decreases northward from Littleton to 83 feet near Lyons, Colo. The equivalent rocks are represented by shale in northernmost Colorado or southern Wyoming.

SUPPLEMENTAL STRATIGRAPHIC SECTIONS

Beaver Creek section

[Section of lower part of Graneros Shale along a tributary to Beaver Creek in the SE¼SE¼SE¼ sec. 26, E½NE¼NE¼ sec. 35, and W½NW¼NW¼ sec. 36, T. 18 S., R. 68 W., Pierce Gulch quadrangle, Fremont County, Colo. Measured by G. R. Scott and W. A. Cobban, Dec. 1, 1965]

Graneros Shale (part):

		Ft	*in*
60.	Bentonite		1½
59.	Shale, dark-gray		8
58.	Bentonite		1
57.	Shale, dark-gray	1	11
56.	Bentonite		1
55.	Shale, dark-gray; contains yellowish-brown-weathering limestone concretions that have cone-in-cone structure	1	6
54.	Bentonite		2
53.	Shale		4½
52.	Bentonite		½
51.	Shale		2
50.	Bentonite		1¼
49.	Shale		10
48.	Bentonite		2
47.	Shale, dark-gray	3	6
46.	Bentonite		¼
45.	Shale, dark-gray	2	2
44.	Bentonite		½
43.	Shale		3
42.	Bentonite		¼
41.	Shale, dark-gray	3	9
40.	Bentonite		2
39.	Shale, dark-gray; contains laminae of siltstone. Lenticular bodies as much as 4 in. thick of calcareous siltstone that have cone-in-cone structure present 51 in. above base	9	10

Graneros Shale (part)—Continued

		Ft	in
38.	Bentonite		2
37.	Shale, dark-gray; contains some laminae of hard siltstone	10	0
36.	Chamosite ironstone, gray, shaly; occurs as very lengthy lenses which are locally capped by cone-in-cone structure		5
35.	Shale		8
34.	Bentonite		1
33.	Shale		4
32.	Bentonite		4
31.	Shale, dark-gray; contains some hard thin siltstone layers		11
30.	Bentonite		¼
29.	Shale, dark-gray; contains some hard thin siltstone layers in upper half	4	0
28.	Bentonite		1
27.	Shale		8½
26.	Bentonite		¼
25.	Shale	2	5
24.	Bentonite		½
23.	Shale		11
22.	Bentonite		¼
21.	Shale		7
20.	Bentonite		½
19.	Shale	1	11
18.	Bentonite		1
17.	Shale		10
16.	Bentonite		¼
15.	Shale, dark-gray	4	7
14.	Bentonite		2
13.	Shale		6
12.	Bentonite		¼
11.	Shale		7
10.	Bentonite		6
9.	Shale		10
8.	Bentonite		½
7.	Shale	1	2
6.	Bentonite		3
5.	Shale, dark-gray; contains a few thin ferruginous layers in upper part	3	7
4.	Bentonite		½
3.	Shale, dark-gray, finely sandy		8
2.	Sandstone, light-olive-gray, very fine grained, glauconitic, soft, shaly		8
1.	Shale, dark-gray, silty		8
	Total Graneros Shale measured (rounded)	65	0

Dakota Sandstone at bottom of gully.

Old Hatchet Ranch section

[Section of basal part of the Greenhorn Limestone and upper part of the Graneros Shale on Greenhorn Creek near Old Hatchet Ranch (now Diamond A Cattle Co.) about in the center of sec. 35, T. 23 S., R. 66 W., Pueblo County, Colo. Measured by G. R. Scott and W. A. Cobban, Dec. 2, 1965]

Lincoln Limestone Member of the Greenhorn Limestone (part):

		Ft	in
35.	Limestone concretions, medium-dark-gray; weather light olive gray; lengthy, fossiliferous		5

Lincoln Limestone Member of the Greenhorn Limestone (part)—Continued

		Ft	in
	USGS D5126:		
	Inoceramus rutherfordi Warren		
	Ostrea beloiti Logan		
	Acanthoceras amphibolum Morrow		
34.	Bentonite, white. Marker bentonite bed	1	6

Graneros Shale (part):

33.	Shale, brownish-gray, calcareous		5
32.	Limestone, medium-brownish-gray, hard; thickens and thins along outcrop. Very fossiliferous, crowded with *Ostrea beloiti* Logan		2
31.	Shale, brownish-gray, calcareous	1	4
30.	Bentonite, impure, limonitic		3
29.	Shale, brownish-gray, calcareous	3	
28.	Bentonite, impure, limonitic		¼
27.	Shale, dark-gray, noncalcareous		6
26.	Bentonite, impure, limonitic		1
25.	Shale, dark-gray, noncalcareous	3	7
24.	Bentonite, impure, limonitic		¼
23.	Shale		1
22.	Bentonite, impure, limonitic		½
21.	Shale		2
20.	Bentonite, impure, limonitic		½
19.	Shale, dark-gray		8
18.	Bentonite, impure, limonitic		½
17.	Shale, dark-gray		11
16.	Bentonite, impure, limonitic		½
15.	Shale, dark-gray, noncalcareous	3	2
14.	Bentonite, impure, limonitic		½
13.	Shale, dark-gray	2	0
12.	Bentonite, impure, limonitic		½
11.	Shale, dark-gray	1	5½
10.	Bentonite, gray		1½
9.	Shale, dark-gray		4
8.	Bentonite, gray		1
7.	Shale, dark-gray, noncalcareous; here and there contains a pyrite nodule from ½ to 4 in. in diameter, some of which were formed around ammonites. Crushed ammonites common in lower half	15	9
	USGS D5125, from 2½ to 2 4/5 ft below top:		
	Acanthoceras muldoonense Cobban and Scott		
	granerosense Cobban and Scott		
	USGS D5292, from 5 to 5½ ft below top:		
	Calcareous worm tubes		
	Acanthoceras granerosense Cobban and Scott		
	USGS D5124, from 7½ to 8½ ft below top:		
	Acanthoceras granerosense Cobban and Scott		
	Turrilites (*Euturrilites*) *scheuchzerianus* Bosc		

Graneros Shale (part)—Continued

	Ft	in
USGS D5291, from 9½ to 10½ ft below top: Calcareous worm tubes *Acanthoceras granerosense* Cobban and Scott		
USGS D5290, from 12 to 12½ ft below top: *Acanthoceras granerosense* Cobban and Scott		
USGS D5289, from 13½ to 14½ ft below top: *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott		
6. Siltstone, medium-gray, very hard, calcareous, more or less laminated. Rare ammonites		2
USGS D5123: *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott		
5. Shale, dark-gray, noncalcareous, somewhat silty; contains rather numerous crushed *Calycoceras*. Small fossiliferous dark-gray limestone concretions present locally at top	3	1
USGS D5123: Calcareous worm tubes *Inoceramus* sp. *Ostrea* sp. *Arrhoges modesta* (Stephenson)? *Stomohamites* sp. *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott		
4. Limestone, dark-gray; weathers yellowish gray; very hard, silty; commonly laminated; dark-gray shale laminae alternate with medium-gray siltstone laminae. Base is irregular and rests sharply on underlying shale unit. Thickens and thins along outcrop from as much as 15 in. to as little as 6 in. Worm burrows common at top and base. Crushed *Calycoceras* common at top; in one area 2 by 5 ft, at least 25 specimens were concentrated (fig. 7). Crushed specimens of *Inoceramus eulessanus* occur here and there, and locally several specimens are concentrated in a small area. Thatcher Limestone Member		10
USGS D5122: Calcareous worm tubes *Inoceramus eulessanus* Stephenson *Ostrea* sp. *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott		
3. Shale, dark-gray		2
2. Bentonite, impure, limonitic; locally associated with calcite that has cone-in-cone structure		½

Graneros Shale (part)—Continued

	Ft	in
1. Shale, dark-gray, noncalcareous; contains inconspicuous siltstone laminae and a few fish scales	8	0
Total Graneros Shale measured (rounded)	47	0

Bed of Greenhorn Creek.

Siloam section

[Lower part of Lincoln Limestone Member of the Greenhorn Limestone and upper part of the Graneros Shale south of Siloam in the NW¼NE¼ sec. 34, T. 21 S., R. 68 W., Owl Canyon 7½-minute quad., Pueblo County, Colo. Measured by W. A. Cobban and G. R. Scott, Sept. 15, 1966]

	Ft	in
Greenhorn Limestone (part):		
Lincoln Limestone Member (part):		
26. Coquina, brown. Composed of shells of *Ostrea beloiti*. Pinches out in places		3
25. Bentonite, light-gray. Marker bentonite bed		10
Graneros Shale (part):		
24. Shale, medium-gray, calcareous	3	6
23. Limestone concretions, dark-gray; weather moderate yellowish brown (10 *YR* 5/4); platy, very closely spaced, commonly 5–10 ft in diameter. Some contain *Ostrea beloiti*, which is common in a coquina at top		8
22. Shale, dark-gray, very slightly calcareous	5	0
21. Bentonite, limonitic		½
20. Shale		7
19. Bentonite, limonitic		½
18. Shale, dark-gray	3	9
17. Shale, jarositic; contains two thin layers of bentonite		6
16. Shale		9
15. Bentonite, light-gray		2
14. Shale		11
13. Bentonite, limonitic		¼
12. Shale, dark-gray	5	0
11. Bentonite, limonitic		¼
10. Shale, dark-gray; at 19 in. above base is a limonitic, impure gray bentonite bed ½ in. thick	5	4
9. Bentonite, pale-yellowish-gray, limonitic		1
8. Shale, dark-gray	7	3
7. Bentonite, light-gray, limonitic		2
6. Shale, dark-gray. Contains a ½-in. lens of calcarenite 18 in. above base, a thin brown quartz-chamosite ironstone layer 6 ft above base, small gray claystone concretions 20 ft above base, and a single very hard brown-weathering dark-gray quartz-chamosite ironstone concretion 24 ft above base	26	0
USGS D5712, from ironstone concretion 24 ft above base: *Ostrea* sp.		

Graneros Shale (part)—Continued

		Ft	in
	Acanthoceras muldoonense Cobban and Scott		
	USGS D5711, from small claystone concretions 20 ft above base:		
	Acanthoceras granerosense Cobban and Scott		
	USGS D5710, from 10 ft above base:		
	Calycoceras (Conlinoceras) gilberti Cobban and Scott		
	USGS D5709, from 6 ft above base:		
	Ostrea sp.		
	Calycoceras (Conlinoceras) gilberti Cobban and Scott		
	Fish bones and scales		
5.	Limestone, dark-gray; weathers moderate yellowish brown (10*YR* 5/4), hard. Decreases to 4 in. in thickness in places. Where thickest, lower and upper parts commonly have cone-in-cone structure. Contains a few crushed fossils.	1	0
	USGS D5708:		
	Anomia sp.		
	Calycoceras leonense (Adkins)		
	Calycoceras (Conlinoceras) gilberti Cobban and Scott		
	Cymatoceras sp.		
4.	Shale, dark-gray	1	0
3.	Bentonite, light-gray		10
2.	Shale, dark-gray	8	2
1.	Bentonite, light-gray		4
	Total Graneros Shale measured (rounded)	71	0

Muldoon Hill section

[Lincoln Limestone Member of the Greenhorn Limestone and upper part of the Graneros Shale on the south side of Muldoon Hill in the north-central part of the S½SW¼ sec. 23, T. 22 S., R. 67 W., Muldoon Hill quad., Pueblo County, Colo. Measured by G. R. Scott and W. A. Cobban, Dec. 7, 1965, and Sept. 15, 1966]

		Ft	in
Greenhorn Limestone (part):			
Lincoln Limestone Member (part):			
43.	Bentonite, brownish-gray, impure		5
42.	Shale, dark-gray, calcareous	6	0
41.	Limestone, medium-gray; unit is a lens several feet long composed largely of shell fragments		2
	USGS D5149:		
	Inoceramus sp.		
	Acanthoceras amphibolum Morrow		
40.	Shale, dark-gray, calcareous	5	0
39.	Limestone concretions, medium-gray; weather light yellowish gray to medium brown; as much as 5 ft in diameter; fossiliferous		6
	USGS D5148:		
	Inoceramus rutherfordi Warren		
	Ostrea beloiti Logan		
	Turrilites sp.		

Greenhorn Limestone (part)—Continued

		Ft	in
Lincoln Limestone Member (part):—Continued			
38.	Bentonite, white. Marker bentonite bed	1	11
	Total Lincoln Limestone Member measured	14	0
Graneros Shale (part):			
37.	Limestone, light-medium-gray; weathers light yellowish gray; hard; thickness variable. Very fossiliferous, crowded with *Ostrea beloiti*		1½
36.	Shale, dark-gray; lower part noncalcareous, upper part slightly calcareous	2	9
35.	Bentonite, impure, limonitic		3½
34.	Shale, dark-gray, noncalcareous	3	7½
33.	Bentonite, impure, limonitic		1
32.	Shale, dark-gray, noncalcareous	4	2
31.	Bentonite, impure, limonitic		2
30.	Shale	1	0
29.	Bentonite, very light gray, limonitic		1½
28.	Shale	1	0
27.	Bentonite, impure, limonitic		1
26.	Shale, dark-gray	3	3
25.	Bentonite		¼
24.	Shale		6
23.	Bentonite		½
22.	Shale		4
21.	Bentonite		¼
20.	Shale, dark-gray	2	1
19.	Bentonite		½
18.	Shale, dark-gray	1	4
17.	Bentonite, light-gray, limonitic		1
16.	Shale, dark-gray. One gypsiferous limonitic ammonite at top	1	4½
	USGS D5146:		
	Acanthoceras sp.		
15.	Bentonite		¼
14.	Shale, dark-gray	1	8
13.	Bentonite, limonitic		½
12.	Shale, dark-gray	3	9
11.	Bentonite, light-gray, limonitic; rarely a gypsiferous limonitic ammonite		1½
	USGS D5146:		
	Acanthoceras muldoonense Cobban and Scott		
10.	Shale, dark-gray	2	1
9.	Chamosite ironstone concretions, dark-gray; weather light olive gray; hard, slightly calcareous, very widely spaced; contain crushed ammonites		6
	USGS D5145:		
	Arrhoges modesta (Stephenson)?		
	Stomohamites cf. *S. simplex* (d'Orbigny)		
	Turrilites (Euturrilites) scheuchzerianus Bosc		
	Euomphaloceras cf. *E. lonsdalei* (Adkins)		

Graneros Shale (part)—Continued

		Ft	in
	Acanthoceras muldoonense Cobban and Scott		
	Calycoceras? sp.		
	Fish scales		
8.	Shale, dark-gray. At 3 ft 11 in. below top is local lens 2 in. thick of hard dark-gray chamosite ironstone that weathers olive brown. Lens of crushed *Acanthoceras* collected 8 ft 11 in. below top. Float phosphatic ammonites collected 4 ft 5 in. below top. Contains a few gypsiferous-limonitic ammonites and fragments of phosphatic ammonites	16	5
	USGS D5144, from upper 4 ft:		
	Ostrea sp.		
	Acanthoceras muldoonense Cobban and Scott		
	granerosense Cobban and Scott		
	USGS D5718, from 7 to 11 ft below top:		
	Ostrea sp.		
	Acanthoceras granerosense Cobban and Scott		
	USGS D5716, from 7 to 7½ ft above base:		
	Calycoceras (*Conlinoceras*) *gilberti* Cobban and Scott		
7.	Limestone, dark-gray; weathers dark brown, very hard. Somewhat fossiliferous. Basal part locally has cone-in-cone structure. Locally thins to 6 in. in thickness. *Calycoceras* and other fossils mainly found at top or in upper few inches. Thatcher Limestone Member	1	0
	USGS 1323 and 22883:		
	Diploconcha? sp.		
	Solitary coral		
	Nuculana? sp.		
	Breviarca sp.		
	Inoceramus sp.		
	Exogyra sp.		
	Pecten (*Camptonectes*) cf. *P. cavanus* Stephenson		
	Limatula? sp.		
	Other small pelecypods		
	Scaphopod		
	Gastropods		
	Turrilites (*Euturrilites*) sp.		
	Calycoceras leonense (Adkins) (*Conlinoceras*) *gilberti* Cobban and Scott		
	Euomphaloceras cf. *E. cunningtoni* (Sharpe)		
	Borissiakoceras compressum Cobban		
6.	Shale	3	
5.	Bentonite, light-yellowish-gray	3	

Graneros Shale (part)—Continued

		Ft	in
4.	Shale, silty; weathers light olive gray (5*Y* 5/2)	2	10
3.	Shale, dark-gray	6	6
2.	Bentonite, light-yellow, limonitic		4
1.	Shale, dark-gray; contains some light-gray hard siltstone layers up to one-quarter in. thick	2+	0
	Total Graneros Shale measured (rounded)	60	0

FAUNAL ZONATION

The Graneros Shale and Greenhorn Limestone are divided into several zones on the basis of contained ammonites. Some of the species of ammonites are more abundant than others, and some of the preserved forms represent part of an orderly evolutionary sequence. We will first show, in stratigraphic order, those fossils that have definite or possible zoning significance in the rocks near Pueblo; then we will compare the fossil succession near Pueblo to a general faunal zonation of the western interior.

FOSSIL ZONES AND AGE OF THE GRANEROS SHALE

Of all the ammonites in the Graneros Shale, only four are abundant enough in most areas to be used as zone fossils. In ascending order, they are *Calycoceras (Conlinoceras) gilberti, Acanthoceras granerosense, A. muldoonense,* and *A. amphibolum.*

Table 2 and the Graneros principal reference section show the occurrence of the zones. The overlapping of ranges of several zone fossils suggests that the variation of the evolving species is so broad that the names of both the waning and waxing species must be used to describe the individuals in some collections.

Eicher's foraminiferal studies (1965, fig. 8) show that the basal beds of the Graneros Shale become older northward (fig. 15). He recognized only two foraminiferal zones for the entire Graneros at Pueblo, but farther north in the Denver area, Eicher found another zone below these two as well as an equivalent of the uppermost part of the Mowry Shale. The entire Graneros Shale in the Pueblo area is Cenomanian in age according to Eicher.

Molluscan fossils have not been found in the Graneros Shale below the Thatcher Limestone Member. The ammonite faunas from the Thatcher Member and overlying part of the Graneros at Pueblo suggest a middle and late Cenomanian age if a threefold division of the Cenomanian is used (for example, Thomel, 1965, p. 138–142) or a late

TABLE 2.—*Fossils and zones of the Graneros Shale*

Unit		Zone	Known ranges of fossils		
Graneros Shale	Upper fossiliferous unit	*Acanthoceras amphibolum*	*Turrilites (Turrilites) acutus americanus* *Desmoceras (Pseudouhligella)* sp. *Tarrantoceras rotatile* *Borissiakoceras* sp.		*Inoceramus rutherfordi*
		Gap in fossil record (level of *Acanthoceras alvaradoense* Moreman)?			
		Acanthoceras muldoonense	*Euomphaloceras* cf. *E. lonsdalei* *Calycoceras*? sp. *Idiohamites* sp. *Borissiakoceras* cf. *B. orbiculatum*	*Stomohamites* cf. *S. simplex*	*Turrilites (Euturrilites) scheuchzerianus*
			Epengonoceras dumbli		
		Acanthoceras granerosense			
		Calycoceras (Conlinoceras) gilberti	*Anisoceras* cf. *A. plicatile*		
	Thatcher Limestone Member		*Calycoceras leonense* *Euomphaloceras* cf. *E. cunningtoni* *Borissiakoceras compressum* *Turrilites (Euturrilites)* sp. *Turrilites (Turrilites) acutus*		
	Lower barren unit		Lacks megafossils		

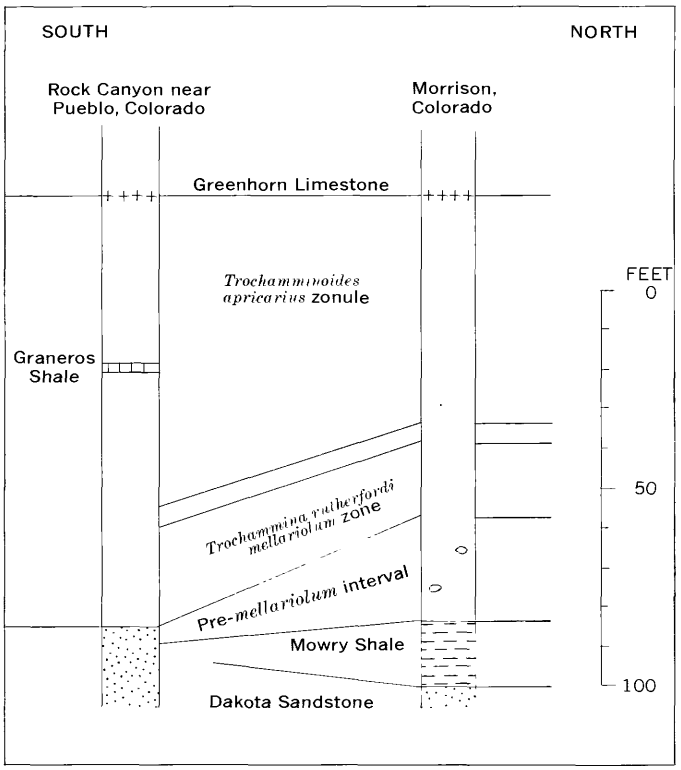

FIGURE 15.—Columnar sections showing microfossil zones of the Graneros Shale and northward increase in age of basal beds. From Eicher (1965, fig. 3).

Cenomanian age if a twofold division is used (for example, Spath, 1926b, p. 425; Wright and Wright, 1951, p. 3).

FOSSIL ZONES AND AGE OF THE GREENHORN LIMESTONE

Only two zone fossils are known in the Lincoln Limestone Member of the Greenhorn Limestone. These are, in ascending order, the zones of *Acanthoceras amphibolum*, which contains *Turrilites* sp. and *Inoceramus rutherfordi*, and the zone of *Calycoceras*? *canitaurinum*, which contains *Metoicoceras* sp. and *Inoceramus pictus*. Both of these zones have been known for some time in Colorado (Scott, 1964) and in other parts of the western interior (Cobban and Reeside, 1952). Other ammonites were observed in the Lincoln Limestone Member, but their vertical and lateral distributions are unknown. The Lincoln Limestone Member is late Cenomanian in age.

Ammonites were found at three levels in the upper part of the Hartland Shale Member (in ascending order): (1) *Metoicoceras* cf. *M. defordi*, (2) *Calycoceras*? sp., and (3) *Tarrantoceras*? sp. and *Stomohamites*? sp.; *Inoceramus pictus* is present throughout the Hartland Shale Member. The zonal significance of the fossils is unknown because so few have been found and their preservation is so poor. The poor preservation of fossils in both the Lincoln and the Hartland Members may be due to the activity of *Ptychodus*, the shell-crushing ray. The few fossils that are described were found by splitting the shale and the thinly layered calcarenite beds. As larger collections become available, useful fossils for zoning the Hartland Member may be discovered. The member is late Cenomanian in age.

Four ammonites in the Bridge Creek Limestone Member are abundant enough in most areas to be used as zone fossils. These four, in ascending order, are *Sciponoceras gracile*, *Watinoceras coloradoense*, *Mammites nodosoides*, and *Collignoniceras woollgari*. Boundaries between the last two species are overlapping (table 3).

Table 3 and plate 41 show the ranges of the zone and subzone fossils in the Bridge Creek Limestone Member. Most of the subzone fossils are as abundant as the zone fossils and are even more useful in locating an exact position within the member. Subzone fossils that are particularly valuable as markers in the section are *Metoicoceras whitei* (bed 67), *Vascoceras (Greenhornoceras) birchbyi* (bed 97), and *Puebloites greenhornensis* (beds 105, chiefly, and 113). The ranges of the subzone fossils shown in table 3 are based on many collections; therefore, further collecting near Pueblo is not likely to alter appreciably the ranges shown.

The age of the earliest part (*Sciponoceras gracile* Zone) of the Bridge Creek Member is controversial. It was considered as earliest Turonian (Cobban and Reeside, 1952, p. 1017) because of the presence of *Metoicoceras whitei*, a fossil assigned to the early Turonian by Spath (1926a, table opposite p. 80) and accepted by Muller and Schenck (1943, fig. 6) in their standard of the Cretaceous System. However, the presence of *Pseudocalycoceras*, *Calycoceras* of the *naviculare* group, and *Inoceramus pictus* gives the basal Bridge Creek beds a distinctive late Cenomanian aspect. Until the *Sciponoceras gracile* Zone is accurately placed in the type Cenomanian or Turonian of France, we consider it to be latest Cenomanian in age.

The rest of the Bridge Creek Member, characterized by *Inoceramus labiatus*, is definitely early Turonian. *Inoceramus labiatus* is widely distributed in the lower Turonian rocks in the Northern Hemisphere.

ZONATION IN THE WESTERN INTERIOR

Faunal zonations of the Cenomanian and Turonian rocks in the western interior have been

TABLE 3.—*Fossils and zones of the Bridge Creek Limestone Member*

Unit		Zone	Known ranges of fossils				
Greenhorn Limestone (part)	Bridge Creek Limestone Member	*Collignoniceras woollgari*	*Baculites calamus*			*Baculites* cf. *B. yokoyamai*	*Inoceramus labiatus*
		Mammites nodosoides	*Chaffaticeras pavillieri*	*Tragodesmoceras bassi*	*Stomohamites* sp. *Pueblites greenhornensis*	*Vascoceras* sp. *Kanabiceras puebloense* *Fagesia* sp.	
				Mammites nodosoides wingi			
		Watinoceras coloradoense	*Watinoceras reesidei*	*Pueblites spiralis* *Ampakabites collignoni* *Vascoceras (Greenhornoceras) birchbyi* *Fagesia* sp. *Neoptychites xetriformis* *Neoptychites* cf. *N. cephalotus*			
		Sciponoceras gracile	*Calycoceras* cf. *C. naviculare*	*Pseudocalycoceras dentonense* *Worthoceras vermiculum* *Kanabiceras septemseriatum*	*Worthoceras gibbosum* *Scaphites* sp.	*Hemiptychoceras reesidei* *Pueblites corrugatus* *Allocrioceras annulatum* *Metoicoceras whitei*	*Inoceramus pictus* s.l. (*Inoceramus subcorvexus* Logan?)

TABLE 4.—*Faunal zones for part of Cenomanian and Turonian time in the western interior and at Pueblo, Colo.*

	Faunal zonation in western interior		Pueblo, Colo. (Cobban and Scott, this report)	Rock units at Pueblo, Colo.	
Turonian	*Collignoniceras woollgari*	*Inoceramus labiatus*	*Collignoniceras woollgari*	Bridge Creek Limestone Member	Greenhorn Limestone
	Mammites nodosoides		*Mammites nodosoides*		
	Watinoceras coloradoense		*Watinoceras coloradoense*		
?	*Sciponoceras gracile*	*Inoceramus pictus*	*Sciponoceras gracile*		
Cenomanian	*Dunveganoceras albertense* *Dunveganoceras conditum*			Hartland Shale Member	
	Dunveganoceras pondi		*Calycoceras? canitaurinum*	Lincoln Limestone Member	
	Plesiacanthoceras wyomingense		*Acanthoceras amphibolum*		
	Acanthoceras amphibolum		*Acanthoceras amphibolum*	Graneros Shale	
	Acanthoceras muldoonense		*Acanthoceras muldoonense*		
	Acanthoceras granerosense		*Acanthoceras granerosense*		
	Calycoceras (Conlinoceras) gilberti		*Calycoceras (Conlinoceras) gilberti*		

established by many authors since the first fossils were collected in the late 19th century. The zonation has gradually become more detailed as the number of fossils and the number of localities have increased. Also, a trend toward measurement of stratigraphic sections in ever increasing detail has permitted fossils to be located more closely in the fossiliferous beds. Not only are the scarcer fossils being found as a result of larger (or statistical) collections, but also the range of each fossil can be plotted more closely.

Table 4 shows the faunal zonation at Pueblo and a general faunal zonation for the western interior. The zonation for the western interior includes *Dunveganoceras pondi, D. conditum, D. albertense,* and *Plesiacanthoceras wyomingense,* which are found mostly in the northern part of the region. In addition, subzone fossils not listed here, but which also have northern affinities, characterize all parts of the Cenomanian and Turonian rocks.

Of the four zone fossils listed at Pueblo, only two, *Calycoceras* sp. and *Acanthoceras amphibolum,* had been previously used in a Graneros faunal zonation. The other two, *Acanthoceras granerosense* and *A. muldoonense,* though closely akin to species in Texas, are new species. Plate 40 shows that a gap exists in the fossil record between the zones of *Acanthoceras muldoonense* and *A. amphibolum.* We believe that this gap probably marks the time of *A. alvaradoense* Moreman. Unfortunately, no concretions are found in this part of the Graneros where the only fossils are unidentifiable gypsiferous limonitic casts of large acanthoceratid ammonites (unit 62 of Graneros principal reference section).

As shown in table 4, the two zone fossils used for the Lincoln Limestone Member at Pueblo are not

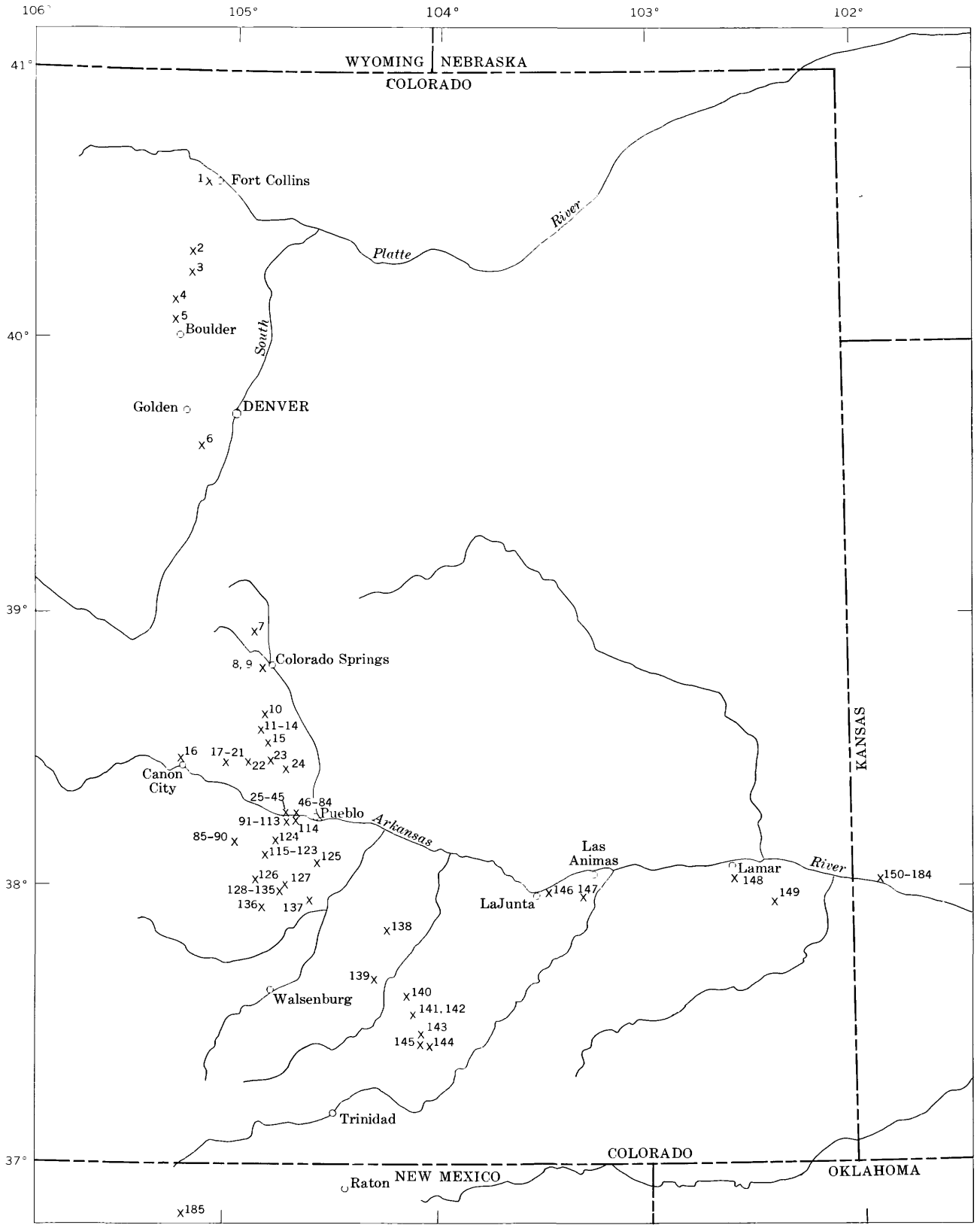

FIGURE 16.—Map showing localities of fossil collections chiefly from the Graneros Shale and Greenhorn Limestone. Numbers refer to the detailed descriptions of localities in table 5.

the principal zone fossils of the western interior. The two principal zone fossils are *Plesiacanthoceras wyomingense* and *Dunveganoceras pondi*. *Plesiacanthoceras wyomingense* lies above *Acanthoceras amphibolum*, but *Dunveganoceras pondi* occurs with *Calycoceras? canitaurinum*.

Because of our lack of sufficient well-preserved fossils from the Hartland Member, we have not shown faunal zones in the Pueblo area; however, the positions of the few fossils found at Pueblo are discussed in the preceding section. Two ammonite zones characterize equivalent beds in the northern part of the western interior, the Zones of *Dunveganoceras conditum* and *D. albertense*. In addition, *Inoceramus pictus* ranges through the Hartland Member and downward almost to the base of the Lincoln Limestone Member. Faunal zones in the Bridge Creek Limestone Member at Pueblo are identical to zones now known in equivalent rocks elsewhere in the western interior.

GEOGRAPHIC DISTRIBUTION OF FOSSILS

In the course of this study, fossils were examined from 185 localities in the eastern half of Colorado, southwestern Kansas, and northeastern New Mexico. These localities are shown in figure 16, and detailed descriptions of each are given in table 5.

TABLE 5.—*Localities where fossils were collected*

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
1	12610 (Washington locality).	J. B. Reeside, Jr., James Gilluly, and K. F. Mather, 1924. East of Dixon Canyon in sec. 17, T. 7 N., R. 69 W., Larimer County, Colo. Bridge Creek Limestone Member of Greenhorn Limestone (bed equivalent to bed 97 at Rock Canyon).
2	-----	Junius Henderson, 1904. West of Berthoud, Larimer County, Colo. [East half T. 4 N., R. 70 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
3	-----	Henderson, 1904. Mouth of Little Thompson Canyon northeast of Lyons, Larimer County, Colo. [NW¼ sec. 2?, T. 3 N., R. 70 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
4	-----	Henderson, 1904. Two miles north of Left Hand Canyon north of Boulder, Boulder County, Colo. [NW¼ T. 2 N., R. 70 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
5	-----	Henderson, 1904. Five miles north of Boulder, Boulder County, Colo. [sec. 36, T. 2 N., R. 71 W.?]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
6	D2409 (Denver locality).	G. R. Scott, W. A. Cobban, and J. H. Smith, 1959. Just north of Turkey Creek road in the NE¼NE¼NE¼ sec. 12, T. 5 S. R. 70 W., Jefferson County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
7	15416	I. A. Keyte, J. S. Williams, and Reeside, 1930. Half a mile west of Cathedral Rock, El Paso County, Colo. [NE¼ sec. 5, T. 12 S., R. 67 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
8	15419	Keyte, 1930. A quarter of a mile south of 31st St. and Colorado Ave., Colorado Springs, El Paso County, Colo. [NE¼ sec. 10, T. 14 S., R. 67 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
9	22905	Reeside and H. R. Christner, 1950. Opposite mouth of Camp Creek in the NE¼ sec. 10, T. 14 S., R. 67 W., El Paso County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
10	15402	Williams, 1930. Deadman Canyon, 14 miles south of Colorado Springs, El Paso County, Colo. [NE¼ sec. 11, T. 16 S., R. 67 W.]. Bridge Creek Limestone Member (mixed collection equivalent to beds 67–97 at Rock Canyon).
11	22910	Reeside and Christner, 1950. SW¼-SE¼ sec. 12, T. 17 S., R. 67 W., El Paso County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
12	22914	Reeside and Cobban, 1950. NE¼-SE¼ sec. 13, T. 17 S., R. 67 W., El Paso County, Colo. Bridge Creek Limestone Member (bed

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
		equivalent to bed 97 at Rock Canyon).
13	22915	Reeside, Cobban, and Christner, 1950. SE¼SE¼ sec. 13, T. 17 S., R. 67 W., El Paso County, Colo. From concretions about 2 ft above base of Bridge Creek Limestone Member (bed equivalent to bed 67 at Rock Canyon).
14	22916	Reeside, Cobban, and Christner, 1950. Same locality as 22915. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
15	22919	Reeside and Christner, 1950. NE¼-NW¼ sec. 30, T. 17 S., R. 66 W., El Paso County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
16	5815	C. W. Washburne, 1908. Two miles north of Canon City, Fremont County, Colo. [W½ sec. 20, T. 18 S., R. 70 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
17	15394	J. H. Johnson, 1928. About 4 miles northeast of Penrose, Fremont County, Colo. [SE¼ sec. 21, T. 18 S., R. 68 W.?]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
18	D6571	Scott, 1968. High bench in SW¼-NW¼NE¼ sec. 21, T. 18 S., R. 68 W., Fremont County, Colo. Limestone bed, 5 ft above base of Bridge Creek Limestone Member (bed equivalent to bed 73 at Rock Canyon).
19	D6572	Scott, 1968. SE¼SW¼SE¼NE¼ sec. 21, T. 18 S., R. 68 W., Fremont County, Colo. Limestone bed, 8 ft above base of Bridge Creek Limestone Member.
20	D1308	Scott and Cobban, 1957. East of Colorado Highway 115 and south of Beaver Creek in SW¼ sec. 22, T. 18 S., R. 68 W., Fremont County, Colo. Limestone bed, about 2 ft above base of Bridge Creek Limestone Member.
21	D1309	Scott and Cobban, 1957. Same locality as D1308. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
22	D5127	Cobban and Scott, 1965. Center SE¼NE¼ sec. 18, T. 18 S., R. 67 W., Pueblo County, Colo.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
		Second limestone bed above base of Bridge Creek Limestone Member.
23	1311	G. K. Gilbert, 1893. Near Turkey Creek at lat 38°28′, long 104°48′, Pueblo County, Colo. [SW¼ sec. 20, T. 18 S., R 66 W.?]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
24	15393	Johnson, 1928. Wild Horse Park in sec. 2, T. 19 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member (mixed collection equivalent to beds 67–97 at Rock Canyon).
25	D3966	Scott, 1962. NW¼SE¼SE¼ sec. 36, T. 20 S., R. 66 W., Pueblo County, Colo. Top of Graneros Shale.
26	D3984	Scott, 1962. NE¼SE¼SE¼SE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, from bed 65 of Rock Canyon section.
27	D3986	Scott, 1962. NW¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, from bed 135.
28	D4305	Scott, 1963. SW¼NE¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, from bed 105.
29	D4438	Cobban and Scott, 1964. NE¼-SE¼NW¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Limestone bed, 2½ ft above base of Bridge Creek Limestone Member.
30	D4439	Cobban and Scott, 1964. Same locality as D4438. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
31	D4440	Cobban and Scott, 1964. North flank Rock Canyon anticline NE¼SW¼NE¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
32	D4441	Cobban and Scott, 1964. Same locality as D4440. Bridge Creek Limestone Member, bed 101.
33	D4442	Scott and Cobban, 1964. NE¼-SE¼NW¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 105.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
34	D4443	Cobban and Scott, 1964. Same locality as D4442. Bridge Creek Limestone Member, bed 113.
35	D6142	W. H. Birchby, 1968. SW¼SE¼-SE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 90.
36	D6143	Birchby, 1967. SE¼SE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
37	D6144	Birchby, 1967. Same locality as D6143. Bridge Creek Limestone Member, bed 101.
38	D6145	Birchby, 1967. Same locality as D6143. Bridge Creek Limestone Member, bed 102 (middle limestone).
39	D6146	Birchby, 1967. West side of Boggs Creek in the SW¼SE¼SE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 105.
40	D6478	Scott, 1968. SW¼NW¼ sec. 25, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
41	D6479	Scott, 1968. Same locality as D6478, Bridge Creek Limestone Member, bed 105.
42	D6482	Scott, 1968. Same locality as D6478. Bridge Creek Limestone Member, bed 102.
43	D6486	Birchby, 1968. NE¼SW¼NE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 120.
44	D6487	Birchby, 1968. SE¼SW¼SE¼ sec. 35, T. 20 S., R. 66 W., Peublo County, Colo. Bridge Creek Limestone Member, bed 131.
45	D6535	Cobban, 1968. NE¼NE¼NE¼ sec. 35, T. 20 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 105.
46	15729	C. H. Dane, W. G. Pierce, and F. E. White, 1931. West of Pueblo and three-quarters of a mile below the Rock Canyon barrier dam on the Arkansas River, Pueblo County, Colo. [SW¼ sec. 31, T. 20 S., R. 65 W.?]. Bridge Creek Limestone Member, bed 97.
47	22876	Reeside, Cobban, and Christner, 1950. Center of N½N½ sec. 31, T. 20 S., R. 65 W., Pueblo County, Colo. Mixed collection from beds 67–113 of Bridge Creek Limestone Member.
48	22887	Cobban, 1950. Northeast of Arkansas River on east flank of Rock Canyon anticline, Pueblo County, Colo. [SW¼NE¼NW¼SW¼ sec. 30, T. 20 S., R. 65 W.]. Graneros Shale. Limestone concretions 2 ft below 2-ft-thick bentonite at base of Lincoln Limestone Member.
49	D1305	Cobban, 1957. SE¼NW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from 6 in. above Thatcher Limestone Member.
50	D1306	Scott, 1957. Same locality as D1305. Graneros Shale, 20 ft below marker bentonite.
51	D1307	Scott and Cobban, 1957. Same locality as D1305. Hartland Shale Member, limestone bed 42 ft above base.
52	D3963	Cobban, 1957. NE¼SW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from ferruginous concretion 11½ ft above Thatcher Limestone Member.
53	D3964	Cobban, 1957. SE¼NW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from greenish-gray phosphatic nodules 1½ ft above Thatcher Limestone Member.
54	D3965	Scott, 1961. NW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from ironstone concretions 20 ft below marker bentonite.
55	D3967	Cobban, 1957. NW¼SE¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Lincoln Limestone Member, from calcarenite bed at top.
56	D3968	Scott and Cobban, 1960. Same locality as D3967. Hartland Shale Member, from limestone bed 3 ft below top.
57	D3970	Cobban, 1964. SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from 6 in. above Thatcher Limestone Member.
58	D3971	Scott, 1961. SW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County,

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
		Colo. Graneros Shale, from large siltstone concretions 18 ft above base.
59	D3972	Cobban, 1957. SE¼SE¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 63.
60	D3973	Harold McGovern, 1961. NW¼-SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 67.
61	D3974	Scott and Cobban, 1964. Same locality as D3972. Bridge Creek Limestone Member, bed 77.
62	D3975	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 86.
63	D3976	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 90.
64	D3977	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 97.
65	D3978	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 101.
66	D3979	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 105.
67	D3980	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 113.
68	D3981	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 118.
69	D3982	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 120.
70	D3983	Scott and Cobban, 1961. Same locality as D3972. Bridge Creek Limestone Member, bed 131.
71	D4001	Scott 1963. SW¼NW¼SE¼ sec. 30, T. 20 S., R. 65 W. Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
72	D4444	Scott and Cobban, 1964. Same locality as D3972. Bridge Creek Limestone Member, bed 73.
73	D4445	Scott, 1964. NW¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from Thatcher Limestone Member.
74	D5150	Scott and Cobban, 1965. SE. corner SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from Thatcher Limestone Member.
75	D5151	Scott and Cobban, 1965. Same locality as D5150. Graneros Shale, 7–11 ft above Thatcher Limestone Member.
76	D5152	Cobban, 1965. Same locality as D5150. Graneros Shale, 21 ft above Thatcher Limestone Member.
77	D5153	Cobban, 1965. Same locality as D5150. Graneros Shale, 31 ft above Thatcher Limestone Member.
78	D5293	Scott and Cobban, 1966. SE¼-SE¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 150.
79	D5294	Scott and Cobban, 1966. NW¼-SE¼SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from concretion 16½ ft above Thatcher Limestone Member.
80	D5728	Scott and Cobban, 1966. Same locality as D5150. Graneros Shale 4½–5 ft above Thatcher Limestone Member.
81	D5729	Scott and Cobban, 1966. Same locality as D5150. Graneros Shale, 12½–14 ft above Thatcher Limestone Member.
82	D6480	Scott, 1968. SE¼NW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 102.
83	D6481	Scott, 1968. Same locality as D6480. Bridge Creek Limestone Member, bed 103.
84	D6488	Cobban, 1968. Just east of center of SW¼ sec. 30, T. 20 S., R. 65 W., Pueblo County, Colo. Hartland Shale Member, from limestone bed 31 ft above base.
85	D3002	Cobban, 1961. Just north of road 4 7/10 miles south of Sloan in the NE¼ sec. 34, T. 21 S., R. 68 W., Pueblo County, Colo. Thatcher Limestone Member.
86	D5708	Arlan Roll and Scott, 1966. West-facing hill slope in NW¼NE¼ sec. 34, T. 21 S., R. 68 W., Pueblo County, Colo. Thatcher Limestone Member.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
87	D5709	Scott and Cobban, 1966. NW¼-NE¼ sec. 34, T. 21 S., R. 68 W., Pueblo County, Colo. Graneros Shale, from 6 ft above Thatcher Limestone Member.
88	D5710	Scott and Cobban, 1966. Same locality as D5709. Graneros Shale, from 10 ft above Thatcher Limestone Member.
89	D5711	Scott and Roll, 1966. Same locality as D5709. Graneros Shale, from claystone concretions 20 ft above Thatcher Limestone Member.
90	D5712	Scott and Roll, 1966. Same locality as D5709. Graneros Shale, from ironstone concretions 24 ft above Thatcher Limestone Member.
91	22875	Reeside and Cobban, 1950. SW¼-NE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, mixed collection from beds 97–113.
92	D4304	Scott, 1963. NE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
93	D6122	Birchby, 1968. SW¼NE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
94	D6123	Birchby, 1967. Hill in SE¼SW¼-NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 86.
95	D6124	Scott and Birchby, 1967. Same locality as D6123. Bridge Creek Limestone Member, bed 105.
96	D6134	Birchby and Cobban, 1968. SW¼-NW¼NW¼ sec. 1, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 102.
97	D6147	Birchby, 1967. SW¼NW¼NW¼ sec. 1, and NE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 97.
98	D6148	Birchby, 1967. Boggs Creek in the NW¼NW¼ sec. 1, and NE¼-NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 101.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
99	D6149	Birchby, 1967. Same locality as D6148. Bridge Creek Limestone Member, bed 105.
100	D6150	Birchby, 1967. Same locality as D6148. Bridge Creek Limestone Member, bed 109.
101	D6151	Birchby, 1967. Boggs Creek SW¼-NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 101.
102	D6472	Birchby, 1968. NW¼NW¼NW¼ sec. 1, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 67.
103	D6473	Birchby, 1968. Same locality as D6472. Bridge Creek Limestone Member, bed 63.
104	D6474	Cobban, 1968. NE¼SE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 118.
105	D6475	Birchby, 1968. Same locality as D6474. Bridge Creek Limestone Member, bed 120.
106	D6476	Birchby, 1968. NW¼SW¼NW¼ sec. 1, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 103.
107	D6477	Birchby, 1968. NE¼SE¼NW¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 107.
108	D6483	Birchby, 1968. NE¼SE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 113.
109	D6484	Birchby, 1968. NW¼NW¼NW¼ sec. 1, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 73.
110	D6489	Birchby, 1968. NE¼SE¼NE¼ sec. 2, T. 21 S., R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 109.
111	D6533	Birchby, 1968. Same locality as D6489. Bridge Creek Limestone Member, bed 110.
112	D6534	Birchby, 1968. NW¼SW¼NW¼ sec. 1, T. 21 S. R. 66 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 99.
113	D6536	Birchby, 1968. Same locality as D6489. Bridge Creek Limestone Member, bed 73.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
114	D3985	Scott, 1961. NW¼NW¼ sec. 6, T. 21 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 135.
115	1323	Gilbert, 1893. 1½ miles west of head of Rock Canyon, lat 38°7′, long 104°53′, Pueblo County, Colo. [SE¼NE¼SW¼SW¼ sec. 23, T. 22 S., R. 67 W.]. Thatcher Limestone Member.
116	22883	Reeside and Cobban, 1950. Same locality as 1323. Thatcher Limestone Member.
117	D5144	Scott and Cobban, 1965. In ravine on south side of Muldoon Hill in NW¼SE¼SW¼ sec. 23, T. 22 S., R. 67 W., Pueblo County, Colo. Graneros Shale, about 30–35 ft below top.
118	D5145	Scott and Cobban, 1965. Same locality as D5144. Graneros Shale, from ironstone concretions 30 ft below top.
119	D5146	Scott and Cobban, 1965. Same locality as D5144. Graneros Shale, from 28 ft below top.
120	D5147	Scott, 1965. Same locality as D5144. Graneros Shale from 21 ft below top.
121	D5148	Cobban, 1965. Same locality as D5144. Lincoln Limestone Member, from limestone concretions overlying marker bentonite.
122	D5149	Scott and Cobban, 1965. Same locality as D5144. Lincoln Limestone Member, from 5½ ft above marker bentonite.
123	D5718	Scott and Cobban, 1966. NW¼-SE¼SW¼ sec. 23, T. 22 S., R. 67 W., Pueblo County, Colo. Float, 5½–9½ ft above Thatcher Limestone Member.
124	D3000	Cobban, 1961. NW¼NW¼ sec. 18, T. 22 S., R. 66 W., Pueblo County, Colo. Graneros Shale, about 20 ft above Thatcher Limestone Member.
125	D6121	Scott, 1967. SE¼NW¼ sec. 23, T. 22 S., R. 65 W., Pueblo County, Colo. Bridge Creek Limestone Member, bed 105.
126	D5716	Cobban, 1966. NW¼SE¼SW¼ sec. 23, T. 23 S., R. 67 W., Pueblo County, Colo. Graneros Shale, 7–7½ ft above Thatcher Limestone Member.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
127	D5128	Cobban and Scott, 1965. In highway cut on line between secs. 25 and 26, T. 23 S., R 66 W., Pueblo County, Colo., 8 3/10 miles south of Burnt Mill road and 2/10 mile south of Muddy Creek on Interstate 25. Graneros Shale, 10–11 ft above Thatcher Limestone Member.
128	D5122	Scott and Cobban, 1965. Bed of Greenhorn Creek in center of sec. 35, T. 23 S., R. 66 W., Pueblo County, Colo. Thatcher Limestone Member.
129	D5123	Cobban, 1965. Same locality as D5122. Graneros Shale, from 2-in.-thick siltstone bed 3 ft above Thatcher Limestone Member and from small limestone concretions at top of underlying 3-ft-thick shale bed.
130	D5124	Scott and Cobban, 1965. Same locality as D5122. Graneros Shale, about 10–11 ft above Thatcher Limestone Member.
131	D5126	Cobban, 1965. Same locality as D5122, but at top of bluff. Lincoln Limestone Member, from limestone concretions overlying marker bentonite.
132	D5289	Scott and Cobban, 1966. Same locality as D5122. Graneros Shale, 5–6 ft above Thatcher Limestone Member.
133	D5290	Scott and Cobban, 1966. Same locality as D5122. Graneros Shale, 6½–7½ ft above Thatcher Limestone Member.
134	D5291	Scott and Cobban, 1966. Same locality as D5122. Graneros Shale, 8½–9 ft above Thatcher Limestone Member.
135	D5292	Scott and Cobban, 1966. Same locality as D5122. Graneros Shale, from 14 ft above Thatcher Limestone Member.
136	D2547	Scott and Cobban, 1960. Beside county road in SE¼NE¼ sec. 36, T. 24 S., R. 67 W., Pueblo County, Colo. Calcarenite layer in Lincoln Limestone Member.
137	D6726	G. R. Scott and James Scott 1967. Badland in Graneros Shale in NE¼ sec. 13, T. 24 S., R. 65 W., Pueblo County, Colo. Graneros Shale, from about 20 ft above Thatcher Limestone Member.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
138	1390	Gilbert, 1894. South of Haystack Butte at lat 37°50′, long 104°15′, Otero County, Colo. [Center W½ T. 25 S., R. 61 W.]. Bridge Creek Limestone Member (equivalent to bed 97 at Rock Canyon).
139	1394	Gilbert, 1894. Seven miles east of Dripping Spring, lat 37°40′, long 104°18′, Las Animas County, Colo. [sec. 26?, T. 27 S., R. 62 W.]. Bridge Creek Limestone Member, from near base.
140	1389	Gilbert, 1894. Lat 37°37′, long 104°09′, Las Animas County, Colo. [NW¼ T. 28 S., R. 60 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
141	D5732	Scott and Cobban, 1966. Arroyo 1 mile south of Thatcher about center N½ sec. 10, T. 29 S., R. 60 W., Las Animas County, Colo. Thatcher Limestone Member.
142	D5733	Scott, 1966. Same locality as D5732. Shale 2 ft above Thatcher Limestone Member.
143	22896	Reeside, Cobban, and Christner, 1950. Near center of Model anticline in the NW¼NW¼NE¼ sec. 35, T. 29 S., R. 60 W., Las Animas County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
144	22900	Reeside, 1950. Model dome in the NE¼NW¼ sec. 13, T. 30 S., R. 60 W., Las Animas County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
145	D6523	Cobban, 1968. SW¼SE¼ sec. 15, T. 30 S., R. 60 W., Las Animas County, Colo. Bridge Creek Limestone Member, from 15 ft above base in bed equivalent to bed 105 at Rock Canyon.
146	D2419	W. G. Weist, Jr., 1959. Thompson Arroyo east of La Junta, in the NW¼ sec. 5, T. 24 S., R. 54 W., Otero County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
147	-----	Henderson, 1904. Tarbox Arroyo east of La Junta, Bent County, Colo. [near center T. 24 S., R. 53 W.]. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
148	-----	Victor Hendrickson. South of Lamar in sec. 20, T. 2? S., R. 46 W., Prowers County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
149	D2401	T. G. McLaughlin, McGovern, and Cobban, 1955. Wolf Creek, in the SW¼NW¼NW¼ sec. 24, T. 24 S., R. 45 W., Prowers County, Colo. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).
150	12768	N. W. Bass, 1924. SW¼ sec. 2, T. 23 S., R. 42 W., 5 miles east of Coolidge, Hamilton County, Kans. Bridge Creek Limestone Member, bed 53 of Hinkle Ranch section.
151	D4867	Scott, 1964. West bank of Bridge Creek in E½NE¼ sec. 22, T. 23 S., R. 42 W., Hamilton County, Kans. Bridge Creek Limestone Member, bed 3 of Hinkle Ranch section.
152	D4868	Scott, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 7.
153	D4869	Scott and Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 9.
154	D4870	Scott and Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 11.
155	D4871	Scott and Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 15.
156	D4872	Scott, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 17.
157	D4873	Scott, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 24.
158	D4874	Scott, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 26.
159	D4875	Scott, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 28.
160	D4876	Scott and Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 40.
161	D4877	Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 42.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
162	D4878	Scott and Cobban, 1964. Same locality as D4867. Bridge Creek Limestone Member, bed 46.
163	D4879	Scott and Cobban, 1964. South bank of Bridge Creek in the NW¼NE¼NW¼ sec. 23, T. 23 S., R. 42 W., Hamilton County, Kans. Bridge Creek Limestone Member, bed 51.
164	D4880	Cobban and Scott, 1964. Same locality as D4879. Bridge Creek Limestone Member, bed 57.
165	D4881	Cobban, 1964. Same locality as D4879. Bridge Creek Limestone Member, bed 59.
166	D4882	Cobban, 1964. Same locality as D4879. Bridge Creek Limestone Member, bed 64.
167	D4883	Scott and Cobban, 1964. Same locality as D4879. Bridge Creek Limestone Member, bed 66.
168	D4884	Scott and Cobban, 1964. West bank of Bridge Creek in the E½ NW¼SW¼ sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Bridge Creek Limestone Member, bed 68.
169	D4885	Scott, 1964. Same locality as D4884. Bridge Creek Limestone Member, bed 70.
170	D4886	Scott, 1964. Same locality as D4884. Bridge Creek Limestone Member, bed 72.
171	D4887	Scott and Cobban, 1964. Floor of Bridge Creek in the SE¼NE¼ SW¼ sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Bridge Creek Limestone Member, bed 74.
172	D4888	Scott and Cobban, 1964. South bank of Bridge Creek in the SE¼ NE¼SW¼ sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Bridge Creek Limestone Member, bed 76.
173	D4889	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 78.
174	D4890	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 80.
175	D4891	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 84.
176	D4892	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 86.

TABLE 5.—*Localities where fossils were collected*—Continued

Loc. No. (figs. 16, 42)	USGS Mesozoic loc. No.	Collector and year of collection, description of locality, and stratigraphic assignment (brackets enclose our opinion of locality, queried if doubtful)
177	D4893	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 86.
178	D4894	Cobban, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 88.
179	D4895	Scott, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 90.
180	D4896	Cobban, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 94.
181	D4897	Scott and Cobban, 1964. Same locality as D4888. Bridge Creek Limestone Member, bed 98.
182	D4898	Scott and Cobban, 1964. West bank of Bridge Creek in the NW¼ SW¼NE¼ sec. 14, T. 23 S., R. 42 W., Hamilton County, Kans. Fairport Chalky Shale Member of Carlile Shale, bed 102.
183	D4899	Scott, 1964. Same locality as D4898. Fairport Chalky Shale Member, bed 104.
184	D4900	Scott, 1964. Same locality as D4898. Fairport Chalky Shale Member, bed 106.
185	D6471	C. L. Pillmore, 1968. Sec. 22, T. 30 N., R. 16 W., Colfax County, N. Mex. Bridge Creek Limestone Member (bed equivalent to bed 97 at Rock Canyon).

SYSTEMATIC DESCRIPTIONS

With one exception, the order of families, arrangement of genera, and terminology follow the treatment in the "Treatise on Invertebrate Paleontology, Part L, Mollusca 4" (Arkell and others, 1957). The repositories of the specimens and collecting localities are abbreviated as follows:

USNM____U.S. National Museum, Washington, D.C.
BEG_____Bureau of Economic Geology, University of Texas, Austin
USGS loc_U.S. Geological Survey Mesozoic locality

In the description of rib density of the heteromorphs, the rib index is the diameter of the shell divided by the distance between the crests of two adjacent ribs on the middle of the venter. This is close to, but not quite the same as, the rib index of Adkins (1931, p. 63) and the rib density of Matsumoto and Obata (1963, p. 21) and Birkelund (1965, p. 44).

Occurrences of ammonites are related wherever possible to numbered beds in measured sections. Accordingly, any one bed may have many locality numbers that represent not only the localities of collections made at the place of measurement but also collecting localities from this bed within a mile or two. Localities of collections listed in the measured sections represent only those at the places of measurement.

Phylum MOLLUSCA
Class CEPHALOPODA
Order AMMONOIDEA

Family PTYCHOCERATIDAE Meek, 1876

Genus WORTHOCERAS Adkins, 1928

Type species.—*Macroscaphites platydorsus* Scott, 1924.

This genus has been best defined by Wiedmann (1965, p. 439), who observed that the specimens were

> of small size, nearly unsculptured, and with one exception provided with a completely open whorled initial coil. This is followed by a long straight shaft with flat, subparallel flanks and a distinctly impressed dorsum, which terminates in a final hook with occasionally lappeted mouth-border. *** suture-line, consisting of four narrow lobes, among them a distinctly trifid *L* and an undivided small *U*.

Worthoceras is known from the upper Albian, Cenomanian, and Turonian of North America, Europe, and possibly Africa. The genoholotype, *Macroscaphites platydorsus* Scott (1924, p. 18, pl. 5, figs. 1, 4; also Adkins, 1928, pl. 12, figs. 1, 3; Arkell and others, 1957, fig. 255–3; and Wiedmann, 1965, pl. 59, fig. 5), from the upper Albian of Texas, has a very small septate coil and a much larger uncoiled part. The septa continue onto the lower half of the straight shaft. The genus has usually been considered as a scaphite, but Wiedmann (1965, p. 441, 449) showed its derivation from *Ptychoceras*.

Worthoceras gibbosum Moreman

Plate 17, figure 2

1942. *Worthoceras gibbosum* Moreman, Jour. Paleontology, v. 16, no. 2, p. 215, pl. 34, figs. 7, 8, text fig. 2q.
1951. *Worthoceras* [*gibbosum* Moreman]. Adkins and Lozo, Fondren Sci. Ser., no. 4, pl. 5, figs. 2, 3.
1965. *Worthoceras gibbosum* Moreman. Wiedmann, Palaeontology, v. 8, pt. 3, p. 441, pl. 60, figs. 3a–d, text fig. 10h.

This is the stoutest known species of *Worthoceras*. The holotype is a complete adult 18 mm (millimeters) long that is smooth except for a few very weak ribs. It differs distinctly from *W. platydorsum* (Scott) by having a much larger septate coil and much shorter uncoiled stage. The septa, which do not extend onto the straight shaft, have a bifid lateral lobe instead of a trifid one as on *W. platydorsum*.

Worthoceras gibbosum is represented in the collections from the Rock Canyon and Hinkle Ranch sections by about 10 poorly preserved internal molds from limestone beds near the base of the Bridge Creek Limestone Member. All are about the size of the holotype.

Types.—Hypotype, USNM 163822.

Occurrences.—Rock Canyon section, beds 73 and 77 (USGS locs. D6536 and D3974); Hinkle Ranch section, bed 11 (USGS loc. D4870). The species has not been hitherto recorded outside of Texas.

Worthoceras vermiculum (Shumard)

1860. *Scaphites vermiculus* Shumard, Acad. Sci. St. Louis Trans., v. 1, p. 594.
1876. *Macroscaphites vermiculus* (Shumard). Meek, U.S. Geol. Survey Terr. (Hayden) Rept. 9, p. 419.
1883. *Scaphites vermiculus* Shumard. White, U.S. Geol. and Geog. Survey Terr. (Hayden) 12th Ann. Rept., pt. 1, p. 39, pl. 18, fig. 8a.
1928. *Scaphites vermiculus* Shumard. Adkins, Texas Univ. Bull. 2838, p. 220, 259.
1942. *Worthoceras vermiculum* (Shumard). Moreman, Jour. Paleontology, v. 16, no. 2, p. 214, pl. 34, figs. 12, 13, text fig. 2p.
1965. *Worthoceras vermiculum* (Shumard). Wiedmann, Palaeontology, v. 8, pt. 3, p. 440, pl. 59, fig. 8; pl. 60, figs. 1, 2, text figs. 10e–g.

This species is characterized by its small size, conspicuous septate coil, and slender body chamber considerably extended beyond the coil. Shumard (1860, p. 594) did not publish an illustration of his species, but White (1883, pl. 18, fig. 8a) presented a drawing of it that had been prepared by Shumard before his death. Shumard (1860, p. 595) gave its dimensions as 0.64 inch long, 0.42 inch wide, and 0.18 inch thick. The surface was said to be marked by "a few obscure, transverse folds, and fine striae ***. The folds are usually perceptible only on the septate portion of the shell." Shumard's specimen came from the Eagle Ford Shale in Grayson County, Tex.

Worthoceras vermiculum is present in two beds in the Hinkle Ranch section low in the Bridge Creek Limestone Member. The specimens are crushed flat and poorly preserved.

Occurrences.—Hinkle Ranch section, beds 9 (USGS loc. D4869) and 11 (USGS loc. D4870). The species is scarce in eastern Colorado, but in the Front Range area it has been found as far north as

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Denver (Scott, 1962, p. L13). It has also been recorded from central Kansas (Hattin, 1965b, p. 15) and from the north flank of the Black Hills uplift in the southeast corner of Montana (Cobban, 1951, p. 2185).

Family HAMITIDAE Hyatt, 1900

Genus STOMOHAMITES Breistroffer, 1940

Type species.—*Hamites virgulatus* Brongniart, 1822.

Stomohamites was originally created as a subgenus of *Hamites* by Breistroffer (1940, p. 156) for heteromorph ammonites whose open planospiral coil is ornamented by ribbing that tends to disappear on the dorsum. Spath (1923–43, p. 634) pointed out that neither of these characters is significant in separating *Stomohamites* from *Hamites*; the differences in suture lines are the more important features. In *Hamites*, the second lateral lobe is small and not symmetrically bifid like the much larger first lateral lobe; in *Stomohamites* both lobes are symmetrically bifid and nearly equal in size. Arkell, Kummel, and Wright (1957, p. L217) noted further that the third lateral saddle is symmetrically bifid and nearly as large as the other saddles. They also pointed out that *Stomohamites* is ordinarily more densely ribbed than *Hamites*, has a venter tending to be flattened, and includes some species having a strongly collared and constricted aperture.

The genus is known from Europe, Madagascar, Australia, and North America. Arkell, Kummel, and Wright (1957, p. L217) gave the range as upper Albian to lower Turonian.

Stomohamites cf. S. simplex (d'Orbigny)

Plate 13, figures 5–10; plate 17, figures 3, 4

A few crushed hamitids were collected from the Graneros Shale and Greenhorn Limestone. All closely resemble the illustrations of specimens of *Stomohamites simplex* (d'Orbigny) described from France (d'Orbigny, 1840–42, p. 550, pl. 134, figs. 12–15), Madagascar (Collignon, 1964, p. 6, pl. 318, fig. 1358), and Australia (Wright, 1963, p. 597, pl. 81, figs. 1a–c), but none has the suture preserved. The specimens from the Graneros Shale (pl. 13, figs. 5–10), from a few feet above the Thatcher Limestone Member, consist of fragments of straight and curved limbs 3–6 mm in whorl height. Ribs are radial, well rounded, and as wide as the interspaces and have an index of 4–5. The two specimens (pl. 17, figs. 3, 4) from the Greenhorn Limestone (upper part of the Bridge Creek Limestone Member) include parts of straight and curved limbs that have rib indices of 4–6 and maximum whorl heights of 5.5 and 6.5 mm.

Figured specimens.—USNM 163814–163821.

Occurrences.—Graneros Shale: Rock Canyon section, bed 55 (USGS locs. D1305, D3964); Muldoon Hill section, bed 9 (USGS loc. D5145). Bridge Creek Limestone: Hinkle Ranch section, bed 76 (USGS loc. D4888).

Genus HEMIPTYCHOCERAS Spath, 1925

Type species.—*Ptychoceras gaultinum* Pictet, 1847.

Spath (1925b, p. 189) created this generic name and did not define it other than to cite *Ptychoceras gaultinum* Pictet (in Pictet and Roux, 1847, p. 395, pl. 15, fig. 5a) from the upper Albian of France as the type. Arkell, Kummel, and Wright (1957, p. L216–L217) included in the genus forms "With 3 shafts of typical *Hamites* closely pressed together; ribs as in *Hamites* except on 2d bend where they tend to be scalelike ***." Pictet's drawing of the type specimen showed parts of the last two limbs and the connecting elbow. The smaller limb is finely ribbed (index of 8) and has a few weak constrictions bounded by moderately strong ribs. The dense ribbing continues around the elbow, but at the base of the larger limb the ribbing becomes abruptly coarser (index of 4).

Hemiptychoceras is known from a very few records. The only species described from the Upper Cretaceous may be *H. tropicum* (Kossmat) and *H. subgaultinum* Breistoffer. Kossmat (1895, p. 150) gave the new name *Hamites (Ptychoceras) tropicus* to the Cenomanian specimen from southern India which had been assigned by Stoliczka (1865, p. 195, pl. 90, figs. 10, 10a) to *Ptychoceras gaultinum* Pictet. Fabre (1940, p. 240, pl. 5, fig. 6) assigned Kossmat's species to *Hemiptychoceras* and described an example from the Cenomanian of southern France (Basse-Provence). She also pointed out that the specimen from the Cenomanian of Madagascar described as *Hamites (Ptychoceras) gaultinus* (Pictet) by Boule, Lemoine, and Thevenin (1907, p. 36, pl. 6, figs. 1, 1a) might be *Hemiptychoceras tropicum*. Breistroffer (1940, p. 159) later renamed the specimen from Madagascar *Hemiptychoceras subgaultinum* and noted that the specimen from the lower Cenomanian of Rumania described by Popovici-Hatzeg (1899, p. 10) as *Ptychoceras* aff. *P. gaultinum* Pictet might be *H. subgaultinum*.

Hemiptychoceras reesidei Cobban and Scott, n. sp.

Plate 17, figures 7, 8

1937. *Neoptychoceras* sp. Dane, Pierce, and Reeside, U.S. Geol. Survey Prof. Paper 186–K, p. 214.

This species is represented in the collections from the Pueblo-Colorado Springs area by two crushed specimens each consisting of parts of the two limbs and the connecting elbow. The larger specimen (pl. 17, fig. 7), the holotype, is 17.3 mm long and 10.0 mm wide. Ribs are very closely spaced on the smaller limb and elbow where they have an index of 10. The spacing widens almost abruptly at the larger end of the complete elbow, and the ribs on the large limb have an index of only 5½. The ribs are narrow, rounded, and wider than the interspaces. The smaller specimen (pl. 17, fig. 8) has similar rib indices. The suture is not preserved on either specimen.

Hemiptychoceras reesidei differs from the example of *H. tropicum* (Kossmat) illustrated from France by Fabre (1940, p. 240, pl. 5, fig. 6) and from the similar specimen from Madagascar figured by Boule, Lemoine, and Thevenin (1907, p. 36, pl. 6, figs. 1, 1a) in that it lacks the conspicuous constriction that separates the small limb from the elbow. Whether this constriction is present on Kossmat's type (Stoliczka, 1865, p. 195, pl. 90, figs. 10, 10a) cannot be determined from the descriptions and illustrations. Kossmat's type, however, is much larger than *H. reesidei*. The species is named in honor of the late Dr. John B. Reeside, Jr.

Types.—Holotype, USNM 163823; paratype, USNM 163824.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 67 (USGS loc. D6472). The paratype was found with *Sciponoceras gracile* (Shumard) at USGS locality 15402 near Colorado Springs, Colo. A smaller but very closely related species was discovered by Prof. Robert E. Stevenson, The University of South Dakota, Vermillion, associated with *Watinoceras coloradoense* (Henderson) and *Inoceramus labiatus* (Schlotheim) in the upper part of the Greenhorn Formation on the northeast flank of the Black Hills in western South Dakota.

Genus PUEBLOITES Cobban and Scott, n. gen.

Type species.—Helicoceras? corrugatum Stanton, 1894 [1893 imprint].

This genus is proposed for certain ammonites that are loosely coiled in a very shallow helical spire and have some of the whorls tending toward elliptical coiling. Whorl sections are circular to elliptical. There are no constrictions, flared ribs, or tubercles. Ribs are numerous and conspicuously cross the flanks, dorsum, and venter obliquely. The suture is moderately complex.

Puebloites resembles *Scalarites* (Wright and Matsumoto, 1954, p. 115, text figs. 1, 2) in its mode of coiling, but *Puebloites* lacks the flared ribs and constrictions. It also resembles *Glyptoxoceras* (Spath, 1925a, p. 30) in having densely ribbed loose coils, but *Glyptoxoceras* is largely coiled in a plane (Wright and Matsumoto, 1954, text fig. 5) and the ribs do not cross the venter and dorsum obliquely.

Puebloites corrugatus (Stanton)

Plate 18, figures 6–19; text figure 17

1894. *Helicoceras? corrugatum* Stanton, U.S. Geol. Survey Bull. 106, p. 165, pl. 35, fig. 5 [1893 imprint].

1898. *Helicoceras? corrugatum* Stanton. Logan, Kansas Univ. Geol. Survey, v. 4, Paleontology, pt. 8, p. 462, pl. 100, fig. 3.

This species was based on a single specimen from the Greenhorn Limestone of Huerfano Park about 40 miles southwest of Pueblo. The holotype, part of an adult, consists of about half a whorl of a very low and broad open spire. Stanton gave the length as 105 mm; the oval end sections were 10 by 12 mm and 18 by 23 mm. Sculpture consists of thin rursiradiate nodeless ribs that are strongest on the venter and weakest on the dorsum. The ribbing is asymmetric to the coiling; this asymmetry results in ribs crossing obliquely both the venter and the dorsum (pl. 18, fig. 15). The ribs are closely spaced and have an index of 8–9. They are a little more closely spaced in the smaller end than on the larger end. The holotype shows considerable taper. The suture is not preserved.

Many somewhat crushed and distorted internal molds from the Pueblo area are referable to this species. The specimens have whorl heights ranging from 7 to 30 mm (pl. 18, figs. 17–19). The longer fragments suggest that the species had an elliptical mode of coiling in the form of a low spire. A complete suture is not preserved on any specimens. Part of a suture is shown in text figure 17.

The largest fragments closely resemble in size and sculpture the piece of a heteromorph from the Turonian of Bohemia described by Fritsch and Schlönbach (1872, p. 47, pl. 13, fig. 17) as the new

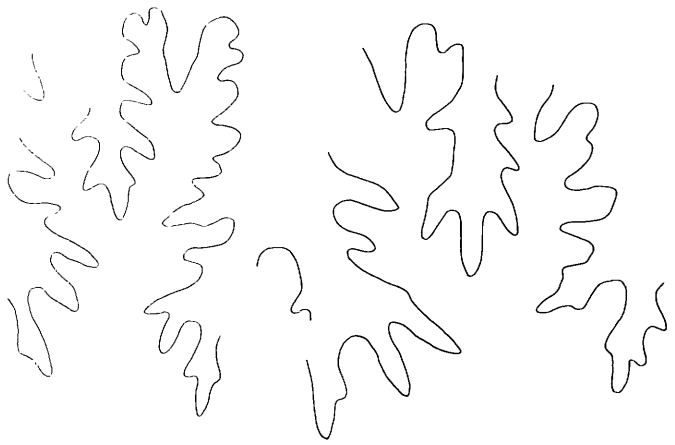

FIGURE 17.—Part of the suture (× 7) at a diameter of 13 mm of a specimen (USNM 163825) of *Puebloites corrugatus* (Stanton) from USGS locality D6472 (fig. 16, map loc. 102). The specimen is illustrated on plate 18, figure 6.

species *Hamites striatus*. The angle of taper recalls the heteromorph from the upper Turonian of Germany described by Leonhard (1897, p. 60, pl. 6, fig. 4) as *Hamites grundeyi*. Leonhard's species, however, has ventrolateral tubercles and may belong to *Allocrioceras*. Basse de Ménorval (1963, p. 874, pl. 23, fig. 4) figured an impression of a densely ribbed heteromorph that has straight and curved limbs from the Turonian of Angola. She assigned her specimen, which closely resembles *Puebloites corrugatus*, to *Diplomoceras* (?) *cascadense* Anderson (1958, p. 199).

Types.—Hypotypes, USNM 163825–163829.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 67 (USGS locs. D3973, D4438, D6472). The species has not been found outside southeastern Colorado, although Rubey and Bass (1925, p. 48) recorded something similar to it in central Kansas.

Puebloites spiralis Cobban and Scott, n. sp.

Plate 18, figures 1–5; plate 19, figures 1–6

This species is based on 12 segments from ammonites characterized by a low open helical coil. The rather even curves of the segments suggest a symmetrical spire. Whorl heights range from 6 to 20 mm. Ornamentation consists of narrow fairly sharp annular ribs that are strongest on the venter and weakest on the dorsum. They are closely spaced on most specimens and commonly have an index of 6–8, but this index may be as low as 4. The ribs conspicuously cross the flanks, venter, and dorsum obliquely. None of the specimens shows more than a bit of the suture. The holotype (pl. 18, figs. 4, 5) is a coarsely ribbed body chamber 62 mm in diameter. Its whorl section is nearly circular.

Puebloites spiralis closely resembles the fragment of a heteromorph from South Africa described by Woods (1906, p. 340, pl. 44, figs. 3a–d) as *Hamites (Anisoceras)* sp.

Types.—Holotype, USNM 163830; paratypes, USNM 163831–163834.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS locs. D3977, D6122, D6147). Aside from the occurrences near Pueblo, this species is represented in the U.S. Geological Survey collections by only a few fragments from areas near Model, Colorado Springs, and Boulder, Colo.

Puebloites greenhornensis Cobban and Scott, n. sp.

Plate 19, figures 7–28

This species is characterized by a low open helicoid coil consisting of hamitid limbs that have densely ribbed early whorls and coarsely ribbed later whorls. It is represented by 80 somewhat crushed internal molds from the middle of the Bridge Creek Limestone Member in the Rock Canyon section.

The smallest specimens are fragments of straight or curved limbs 4–5 mm in whorl height. The largest specimens, as much as 25 mm in whorl height, are parts of curved limbs. Ribs are rather sharp, are narrower than the interspaces, and obliquely cross the flanks, venter, and dorsum. They are very closely spaced (index of 5–9, commonly 8) on the smaller whorls. The spacing widens considerably when the whorls attain a diameter of 12–15 mm, and the larger whorls ordinarily have a rib index of 4–5.

The holotype (pl. 19, figs. 14–16) is a fragment of a gently curved limb 32.5 mm long that has an elliptical costate section in its middle which is 16.1 mm high and 12.0 mm wide. It is partly septate, but only small traces of the suture are visible.

The species closely resembles *Puebloites corrugatus* (Stanton) in its mode of coiling as well as in its densely ribbed early whorls, but it distinctly differs from Stanton's species in the coarsely ribbed later whorls.

Types.—Holotype, USNM 163835; paratypes, USNM 163836–163846.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 105 (USGS locs. D3979, D4305, D4442, D6124, D6149, D6479, D6535, 22875, 22876) and 113 (USGS locs. D4443, D6483). The

species has been found at several other localities in southeastern Colorado.

Family BACULITIDAE Meek, 1876

Genus SCIPONOCERAS Hyatt, 1894

Type species.—Hamites baculoides Mantell, 1822.

Matsumoto (1959d, p. 103) presented the following excellent definition of *Sciponoceras*:

> Straight shell resembling *Lechites*, with prorsiradiate constrictions on the internal mould; section slightly to moderately compressed, subcircular to elliptical. Surface normally with prorsiradiate ribs which may be weakened and in the latest species slightly rursiradiate on the dorsal third. Aperture facing dorsally, with ventral rostrum and in some forms with lateral lappets. Suture similar to that of *Lechites*, with bifid lateral lobes and trifid, small, antisiphonal lobe, complex in some forms but simple in others.

The genus has a worldwide distribution in strata of Cenomanian and Turonian age.

Sciponoceras gracile (Shumard)

Plate 17, figures 9–29; text figure 18

1860. *Baculites gracilis* Shumard, Acad. Sci. St. Louis Trans., v. 1, p. 596.
1877. *Baculites ovatus* [part] Say. White, U.S. Geog. and Geol. Surveys West of 100th Meridian (Wheeler), v. 4, pt. 1, p. 199, pl. 19, figs. 4b, c.
1894. *Baculites gracilis* Shumard?. Stanton, U.S. Geol. Survey Bull. 106, p. 166, pl. 36, figs. 1–3 [1893 imprint].
1910. *Baculites gracilis* Shumard. Grabau and Shimer, North American index fossils, v. 2, p. 179, fig. 1432.
1926. *Baculites gracilis* Shumard. Scott, Études stratigraphiques et paléontologiques sur les terrains crétacés du Texas, Univ. Grenoble Fac. Sci., thesis, p. 153.
1928. *Baculites gracilis* Shumard. Adkins, Texas Univ. Bull. 2838, p. 206, pl. 24, fig. 3.
1942. *Baculites gracilis* Shumard. Moreman, Jour. Paleontology, v. 16, no. 2, p. 210.
1944. *Baculites gracilis* Shumard. Shimer and Shrock, Index fossils of North America, p. 583, pl. 240, fig. 9.
1951. *Sciponoceras gracile* (Shumard). Cobban, Am. Assoc. Petroleum Geologists Bull., v. 35, no. 10, p. 2185.
1955. *Sciponoceras gracile* (Shumard). Cobban, Billings Geol. Soc. Guidebook, 6th Ann. Field Conf., Sweetgrass arch–Disturbed belt, Montana, 1955, p. 202, pl. 2, fig. 3.
1959. *Sciponoceras gracile* (Shumard). Matsumoto (1959d), Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, v. 8, no. 4, p. 107, text fig. 3.

Shumard's type specimen is apparently lost. It was said to have come from an ironstone concretion on Shawnee Creek in Grayson County, Tex., where it was associated with Shumard's *Ancyloceras* [*Allocrioceras*] *annulatus*. Adkins (1928, p. 207, 217) and Stephenson (1953, p. 65) questioned this locality because Shawnee Creek lies wholly in Comanche strata (Bullard, 1931, geol. map). However, the Eagle Ford Shale, which should be the source of Shumard's specimens, crops out within a few miles of the head of Shawnee Creek (Bullard, 1931, p. 60). Shumard probably used Shawnee Creek in an area sense because it was the nearest locality that had a geographic name.

Shumard described his species as having a very slender gradually tapering shell whose cross section is broadly ovate to subcircular. Ornamentation was said to consist of "moderately prominent, rounded costae, which on the dorsum [venter] are distinct and arched towards the aperture, and on the sides curve obliquely backwards and downwards to the ventral [dorsal] margin, before reaching which they become nearly obsolete." The largest specimen in his collection was said to be half an inch in diameter, but most specimens did not exceed a quarter of an inch.

The specimens described by White (1877, p. 199, pl. 19, figs. 4b, c) and Stanton (1893, p. 166, pl. 36, figs. 1–3) came from the Tropic Shale of southern Utah. Large collections from the Tropic Shale made since the publication of White's and Stanton's papers show that this species has an initial coil of one complete whorl beyond the protoconch, attains a diameter of at least 19 mm, and ends in an upturned ventral rostrum and dorsal-facing aperture. The cross section is circular up to a diameter of about 2 mm; at greater diameters the height slightly exceeds the width, the result being a stout elliptical shape. Ventral ribs first appear at a diameter of about 3–4 mm, and constrictions appear at a diameter between 4.5 and 5 mm. The ribs ordinarily have an index of 4–5, and the constrictions usually have an index of 0.7–1.0. On some individuals, the constrictions completely encircle the internal molds and cross the dorsum as a faint forward arching. The suture is simple for the genus; the saddles and *E*, *L*, and *U* are rectangular like those in the early forms of *Baculites*.

Sciponoceras gracile is a common fossil in the lower beds of the Bridge Creek Limestone Member in southeastern Colorado. Over 100 specimens are present in the collections from the Rock Canyon section near Pueblo. Almost all are internal molds, and many are somewhat crushed or distorted. A very few specimens retain a little of their nacreous shell material. The specimens range in diameter from 5 to 18 mm. Rib indices range from 2 to 5. Constrictions are commonly spaced slightly more

than a shell diameter apart and have an index range of 0.7–1.4. None of the specimens from the Rock Canyon section has the aperture preserved. A laterally crushed specimen (pl. 17, figs. 23, 24) from a nearby area (text fig. 16, loc. 13) reveals an aperture typical of the genus. The margins are slightly flared, and the ribbing, although weakened, extends to the tip of the ventral rostrum. Several specimens have the sutures preserved (fig. 18).

Types.—Hypotypes, USNM 163847–163855.

Occurrences.—Rock Canyon section, beds 67 (USGS locs. D3973, D4438, D6472) and 73 (USGS locs. D4444, D6484, D6536); Hinkle Ranch section, bed 3 (USGS loc. D4867).

The species is widely distributed in the western interior region where it had been selected as a leading guide fossil for the base of the Turonian (Cobban and Reeside, 1952, p. 1017). It has been recorded from the Sweetgrass arch area of northwestern Montana (Cobban, 1951, p. 2186; 1955, p. 202), from the west flank of the Powder River Basin in north-central Wyoming (Hose, 1955, p. 98), from the north flank of the Black Hills uplift in the southeast corner of Montana (Cobban, 1951, p. 2185), from central Kansas (Rubey and Bass, 1925, p. 48; Hattin, 1965b, p. 15), from the Front Range area in northern Colorado (Scott, 1962, p. L13), from the northeast flank of the San Juan Basin in north-central New Mexico (Landis and Dane, 1967, p. 5), from the Black Mesa area of northeastern Arizona (Repenning and Page, 1956, p. 267), and from south-central Utah (Stanton, 1893, p. 35, 166).

Sciponoceras gracile occurs in the Turonian of England, according to Mr. C. W. Wright (in Matsumoto, 1959d, p. 106). It may also be present in Germany if *Baculites subbaculoides* Geinitz (1871–75, p. 281, pl. 63, fig. 1) is *S. gracile*, as suggested by Wright (1963, p. 600). The specimen Collignon (1931, p. 94, pl. 9, fig. 28, text fig. 26) described and illustrated as *Baculites gracilis* Shumard from the Cenomanian of northern Madagascar has somewhat triangular lobes and saddles and probably is not Shumard's species. Boule, Lemoine, and Thevenin (1907, p. 44) also assigned to *B. gracilis* small baculites having simple sutures from the Cenomanian of Madagascar but did not present any illustrations.

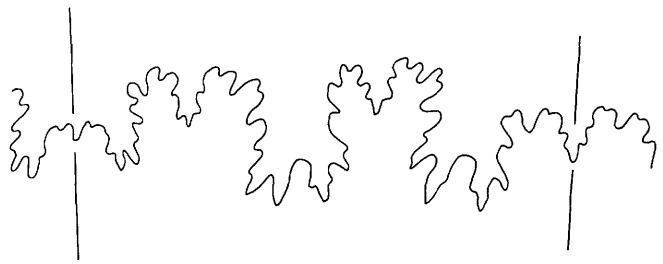

FIGURE 18.—Second from last suture (× 6) at a diameter of 8 mm of a specimen (USNM 163850) of *Sciponoceras gracile* (Shumard) from USGS locality D6472 (text fig. 16, loc. 102). This specimen is shown on plate 17, figures 15, 16.

Genus BACULITES Lamarck, 1799

Type species.—*Baculites vertebralis* Lamarck, 1801.

This genus comprises Upper Cretaceous ammonites that are straight to slightly curved in all their growth except for an initial planospiral coil of one to two whorls. The cross section is ordinarily oval, but it may be elliptical, subcircular, circular, or triangular. The adult aperture has a short dorsal lappet, lateral sinus, and a longer ventral lappet that is either straight or partly curved upward. The venter is commonly crossed by ribs that have conspicuous forward arching. The flank may be ornamented by arcuate ribs whose concave side is forward or by arcuate tubercles or nodate tubercles. The suture, which is simple to complex, has bifid *E*, *L*, and *U*, undivided *I*, and three bifid saddles.

Baculites has a worldwide distribution in strata of Turonian through Maestrichtian age. It evolved from *Sciponoceras* by losing the constrictions and lengthening and straightening the ventral rostrum.

Baculites cf. B. yokoyamai Tokunaga and Shimizu

Plate 20, figures 15–21

Small baculites that have smooth flanks and finely ribbed venters occur sparsely in the upper two-thirds of the Bridge Creek Limestone Member in the Rock Canyon and Hinkle Ranch sections. The specimens are either impressions or distorted and crushed internal molds 5–21 mm in diameter. None has the suture preserved. The cross section is elliptical. Ventral ribbing is dense, and the index is 6–10. The specimens closely resemble *Baculites yokoyamai* Tokunaga and Shimizu (1926, p. 195, pl. 22, figs. 5a, b; pl. 26, fig. 11; also Matsumoto and Obata, 1963, p. 30, pl. 8, fig. 5; pl. 10, figs. 1–6; pl. 11, figs. 1, 4, 5; pl. 12, fig. 3; pl. 14, fig. 4; text figs. 72–87) from the Coniacian of Japan and may be that species.

Types.—*Hypotypes*, USNM 163856–163858.

Occurrences.—

Bed	USGS locality	Bed	USGS locality	Bed	USGS locality
Rock Canyon section:					
90	D3976	105	D4442	113	D6483
102	D6134		D6479	118	D3981
	D6480	113	D3980	131	D3983
103	D6481		D4443		

Bed	USGS locality	Bed	USGS locality	Bed	USGS locality
Hinkle Ranch section:					
42	D4877	57	D4880	94	D4896
46	D4878	70	D4885	102	D4898
51	D4879	76	D4888	106	D4900
53	12768	86	D4893		

Small smooth-flanked baculites of this type occur in the Greenhorn Limestone of central Kansas (Hattin, 1965b, p. 16) and in the upper part of the Greenhorn Formation on the northeast flank of the Black Hills uplift in western South Dakota (U.S. Geol. Survey collections).

Baculites calamus Morrow

Plate 34, figure 7

1935. *Baculites calamus* Morrow, Jour. Paleontology, v. 9, no. 6, p. 473, pl. 49, figs. 8a, b.

Baculites calamus Morrow is a small species characterized by closely spaced weak lateral ribs and a very simple suture. It was described by Morrow from the upper part of the Bridge Creek Member of the Greenhorn Limestone in Hamilton County, Kans. The species is uncommon; we found it in only one bed at one locality.

Type.—Hypotype, USNM 163859.

Occurrence.—Hinkle Ranch section, bed 98 (D4897).

Family ANISOCERATIDAE Hyatt, 1900

Genus ANISOCERAS Pictet, 1854

Type species.—Hamites saussureanus Pictet, 1847.

Spath (1923–43, p. 542) presented an excellent definition of *Anisoceras,* as follows:

> Coiling very irregular, generally not in one plane, shell being an open, helicoid spire in young; later, more or less prolonged and with apertural portion bent back in the form of a hook, when complete. Ornamentation consisting of transverse ribs with generally two ventral and two lateral tubercles, typically connected in button-and-loop fashion and often separated by untuberculate intermediaries. Ribbing generally faint on dorsal area. Suture-line with rather high external lobe, deep, bifid first and second lateral lobes, and dorsal lobe seldom larger than incisions in bifid external and lateral saddles.

Owing to the fragility of the open coiled shell, almost all specimens illustrated have been small fragments, but Luppov and Drushchits (1958, pl. 23, figs. 8a, b) illustrated a remarkable specimen from the Albian of Russia that shows the helicoid spire as well as part of a straight limb.

Arkell, Kummel, and Wright (1957, p. L220) noted that the genus ranges from late Albian to late Turonian and that it has been found in Europe, north Africa, east Africa, Madagascar, Pakistan, India, Texas, and Mexico.

Anisoceras cf. A. plicatile (J. Sowerby)

Text figure 19

The genus *Anisoceras* is represented by a single crushed fragment from just above the Thatcher Limestone Member. The fragment represents a specimen that has a whorl height of about 10 mm and a width of possibly 9 mm. The specimen has blunt lateral and ventral tubercles connected by two or three narrow radial ribs, and the sets of tubercles are separated by two or three thin nontuberculate ribs. The specimen closely resembles the drawing of the holotype of *A. plicatile* (James Sowerby, 1819, p. 59, pl. 234, fig. 1) and almost exactly duplicates part of the specimen illustrated by Spath (1923–43, text figs. 196f–h) from the lower Cenomanian of England. It also closely resembles the specimen of *A. plicatile* described from the lower Cenomanian of Poland by Cieśliński (1959, p. 36, pl. 4, fig. 2) and the specimens from the lower Cenomanian illustrated by Collignon (1964, pl. 319, figs. 1363, 1364; pl. 325, fig. 1453).

Figured specimen.—USNM 163860.

Occurrence.—Rock Canyon section, bed 55 (USGS loc. D3970).

Anisoceras sp.

Plate 17, figures 5, 6

A single small specimen in which only one side is

FIGURE 19.—Lateral view (× 3) of a crushed specimen of *Anisoceras* cf. *A. plicatile* (J. Sowerby) from the Thatcher Limestone Member at USGS locality D3970. The venter is at the left. USNM 163860.

preserved was found in the lower part of the Bridge Creek Limestone Member in the Rock Canyon section. It is 15 mm long, uniformly curved, and abruptly tapered. Ribbing is dense and the index is 7 or 8. Each rib is narrow, and every third or fourth is a little higher than the intermediate ribs. Four poorly defined blunt tubercles are present on the outer part of the flank, but the ventral tubercles cannot be seen.

The specimen resembles the Cenomanian *Anisoceras plicatile* (James Sowerby, 1819, p. 59, pl. 234, fig. 1) in its curvature, degree of taper, and dense ribbing, but the tubercles are farther apart on the Pueblo species and the periodic raised ribs are lacking on Sowerby's specimen. Schlüter (1871–72, p. 114, pl. 34, figs. 6–8), however, assigned to *A. plicatile* a specimen that has periodic raised ribs.

Figured specimen.—USNM 163861.

Occurrence.—Rock Canyon section, bed 86 (USGS loc. D3975).

Genus IDIOHAMITES Spath, 1925

Type species.—*Hamites tuberculatus* J. Sowerby, 1818.

Spath (1923–43, p. 582) defined this genus as follows:

> Laterally flattened shells, with hamitid or ancyloceratid coiling, in which the ventro-lateral edges are provided with tubercles. Lateral tubercles present in some, but never strong. Ribbing radial or projected, intermediate ribs sometimes present between the tuberculate costae. Suture-line hamitid, with bifid lateral lobes and bifid saddles, but dorsal (internal) lobe sometimes subtrifid.

According to Arkell, Kummel, and Wright (1957, p. L220), *Idiohamites* is known from the upper Albian and Cenomanian of western Europe, north Africa, Madagascar, and Texas. Daugherty and Powell (1963, p. 2062) also recorded it from Coahuila, Mexico.

Idiohamites sp.

Plate 13, figures 1–4

Several crushed fragments of heteromorphs from ferruginous concretions in the Graneros Shale seem to represent a densely ribbed species of *Idiohamites* that is further characterized by lateral tubercles. Ribs are sharply rounded, narrower than the interspaces, and numerous, and they have indices of as much as 8 or 9. Lateral tubercles are small, conical, and ordinarily occur on every fourth or fifth rib. The ventrolateral tubercles are also conical but larger. On one individual (pl. 13, fig. 1) tubercles are present on every third rib.

Figured specimens.—USNM 163862–163865.

Occurrence.—Known only from the Graneros Shale at USGS locality D6726 (fig. 16, loc. 137) where the specimens are associated with *Acanthoceras muldoonense* n. sp.

Genus ALLOCRIOCERAS Spath, 1926

Type species.—*Crioceras ellipticum* (Mantell) of Woods, 1896.

Spath (1926a, p. 80) did not define *Allocrioceras*, but rather he designated as the type a specimen described by Woods (1896, p. 84, pl. 3, figs. 9, 9a) as *Crioceras ellipticum* (Mantell) and merely remarked: "No one will now maintain the generic identity of the Turonian forms with the true Hauterivian *Crioceras*." Woods' specimen is a segment about 68 mm long whose whorl height is nearly 28 mm of an open-coiled ammonite. The lateral view and cross section suggest that this segment is from a planospirally coiled part of an ammonite. Ornamentation consists of undivided ribs numbering four or five for the shell diameter and bearing nodate ventrolateral tubercles. The suture, which is rather simple for a heteromorph, has long and narrow bifid *L* and *U* lobes and wide bifid saddles.

Arkell, Kummel, and Wright (1957, p. L220) defined *Allocrioceras* as having irregular coils largely in one plane but having the early whorls distinctly helical and twisted. They noted further that ornamentation consists of annular ribs which have a pair of ventrolateral tubercles joined by a single rib on the venter.

Allocrioceras seems to be confined to the Turonian. Outside the United States, the genus has been recorded from England (Woods, 1896, p. 84, pl. 3, figs. 9, 9a, as *Crioceras ellipticum;* Wright and Wright, 1951, p. 15), from Germany (Schlüter, 1876, p. 164, pl. 43, figs. 1, 2, as *Crioceras ellipticum*), from Mexico (Powell, 1963a, p. 310, 322, pl. 31, fig. 18, text fig. 3a; 1965, p. 518), and from Japan (Matsumoto, 1959b, p. 65; Matsumoto and Obata, 1963, p. 18).

A segment of an open-coiled heteromorph from Texas described by Shumard (1860, p. 595) as *Ancyloceras annulatus* and one from Utah described by White (1877, p. 203, pl. 19, figs. 2a–d) as *Helicoceras pariense* were assigned to *Allocrioceras* by Adkins (1932, p. 434, 437) and Moreman (1942, p. 208), and this assignment has been accepted by all later authors. Excellent specimens from Texas and Utah collected since the publication of Shumard's and White's papers reveal the following sequence of coiling: (1) An initial tight coil of one full whorl,

(2) a straight limb 3–12 mm long, (3) a loose open planospiral coil of about two whorls, and (4) a final open helical coil. Although these specimens do not have the early whorls "distinctly helical and twisted" as noted by Arkell, Kummel, and Wright (1957, p. L220), we are accepting the assignment to *Allocrioceras* because of the close similarity in form, ornamentation, and suture pattern of the Texas and Utah specimens to the specimens illustrated by Woods.

Allocrioceras annulatum (Shumard)

Plate 20, figures 1–14

1860. *Ancyloceras annulatus* Shumard, Acad. Sci. St. Louis Trans., v. 1, p. 595.
1877. *Helicoceras pariense* White, U.S. Geog. and Geol. Surveys West of 100th Meridian (Wheeler), v. 4, pt. 1, p. 203, pl. 19, figs. 2a–d.
1883. *Ancyloceras annulatum* Shumard. White, U.S. Geol. and Geog. Survey Terr. (Hayden) 12th Ann. Rept., pt. 1, p. 39, pl. 18, figs. 10a, b.
1889. *Ancyloceras? annulatus* Shumard. Hill, Texas Geol. Survey Bull. 4, p. 52.
1894. *Helicoceras pariense* White. Stanton, U.S. Geol. Survey Bull. 106, p. 164, pl. 35, figs. 2–4 [1893 imprint].
1894. *Exiteloceras pariense* (White). Hyatt, Am. Philos. Soc. Proc., v. 32, no. 143, p. 577.
1910. *Exiteloceras pariense* (White). Grabau and Shimer, North America index fossils, v. 2, p. 206, fig. 1475.
1926. *Helicoceras pariense* White. Scott, Études stratigraphiques et paléontologiques sur les terrains crétacés du Texas, Univ. Grenoble Fac. Sci., thesis, p. 152.
1927. *Helicoceras pariense* White. Moreman, Jour. Paleontology, v. 1, no. 1, p. 92, pl. 14, fig. 3.
1928. *Exiteloceras pariense* (White). Adkins, Texas Univ. Bull. 2838, p. 212, pl. 26, fig. 3.
1931. *Allocrioceras* n. sp. Adkins, Texas Univ. Bull. 3101, p. 63, pl. 2, figs. 6, 8.
1933. *Allocrioceras pariense* (White). Adkins, Texas Univ. Bull. 3232, v. 1, p. 434, 437 [1932 imprint].
1942. *Allocrioceras annulatum* (Shumard). Moreman, Jour. Paleontology, v. 16, no. 2, p. 208.
1942. *Allocrioceras pariense* (White). Moreman, Jour. Paleontology, v. 16, no. 2, p. 208.
1944. *Exiteloceras pariense* (White). Shimer and Shrock, Index fossils of North America, p. 593, pl. 246, figs. 7–9.
1963. *Allocrioceras annulatum* (Shumard). Swensen, Brigham Young Univ. Geology Studies, v. 9, pt. 2, p. 76, pl. 1, fig. 9; pl. 3, figs. 1, 2, 10, 12; text figs. 17, 18 [1962 imprint].
1963. *Allocrioceras pariense* (White). Swensen, Brigham Young Univ. Geology Studies, v. 9, pt. 2, p. 77, pl. 2, figs. 12, 13; text fig. 19 [1962 imprint].
1965. *Allocrioceras annulatum* (Shumard). Clark, Geol. Soc. America Mem. 95, p. 31, pl. 1, fig. 9; pl. 5, figs. 1, 2, 10, 12; text figs. 10B, 11.
1965. *Allocrioceras pariense* (White). Clark, Geol. Soc. America Mem. 95, p. 31, pl. 2, figs. 12, 13; text fig. 12A.
[Not] 1923. *Helicoceras pariense* White?. Reeside, U.S. Geol. Survey Prof. Paper 132–B, p. 31, pl. 20, figs. 5, 6.

The original specimens were collected by Dr. G. G. Shumard from a clay ironstone concretion near Shawnee Creek, Grayson County, Tex., and described by his brother (Shumard, 1860, p. 595) as follows:

> We have merely fragments of this small species, consisting of about two-thirds of the outer coil of the spire and parts of the non-septate portion. The former is very slender, and forms a broad curve on the same plane; sides and dorsum rounded, the latter being somewhat the less convex; transverse section nearly circular; surface marked with numerous prominent, oblique, simple rings, which are strongest on the dorsal [ventral] half of the volution. Each annulation is provided with two small, rather prominent tubercles, one of which is situated on each side of the dorsum [venter].
>
> It is not possible from any of the specimens under examination to determine the form of the septae.
>
> The transverse diameter of the largest fragment of the outer volution in the collection is a little more than the third of an inch.

Shumard did not present illustrations of his species, but a drawing of the holotype prepared by Shumard was published by White (1883, pl. 18, figs. 10a, b) after Shumard's death. It reveals a rib index of 3.

White (1877, p. 203, pl. 19, figs. 2a–d) described a segment of a heteromorph from southern Utah, which he named *Helicoceras pariense;* he noted: "The species described by Shumard without figures under the name *Ancyloceras annulatus* seems to be closely related to this Utah form and may be identical with it."

White's holotype (pl. 20, figs. 1–3) is an uncrushed fragment about 55 mm long whose end diameters (costal) are 14.3 and 8.5 mm. The intercostal section is nearly circular. Ribs, which are strong and narrowly rounded, cross the whorl obliquely and number three for the shell diameter. The ribs flatten a little on the venter, and the flattened area is bounded on each end by a nodate ventrolateral tubercle. Opposite tubercles are connected by a pair of low riblets that diverge toward the middle of the venter and bound the flattened area of the rib on its adapical and adoral edges. This looped ribbing on the middle of the venter was not described or illustrated by White. The suture of the holotype was described by White but not illustrated.

Stanton (1893, pl. 35, fig. 2) later figured it. The suture is very simple for a heteromorph. The lobes *L* and *U* are very narrow, long, and bifid, and lobe *L* is a little larger than *U*. The saddles are wide, bifid, and barely incised.

White's specimen came from the Tropic Shale a few miles southeast of the former settlement of Paria in Kane County, Utah. Many excellent specimens from the Tropic Shale are now available for study. These show that the early whorls tend to be higher than wide, whereas the later whorls are more circular. Most ribs and tubercles are rounded, but on a few individuals the ribs are sharp and the tubercles pointed. Most specimens have a rib index of 3 or 4. Ribs are usually well rounded to broadly rounded on the venter, but they may be flattened or even have a middle depressed area like that of White's specimen. Tubercles may appear at any diameter from 2 to 10 mm.

Allocrioceras annulatum is represented in the collections from the Pueblo area by about 30 fragments from near the base of the Bridge Creek Limestone Member. None has whorl sections less than 5 mm in diameter, and most are from the helical spire. These fragments do not differ from specimens of similar size from the Tropic Shale of southern Utah and from the Eagle Ford Shale of Texas.

Types.—Hypotypes, USNM 163866–163870.

Occurrences.—Rock Canyon section, bed 67 (USGS locs. D3973, D4438, D6472). The species has been recorded (as *Allocrioceras pariense* or *Helicoceras pariense*) in the western interior region from the Bighorn Mountains area of Wyoming (Hose, 1955, p. 98) and the Black Hills (Cobban, 1951, p. 2185), south to the Denver area (Scott, 1962, p. L13), and east to central Kansas (Rubey and Bass, 1925, p. 48; Hattin, 1965b, p. 15). The species is common in southern Utah (Swensen, 1962, p. 57, 58, 76–78), and it is known also from the nearby Black Mesa area of northeastern Arizona (Repenning and Page, 1956, p. 267, as *Helicoceras* sp.) and from the San Juan Basin of northwestern New Mexico (U.S. Geol. Survey collections).

Family TURRILITIDAE Meek, 1876

Genus TURRILITES Lamarck, 1801

Type species.—*Turrilites costatus* Lamarck, 1801.

Arkell, Kummel, and Wright (1957, p. L222) characterized this genus as a tight spire having an acute apical angle and ornamented by weak to strong ribs that sometimes have three or four rows of equal numbers of tubercles. Forms not having tubercles were considered to belong to a separate genus by Dubourdieu (1953, p. 42, 44), who proposed the name *Turbinites*. Breistroffer (1953, p. 1351) pointed out that *Turbinites* was preoccupied and replaced it with *Euturrilites*.

The earliest whorls of the type species of *Euturrilites*—*Turrilites scheuchzerianus* Bosc—apparently have bullate tubercles or nodelike ribs, according to the illustrations by Sharpe (1856, pl. 23, figs. 2, 3); a small specimen loaned to us by Mr. C. W. Wright (C.W.W. 2382) shows ornamentation that can be described either as bullate tubercles or nodelike ribs. The distinction between *Turrilites* and *Euturrilites* does not seem very great, especially in the early whorls. Reyment (1955, p. 13), Arkell, Kummel, and Wright (1957, p. L222), and Wiedmann (1962, p. 192) considered *Euturrilites* to be a subgenus of *Turrilites*; Reyment remarked: "*** It may eventually prove desirable to include this group [*Euturrilites*] under *Turrilites* without any particular distinction." We, likewise, believe that the distinction between these turrilitids is of no more than subgeneric rank.

Turrilites (Turrilites) acutus Passy

Plate 14, figure 6; text figure 20

1832. *Turrilites acutus* Passy, Description géologique du Département de la Seine-Inférieure, atlas, p. 9, pl. 16, figs. 3, 4.
1857. *Turrilites wiestii* Sharpe, Description of the fossil remains of Mollusca found in the Chalk of England, Palaeontographical Soc. [Mon.], p. 67, pl. 27, figs. 8, 9a, b, 14a, b, 17 [1856 imprint].
1862. *Turrilites tevesthensis* Coquand, Géologie et paléontologie de la région sud de la Province de Constantine, p. 174, pl. 2, fig. 5.
1876. *Turrilites acutus* Passy. Schlüter, Palaeontographica, v. 24, p. 127, pl. 38, figs. 15, 16.
1907. *Turrilites acutus* Passy. Crick, Third and final report of the Geological Survey of Natal and Zululand, pt. 3, p. 176, pl. 11, figs. 3, 3a, 4, 4a.
1910. *Turrilites acutus* Passy. Pervinquière, Soc. Géol. France Mém. 42, Paléontologie, v. 17, pts. 2–3, p. 51, pl. 14, figs. 8–11; text fig. 23.
1916. *Turrilites wiestii* Sharpe. Douvillé, Palaeontologia Indica, Mem. 3, new ser., v. 5, p. 5, pl. 3, fig. 2.
1936. *Turrilites acutus* Passy. Venzo, Palaeontographica Italica, v. 36, p. 115, pl. 10, fig. 10.
1947. *Turrilites acutus* Passy. Wright, *in* Arkell, W. J., The geology of the country around Weymouth, Swanage, Corfe, and Lulworth, Great Britain Geol. Survey Mem., text fig. 41–3.
1953. *Turrilites dearingi* Stephenson, U.S. Geol. Survey Prof. Paper 242, p. 197, pl. 44, figs. 6–8 [1952 imprint].
1964. *Turrilites acutus* Passy. Collignon, Atlas des fossiles caractéristiques de Madagascar (Ammonites), Pt. 11, (Cénomanien), Republique Malgache Service Géol., Tananarive, p. 47, 53, pl. 329, fig. 1473; pl. 331, fig. 1489.

1965. *Turrilites (Turrilites) acutus* Passy. Clark, Geol. Soc. America Mem. 95, p. 54, pl. 19, fig. 7; text fig. 15.
1965. *Turrilites (Turrilites) dearingi* Stephenson. Clark, Geol. Soc. America Mem. 95, p. 55, pl. 20, fig. 4.

Passy (1832, atlas, p. 9, pl. 16, figs. 3, 4) illustrated two specimens of his *Turrilites acutus* from the Cenomanian of the Rouen area in France. These have three rows of equal numbers of sharp conspicuous tubercles connected by sharp ribs that obliquely cross the entire flank of the whorl. The row of largest tubercles is located near the base of the adapical half of the whorl. A row of slightly smaller tubercles is present near the base of the whorl, and a row of still smaller tubercles is located at the base. Although the basal tubercles are smaller than the others, they are nevertheless conspicuous and create a zigzag line of contact between the whorls. The apical angle is about 35° for the one specimen that shows a side view.

Crick (1907, p. 176, pl. 11, figs. 3, 3a, 4, 4a) described two specimens from South Africa that closely resemble those of Passy. Crick's specimens have apical angles of 30° and 43° and show the crenulated commissure. Pervinquière (1910, pl. 14, figs. 8a, 10) illustrated two specimens from Algeria that have apical angles of 23° and 30° but have a smooth area between the adapical and abapical rows of tubercles. Examples of *T. acutus* illustrated by Schlüter (1876, pl. 38, fig. 15) and Collignon (1964, pl. 329, fig. 1473; pl. 331, fig. 1489) also reveal a smooth area between these rows. Sharpe (1856, p. 67, pl. 27, figs. 8, 9a, b, 17) described a new species, *T. wiestii*, a form from England considered to be a synonym of *T. acutus* by later authors. The smaller of Sharpe's figured specimens closely resembles *T. acutus*, but the larger specimen apparently lacks ribs. The turrilitid from the Woodbine Formation of Texas described by Stephenson (1952, p. 197, pl. 44, figs. 6–8) as the new species *T. dearingi* resembles the larger of Sharpe's specimens in that it lacks distinct ribs, although Stephenson observed that some of the adapical tubercles revealed "a slight tendency to vertical elongation."

The suture of *T. acutus* was illustrated by Sharpe (1856, pl. 27, fig. 17) and Schlüter (1876, pl. 38, fig. 16). It is moderately simple for a turrilitid and is further characterized by a very wide first lateral saddle that is rather shallow and more or less symmetrically bifid.

One crushed specimen from the Thatcher Limestone Member of the Graneros Shale closely resembles the specimens in Passy's illustrations in that it has high sharp tubercles and ribs. The specimen is 51 mm high and has an apical angle of about 35°. It consists of parts of four whorls that have a zigzag commissure owing to the strong tubercles at the base of the whorls. The adapical row of tubercles is the largest, but the other two rows are strong and conspicuous. The specimen is septate, but only part of the suture is visible (fig. 20).

Turrilites acutus is closely allied to *T. costatus* Lamarck, and some authors (for example, d'Orbigny, 1840–42, p. 598, 601) considered *T. acutus* to be only a variety of *T. costatus*. Wright (1963, p. 613), on the other hand, suggested that *T. costatus* gave rise to *T. acutus*. *T. costatus* has three rows of tubercles as does *T. acutus*, but they are less pronounced, and the basal row is smaller and does not create a conspicuous crenulated commissure.

Type.—Hypotype, USNM 163871.

Occurrence.—Thatcher Limestone Member of Graneros Shale at USGS locality D3002 (fig. 16, loc. 85). *Turrilites acutus* has been recorded from the Cenomanian of England, France, Germany, Italy, Algeria, South Africa, Madagascar, Japan, and Texas (in Texas as *T. dearingi* Stephenson).

Turrilites (Turrilites) acutus Passy americanus Cobban and Scott, n. subsp.

Plate 11, figures 1–11; text figures 21

Many crushed fragments of turrilites from the limestone concretions that are associated with the marker bentonite bed differ from the specimens in Passy's illustrations mainly in having much smaller tubercles at the base of the whorls and in having shorter ribs. The basal tubercles are conical to somewhat bullate and lie very close to the second row of tubercles. The tubercles are barely covered by the next younger whorl; but owing to their very small size, the contact between the whorls is not

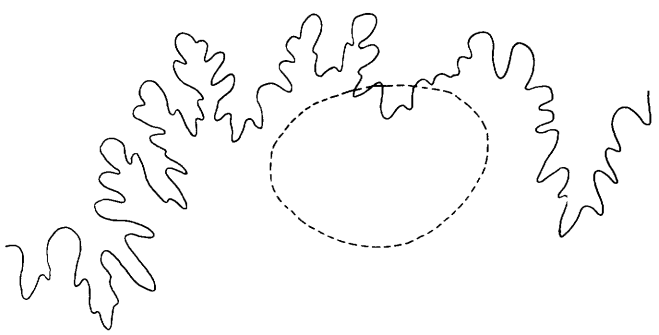

FIGURE 20.—Part of the suture (× 8) of *Turrilites* (*Turrilites*) *acutus* Passy from the Thatcher Limestone Member of the Graneros Shale at USGS locality D3002 (fig. 16, loc. 85). The venter is to the left of the drawing. USNM 163871.

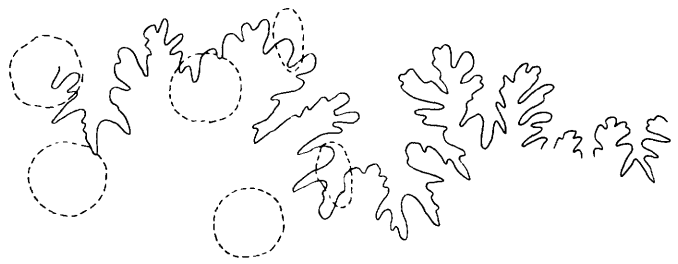

FIGURE 21.—Part of the suture (× 8) of *Turrilites* (*Turrilites*) *acutus* Passy subsp. *americanus* Cobban and Scott from USGS locality 22887 (fig. 16, loc. 48). USNM 163883.

conspicuously crenulated as it is shown in many illustrations of *Turrilites acutus* (Sharpe, 1856, pl. 27, fig. 9a; Crick, 1907, pl. 11, figs. 3, 4; Pervinquière, 1910, pl. 14, figs. 8a, 10; Collignon, 1964, pl. 329, fig. 1473; pl. 331, fig. 1489). The second and third rows of tubercles are conical and sharp, and the area between the rows is smooth. The tubercles of the third (adapical) row, which are about twice as large and high as those of the second row, pass upward into ribs that disappear short of the edge of the whorl. The subspecies is also a little more densely tuberculated than the typical *T. acutus*.

Only a few of the specimens consist of more than one whorl. The apical angles of these range from 30° to 34°, but larger angles are suggested by fragments of individuals having very low whorls (pl. 11, fig. 9).

A complete suture cannot be seen on any of the specimens. The suture (text fig. 21) is incised to about the same degree as that shown by Schlüter (1876, pl. 38, fig. 16), but the lobes and saddles are shallower.

The type specimen (pl. 11, fig. 7) is part of an adult whorl that had an estimated 25 or 26 tubercles in each row per whorl.

Types.—Holotype, USNM 163872; paratypes, USNM 163873–163883.

Occurrences.—Graneros Shale: Rock Canyon section, bed 69 (USGS loc. 22887). The subspecies has been found at many localities in southeastern Colorado and northern New Mexico in association with *Acanthoceras amphibolum* (U.S. Geol. Survey collections).

Subgenus EUTURRILITES Breistroffer, 1953

Type species.—*Turrilites scheuchzerianus* Bosc, 1801, emended by Sharpe, 1856.

Euturrilites Breistroffer (1953, p. 1351) was proposed as a genus of turrilitids characterized by simple ribs not having tubercles. A very fine specimen illustrated by Sharpe (1856, pl. 26, fig. 1) was designated the type. This specimen, which consists of the last six whorls of an adult, reveals that the middle part of the ribs is depressed on the early whorls. This depression weakens on the succeeding whorls and finally disappears, the result being that the ribs on the last two or three whorls are strong and complete. On the smaller whorls, the depression in the middle of the ribs becomes more pronounced in increasing proximity to the apex of the shell, and the two segments of each rib become nodelike (Sharpe, 1856, pl. 26, figs. 2, 3). Accordingly, *Euturrilites* might be defined better as those turrilitids that have nontuberculate ribs on all or most whorls but may have two rows of equal numbers of nodelike ribs or bullae on the early whorls.

Turrilites (Euturrilites) scheuchzerianus Bosc

Plate 12, figures 2–4

1801. *Turrilites scheuchzeriana* Bosc, in de Déterville, Buffon, Histoire Nat., Coquilles volume, Annex 10, p. 190.

1814. *Turrilites undulata* Sowerby, The mineral conchology of Great Britain, v. 1, p. 171, pl. 75, figs. 1–3.

1822. *Turrilites undulata* Sowerby. Mantell, The fossils of the South Downs, or illustrations of the geology of Sussex, p. 124, pl. 23, figs. 14, 16; pl. 24, fig. 8.

1840. *Turrilites desnoyersi* d'Orbigny, Description des animaux invertébrés; Cephalopodés—Paléontologie française, terrain Crétacé, ser. 1, v. 1, p. 601, pl. 146, figs. 1, 2.

1840. *Turrilites scheuchzerianus* Bosc. d'Orbigny, Description des animaux invertébrés; Cephalopodés—Paléontologie française, terrain Crétacé, ser. 1, v. 1, p. 602, pl. 146, figs. 3, 4.

1844. *Fusus amictus* Goldfuss, Petrefacta germaniae, v. 3, p. 24, pl. 171, fig. 19.

1849. *Turrilites undulata* Sowerby. Brown, Illustrations of the fossil conchology of Great Britain and Ireland, p. 4, pl. 3, figs. 4, 9; pl. 4, fig. 1.

1850. *Turrilites scheuchzerianus* Bosc. Dixon, The geology and fossils of the Tertiary and Cretaceous formations of Sussex, p. 359, pl. 29, fig. 17.

1857. *Turrilites scheuchzerianus* Bosc. Sharpe, Description of the fossil remains of Mollusca found in the Chalk of England, Palaeont. Soc. [Mon.], p. 64, pl. 26, figs. 1–3 [1856 imprint].

1861–62. *Turrilites scheuchzerianus* Bosc. Pictet, Description des fossiles des terrains crétacés de Sainte-Croix, Matériaux pour la paléontologie Suisse, p. 144, pl. 58, fig. 6.

1876. *Turrilites scheuchzerianus* Bosc. Schlüter, Palaeontographica, v. 24, p. 123, pl. 36, figs. 11–15.

1905. *Turrilites scheuchzerianus* Bosc. De Stefano, Milano, Soc. Italiana Sci. Nat. e Mus. Civico Storia Nat., v. 43, pt. 4, p. 381, pl. 8, fig. 10.

1907. *Turrilites scheuchzerianus* Bosc. Pervinquière, Études de paléontologie tunisienne—Pt. 1, Carte Geol. Tunisie, p. 97, text fig. 26.

1907. *Turrilites scheuchzerianus* Bosc. Crick, in Anderson, William, Third and final report of the Geological Survey of Natal and Zululand, pt. 3, p. 173, pl. 11, figs. 1, 1a.
1910. *Turrilites scheuchzerianus* Bosc. Pervinquière, Soc. Géol. France Mém. 42, p. 50, pl. 14, fig. 2.
1916. *Turrilites desnoyersi* d'Orbigny. Douvillé, Palaeontologia Indica Mem. 3, new ser., v. 5, p. 6, pl. 3, figs. 4, 5.
1923. *Turrilites scheuchzeri* var. *mexicana* Böse, Inst. Geol. Mexico Bull. 42, p. 145, pl. 10, figs. 20, 21.
1925. *Turrilites scheuchzerianus* Bosc. Diener, Fossilium Catalogus, 1, Animalia, Pt. 29, p. 84.
1939. *Turrilites scheuchzerianus* Bosc. Dacqué, Bayerische Akad. Wiss. Abt., Math-Naturw. Kl., Abh., new ser., no. 45, p. 193.
1940. *Turrilites scheuchzerianus* Bosc. Fabre, Marseille Univ. Fac. Sci. Annales, ser. 2, v. 14, p. 241, pl. 8, fig. 10.
1943. *Ostringoceras* [*Ostlingoceras*] *scheuchuzerianum* (Bosc). Matsumoto, Kyusyu Imp. Univ. Fac. Sci. Mem., Ser. D, Geology, v. 2, no. 1, p. 132.
1953. *Turbinites scheuchzerianus* (Bosc). Dubourdieu, Algeria Service Carte Géol. Bull., 1st ser., no. 16, p. 44.
1953. *Euturrilites scheuchzerianus* (Bosc). Breistroffer, Acad. Sci. Comptes Rendus, v. 237, no. 21, p. 1351.
1955. *Turrilites* (*Euturrilites*) *scheuchzerianus* Bosc. Reyment, Nigeria Geol. Survey Bull. 25, p. 13, pl. 1, fig. 2.
1957. *Turrilites* (*Euturrilites*) *scheuchzerianus* Bosc. Reyment, Palaeontographica, v. 109, pt. A, nos. 3–6, p. 56, pl. 10, fig. 6.
1959. *Turrilites scheuchzerianus* Roissy. Cieśliński, [Poland] Inst. Geol. Prace, v. 28, p. 45, text fig. 21.
1962. *Turrilites* (*Euturrilites*) *scheuchzerianus*. Bosc. Wiedmann, Palaeontographica, v. 118, pt. A, p. 192, pl. 11, fig. 5.
1964. *Euturrilites scheuchzeri* (Bosc). Collignon, Atlas des fossiles caractéristiques de Madagascar, Pt. 11, Cenomanien, Republique Malgache Service Géol., Tananarive, p. 42, pl. 327, fig. 1464.
1964. *Euturrilites desnoyersi* (d'Orbigny). Collignon, Atlas des fossiles caractéristiques de Madagascar, Pt. 11, Cenomanien, Republique Malgache Service Géol., Tananarive, p. 45, pl. 328, fig. 1471.
1965. *Turrilites* (*Euturrilites*) *scheuchzerianus* Bosc. Clark, Geol. Soc. America Mem. 95, p. 56, pl. 20, figs. 3, 5.
1966. *Euturrilites scheuchzerianus* (Bosc). Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 24, pl. 12, fig. 1.

A few fragments of turrilitids from the Graneros Shale are referable to this species. All are crushed, and none consists of more than three whorls. The early and the latest whorls are not represented. Ribs are straight to slightly curved, are narrower than the interspaces, and lie at an angle to the commissure of the whorls. Each rib is depressed a little below its middle. Ribs number 18 and 21 per whorl on the two specimens that have complete whorls. The suture is not preserved.

Types.—Hypotypes, USNM 163884–163886.

Occurrences.—Old Hatchet Ranch section, bed 7 (USGS loc. D5124); Muldoon Hill section, bed 9 (USGS loc. D5145). These specimens were associated with *Acanthoceras muldoonense*. *Turrilites (Euturrilites) scheuchzerianus* has also been collected with this acanthoceratid in the Graneros Shale south of Pueblo at USGS localities D5128 and D6726 (fig. 16, locs. 127 and 137).

Turrilites (Euturrilites) scheuchzerianus has been recorded from the Cenomanian of England, France, Germany, Switzerland, Italy, Spain, Tunisia, Algeria, Morocco, Nigeria, Natal, Madagascar, Japan, Tibet, and Mexico. Most European records are from the lower Cenomanian. Dacqué (1939, p. 14, 193, 194) recorded it from the middle Turonian of Bavaria, but this identification so high in the Cretaceous seems doubtful to us. Reyment (1956a, p. 52) found the species to be confined to the basal part of the upper Cenomanian in Nigeria, and Matsumoto (1942b, v. 1, no. 3, p. 132; 1959b, p. 80) found it in both the lower and the upper Cenomanian of Japan.

Turrilites (Euturrilites) sp.
Plate 12, figure 1

At one locality the Thatcher Limestone Member of the Graneros Shale yielded two small badly crushed turrilitids. The larger specimen, 42 mm high, consists of nine whorls and has an apical angle of 35°. It is ornamented by simple thick slightly curved ribs that cross the whorls obliquely. About nine ribs are visible on half a whorl on the larger part of the specimen. The suture is not visible.

The specimens resemble *Turrilites (Euturrilites) scheuchzerianus* var. *mexicana* Böse (1923, p. 145, pl. 10, figs. 20, 21) in having complete ribs, but the lower Cenomanian form from Mexico has a narrower apical angle, and the ribs are narrower than the interspaces. The specimens from the Thatcher Limestone Member also resemble the small turrilitid from the Cenomanian of Algeria assigned to *Turrilites scheuchzerianus* by Pervinquière (1910, p. 50, pl. 14, fig. 2), which has a comparable apical angle and complete ribs, but its whorls are not so high and its ribs are as narrow or narrower than the interspaces.

Figured specimen.—USNM 163887.

Occurrence.—Thatcher Limestone Member of Graneros Shale: Muldoon Hill section, USGS locality 1323 (fig. 16, loc. 115).

Family SCAPHITIDAE Meek, 1876

Genus SCAPHITES Parkinson, 1811

Type species.—*Scaphites equalis* J. Sowerby, 1813.

Birkelund (1965, p. 79) gave the following excellent definition:

> *Scaphites* with involute phragmocone and scaphitoid body chamber with a rather long shaft and a very recurved hook; umbilical ratio decreases with increasing age; aperture constricted and commonly collared, in some with a long dorsal lappet touching the phragmocone; early whorls depressed, later whorls depressed or slightly compressed; surface with branching or intercalated, straight or nearly straight ribs; ventrolateral, umbilical and lateral rows of tubercles may be present on body chamber and occasionally on parts of phragmocone; suture with a bifid lateral lobe and a bifid or trifid first auxiliary lobe.

Scaphites has a worldwide distribution in rocks of late Albian to Maestrichtian age.

Scaphites sp.

Plate 17, figure 1

Scaphites is represented in the Bridge Creek Limestone Member by a few poorly preserved crushed internal molds. None is longer than 22 mm. Primary and secondary ribs are faintly visible in places. The primaries on the body chamber are fewer than those on the body chambers of other North American lower Turonian species.

Figured specimen.—USNM 163888.

Occurrence.—Hinkle Ranch section, bed 11 (USGS loc. D4870).

Family DESMOCERATIDAE Zittel, 1895

Genus DESMOCERAS Zittel, 1884

Subgenus PSEUDOUHLIGELLA Matsumoto, 1942

Type species.—*Desmoceras dawsoni* Whiteaves var. *japonica* Yabe, 1904.

Matsumoto (1953, p. 251) characterized this subgenus as fairly small to moderate-sized ammonites that are very involute and narrowly umbilicate and have a rounded to subrounded umbilical margin. The whorls are inflated in the juvenile stage and compressed in the adult stage; the venter is rounded. Constrictions are present, and these have a forward curvature on the venter. The outer shell is ordinarily smooth, but on the larger specimens faint subcostae may be present on the ventral half of the whorls. The suture is considerably incised; it has a symmetrically trifid lateral lobe and numerous auxiliary elements decreasing in size away from the lateral lobe.

Desmoceras (Pseudouhligella) sp.

Plate 3, figures 8–10; text figure 22

Two crushed specimens from the *Turrilites* bed seem referable to *Pseudouhligella*. They are phragmocones 34 and 38 mm in diameter whose umbilical ratios are about 16 percent. The umbilical shoulder is narrowly rounded, and the umbilical wall is steep. The flanks seem to be fairly flat and the venter well rounded. Although the specimens are crushed, the less deformed parts suggest a compressed species. Constrictions are not visible. The shells are smooth except for faint forwardly bent subcostae on the venter at the adoral end of the larger individual. The suture (text fig. 22) is comparable in its complexity to the sutures of *Desmoceras (Pseudouhligella) japonicum* (Yabe) illustrated by Matsumoto (1953b, text figs. 49, 50) from the Cenomanian strata of Japan.

Owing to their imperfect condition, the two specimens from the *Turrilites* bed are not referred to any named species. *Pseudouhligella* has not been recorded from the western interior region north of western Texas. The Texas species, *P. elgini* Young (1958, p. 292, pl. 39, figs. 4–20, 24, 25, 30, 31; text figs. 1a–e), from the lower Cenomanian, closely resembles the Colorado form in its narrow whorls and similar umbilical ratio, but the suture illustrated by Young (1958, text fig. 1a) is very simple. Powell (1963a, pl. 31, figs. 13–16) figured other examples of Young's species, but he did not illustrate the suture. The narrow cross section and the lack of conspicuous constrictions in the Colorado specimens are reminiscent of the early growth stages of *D. (P.) dawsoni* Whiteaves as illustrated by Matsumoto (1959a, pl. 15, figs. 1b, c) from the upper Albian of Alaska. The Japanese Cenomanian species *D. (P.) ezoanum* Matsumoto (1942, p. 26, text fig. 1b; 1953, p. 260, pl. 19, figs. 1–6) and *D. (P.) poronaicum* Yabe (1904, p. 39, pl. 6, figs. 1, 2) closely resemble the Colorado specimens in their narrow whorls and lack of conspicuous constrictions.

Figured specimens.—USNM 163889–163891.

Occurrence.—Graneros Shale: Rock Canyon section, bed 69 (USGS loc. 22887).

Family MUNIERICERATIDAE Wright, 1952

Genus TRAGODESMOCERAS Spath, 1922

Type species.—*Desmoceras clypealoides* Leonhard, 1897.

The genus *Tragodesmoceras* was established by Spath (1922, p. 127) for ammonites resembling *Desmoceras clypealoides* Leonhard (1897, p. 57, pl. 6, figs. 2a, b) whose compressed whorl section has a

very narrow arched venter crossed by conspicuous ribs. Leonhard showed two views of one specimen that is about 80 mm in diameter (umbilical ratio of 21 percent). It is ornamented by strong ribs, differing in length and strength, that number about 38–40 per half whorl. The ribs are sigmoidal and forwardly arched on the venter. About every eighth or ninth rib is thickened (five per half whorl). Leonhard did not illustrate the suture.

Spath (1922, p. 128) also assigned to *Tragodesmoceras* the species *Ammonites clypealis* Schlüter (1871–72, p. 51, pl. 15, figs. 9–14), *Ammonites hernensis* Schlüter (1867, p. 35, pl. 6, fig. 4), and *Puzosia mülleri* de Grossouvre (1893, p. 172), all from the Turonian and Coniacian of Germany. Of these species only *Tragodesmoceras clypeale* (Schlüter) closely resembles *T. clypealoides* (Leonhard). Schlüter illustrated two specimens, the larger of which has ribs that become nodate on the middle of the nearly sharp venter. Two external sutures illustrated by Schlüter (1871–72, pl. 15, figs. 13–14) show a complex pattern characterized by a large trifid lateral lobe and by smaller lobes on the suspensive lobe which progressively decrease in size toward the umbilicus.

Tragodesmoceras is an uncommon genus. Aside from the German occurrences, the genus has been recorded from the lower Santonian of Sweden (Ødum, 1953, p. 24, pl. 4, fig. 3), the upper Santonian of Madagascar (Collignon, 1966a, p. 86, pl. 490, fig. 1974), and the Turonian of Kansas (Morrow, 1935, p. 468, pl. 52, figs. 1a–c; pl. 53, figs. 3–5; text figs. 1, 3), Colorado (Dane and others, 1937, p. 214), and California and Oregon (Anderson, 1902,

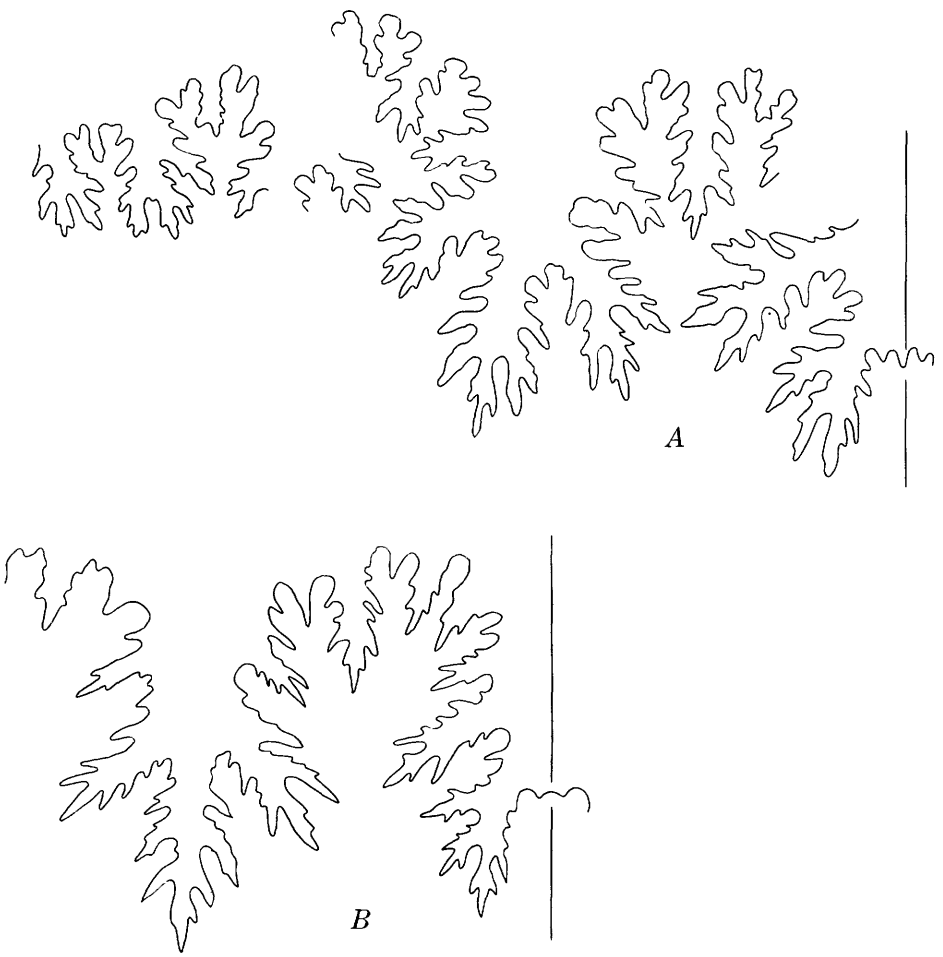

FIGURE 22.—Sutures of *Desmoceras* (*Pseudouhligella*) sp. from the top of the Graneros Shale at USGS locality 22887 (fig. 16, loc. 48). *A*, Most of the external suture (× 6) at a diameter of about 33 mm of the largest specimen, USNM 163890 (pl. 3, figs. 9, 10). *B*, External and lateral lobes and intervening saddle (× 6) at a diameter of about 30 mm of another specimen, USNM 163891.

p. 100, pl. 4, figs. 107, 109, as *Desmoceras ashlandicum*).

Tragodesmoceras bassi Morrow

Plate 38, figures 2, 3, 5–13; plate 39

1935. *Tragodesmoceras bassi* Morrow, Jour. Paleontology, v. 9, no. 6, p. 468, pl. 52, figs. 1a–c; pl. 53, figs. 3–5; text figs. 1, 3.

The holotype from the Jetmore Chalk Member of the Greenhorn Limestone in Republic County, Kans., consists of half an adult about 250 mm in diameter. It is an internal mold badly weathered on one side. The innermost preserved part is the outer flank of less than half a whorl about 50 mm in diameter; it is strongly ornamented by curved ribs that possibly number 18 or 19 per half whorl. These ribs are slightly visible on Morrow's plate 52, figure 1a. The next whorl of the holotype, entirely septate, has a diameter of 160 mm and an umbilical width of 37 mm (ratio of 23 percent). It is very compressed and has flattened flanks and a high narrowly arched venter. It is almost smooth except for a few weak constrictions and, on the outer half of the flank, faint closely spaced ribs. The constrictions number four per half whorl and curve forward on crossing the venter. A piece of the body chamber embraces part of the septate whorl. This piece is very poorly preserved and shows no indication of ornamentation. It has broadly rounded flanks and an almost sharp venter.

Morrow (1935, pl. 53, figs. 4, 5) illustrated in addition to the holotype, part of another adult and a juvenile. The smaller specimen was collected by Bass (1926b, text fig. 21, loc. 12768) from his Bridge Creek section in Hamilton County, Kans. (bed 53 of our Hinkle Ranch section, p. 21). This specimen (pl. 38, figs. 2, 3), somewhat distorted, has a diameter of 56 mm and an umbilical ratio of about 26 percent. Ribs are conspicuous, narrow, sigmoidal, curved forward on the venter, and number 20 per half whorl. About every third rib is stronger than the others and extends to the umbilicus where it rises into an incipient bullate tubercle. Each of these primary ribs also rises into a low pointed tubercle on the middle of the venter.

The suture of the holotype was illustrated by Morrow (1935, pl. 53, fig. 3). It is characterized by denticulate elements whose lateral lobe has a length much greater than that of the ventral lobe.

Tragodesmoceras bassi is a rare species. Five specimens from the Rock Canyon and Hinkle Ranch sections are illustrated on plate 38. The example from the Hinkle Ranch section (pl. 38, figs. 10, 11) has 22 conspicuous ribs per half whorl at a diameter of 69 mm and closely resembles the paratype from that locality illustrated by Morrow (1935, pl. 53, fig. 5). One of the larger specimens (pl. 38, figs. 6, 7) illustrated from the Rock Canyon section also has conspicuous ribs that probably number about 23 per half whorl at a diameter estimated at 83 mm. This individual has an unusually wide umbilicus whose ratio is estimated at 33 percent. Another specimen (pl. 38, figs. 12, 13) of similar size has an umbilical ratio of about 30 percent at a diameter of 87 mm (estimate) and a rib count of 16 per half whorl. Another example (pl. 38, fig. 5) illustrated from the Rock Canyon section has conspicuous ribs that number 20 per half whorl at a diameter of 55 mm.

An adult specimen from Wild Horse Park, 13 miles northwest of Pueblo, is illustrated on plate 39. This individual, 310 mm in diameter, has an umbilical ratio of 32 percent. The body chamber is smooth and occupies a little more than half a whorl.

Types.—Paratype, USNM 163892; hypotypes, USNM 163893–163898.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 105 (USGS loc. D3979), 113 (USGS locs. 22875, D4443, D6483), and 120 (USGS loc. D6475); Hinkle Ranch section, beds 53 (USGS loc. 12768), 57 (USGS loc. D4880), and 59 (USGS loc. D4881). Aside from these occurrences and the few Kansas occurrences, *Tragodesmoceras bassi* is known only from scarce specimens in southeastern Colorado, chiefly in the La Junta and Colorado Springs area.

Tragodesmoceras sp.

Plate 14, figures 1, 2

Half a whorl of an ammonite from bed 105 (D3979) of the Rock Canyon section represents a very inflated form of *Tragodesmoceras*. The specimen is 72 mm in diameter, and its umbilical ratio is 26 percent. The umbilical tubercles are unusually strong, rather nodose, and number six per half whorl. The ribs are prorsiradiate and arch forward on crossing the venter. Midventral tubercles seem to be missing.

Figured specimen.—USNM 163899.

Family ENGONOCERATIDAE Hyatt, 1900

Genus EPENGONOCERAS Spath, 1924

Type species.—*Sphenodiscus dumbli* Cragin, 1893.

Spath (1924, p. 508) did not define this genus but merely said the name was proposed for "Hyatt's

'Metengonoceras' from the Eagle Ford Shales." The best definition of *Epengonoceras* is that by Reeside and Weymouth (1931, p. 14) as follows:

> Shell with nearly smooth flanks, only low broad folds showing on some shells; venter relatively broad, slightly concave in early stages, becoming narrow (1 to 2 mm) but still concave or flat in later stages, and in old age rounded. The shell is not acute at any stage of growth, though the internal molds often are narrowly rounded in the adult stages and show no reflection of the truncation of the shell. Suture, in general, has the lobes more deeply dissected than in *Metengonoceras*, but the saddles are usually simple as in that genus.

Epengonoceras is closely related to *Metengonoceras* Hyatt (1903, p. 179) from the Albian of Texas. Stephenson (1952, p. 206) considered them to be one genus (*Metengonoceras*), but most authors (for example, Reeside and Weymouth, 1931, p. 14; Arkell and others, 1957, p. L388–L389) treated them as separate genera. Reeside and Weymouth concluded that better preserved specimens of the Albian *Metengonoceras* would need to be collected before a final decision could be made as to whether to combine the genera.

Epengonoceras dumbli (Cragin)?

Plate 8

1893. *Sphenodiscus dumbli* Cragin, Texas Geol. Survey 4th Ann. Rept., pt. 2, p. 243, pl. 44, fig. 6.
1903. *Metengonoceras dumbli* (Cragin). Hyatt, U.S. Geol. Survey Mon. 44, p. 185, pl. 27, figs. 3–14.
1924. *Epengonoceras dumbli* (Cragin). Spath, Annals and Mag. Nat. History, 9th ser., v. 14, no. 82, p. 508.
1928. *Epengonoceras dumbli* (Cragin). Adkins, Texas Univ. Bull. 2838, p. 264.
1931. *Epengonoceras dumbli* (Cragin). Reeside and Weymouth, U.S. Natl. Mus. Proc., v. 78, art. 17, p. 14.
1935. *Metengonoceras dumbli* (Cragin). Furon, Mus. Natl. Histoire Nat. Archives, 6th ser., v. 13, p. 55.
?1935. *Metengonoceras nigeriensis* Furon, Mus. Natl. Histoire Nat. Archives, 6th ser., v. 13, p. 55, pl. 3, figs. 1a, b; text fig. 16.
1942. *Epengonoceras dumbli* (Cragin). Moreman, Jour. Paleontology, v. 16, no. 2, p. 217.
1943. *Metengonoceras dumbli* (Cragin). Schneegans, French West Africa Direction Mines Bull. 7, p. 136, text fig. 17.
1951. *Metengonoceras dumbeli* [sic] (Cragin). Adkins and Lozo, Fondren Sci. Ser., no. 4, pl. 2, fig. 5.
1952. *Metengonoceras dumbli* (Cragin). Stephenson, U.S. Geol. Survey Prof. Paper 242, p. 206, pl. 55, figs. 1–4.
1957. *Epengonoceras dumbli* (Cragin). Barber, Nigeria Geol. Survey Bull. 26, p. 9, pl. 25, figs. 9, 10.

Epengonoceras is known from Cenomanian and Turonian rocks in North America, Europe, and Africa. The best record from the United States is that by Stephenson (1952, p. 206, pl. 55, figs. 1–4), who recorded specimens from the middle Cenomanian and lower Turonian of Texas and illustrated examples from the Cenomanian. The European occurrence is best documented by de Grossouvre (1912, p. 32–37, pl. 3, figs. 5–8), who described the new species *Metengonoceras douvillei*, *M. arnaudi*, and *M. tolveiense* from the Cenomanian and lower Turonian of western France (Loire-Inférieure). The African records (as *Metengonoceras* or *Epengonoceras*) are from the lower Turonian of Niger (Furon, 1935, p. 55, pl. 3, figs. 1a, b, text fig. 16; Lambert, 1943, p. 18; Schneegans, 1943, p. 136–137, text fig. 17) and Nigeria (Reyment, 1956a, p. 58; 1956b, p. 523; Barber, 1957, p. 9, pl. 25, figs. 9, 10).

This is a very involute and compressed species that has a smooth shell except for sinuous growth lines. The suture has numerous lobes and saddles of which most of the latter are undivided.

A single specimen from an ironstone concretion in the Graneros Shale is probably *Epengonoceras dumbli*. It is a large crushed adult 250 mm in diameter that shows one side and very little of the venter. The venter visible on the body chamber is narrowly rounded, whereas the venter on the badly crushed phragmocone is more or less acute. The sutures are not preserved.

Type.—Hypotype, USNM 163900.

Occurrence.—Graneros Shale: Rock Canyon section, bed 55 (USGS loc. D3963).

Family ACANTHOCERATIDAE Hyatt, 1900

Genus CALYCOCERAS Hyatt, 1900

Type species.—*Ammonites navicularis* Mantell, 1822.

Matsumoto, Saito, and Fukada (1957, p. 8, 9) presented the following excellent definition:

> Whorls are typically depressed to subrounded, but sometimes not so inflated, having an arched venter. Ribs are elevated but relatively narrow and consist of alternating long and short ones up to the full-grown stage. In the more or less young stage median-ventral, outer and inner ventrolateral and umbilical tubercles are well developed. As a general tendency the outer tubercles are sooner or later weakned or nearly completely obsolete as the shell grows on, while the ribs are prominent throughout life, crossing the external side without weakening. However in some cases the peripheral tubercles persist to, or rejuvenate on, the full-grown, outer whorl. Even in such cases the ribs are still prominent. The suture is similar to that of *Mantelliceras*.

Mantell (1822, pl. 22, fig. 5) presented only one view in his sketch of the type specimen, and this revealed mostly the ventral part of the last half of the outer whorl. Almost a hundred years later, Crick (1919) refigured the holotype and redescribed it.

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Collignon (1937, p. 44–49) and Spath 1937) presented good résumés of the manner in which *C. naviculare* had been treated by authors since the publication of Mantell's paper.

Matsumoto, Saito, and Fukada (1957, p. 9) noted that the various species of *Calycoceras* could be assigned to the following three groups that are intimately related:

"(1) the subgroup of *C. newboldi* (Kossmat)—*C. spinosum* (Kossmat)

(2) the subgroup of *C. naviculare* (Mantell) and

(3) the subgroup of *C. subgentoni* Spath—*C. baylei* (Pervinquière)."

The first group is characterized by a polygonal to subquadrate whorl section and by lower and upper ventrolateral tubercles that persist onto the large outer whorl of the adult. The second group has depressed and inflated whorls, and ventrolateral tubercles are either lacking, present on the early whorls only, or present on the late adult whorl. The third group has less inflated whorls and a tendency to lose the ventrolateral tubercles with growth.

Calycoceras is widely distributed in strata of Cenomanian and early Turonian age.

Calycoceras cf. C. naviculare (Mantell)

Plate 21, figures 1, 3, 4

Crushed calycoceratids that seem to lack ventrolateral tubercles are sparsely present at or near the base of the Bridge Creek Limestone Member. None has the suture preserved. The largest specimen, badly crushed, is about 160 mm in diameter (pl. 21, figs. 3, 4). The last whorl has 37 nearly straight ribs of which every other one extends to the umbilicus where it rises into a bullate tubercle.

Types.—Figured specimens, USNM 163901, 163902.

Occurrences.—Rock Canyon section, bed 63 (USGS loc. D6473); Hinkle Ranch section, bed 11 (D4870).

Calycoceras leonense (Adkins)

Plate 3, figures 1–4

1928. *Eucalycoceras leonense* Adkins, Texas Univ. Bull. 2838, p. 240, pl. 28, fig. 1; pl. 29, fig. 3.
1928. *Metacalycoceras*(?) sp. 2. Adkins, Texas Univ. Bull. 2838, p. 242, pl. 28, fig. 2; pl. 29, fig. 2.
1942. *Eucalycoceras leonense* Adkins. Moreman, Jour. Paleontology, v. 16, no. 2, p. 207.
1969. *Eucalycoceras (Proeucalycoceras) leonense* Adkins. Thomel, Acad. Sci. [Paris] Comptes Rendus, v. 268, ser. D, no. 4, p. 650.

Judging from large collections of *Calycoceras leonense* from the type area in Bell County, Tex., the holotype is probably the penultimate whorl. It is a robust specimen that has an intercostal whorl section a little wider than high, slightly flattened on the flanks, and well rounded on the venter. The umbilical shoulder is sharply rounded, and the umbilical ratio is 38 percent. Sculpture consists of high radial ribs that are distinctly narrower than the interspaces and number 13 for half a whorl. Every other rib extends to the umbilical shoulder where it rises into a bullate tubercle. All ribs are highest on crossing the venter, and there each rib bears small lower and upper ventrolateral and siphonal tubercles, of which the upper ventrolateral tubercles are slightly larger than the others. The lower ventrolateral tubercles weaken rapidly and disappear at a diameter of about 30 mm. The collections of *C. leonense* from Bell County show that the upper ventrolateral and siphonal tubercles also weaken and disappear but at positions farther along on the adult body chamber. Most specimens have every other rib extended to the umbilical shoulder, but on a few individuals an extra intercalated rib may be present on parts of the whorls. The adults range in diameter from about 50 to 92 mm. The specimen described by Adkins (1928, p. 242, pl. 28, fig. 2; pl. 29, fig. 2) as *Metacalycoceras*(?) sp. 2 is an adult of *C. leonense*.

C. leonense is represented in the collections from the Pueblo area by three specimens from the Thatcher Limestone Member of the Graneros Shale. All are somewhat crushed and distorted. The largest specimen is almost half a whorl that closely resembles the holotype in rib density, in strength of ribs and tubercles, and in having every other rib extended to the umbilical shoulder where each rises into a tubercle. The smallest specimen has one to two intercalated ribs between those that extend to the umbilicus. All individuals have small siphonal and upper ventrolateral tubercles, but the lower ventrolateral tubercles have disappeared owing to the large size of the specimens.

Types.—Hypotypes, USNM 163903, 163904.

Occurrence.—Muldoon Hill section, bed 7 (USGS loc. 22883).

Calycoceras? canitaurinum (Haas)

Plate 21, figure 2

1949. *Mantelliceras canitaurinum* Haas, Am. Mus. Nat. History Bull., v. 93, art. 1, p. 9, pls. 1–3; pl. 4, figs. 1, 2, 4; text figs. 1–4.

Fragments of large crushed ammonites that seem assignable to Haas' *Mantelliceras canitaurinum* are

present in the Lincoln Limestone Member of the Greenhorn Limestone. Ribs alternate in length, and the longest ones rise from bullate umbilical tubercles. Each rib rises into a low blunt tubercle on the ventrolateral shoulder before crossing the venter. The largest fragments suggest diameters of as much as 380 mm. None of the specimens has the suture preserved.

Type.—Hypotype, USNM 163905.

Occurrences.—Lincoln Limestone Member: Rock Canyon reference section, bed 10 (USGS loc. D3967). This ammonite is widely distributed in the western interior region in rocks equivalent to the Lincoln Limestone Member (U.S. Geological Survey collections).

Calycoceras? sp.

Plate 5, figure 5

One fragment of a crushed ammonite from a limestone concretion 29 feet below the marker bentonite bed in the Muldoon Hill section may be a *Calycoceras* of the *C. newboldi* (Kossmat) group. The ribs are strong, thin, flexuous, and fairly closely spaced. The umbilical tubercles are bullate. The specimen is unusual in that intercalated ribs are sparse and inconspicuous.

Figured specimen.—USNM 163906.

Occurrence.—Graneros Shale: Muldoon Hill section, bed 9 (USGS loc. D5145).

Subgenus CONLINOCERAS Cobban and Scott, n. subgen.

Type species.—*Calycoceras (Conlinoceras) gilberti* Cobban and Scott, n. sp.

Conlinoceras differs from the other groups of *Calycoceras* chiefly in its sparser ribbing and in reduction in strength of the umbilical tubercles to bullae or even to slightly accentuated ribs. The umbilical wall is low compared to the high steep wall of typical *Calycoceras*.

Conlinoceras is named for Mr. James P. Conlin, Fort Worth, Tex., who greatly aided the authors on several occasions by loans and gifts from his excellent collection of Cretaceous ammonites.

Calycoceras (Conlinoceras) gilberti Cobban and Scott, n. sp.

Plate 1; plate 2, figures 5–9, 13–18; plate 3, figures 5–7, 11; text figures 23, 24

1952. *Calycoceras* sp. Cobban and Reeside, Geol. Soc. America Bull., v. 63, no. 10, p. 1017.

Calycoceras (Conlinoceras) gilberti is a moderate-sized ammonite that has broadly rounded flanks, a somewhat flattened venter, widely spaced ribs, and the inner whorls, a row of siphonal tubercles and rows of lower and upper ventrolateral tubercles. The species attains a diameter of abut 200 mm.

The shell becomes more evolute with growth. The intercostal umbilical ratios of some of the figured specimens are 16 percent at diameter of 13.8 mm (pl. 2, fig. 5), 21 percent at diameter of 25 mm (pl. 2, fig. 9), 25 percent at diameter of 94 mm (pl. 2, fig. 18), and 31 percent at diameter of 134 mm (pl. 1).

The ribs are much narrower than the interspaces, rectiradiate to somewhat rursiradiate, and straight to slightly curved back. They number 16–22 per whorl and increase insignificantly with growth. The ribs are of equal strength where they cross the venter, but ordinarily only every other one extends to the umbilicus. The ribs are especially strong and high on the adult body chamber (pl. 1; pl. 3, figs. 7, 11), and on some large individuals every rib extends to the umbilicus. On the inner whorls of the more strongly sculptured specimens, the umbilical ribs rise into bullae well out from the umbilicus, whereas on the more weakly sculptured individuals, bullae are lacking and the umbilical ribs may be only slightly accentuated.

The siphonal and ventrolateral tubercles are somewhat nodate and equisized on the early whorls, but at some diameter greater than 10 mm the siphonal tubercles and lower row of ventrolateral tubercles weaken (text fig. 23*A*), but the upper row remains strong and becomes clavate. At some diameter between 50 and 90 mm the siphonal and lower ventrolateral tubercles disappear, and the upper row weakens and becomes nodate. The upper ventrolateral tubercles disappear on the adult body chamber where their position is marked for at least a quarter of a whorl by an angularity on the ribs (text fig. 23 *C*).

The suture (text fig. 24) is moderately incised and fairly typical of *Calycoceras*. The external lobe is long and rather narrow; the first lateral saddle is much broader than the external lobe and is divided symmetrically by a deep narrow element; the lateral lobe is symmetrically bifid and much shorter than the external lobe although about as wide; the remaining elements are shallow and short. In general, the suture is much like that of *C. boulei* Collignon as illustrated by Matsumoto (1959e, text fig. 32 on p. 77).

The holotype (pl. 2, figs. 15, 18; text figs. 23, 24) is a partly crushed specimen 134 mm in diameter. About half the body chamber is preserved. Inasmuch as all tubercles are lost on the older part of

the body chamber, the specimen probably represents an individual that attained the adult stage at a rather small diameter.

C. (Conlinoceras) gilberti is named in honor of Mr. G. K. Gilbert for his early work on the Graneros and Greenhorn Formations and for collecting the holotype and many of the other specimens used in the present study.

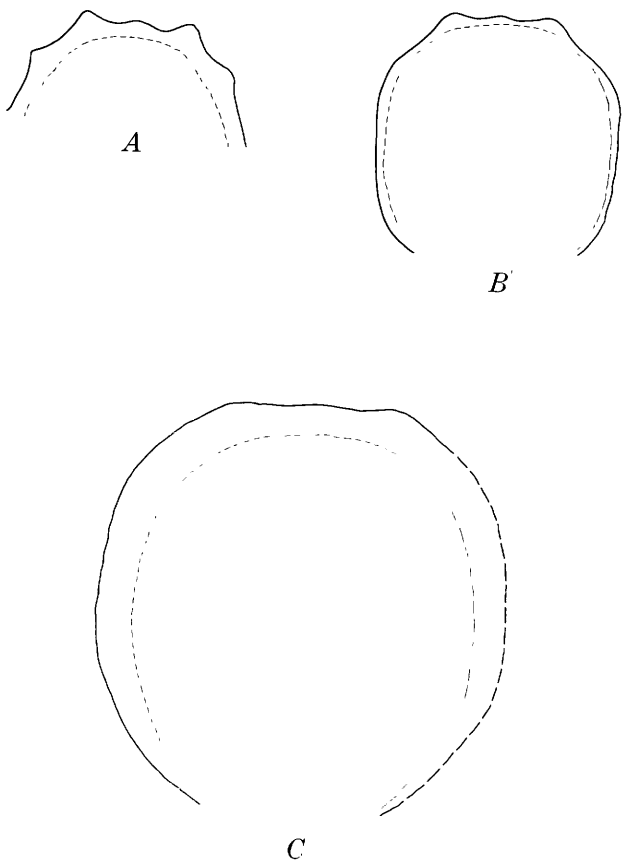


FIGURE 23.—Cross sections, natural size, through whorls of three specimens of *Calycoceras (Conlinoceras) gilberti* Cobban and Scott, n. sp., from the Thatcher Limestone Member of the Graneros Shale. *A*, Ventral half of a paratype, USNM 163914 (pl. 2, figs. 13, 14). *B*, Paratype, USNM 163911 (pl. 2, figs. 16, 17). *C*, Body chamber of the holotype, USNM 163907 (pl. 2, figs. 15, 18).

C. (Conlinoceras) gilberti is closely related to ammonites from Texas described by Adkins (1928, p. 241, 243, pl. 25, figs. 2, 3; pl. 28, fig. 3; pl. 29, fig. 1) as the new species *Metacalycoceras? tarrantense* and *Acanthoceras wintoni*. Large collections from the Woodbine Formation show that these two forms occur together and intergrade from a large stout type *(tarrantense)* to a smaller and more slender form *(wintoni)*. The two forms are herein considered as one species *C. (Conlinoceras) tarrantense*. This species differs from *C. gilberti* in that it lacks high strong costae. *C. gilberti* also resembles the Woodbine species described by Stephenson (1952, p. 200, pl. 47, figs. 3, 4) as the new species *Acanthoceras adkinsi*. Stephenson's form, which may be just a densely ribbed variant of *C. tarrantense*, differs from *C. gilberti* in having more ribs and in maintaining the nodate tuberculation of the early whorls to a larger diameter.

Types.—Holotype, USNM 163907; paratypes, USNM 163908–163914.

Occurrences.—

Graneros Shale:

Rock Canyon section:

Bed	USGS locality	Bed	USGS locality	Bed	USGS locality
54	D4445, D5150	55	D1305, D3964	55	D3970, D5728

Old Hatchet Ranch section:

4	D5122	5, 6	D5123	7	D5289

Siloam section:

5	D5708	6	D5709	6	D5710

Muldoon Hill section:

7	1323	7	22883	8	D5716

Type section of Thatcher Limestone Member:

10	D5732	11	D5733		

In addition, the species is widely distributed in southeastern Colorado.

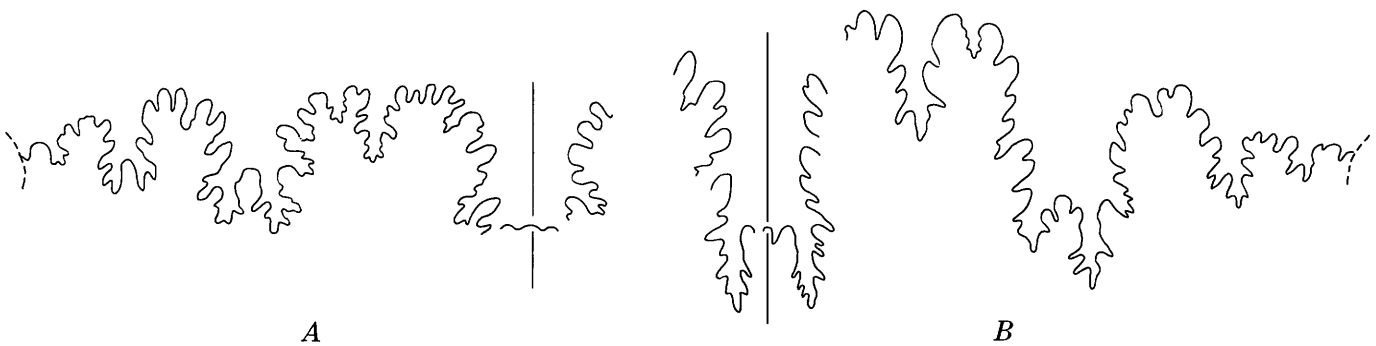


FIGURE 24.—External sutures of *Calycoceras (Conlinoceras) gilberti* Cobban and Scott, n. sp. (× 2) from the Thatcher Limestone Member of the Graneros Shale at USGS locality 1323 (fig. 16, loc. 115). *A*, Paratype, USNM 163911 (pl. 2, figs. 16, 17). *B*, Holotype, USNM 163907, composite of three sutures at a diameter of about 94 mm (pl. 2, figs 15, 18).

Genus PSEUDOCALYCOCERAS Thomel, 1969

Type species.—Ammonites harpax Stoliczka, 1865.

Thomel (1969, p. 650) created this generic name for ammonites like *Ammonites harpax* Stoliczka (1865, p. 72, pl. 39, figs. 1, 1a, 1b). Stoliczka's species is a moderate-sized ammonite neither evolute nor involute and characterized by strong ribs that curve backward on crossing the flank of the adult body chamber. Every other rib or two extends to the umbilicus where it rises into a tubercle that may be bullate and twisted on the younger part of the body chamber. Every rib bears small nearly equispaced clavate siphonal and upper and lower ventrolateral tubercles that weaken and disappear near the aperture.

The generic assignment of Stoliczka's species has been a problem. Besides *Ammonites*, the species has been assigned to *Acanthoceras* (Kossmat, 1897, p. 13; Taubenhaus, 1920, p. 16; Basse, 1931, p. 38), *Protacanthoceras* (Collignon, 1937, p. 33; 1964, p. 145; Fabre, 1940, p. 223–225; Thomel, 1965, p. 141–142), *"Protacanthoceras"* (Wiedmann, 1959, p. 711, 716, 718), *Calycoceras* (Basse, 1940, p. 448, 451; Avnimelech and Shoresh, 1962, p. 532), and *Eucalycoceras* (Thomel, in Porthault and others, 1966, p. 428).

In defining his new genus *Pseudocalycoceras*, Thomel (1969, p. 650) noted that it differed from *Eucalycoceras* Spath (1923, p. 144; type species, *Ammonites pentagonus* Jukes-Browne, in Jukes-Browne and Hill, 1896, p. 156, pl. 5, figs. 1, 1a) in having fewer ribs (about 25 per whorl in contrast to 35–50 for *Eucalycoceras*) and in having the ribs curved backward instead of having a rectiradiate trend. Three subgenera were assigned to *Eucalycoceras* by Thomel: *Eucalycoceras* s. s., *Proeucalycoceras* (new name), and *Subeucalycoceras* (new name). *Proeucalycoceras* was based on the Madagascar form described by Collignon (1937, p. 37, pl. 3, figs. 1–4; pl. 8, fig. 5) as the new species *Calycoceras (Eucalycoceras) besairiei*. Among the American species assigned to *Proeucalycoceras* by Thomel were *Eucalycoceras dentonense* Moreman (1942, p. 205, pl. 33, figs. 4, 5; text fig. 2k) and *E. lewisvillense* Moreman (1942, p. 206, pl. 33, figs. 6, 7; text figs. 2n, u). The originals of Moreman's *E. dentonense* and *E. lewisvillense* as well as his *E. indianense* came from the Eagle Ford Shale on Indian Creek 5½ miles east of Lewisville, Denton County, Tex. The specimens differ very little from one another and are herein interpreted as one species. The types are moderately stout adult body chambers that have strong rursiradiate ribs numbering 15 or 16 per half whorl. Similar specimens are found in the Greenhorn Limestone in the Pueblo area, and these as well as Moreman's types seem better assigned to *Pseudocalycoceras* than to *Eucalycoceras*.

Pseudocalycoceras is known only from the upper Cenomanian. In addition to *Ammonites harpax* Stoliczka, Thomel assigned the following forms to *Pseudocalycoceras: Ammonites morpheus* Stoliczka (1865, p. 80, pl. 38, figs. 1, 1a, 1b), *Calycoceras alaouitense* Basse (1940, p. 449, pl. 8, figs. 1, 4a, 4b), *C. paralaouitense* Basse (1940, p. 449, pl. 7, fig. 4; pl. 8, figs. 2, 3; pl. 9, fig. 3), *Protacanthoceras jullieni* Collignon (1937, p. 36, pl. 2, figs. 1, 1a, 1b, 2; pl. 8, fig. 3), *P. angolaense* Spath (1923–43, p. 316; type, *Acanthoceras lyelli* of Douvillé, 1931, p. 31, pl. 1, figs. 1a, b; text fig. 1), *P. batnense* Collignon (1937, p. 36, pl. 2, figs. 3, 3a, 3b, 4, 4a, 4b), *P. flandrini* Thomel (in Porthault and others, 1966, p. 430, pl. 10, figs. 3–5), *Acanthoceras haugi* Pervinquière (1907, p. 270, pl. 14, figs. 1a, b; text figs. 104, 105), *A. rotomagense* Brongniart var. *judaica* Taubenhaus (1920, p. 13, pl. 3, fig. 1), *Barroisiceras trinodosum* Moreman (1942, p. 212, pl. 33, figs. 1, 2; text fig. 2a), and *B. brittonense* Moreman (1942, p. 212, pl. 33, fig. 3; text fig. 2b). Moreman's *B. trinodosum* and *B. brittonense*, which are much more involute than other species assigned to *Pseudocalycoceras*, are abnormally formed specimens of *Metoicoceras whitei* Hyatt (Dr. J. Dan Powell, oral commun., April 1969). Stoliczka's *Ammonites morpheus*, which lacks a row of tubercles, is probably an abnormally formed specimen of *Pseudocalycoceras harpax*.

Pseudocalycoceras dentonense (Moreman)

Plate 13, figures 11–29; plate 15, figures 1–7, 10–13

1927. *Acanthoceras* sp. A. Moreman, Jour. Paleontology, v. 1, no. 1, p. 95, pl. 15, fig. 2.
1942. *Eucalycoceras dentonense* Moreman, Jour. Paleontology, v. 16, no. 2, p. 205, pl. 33, figs. 4, 5; text fig. 2k.
1942. *Eucalycoceras indianense* Moreman, Jour. Paleontology, v. 16, no. 2, p. 206, pl. 33, figs. 9, 10; text fig. 2l.
1942. *Eucalycoceras lewisvillense* Moreman, Jour. Paleontology, v. 16, no. 2, p. 206, pl. 33, figs. 6, 7; text figs. 2n, u.
1959. *Eucalycoceras dentonense* Moreman. Matsumoto (1959e), Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, Spec. v. 1, p. 97, text fig. 51.
1959. *Eucalycoceras indianense* Moreman. Matsumoto (1959e), Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, Spec. v. 1, p. 98.
1969. *Eucalycoceras (Proeucalycoceras) dentonense* Moreman. Thomel, Acad. Sci. [Paris] Comptes Rendus, v. 268, ser. D, no. 4, p. 650.

1969. *Eucalycoceras (Proeucalycoceras) lewisvillense* Moreman. Thomel, Acad. Sci. [Paris] Comptes Rendus, v. 268, ser. D, no. 4, p. 650.

The holotype of *Pseudocalycoceras dentonense* is the stoutest of the three specimens described by Moreman as separate species of *Eucalycoceras*. It is 79 mm in diameter and consists of a body chamber that lacks the oral end.The ribs are strong, number about 16 per half whorl, and curve backward on crossing the flank. They are inflated a little on the flanks but they do not rise into an extra row of tubercles as shown on cross sections drawn by Moreman (1942, text fig. 2k) and Matsumoto (1959e, text fig. 51). The siphonal and upper ventrolateral tubercles are clavate and about equal in size. The lower ventrolateral tubercles are smaller and nodate. The distance separating them from the upper ventrolateral tubercles is more than that separating the latter from the siphonal ones. Umbilical tubercles are nodate on the older part of the body chamber and bullate on the younger part.

Pseudocalycoceras dentonense is represented in the collections from the Rock Canyon section by 20 specimens from bed 67 near the base of the Bridge Creek Limestone Member. All are internal molds, and most are somewhat distorted. Most adults range in diameter from 25 mm (pl. 13, figs. 20–23) to 103 mm (pl. 15, fig. 13). Umbilical ratios range from 30 to 37 percent. Ribs number 15–21 per half whorl. They are somewhat flexuous and either rectiradial or prorsiradial on the early whorls and rursiradial on most of the last whorl. The ribs become slightly crowded and rectiradial near the aperture (pl. 13, figs. 18, 19). The ventrolateral and siphonal tubercles weaken and disappear usually at some diameter between 25 and 80 mm. A very small poorly preserved specimen from bed 73 of the Rock Canyon section that loses its tubercles at a smaller diameter may be the smallest adult of this species (pl. 13, figs. 11–14). Only parts of the suture are visible.

Types.—Hypotypes, USNM 163915–163926.

Occurrences.—Rock Canyon section, bed 67 (USGS locs. D3973, D3984, D6472), possibly bed 73 (USGS loc. D4444); Hinkle Ranch section, bed 9 (USGS loc. D4869). The species is known from a few other localities in the eastern half of Colorado, all near the base of the Bridge Creek Limestone Member of the Greenhorn Limestone.

Genus TARRANTOCERAS Stephenson, 1955

Type species.—*Tarrantoceras rotatile* Stephenson, 1955.

Stephenson (1955, p. 59) separated his genus from *Eucalycoceras* on differences in the suture line. He noted that the first two lateral saddles and intervening lobe in the suture of *Tarrantoceras* were shallow and slightly incised, whereas the corresponding elements of the suture of *Eucalycoceras* were deep and digitate. In addition, the following features should be added as a means of separating *Tarrantoceras* from typical *Eucalycoceras* of the *pentagonum* type: *Tarrantoceras* is a smaller and more compressed ammonite whose upper ventrolateral tubercles are larger than its siphonal and lower ventrolateral tubercles. The venter is flatter on the last septate whorl, and this feature combined with the larger upper ventrolateral tubercles results in these tubercles rising either above or as high as the siphonal ones. On the last septate whorl of *Eucalycoceras pentagonum*, the well-arched venter and nearly equisized tubercles cause the siphonal tubercles to rise conspicuously above the upper ventrolateral ones.

Stephenson's specimens came from the basal part of the Eagle Ford Shale in northern Texas. Outside the United States, the genus is known from the Cenomanian of Mexico (Daugherty and Powell, 1963, p. 2062), Bolivia (Bürgl, 1957, p. 137, pl. 12, figs. 2a–d), Venezuela (Sutton, 1946, pl. 5, figs. 6, 7, as *Eucalycoceras* sp.), and Morocco (Collignon, 1966b, p. 30–32, pl. 16, figs. 2–7; pl. 17, fig. 1).

Tarrantoceras rotatile Stephenson

Plate 10, figures 1–11; text figure 25

1955. *Tarrantoceras rotatile* Stephenson, U.S. Geol. Survey Prof. Paper 274–C, p. 59, pl. 5, figs. 1–10.

1955. *Tarrantoceras stantoni* Stephenson, U.S. Geol. Survey Prof. Paper 274–C, p. 60, pl. 5, figs. 11–21.

1955. *Tarrantoceras lillianense* Stephenson, U.S. Geol. Survey Prof. Paper 274–C, p. 60, pl. 5, figs. 22–27.

?1955. *Tarrantoceras multicostatum* Stephenson, U.S. Geol. Survey Prof. Paper 274–C, p. 61, pl. 6, figs. 21–23.

1969. ?*Eucalycoceras (Eucalycoceras) rotatile* (Stephenson). Thomel, Acad. Sci. [Paris] Comptes Rendus, v. 268, ser. D, no. 4, p. 650.

The holotype of *Tarrantoceras rotatile* is from the basal part of the Eagle Ford Shale of Tarrant County, Tex. It is a nearly complete adult, 61 mm in diameter, that is moderately evolute and whose umbilical ratio is 32 percent. Ribs are narrow, strong, prorsiradiate, slightly flexuous, and number 44 on the last whorl. Fourteen of the ribs extend to the umbilical shoulder where they rise into conspicuous bullate tubercles. Both the siphonal and the lower ventrolateral tubercles are very weak. The si-

phonal tubercles disappear about halfway up the body chamber, and the lower ventrolateral tubercles disappear about at the base of the body chamber. The upper ventrolateral tubercles weaken but persist possibly to the aperture. Stephenson's *Tarrantoceras stantoni* and *T. lillianense* were found with his *T. rotatile;* they differ from it only in being a little more robust and in having a coarser sculpture. All three of Stephenson's forms are herein considered as one species of normal variation.

Tarrantoceras rotatile is represented in the collections from the Pueblo area by many crushed fragments in the limestone concretions associated with the marker bentonite bed. The fragments show gradations from finely ribbed forms like Stephenson's *Tarrantoceras rotatile* (pl. 10, figs. 1–3, 5, 6) to coarsely ribbed forms similar to his *T. stantoni* (pl. 10, figs. 7–9). The suture (fig. 25) is typical of the species.

Types.—Holotype, USNM 108835; hypotypes, USNM 163927–163934.

Occurrence.—Graneros Shale: Rock Canyon section, bed 69 (USGS loc. 22887). The species occurs at several localities in southeastern Colorado in limestone concretions or in thin beds of limestone associated with the marker bentonite bed at the contact of the Graneros Shale and Greenhorn Limestone. It has been found also at a few localities in the northern half of New Mexico (U.S. Geol. Survey collections).

Genus ACANTHOCERAS Neumayr, 1875

Type species.—*Ammonites rhotomagensis* Defrance, in Cuvier and Brongniart, 1822.

Arkell, Kummel, and Wright (1957, p. L414) summarized the characters of this genus as follows:

> Middle stages generally with round or squarish whorl section and umbilical, lower and upper ventrolateral and siphonal tubercles, with or without distinct ribs; later in large adults, 2 clavate ventrolateral tubercles may fuse to produce large horn, while siphonal tubercles disappear, leaving a broad flat venter.

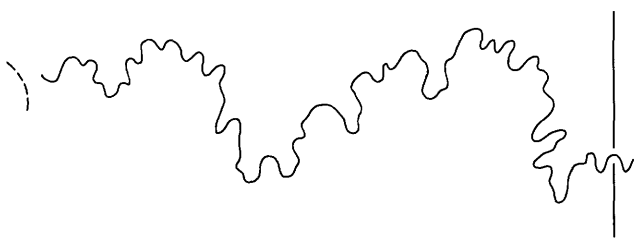


FIGURE 25.—External suture (× 3) of *Tarrantoceras rotatile* Stephenson (pl. 10, figs. 2, 3) from near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48). USNM 163928.

The specimen illustrated by Brongniart (Cuvier and Brongniart, 1822, pl. 6, figs. 2 *A*, *B*) represents the inner whorls at a diameter of about 38 mm. The lateral view shows rather strong ribs numbering 22 per whorl. Most ribs extend to the umbilicus where they rise into bullate tubercles. Those ribs that do not extend to the umbilicus occur irregularly and may be separated by as many as four umbilical ribs. The magnificent illustrations by Bayle (1878, pl. 63) also show this irregular ribbing on the inner whorls, but the large specimen figured by him shows that all ribs extend to the umbilicus. Other illustrations of large specimens of *A. rhotomagense* show that most ribs of the adult whorls extend to the umbilicus (for example, J. De C. Sowerby, 1826, pl. 515, fig. 2; Bronn, 1851–52, pl. 33, figs. 1, 3; Pictet and Campiche, 1858–60, pl. 25, fig. 1a; Pictet, 1863, pl. 2, fig. 1a; Römer, 1870, pl. 27, fig. 1; Schlüter, 1871–72, pl. 6, fig. 13). The large whorls of other European species of *Acanthoceras* also have all or nearly all ribs extended to the umbilicus, for example, *A. vectense* Spath (1926a, p. 82; type, *Ammonites rhotomagensis* Defrance in Sharpe, 1854, pl. 16, figs. 1a–c), *A. sherborni* Spath (1926a, p. 82; type, *Ammonites cenomanensis* d'Archiac in Sharpe, 1856, pl. 17, figs. 1a, b), *A evolutum* Spath (1926a, p. 82; figured as *Ammonites sussexiensis* Mantell in Sharpe, 1854, pl. 15, figs. 1a–d), and *A. diadema* Spath (1926b, p. 431; type *Ammonites cunningtoni* Sharpe in Pictet, 1863, pl. 5, figs. 1a–c). Other species commonly assigned to *Acanthoceras* that have alternate long and short ribs and lose the ventral tubercles near the base of the body chamber are better placed in *Calycoceras* (examples are *A. baylei* Pervinquière, 1907, p. 282, and *Ammonites cenomanensis* d'Archiac as figured by Pictet, 1863, p. 47, pl. 3, figs. 1a–c, 2a–c; pl. 4, figs. 1a, b).

Acanthoceras amphibolum Morrow

Plate 9; plate 10, figures 12–16; text figure 2?

1935. *Acanthoceras? amphibolum* Morrow, Jour. Paleontology, v. 9, no. 6, p. 470, pl. 49, figs. 1–4, 6; pl. 51, figs. 3, 4; text fig. 4.

1953. *Acanthoceras hazzardi* Stephenson, U.S. Geol. Survey Prof. Paper 242, p. 201, pl. 48, figs. 1, 2; pl. 49, fig. 4 [1952 imprint].

1963. *Paracanthoceras amphibolum* (Morrow). Haas, Am. Mus. Novitates, no. 2151, p. 18.

1964. *Plesiacanthoceras* [*amphibolum* (Morrow)]. Haas, Jour. Paleontology, v. 38, no. 3, p. 610.

1965. *Plesiacanthoceras amphibolum* (Morrow). Hattin, Geol. Soc. America Field Conf. Guidebook Ann. Mtg., 1965, text fig. 3.

1965. *Plesiacanthoceras amphibolum* (Morrow). Hattin, Kansas Geol. Survey Bull. 178, pl. 4, figs. J, K; pl. 5, figs. C–F.

1966. *Acanthoceras amphibolum* Morrow. Matsumoto and Obata, Natl. Sci. Mus. [Tokyo] Bull., v. 9, no. 1, p. 45, text figs. 4–6.
1966. *Acanthoceras hazzardi* Stephenson. Matsumoto and Obata, Natl. Sci. Mus. [Tokyo] Bull., v. 9, no. 1, p. 45, text fig. 7.
1968. *Acanthoceras amphibolum* Morrow. Hattin, Jour. Paleontology, v. 42, no. 4, p. 1087.
1969. *Acanthoceras amphibolum* Morrow. Matsumoto, *in* Matsumoto, Muramoto, and Takahashi, Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, v. 19, no. 2, p. 266, pl. 31, figs. 1a, b.

Acanthoceras amphibolum is characterized by the adult whorls having ventrolateral horns and a broadly arched venter whose midventral ridge is low. All ribs extend to the umbilicus except for a very few on the early whorls. The early whorls have clavate siphonal tubercles which become more numerous than the ventrolateral tubercles before they disappear.

At the smallest diameter visible (about 11 mm) on the smallest of Morrow's types (1935, pl. 49, figs. 2a–c), the siphonal and upper ventrolateral tubercles are asymmetrically clavate, the steep side being forward. The lower ventrolateral tubercles are about the same size as these but nodate. This arrangement in size and form of the tubercles and the presence of one siphonal tubercle for each ventrolateral tubercle continues to the large end of the specimen (diameter of nearly 29 mm). The next larger of Morrow's types (1935, pl. 49, figs. 3a, b) shows an interesting midventral change. The siphonal tubercles weaken, and at a diameter of about 36 mm, they become nodate and more numerous than the ventrolateral tubercles. At about this same diameter the middle of the venter rises into a very low keel. A weak upper ventrolateral tubercle appears between the larger and normally spaced upper ventrolateral tubercles at a diameter of 50 mm, and the presence of this and the numerous siphonal tubercles imparts a sort of euomphaloceratid appearance to the venter. The venter at this stage resembles similar-sized specimens of *A. alvaradoense* Moreman (1942, p. 205), as described and figured by Stephenson (1955, p. 63, pl. 7, figs. 4, 7, 8). The next larger two of Morrow's types (Morrow, 1935, pl. 49, figs. 1, 4) show that the siphonal tubercles disappear by a diameter of 60 mm, but that the keel continues outward to a much larger diameter although it is very low and inconspicuous. The lower ventrolateral tubercles enlarge into horns, whereas the upper ventrolateral tubercles weaken and disappear. Umbilical tubercles are nodate on the very early whorls and bullate on the later ones.

Ribs are straight and rectiradiate. They number 15 and 18 per whorl on Morrow's two specimens that have complete whorls. Six specimens, 25–92

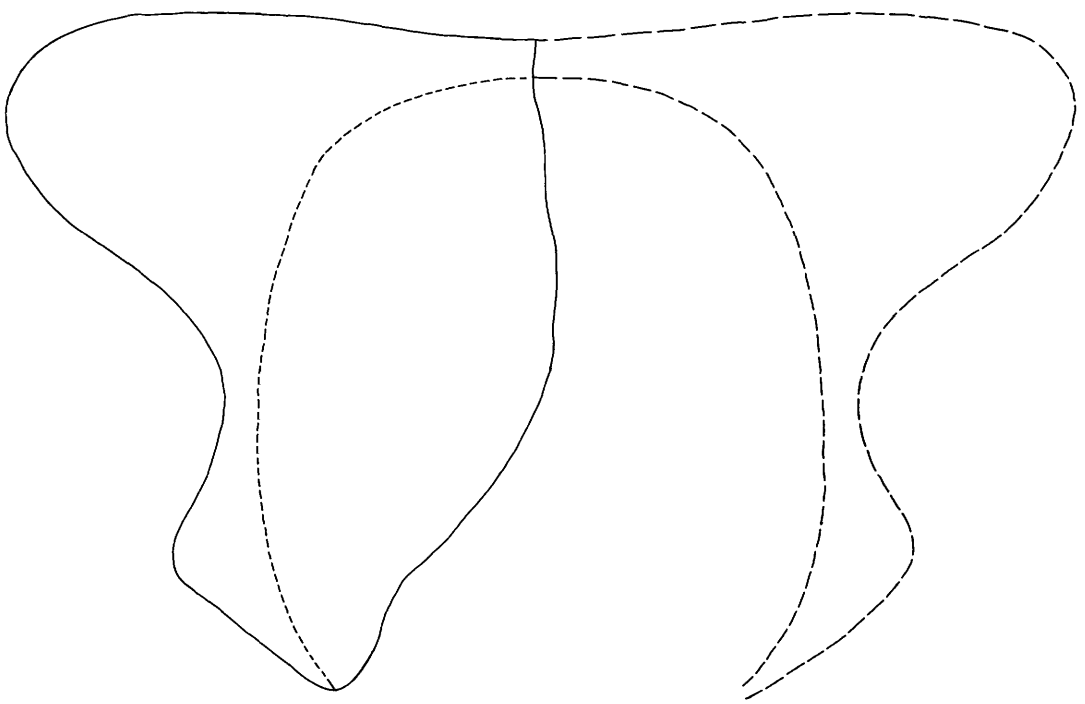


FIGURE 26.—Whorl section, natural size, of the largest specimen of *Acanthoceras amphibolum* Morrow from near the top of the Graneros Shale at USGS locality 22887 (fig. 16, loc. 48). USNM 163940.

mm in diameter from a limestone concretion near the top of the Graneros Shale of Kansas, have 14–19 ribs (loc. 32 of Hattin, 1965a, p. 82). Ribs become very widely spaced on the adult body chamber where they number about five per half whorl (Morrow, 1935, pl. 49, fig. 6; Hattin, 1965a, pl. 5, figs. C, E).

The sutures shown by Morrow (1935, pl. 51, figs. 3, 4) are typical for the genus. (See de Grossouvre, 1893, text figs. 8, 12 for suture of *A. rhotomagense*.)

A. amphibolum has been assigned to *Plesiacanthoceras* Haas (1963, p. 18; 1964). Because of its horns on the adult body chamber, this part of *A. amphibolum* resembles the outer whorls of *Plesiacanthoceras wyomingense* (Reagan), the genotype of *Plesiacanthoceras*. The inner whorls, however, are very different. They are considerably more involute for *P. wyomingense*, the siphonal tubercles are never so strong as the ventrolateral ones and disappear at a very small diameter, and the ribs are of alternate lengths out to a large diameter.

A. amphibolum resembles certain European species of *Acanthoceras*. The growth stage in which the venter has more siphonal and upper ventrolateral tubercles than lower ventrolateral tubercles recalls that of *A. evolutum* Spath (1926a, p. 82; type, *Ammonites sussexiensis* Sharpe, 1854, p. 34, pl. 15, figs. 1a–d) from the Cenomanian of England which also has about as many ribs. A combination of ventrolateral horns and a low siphonal ridge is shown in the illustrations of *A. diadema* Spath (1926b, p. 431;* type, *Ammonites cunningtoni* Sharpe in Pictet, 1863, p. 51, pl. 5, figs. 1a–c) and the specimen identified as *Ammonites cenomanensis* d'Archiac by Pictet and Campiche (1858–60, p. 193, pl. 25, figs. 4a, b).

A. amphibolum is represented in the Pueblo area by many crushed fragments in the limestone concretions associated with the marker bentonite bed near the top of the Graneros Shale. The inner whorls commonly have 14–15 ribs per whorl but may have as few as 13 on coarsely sculptured specimens (pl. 10, fig. 13) or as many as 21 on finely sculptured ones (pl. 10, fig. 12). The change in high rib density to widely spaced ribbing on the adult body chamber is well shown on one individual that attained the adult stage at a rather small diameter of about 165 mm (pl. 9). Other specimens may have been twice as large before attaining the same growth stage. The ribs tend to disappear on the older part of the body chamber, and the ornament there consists of strong conical umbilical tubercles and large ventrolateral horns (text fig. 26). The ribs reappear near the aperture where they form narrow flanges that extend from the umbilicus entirely across the flank and venter (pl. 9; pl. 10, fig. 16).

Types.—Hypotypes, USNM 163935–163940.

Occurrences.—Graneros Shale: Rock Canyon section, bed 69 (USGS loc. 22887), possibly bed 64 (USGS loc. D5153); Old Hatchet Ranch Section, bed 35 (USGS loc. D5126); Muldoon Hill section, bed 41 (USGS loc. D5149). The species is widely distributed in the western interior region from Montana to New Mexico.

Acanthoceras muldoonense Cobban and Scott, n. sp.

Plate 4, figures 1, 3; plate 7, figures 1–13; plate 11, figures 12, 13; text figures 27, 28

Sparse ribbing and early loss of siphonal and upper ventrolateral tubercles characterize this species. Ventrolateral horns are conspicuous in the later growth stages. The species is represented by many more or less crushed and distorted specimens from the Graneros Shale a little below the middle of the shale unit that separates the Thatcher Limestone Member from the Greenhorn Limestone.

At the smallest diameter observed, 12.5 mm, the whorls are stout and have flattened flanks and a broadly rounded venter. Ribs number 10 per half whorl and are strongest on the outer parts of the flank and venter. Every second or third extends to the umbilical shoulder. Each rib has weak nodate lower and upper ventrolateral tubercles and a nodate siphonal tubercle. As the shell enlarges, all these tubercles become more or less clavate. The siphonal ones remain weak and disappear at a shell diameter of not more than 40 mm. The ventrolateral tubercles increase in strength up to a diameter of about 30–35 mm. At greater diameters, the lower ventrolateral tubercles continue to increase in size and rise high above the venter. At the same time, the upper ventrolateral one weakens and becomes reduced to a small clavate ridge on the siphonal side of the lower ventrolateral tubercle (fig. 27). At some diameter between 50 and 80 mm, the upper ventrolateral tubercles disappear, and the lower ones rise into conspicuous horns high above the venter and are directed outward from it at angles from 30° to 45° (fig. 27).

Umbilical tubercles are conspicuous on adults of this species. They are bullate, number the same as the ventrolateral tubercles (6–8 per half whorl), and are located well out on the flank. They first appear, at a diameter of approximately 15 mm, as low bullae on about every other rib. As the shell en-

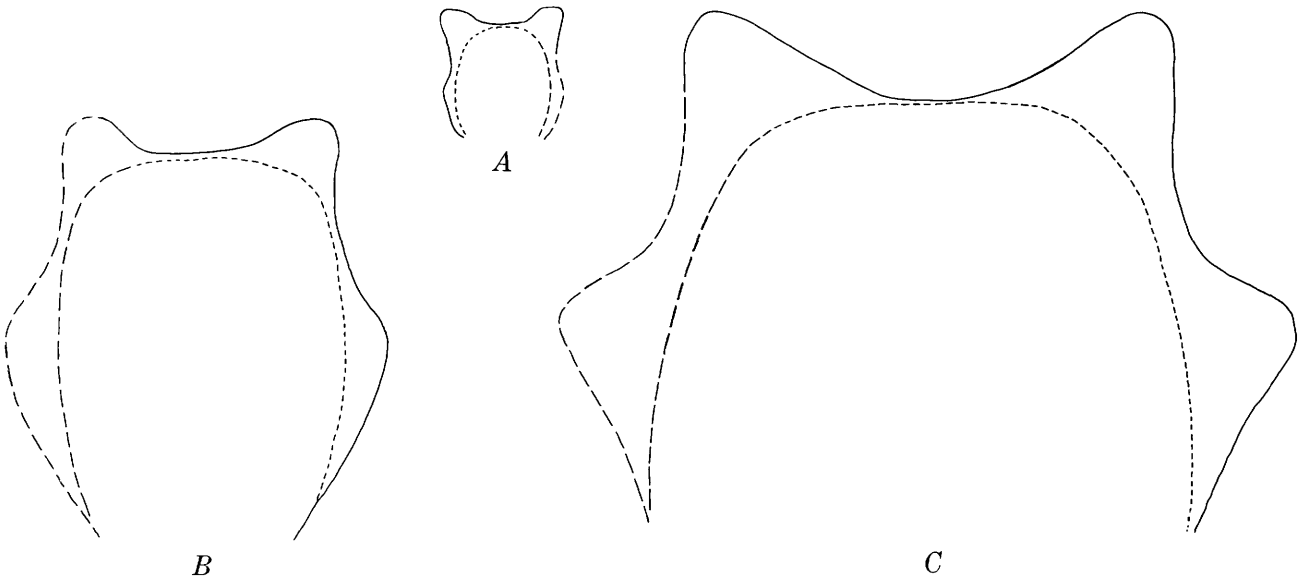


FIGURE 27.—Cross sections, natural size, of three specimens of *Acanthoceras muldoonense* Cobban and Scott, n. sp. *A* and *B*, Paratypes, USNM 163950, 163952, from USGS locality D5145 (fig. 16, loc. 118). *C*, Paratype, USNM 163943, from USGS locality D3965 (fig. 16, loc. 54).

larges, bullae gradually appear on every rib, become stronger, and migrate away from the umbilicus. On the adult whorls the umbilical tubercles are located from one-third to one-half the distance from the umbilical seam to the row of lower ventrolateral tubercles.

The ribs nearly disappear on the adult whorls (pl. 11, fig. 13), but the last one or two may become strong again and flangelike. The part of the adult venter between opposite ventrolateral tubercles is commonly elevated a little and flattened, and on some specimens the middle of the flattened area may be depressed slightly.

Fragments of the largest specimens suggest that the species attained a diameter of about 200 mm (pl. 7, figs. 10, 13). The suture is typical of the genus.

The holotype (pl. 11, fig. 13) is a small crushed adult 143 mm in diameter that has an umbilical width of 35.4 mm (ratio of 25 percent). The last half whorl has eight clavate ventrolateral tubercles and eight bullate umbilical tubercles.

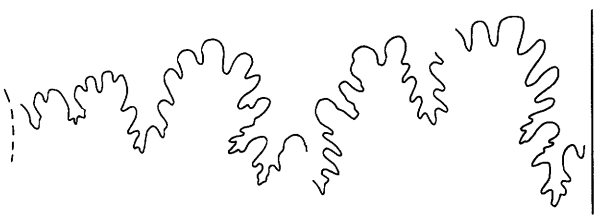


FIGURE 28.—Last suture (× 1½) of the specimen of *Acanthoceras muldoonense* Cobban and Scott, n. sp., shown on plate 11, figure 12. From USGS locality D5145 (fig. 19, loc. 118). USNM 163951.

The adult whorls of *Acanthoceras muldoonense* very closely resemble those of *A. alvaradoense* Moreman (1942, p. 205, pl. 32, fig. 6; text figs. 2o, t), but the inner whorls are very different. The juvenile whorls of *A. alvaradoense* are somewhat euomphaloceratid and have more siphonal tubercles than ventrolateral ones, and the siphonal and upper ventrolateral tubercles persist out to greater shell diameters than on *A. muldoonense*.

Type.—Holotype, USNM 163941; paratypes, USNM 163942–163952.

Occurrences.—Graneros Shale: Rock Canyon section, beds 55 (USGS locs. D5151, D3963, D5729, D5294), 57 (USGS locs. D3965, D1306), 60 (USGS loc. D5152); Siloam section, bed 6 (USGS loc. D5712); Muldoon Hill section, beds 8, 9, and 11 (USGS locs. D5144, D5145, D5146). The species is known only from the Graneros Shale above the Thatcher Limestone Member in southeastern Colorado.

Acanthoceras granerosense Cobban and Scott, n. sp.

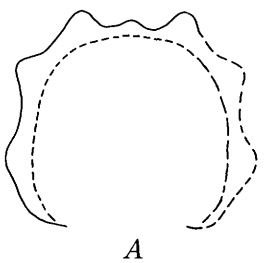
Plate 2, figures 1–4; plate 4, figure 2; plate 5, figure 3; plate 6, figures 1–3; text figures 29, 30

This species is characterized by very strong lower ventrolateral tubercles and by sparse ribbing in which alternate ribs extend to the umbilicus on sev-

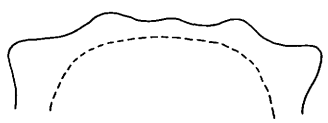
eral of the inner whorls. The species is represented by many somewhat crushed and distorted specimens from the Graneros Shale 6–8 feet above the Thatcher Limestone Member.

At the smallest diameter observed (15.6 mm), the whorls are stout and typically acanthoceratid and have umbilical, lower and upper ventrolateral, and siphonal tubercles, all of which are nodate and nearly equisized. Juveniles are rather involute; umbilical ratios of two specimens of about 27- and 42-mm diameter are approximately 17–18 percent. This ratio increases on larger specimens to about 25–26 percent at a diameter of 190 mm. The umbilical wall is gently sloping at all growth stages observed. Flanks and venter of adults are flattened, the result being a squarish cross section (text fig. 29).

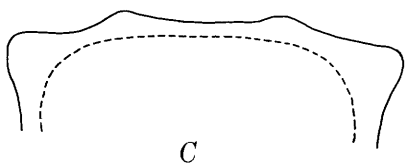
Ribs are strong and rectiradiate, and most are straight. They are sparse, numbering only seven to nine per half whorl. On most of the inner whorls, alternate ribs extend to the umbilicus where they rise into strong bullate tubercles well out from the umbilical seam. Each rib has lower and upper ventrolateral tubercles that are commonly clavate on most of the whorls. On the last whorl the upper ventrolateral tubercles weaken and disappear, whereas the lower ones increase in size (pl. 5, fig. 3; text fig. 29). The siphonal tubercles begin to weaken and become clavate at a diameter of about 18–20 mm. They disappear at some diameter between 50 and 70 mm. Only part of the suture is clearly visible on a few of the very small specimens.



A



B



C

FIGURE 29.—Cross sections, natural size, of whorls of *Acanthoceras granerosense* Cobban and Scott, n. sp., from the Graneros Shale at USGS locality D5124 (fig. 16, loc. 130). *A*, Paratype, USNM 163958. *B*, Paratype, USNM 163956 (pl. 5, fig. 3). *C*, Paratype, USNM 163959.

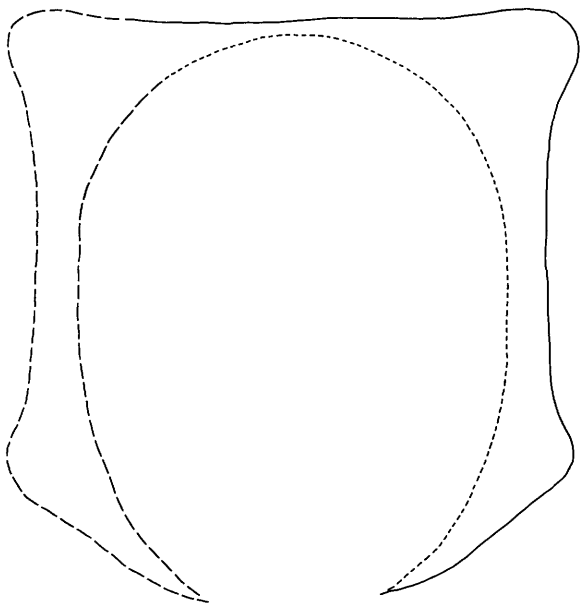


FIGURE 30.—Section, natural size, through the body chamber of the holotype of *Acanthoceras granerosense* Cobban and Scott, n. sp. USNM 163953.

The holotype is part of a large adult that was at least 190 mm in diameter. It consists of about half of two whorls. Much of the specimen is crushed, but the larger end is undeformed enough to reveal a squarish cross section (text fig. 30). Ribs are of equal strength on the outer whorl where they number about nine per half whorl and bear strong umbilical and lower ventrolateral tubercles.

A. granerosense is probably most closely related to *A. latum* Crick (1907, p. 195, pl. 12, figs. 2, 2a) from the upper Cenomanian of South Africa; *A. latum* has about the same rib density and has similar large hornlike lower ventrolateral tubercles. *A. latum*, however, maintains its siphonal tubercles to a larger diameter and has a more depressed whorl section.

A. quadratum Crick (1907, p. 192, pl. 13, figs.

2, 2a), also from the upper Cenomanian of South Africa, resembles *A. granerosense* in having alternate ribs which extend to the umbilicus on the inner whorls, but its rib density is greater and its umbilical and lower ventrolateral tubercles are smaller. Of the American species, *A. granerosense* most closely resembles *A. stephensoni* Adkins (1928, p. 246, pl. 31, figs. 1, 2) from the basal part of the Eagle Ford Shale of Texas. *A. stephensoni*, which probably should be assigned to *A. latum* Crick, maintains its siphonal tubercles to a larger diameter and lacks the alternate ribbing on the inner whorls.

Types.—Holotype, USNM 163953; paratypes, USNM 163954–163960.

Occurrences.—Graneros Shale: Rock Canyon section, bed 55 (USGS loc. D5151); Old Hatchet Ranch section, bed 7 (USGS locs. D5290–92, D5124, D5125); Siloam section, bed 6 (USGS loc. D5711); Muldoon Hill section, bed 8 (USGS locs. D5718, D5144). These occurrences are in the Graneros Shale above the Thatcher Limestone Member. The species is not known outside of southeastern Colorado.

Genus EUOMPHALOCERAS Spath, 1923

Type species.—*Ammonites euomphalus* Sharpe, 1854.

Spath (1923, p. 144) did not describe *Euomphaloceras*, but instead he designated *Ammonites euomphalus* Sharpe (1854, p. 31, pl. 13, figs. 4a–c) as the type. Arkell, Kummel, and Wright (1957, p. L414) gave the following definition: "Very evolute, rather depressed; prominent umbilical and ventrolateral tubercles on some or all main ribs; venter broad and flat, with 3 rows of small tubercles or ribs, more numerous than ventrolateral tubercles; with shallow ventral constrictions."

Sharpe's illustrations are of a small immature specimen. Wright (1963, p. 609) pointed out that *E. euomphalus* is variable at all growth stages. Specimens less than 40 mm in diameter have ventral ornamentation consisting of transverse ventral ribs, weak to strong siphonal tubercles, and either high pointed ventral tubercles on some ribs or paired equisized ventral tubercles on all the ventral ribs—there are three or four noded ventral ribs to each ventrolateral tubercle. At a diameter of about 40 mm, the ratio of noded ventral ribs to ventrolateral tubercles changes to 2:1 and at larger diameters alternate rows of ventral tubercles disappear which results in the mature ammonite having simple ventrolateral horns and large umbilical tubercles.

Euomphaloceras has a wide geographic distribution in rocks of middle and late Cenomanian age.

Euomphaloceras cf. E. cunningtoni (Sharpe)

Plate 4, figures 4, 5; plate 5, figures 6–8; text figures 31–33

Six distorted specimens from the Thatcher Limestone Member represent *Euomphaloceras*. The inner whorls are badly crushed, and the ventral ornamentation is visible on only two. Both show that at diameters of about 35 and 45 mm three ventral ribs having small siphonal tubercles are present for each ventral and ventrolateral tubercle. The ventrolateral tubercles are large, high, and rounded, whereas the ventral ones are smaller and clavate (fig. 31). On the adult whorls the siphonal tubercles disappear, and the ventral and ventrolateral tubercles unite into laterally directed horns that rise well above the middle of the venter (fig. 32). From each horn a conspicuous rib extends straight across the flank to the umbilicus. Each rib rises into a sharp bullate tubercle near the umbilical shoulder. The ribs number about seven per half whorl on the large specimens. Opposite ventrolateral horns are connected by two weak ribs that extend straight across the venter, and the area enclosed within each pair

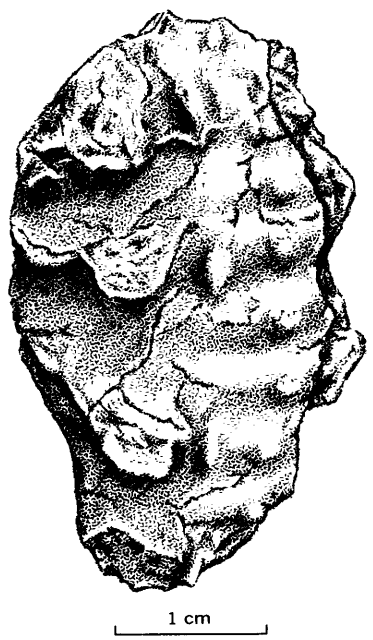


FIGURE 31.—Drawing showing ventrolateral view (× 2) of a specimen of *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) from the Thatcher Limestone Member of the Graneros Shale from USGS locality D4445 (fig. 16, loc. 73). USNM 163964.

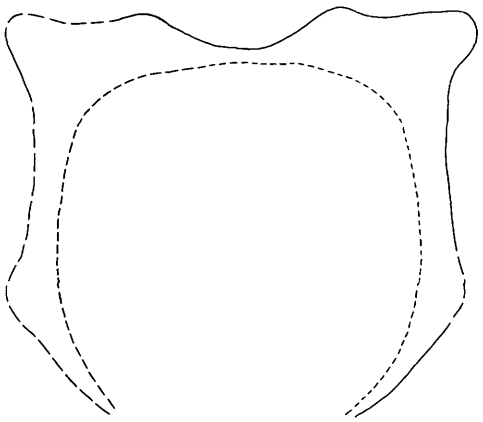


FIGURE 32.—Section, natural size, through the larger end of the specimen of *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) shown on plate 4, figures 4, 5. USNM 163961.

of ribs tends to be conspicuously depressed. Only part of the suture is visible on one of the specimens (fig. 33) which shows most of the first lateral saddle and lateral lobe. These are rather broad and shallow, symmetrically bifid, and moderately incised.

The specimens of *Euomphaloceras* from the Thatcher Limestone Member are possibly *E. cunningtoni* (Sharpe) (1854, p. 35, pl. 15, figs. 2a–c). The adults have the same type of cross section in which the ventrolateral horns rise well above the middle part of the venter, and the ventral tubercles form a small projection on the siphonal side of the ventrolateral horns as shown in the excellent illustrations by Sharpe, Kossmat (1897, pl. 5, fig. 1b), and Wright (1963, pl. 88, figs. 2b, c). The specimen from the Woodbine Formation of Texas described by Stephenson (1952, p. 201, pl. 47, fig. 5; pl. 48, figs. 3, 4) as *Acanthoceras*? *eulessanum* also has this type of cross section as well as other ornamentation that suggests assignment to *E. cunningtoni*, as already pointed out by Wright (1963, p. 608). The specimens, illustrated by Ooster (1860, pl. 27, figs. 1–5) as examples of *Ammonites rhotomagensis* Defrance, also show this same cross section and other features that suggest assignment to *E. cunningtoni*. The last half whorl on the large specimens illustrated by Sharpe, Kossmat, Wright, Stephenson, and Ooster, has five to seven rectiradiate ribs on the flank; this number is comparable to the seven ribs on the last half whorl of the largest specimens from the Thatcher Limestone Member.

Figured specimens.—USNM 163961–163964.

Occurrences.—Graneros Shale: Rock Canyon section, bed 54 (USGS loc. D4445). The species has also been found in the Thatcher Limestone Member of the Graneros Shale southwest of Pueblo at USGS localities 1323 and 22883 (fig. 19, loc. 116).

Euomphaloceras cf. E. lonsdalei (Adkins)

Plate 5, figures 1, 2, 4

A few badly crushed ammonites from the upper part of the Graneros Shale probably represent the species described as *Acanthoceras lonsdalei* by Adkins (1928, p. 244, pl. 26, fig. 5; pl. 27, fig. 3) and assigned to *Euomphaloceras* by Stephenson (1955, p. 62) and Wright (1963, p. 609). The specimens show the dense ribbing and tuberculation characteristic of that species, but none is complete enough for positive identification.

Figured specimens.—USNM 163965–163967.

Occurrence.—Known only from ironstone concretions 16.5–20 feet above the Thatcher Limestone Member at USGS localities D6726 and D5145 (fig. 16, loc. 137 and 118).

Genus KANABICERAS Reeside and Weymouth, 1931

Type species.—*Acanthoceras*(?) *kanaberse* Stanton, 1893 [1894] (=*Scaphites*? *septemseriatus* Cragin, 1893).

This genus is moderately evolute; the type species has an umbilical ratio of about 32 percent for specimens 25–70 mm in diameter. The umbilical wall is steep, and the umbilical shoulder is rounded. The whorls are stout and have short slightly flattened

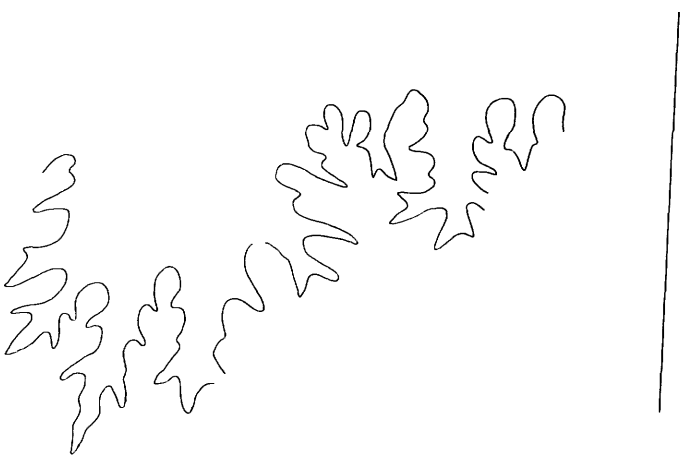


FIGURE 33.—Part of the external suture (× 2) of a specimen of *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) from the Thatcher Limestone Member of the Graneros Shale at USGS locality 22883 (fig. 16, loc. 116). The middle of the venter is indicated by the straight line. USNM 163963.

flanks and a very broadly rounded venter. The sculpture is very diagnostic: it consists of umbilical, lower ventrolateral, upper ventrolateral, and siphonal tubercles that tend to be spinose and ribs that are ordinarily narrow, sharp, and irregular in height and spacing on all but the earliest whorls. The ventrolateral tubercles are set back at an angle to the siphonal tubercles. The siphonal tubercles are nodate to clavate and form a low keel. The upper ventrolateral tubercles are as numerous as the siphonal ones, but there are more siphonal tubercules than lower ventrolateral and umbilical ones. The suture is rather simple and has a broad little incised lateral lobe.

Kanabiceras septemseriatum (Cragin)
Plate 12, figures 5–27

1893. *Scaphites septem-seriatus* Cragin, Texas Geol. Survey 4th Ann. Rept., pt. 2, p. 240.
1894. *Acanthoceras*? *kanabense* Stanton, U.S. Geol. Survey Bull. 106, p. 181, pl. 36, figs. 6–8 [1893 imprint].
1898. *Acanthoceras kanabense* Stanton. Logan, Kansas Univ. Geol. Survey, v. 4, pt. 8, pl. 107, figs. 4–6.
1927. *Acanthoceras*? *knabense* [sic] Stanton. Moreman, Jour. Paleontology, v. 1, no. 1, p. 95, pl. 13, fig. 5.
1928. *Scaphites septem-seriatus* Cragin. Adkins, Texas Univ. Bull. 2838, p. 259.
1931. *Kanabiceras kanabense* (Stanton). Reeside and Weymouth, U.S. Natl. Mus. Proc., v. 78, art. 17, p. 11.
1931. *Neocardioceras septem-seriatum* (Cragin). Adkins, Texas Univ. Bull. 3101, p. 60, 72.
1931. *Neocardioceras* n. sp. Adkins, Texas Univ. Bull. 3101, p. 61, pl. 2, figs. 7, 9.
1931. *Prionotropis echinatus* Douvillé, Lisboa Univ. Mus. e Lab. Mineral. e Geol. Bol., 1st ser., v. 1, no. 1, p. 34, pls. 3, 4.
1942. *Neocardioceras septemseriatum* (Cragin). Moreman, Jour. Paleontology, v. 16, no. 2, p. 213, pl. 33, figs. 11, 12; text fig. 2f.
1951. *Neocardioceras* [*septemseriatum* (Cragin)]. Adkins and Lozo, Fondren Sci. Ser., no. 4, pl. 6, figs. 7, 8.
1957. *Kanabiceras septemseriatum* (Cragin). Wright, *in* Arkell, Kummel, and Wright, Treatise on invertebrate paleontology, Pt. L, Mollusca 4, p. L414, text figs. 534–5a, b.
1958. *Lyelliceras stanislausense* Anderson, Geol. Soc. America Mem. 71, p. 247, pl. 8, figs. 5, 5a.
1959. *Kanabiceras septemseriatum* (Cragin). Matsumoto (1959e), Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, Spec. v. 1, p. 99, pl. 24, figs. 1a–c, text figs. 52, 53.
1963. *Kanabiceras septemseriatum* (Cragin). Powell, Jour. Paleontology, v. 37, no. 2, p. 316, pl. 31, figs. 9, 10.
1969. *Kanabiceras septemseriatum* (Cragin). Matsumoto, *in* Matsumoto, Muramoto, and Takahashi, Kyushu Univ. Fac. Sci. Mem., Ser. D, Geology, v. 19, no. 2, p. 279, pl. 37, figs. 1–3.

The holotype (pl. 12, figs. 24, 25) is from a clay-ironstone concretion from the Eagle Ford Shale of Dallas County, Tex. It consists of most of an adult. The specimen has not been hitherto illustrated, but both Cragin (1893, p. 240) and Adkins (1931, p. 61) adequately described the outer whorl. At the time of their study, neither Cragin nor Adkins uncovered the inner whorls which were largely concealed by matrix. The specimen is 70.3 mm in diameter and has an umbilical width of 25.2 mm (ratio of 36 percent). The outer whorl has an intercostal height of 25.3 mm and thickness of 33 mm. At a diameter of about 10.5 mm, 11 strong ribs cross the umbilical wall on half a whorl. Each rib weakens greatly on crossing the flank, but at the ventrolateral margin each one rises into a conspicuous nodate tubercle. These tubercles are unequal in size, and the larger are elongated into spines. On the next whorl (penultimate), most of the ribs rise into bullate umbilical tubercles of unequal heights, and these number nine per half whorl at a diameter of about 27 mm. Ribs and tubercles are very irregular in height and spacing on the outer whorl.

Kanabiceras septemseriatum is represented by 45 internal molds from the basal beds of the Bridge Creek Limestone Member from the Pueblo and Hamilton County areas. They range in diameter from 5 to 70 mm. A considerable degree of stoutness is revealed by these specimens (pl. 12, figs. 14, 15).

On the inner whorls the siphonal tubercles are nodate to clavate and number about 18 per half whorl. On these same whorls the upper ventrolateral tubercles are nodate to bullate, as numerous as the siphonal ones, and of about the same size. The lower ventrolateral tubercles, however, are not quite so numerous, and every second, third, or fourth one tends to be larger than the intervening ones. The larger ones are nodate whereas the smaller ones are bullate. The umbilical tubercles are bullate, about as numerous as the lower ventrolateral ones and, like them, irregular in strength. Ribs are numerous, narrow, and variable in strength. They are a little rectiradiate on crossing the flank, and at the ventrolateral margin, they are arched forward (pl. 12, figs. 13, 21). On the adult whorl, all ribs and tubercles become irregular in strength, the upper ventrolateral tubercles become a little larger than the siphonal ones, and the siphonal tubercles range in shape from nodate to clavate for the larger ones to bullate for the smaller ones.

Types.—Holotype, BEG 21058; hypotypes, USNM 163968–163977.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 67 (USGS locs. D3973, D6472), 73 (USGS locs. D4444, D6484), 77 (USGS

loc. D3974); Hinkle Ranch section, beds 9, 11, and 15 (USGS locs. D4869, D4870, D4871). In addition the species is present in many of the U.S. Geological Survey's collections from the basal part of the Bridge Creek Limestone Member of the Front Range and Arkansas River valley areas of central and eastern Colorado, as well as from the equivalent part of the Mancos Shale of northwestern New Mexico and northeastern Arizona. The species has also been recorded from the Tropic Shale of southern Utah (Stanton, 1893, p. 35, as *Acanthoceras kanabense*), from the Greenhorn Formation on the north flank of the Black Hills uplift in the southeast corner of Montana (Cobban, 1951, p. 2185, as *Neocardioceras septemseriatum*), and from the Hartland Shale Member of the Greenhorn Limestone of central Kansas (Hattin, 1965b, p. 15, 51, as *Kanabiceras kanabense*). In Texas, *Kanabiceras septemseriatum* is known from the Eagle Ford Shale of the Dallas area (Moreman, 1927, p. 95, pl. 13, fig. 5; 1942, p. 213, pl. 33, figs. 11, 12, text fig. 2f) and from the equivalent rocks of west Texas (Powell, 1963a, p. 316, pl. 31, figs. 9, 10; 1965, p. 516, 517). The species seems to be present in California as indicated by the specimen described by Anderson (1958, p. 247, pl. 8, figs. 5, 5a) as the new species *Lyelliceras stanislausense* and the specimen illustrated by Matsumoto (1959e, p. 99, pl. 24, figs. 1a–c) as *Kanabiceras septemseriatum*. Anderson's specimen is a little more coarsely sculptured than specimens of similar size from the western interior region, but this difference may be due to geographic separation. Matsumoto (1959e, p. 102; 1959b, p. 65) recorded the species from Hokkaido, Japan.

Kanabiceras puebloense Cobban and Scott, n. sp.

Plate 15, figures 8, 9; plate 37, figures 1–8; plate 38, figure 1

This species differs from *Kanabiceras septemseriatum* chiefly in having fewer tubercles and more uniform sculpture. The holotype has nine lower and nine upper ventrolateral tubercles on the last half whorl, and it probably has the same number of siphonal tubercles. Comparable-sized specimens of *K. septemseriatum* have about twice as many tubercles.

K. puebloense is represented by 15 internal molds all from bed 105 in the middle of the Bridge Creek Limestone Member in the Rock Canyon anticline section. The larger inner whorls are visible on only a few of the specimens, and none is well preserved. The details of the venter of one of the inner whorls at a diameter of approximately 25 mm are revealed on the dorsum of the next larger whorl (pl. 37, fig. 4). It shows clavate siphonal tubercles and an equal number of nodate upper ventrolateral tubercles; the tubercles of both rows are irregular in strength. Lower ventrolateral tubercles are fewer in number, and each one is elongated into a spine directed outward at a high angle away from the plane of symmetry. This inner whorl as well as the next outer whorl had possibly 15–16 upper ventrolateral tubercles per half whorl, and it represents the most densely tuberculated specimen at hand. The other specimens have 13–14 ventrolateral tubercles per half whorl except for the holotype which has nine.

The holotype has a midventral diameter of 51.5 mm. The outer whorl has a maximum midventral height of 20.5 mm and an intercostal width of about 22.7 mm. Its umbilicus is 19.8 mm in diameter (ratio is 38 percent). The suture cannot be delineated on this specimen or on any of the paratypes.

K. puebloense is similar to *K. septemseriatum* in size. The largest specimen of *K. puebloense* is about 83 mm in diameter.

Types.—Holotype, USNM 163978; paratypes, USNM 163979–163985.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 105 (USGS locs. D3979, D4305, D4442, D6121, D6124, D6479, D6525). The species has also been found in this bed on the Model anticline northeast of Trinidad, Colo. (USGS loc. D6523).

Genus METOICOCERAS Hyatt, 1903

Type species.—*Ammonites swallovi* Shumard, 1860.

Reeside and Weymouth (1931, p. 20) gave a very good definition of this genus which is as follows:

> *Metoicoceras* may be considered to include ammorites with more or less compressed shells. Umbilicus small, with or without umbilical nodes; ribs near umbilicus may be nearly obsolete if there are no umbilical nodes, or strong, rounded if there are. Ribs somewhat flexed to nearly straight, usually forking on the flank; intercalated secondary ribs common. Outer part of flank usually bears distinct ribs and a row of nodes which forms the inner margin of a ventrolateral facet. Venter bordered by two rows of elongated nodes and in the earlier stages concave or flattened. In late stages the nodes decrease in prominence, the venter becomes rounded, and the ribs pass across as coarse rounded folds. Living chamber usually scaphitoid in large individuals. Suture relatively simple, ceratitic, consisting of three principal lobes, two principal saddles, all more or less clearly bifid, and a few small auxiliaries.

Metoicoceras seems to be confined to the uppermost Cenomanian and lowermost Turonian and is widely distributed in the Tethyan region and marginal areas of the world. It is perhaps most common

in the United States: Texas (Hyatt, 1903, p. 118–128; Moreman, 1942, p. 210–212), Arizona (Young, 1957, p. 1169–1171), Utah (Hyatt, 1903, p. 122–127), Wyoming (Haas, 1949, p. 15–20), Montana (Cobban, 1953, p. 45–51), Minnesota (Bergquist, 1944, p. 30), and Mexico (Böse, 1918, p. 184–185). Farther south the genus has been recorded from Colombia (Petters, 1955, p. 213, 224). In Europe *Metoicoceras* has been found in England (Wright and Wright, 1951, p. 27), France (Leriche, 1905; de Grossouvre, 1912, p. 19–24, as *Mammites pervinquièrei, M. gourdoni, M. geslini, M. petraschecki, M. bureaui, M. dumasi,* and *M. pontieri*), Germany (Petrascheck, 1902, p. 140, as *Pulchellia geslinianа*), and Spain (Karrenberg, 1935, p. 137–139; Wiedmann, 1959, p. 725–727). The genus is known from Africa by specimens described from Nigeria by Reyment (1955, p. 47–49) and from Madagascar by Collignon (1964, p. 149–151). *Metoicoceras* has recently been discovered in India (Sastry and Matsumoto, 1967) and Iran (James and Wynd, 1965, p. 2213).

Metoicoceras whitei Hyatt

Plate 14, figures 3, 4, 9–11; plate 16, figures 1, 2; text figure 34

1877. *Buchiceras swallovi* (Shumard). White, U.S. Geog. and Geol. Surveys West of 100th Meridian (Wheeler), v. 4, pt. 1, p. 202, pl. 20, figs. 1a–c.
1894. *Buchiceras swallovi* (Shumard). Stanton, U.S. Geol. Survey Bull. 106, p. 168, pl. 37, fig. 1; pl. 38, figs. 1–3 [1893 imprint].
1901. *Buchiceras swallovi* (Shumard). Hill, U.S. Geol. Survey 21st Ann. Rept., pt. 7, pl. 40, fig. 2.
1903. *Metoicoceras whitei* Hyatt, U.S. Geol. Survey Mon. 44, p. 122, pl. 13, figs. 3–5; pl. 14, figs. 1–10, 15.
1903. *Metoicoceras gibbosum* Hyatt, U.S. Geol. Survey Mon. 44, p. 121, pl. 15, figs. 5–8.
1903. *Metoicoceras kanabense* Hyatt, U.S. Geol. Survey Mon. 44, pl. 15, figs. 9–11.
1910. *Metoicoceras whitei* Hyatt. Grabau and Shimer, North American index fossils, v. 2, p. 197, text figs. 1457c–e.
1912. *Mammites whitei* (Hyatt). de Grossouvre, Soc. Sci. Nat. l'Ouest France Bull., 3d ser., v. 2, p. 24.
1912. *Mammites kanabensis* (Hyatt). de Grossouvre, Soc. Sci. Nat. l'Ouest France Bull., 3d ser., v. 2, p. 24.
1912. *Mammites gibbosus* (Hyatt). de Grossouvre, Soc. Sci. Nat. l'Ouest France Bull., 3d ser., v. 2, p. 25.
?1920. *Metoecoceras* aff. *whitei* Hyatt. Böse, Texas Univ. Bull. 1856, p. 203, pl. 12, figs. 4, 7 [1918 imprint].
1926. *Metoicoceras whitei* Hyatt. Scott, Études stratigraphiques et paléontologiques sur les terrains crétacés du Texas, Univ. Grenoble Fac. Sci., thesis, p. 142.
1927. *Metoicoceras whitei* Hyatt. Moreman, Jour. Paleontology, v. 1, no. 1, p. 94, pl. 15, fig. 1.
1927. *Metoicoceras gibbosum* Hyatt. Moreman, Jour. Paleontology, v. 1, no. 1, p. 96, pl. 14, fig. 4.
1928. *Metoicoceras whitei* Hyatt. Adkins, Texas Univ. Bull. 2838, p. 249, pl. 26, figs. 1, 2.
1928. *Metoicoceras gibbosum* Hyatt. Adkins, Texas Univ. Bull. 2838, p. 248.
?1931. *Pulchellia caicedoi* Karsten. Douvillé, Lisboa Univ. Mus. e Lab. Mineral. e Geol. Bol., 1st ser., v. 1, no. 1, p. 26, pl. 2, figs. 1a, b.
1942. *Metoicoceras whitei* Hyatt. Moreman, Jour. Paleontology, v. 16, no. 2, p. 210.
1942. *Metoicoceras gibbosum* Hyatt. Moreman, Jour. Paleontology, v. 16, no. 2, p. 211.
1944. *Metoicoceras whitei* Hyatt. Shimer and Shrock, Index fossils of North America, p. 591, pl. 245, figs. 8–10.
1951. *Metoicoceras* [*whitei* Hyatt]. Adkins and Lozo, Fondren Sci. Ser., no. 4, pl. 6, fig. 13.
1960. *Metoicoceras whitei* Hyatt. Easton, Invertebrate paleontology, text figs. 11.32–5a–c.

Hyatt (1903, p. 122–127) included specimens from Texas and Utah in his description of *Metoicoceras whitei*. As pointed out by Reeside and Weymouth (1931, p. 22), confusion exists as to the source of the holotype. At one place, Hyatt (1903, p. 126) indicated that the type was from Utah, but on the explanation of his plate 14, he stated that it was probably from Texas. The holotype is a large phragmocone 122 mm in diameter whose umbilical ratio is 11 percent. The last half whorl has 11 straight rectiradiate ribs which, according to Hyatt's illustration (pl. 14, fig. 7), weaken toward the umbilicus. Each rib has a lower and an upper ventrolateral tubercle. Hyatt (1903, pl. 13, figs. 3, 4) also figured a nearly complete adult from southern Utah about 146 mm in diameter whose umbilical ratio is 13 percent. Ribs number 13 or 14 per half whorl and, on the living chamber, every other one extends to the umbilicus. On the phragmocone, every second or third rib extends to the umbilicus where it becomes bullate. Each rib has a nodate lower ventrolateral tubercle and a clavate upper ventrolateral tubercle; on the orad part of the phragmocone and on the living chamber, the rib area between these tubercles is conspicuously flattened.

The smallest specimen available to Hyatt (1903, pl. 14, figs. 1, 2) was an individual about 26 mm in diameter whose umbilical ratio is 10 per cent. Ribs number about 11 per half whorl, and every second or third extends to the umbilicus.

Large collections of *M. whitei* now available from southern Utah include specimens less than 10 mm in diameter. These reveal the presence of four or five ventral constrictions per half whorl at diameters from 4 to 9 mm. Just after the appearance of the initial constriction, the margins of the succes-

sive constrictions gradually rise into ribs which support nodate upper ventrolateral tubercles, and the apicad rib of each pair bears a nodate lower ventrolateral tubercle.

M. whitei is represented in the collections from the Pueblo area by about a dozen specimens from near the base of the Bridge Creek Limestone Member. A nearly complete adult (pl. 16, figs. 1, 2) 175 mm in diameter has a shallow umbilicus whose ratio is 15 percent. Ribs number 11 or 12 per half whorl, and nearly every other one extends to the umbilicus. The largest collection (USGS loc. D6472) has four specimens suitable for rib counts. The diameters in millimeters of the specimens and number of ribs per half whorl are as follows:

Specimen (USNM No.)	*Diameter*	*Ribs*
163987	72.5	16
163988	108.4	15
163989	148.0	12
163990	185.0±	13

Sutures are barely visible on a few specimens. A nearly complete external suture on a specimen from USGS locality D5127 18 miles northwest of Pueblo is shown in figure 34.

Types.—Hypotypes, USNM 163986–163991.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 67 (USGS locs. D3973, D6472). The species is known from the *Sciponoceras gracile* Zone near the base of the Bridge Creek Limestone Member at many localities in eastern Colorado and Kansas and from equivalent strata in much of the western interior region, as well as in Texas.

Metoicoceras cf. M. defordi Young

A few fragments of crushed ammonites from bed 38 (USGS loc. D6488) of the Rock Canyon section of the Hartland Shale Member may represent *Metoicoceras defordi* Young (1957, p. 1169, pl. 149, figs. 1–8; text figs. 1a, e, g, i). Young's species is widely distributed in rocks equivalent to the Hartland Shale Member in Wyoming, Colorado, and New Mexico (U.S. Geol. Survey collections).

FIGURE 34.—Second from last suture, natural size, of a specimen of *Metoicoceras whitei* Hyatt (pl. 14, figs. 3, 4) from the second limestone bed above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone at USGS locality D5127 in the SE¼NE¼ sec. 18, T. 18 S., R. 67 W., Pueblo County, Colo. USNM 163986.

Genus WATINOCERAS Warren, 1930

Type species.—*Watinoceras reesidei* Warren, 1930.

This is a moderately evolute genus that has somewhat compressed whorls, narrow but conspicuous ribs, and umbilical, lower ventrolateral, and upper ventrolateral tubercles of which the upper ventrolateral ones are the strongest. The siphonal area is narrow, somewhat flattened, and bordered by the high closely spaced upper ventrolateral tubercles. Ribs are prorsiradiate and, on the inner whorls, sigmoidal. The suture is rather simple and has a wide slightly incised first lateral saddle and much narrower lateral lobe.

The genus is widely distributed in North America in lower Turonian strata. It is known from northern Alaska (Cobban and Gryc, 1961, p. 186–187), Canada (District of Mackenzie, Warren, 1947, p. 122; Alberta, Warren, 1930, p. 66–68), and the conterminous United States (Montana, Cobban, 1956a, p. 1003–1004; Wyoming, Hose, 1955, p. 98; Colorado, Henderson, 1908, p. 259–260; Kansas, Hattin, 1965b, p. 16; and Texas, Adkins, 1931, p. 38, 62; Powell, 1965, p. 516–517). The species has been recorded with some question from northern Mexico (Kellum and Robinson, 1963, p. 240). Outside North America, *Watinoceras* has been described from the Turonian of Turkestan (Arkhangelskii, 1916, p. 48–49, pl. 7, figs. 8–13; pl. 8, figs. 8–10), Madagascar (Collignon, 1965a, p. 38, pl. 392, fig. 1671), Cameroon (Reyment, 1955, p. 55–57, text figs. 25b–f; 1957, p. 57–58, pl. 9, figs. 6a–c, pl. 11, figs. 4a–c), and Morocco (Collignon, 1966b, p. 35–38, pl. 19, figs. 4–15; pl. 20, figs. 1–3). It has also been reported from Spain (Wiedmann, 1959, p. 723), England (Smith and Drummond, 1963, p. 338), and Japan (Matsumoto, 1959c, p. 359).

Watinoceras reesidei Warren?

Plate 27, figures 7–10; plate 28, figure 4

1930. *Watinoceras reesidei* Warren, Alberta Research Council Geol. Survey Rept. 21, p. 67, pl. 3, fig. 2; pl. 4, figs. 9–12.
1947. *Watinoceras reesidei* Warren. Warren, Jour. Paleontology, v. 21, no. 2, p. 122, pl. 30, fig. 6.
1961. *Watinoceras reesidei* Warren. Cobban and Gryc, Jour. Paleontology, v. 35, no. 1, p. 186, pl. 38, figs. 44–49; text figs. 2g, h.
1965. *Watinoceras reesidei* Warren. Hattin, Upper Cretaceous stratigraphy, paleontology, and paleoecology

of western Kansas, Geol. Soc. America Field Conf. Guidebook Ann. Mtg., 1965, text fig. 3–3.

This species was based on juvenile specimens less than 20 mm in diameter. The five individuals illustrated by Warren (1930, 1947) are moderately evolute, and their umbilical ratio is about 40 percent. The whorls, which are higher than wide, are ornamented with numerous narrow slightly sigmoidal prorsiradiate ribs of which about every other one extends to the umbilicus. Each rib bears a small sharp lower ventrolateral tubercle and a slightly larger upper ventrolateral tubercle. Most of the ribs that extend to the umbilicus have a low bullate umbilical tubercle. The last half whorl of the holotype has 22 ribs. Impressions of *Watinoceras reesidei* from northwestern Montana (Cobban, 1956a, p. 1003–1004) suggest that the adults attain diameters of 70–80 mm and that the adult whorls are about as densely ribbed as the juvenile whorls.

W. reesidei may be represented in the fossil collections from the Pueblo area by five juveniles. The largest specimen consists of half a whorl 43 mm in diameter (pl. 27, figs. 9, 10). The specimen is distorted, but the whorl section is compressed; it has flattened flanks and an arched venter that is flat in the middle. Ribs are slightly flexuous, inclined forward, and numerous (about 30 per half whorl). Umbilical tubercles are strong and bullate. A small sharp upper ventrolateral tubercle is present on each rib. Lower ventrolateral tubercles are not so numerous, and on the younger half of the specimen, a small one is present on every second or third rib. The species may be represented in the Hinkle Ranch section in Hamilton County, Kans., by a few poorly preserved fragments.

Types.—Hypotypes, USNM 163992–163994.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS locs. D3977, D6147, D6478); Hinkle Ranch section, bed 24 (USGS loc. D4873).

Watinoceras coloradoense (Henderson)

Plate 27, figures 11–19; plate 28, figures 1–3, 5–9; text figures 35–37

1908. *Acanthoceras coloradoensis* Henderson, U.S. Natl. Mus. Proc., v. 34, no. 1611, p. 259, pl. 13, figs. 10, 11.

?1916. *Acanthoceras amudariense* Arkhangel'skii var. *horridum* Arkhangel'skii, Comité Géol. Mém., new ser., no. 152, p. 49, pl. 8, figs. 8–10.

The holotype is most of an adult whose dimensions are given by Henderson as 80 mm in diameter; the outer whorl is 31 mm high and 14 mm wide between the tubercles. The umbilical ratio is 36 percent at an intercostal diameter of 74.5 mm. The umbilical wall is steep, and its shoulder is rounded. Flanks are flattened a little, and the venter is arched on the outer whorl. Inner whorls are missing, but some of their sculpture is revealed in an impression which shows strong narrow rectiradiate ribs numbering 15 per half whorl at a diameter of approximately 24 mm. On the outer whorl, ribs number 11 per half whorl at a diameter of 79 mm, and all but one are strong, narrow, prorsiradiate, and extend to the umbilicus. Each has a bullate umbilical tubercle, a nodate to clavate lower ventrolateral tubercle, and a clavate upper ventrolateral tubercle. The upper ventrolateral tubercle is the largest and rises high above the narrow siphonal area.

Watinoceras coloradoense is common in a bed of limestone near the top of the lower third of the Bridge Creek Limestone Member in the Pueblo area. Most specimens are internal molds of juveniles, but several complete adults are in the collections. Specimens less than 10 mm in diameter are too poorly preserved for study. Umbilical ratios of all the specimens range from 30 to 43 percent, there being no apparent change from the juvenile stage to the adult stage (fig. 35). Most specimens 10–30 mm in diameter have 15–20 ribs per half whorl (fig. 35). Rib density decreases as the shell enlarges so that specimens 40–50 mm in diameter have 13–17 ribs per half whorl, and those 50–60 mm in diameter have only 10–13 ribs. Rib density then gradually increases on adult shells. On early whorls, about every second, third, or fourth rib begins in a nodate or bullate tubercle at the edge of the umbilicus. At first, these ribs, as well as the intervening ones, are somewhat sigmoidal on crossing the flank (pl. 28, fig. 8), but later they become straight. Each bears a nodate to clavate lower ventrolateral tubercle and terminates in a clavate upper ventrolateral tubercle. The two rows of ventrolateral tubercles are about equal in size on the early more densely ribbed whorls, but as the shell enlarges and the ribbing becomes sparser, the upper row become the larger (fig. 36). On the last quarter of the adult shell, all tubercles decrease in size, and the ribs become thinner and denser (pl. 27, figs. 17, 18). The ribs commonly cross the venter on the adult body chamber as broad bulges, well defined on some specimens (pl. 27, fig. 18) and poorly defined on others (pl. 28, fig. 5). Adults attained diameters of 78–116 mm.

Only parts of sutures are visible. Most of an external suture is shown in figure 37.

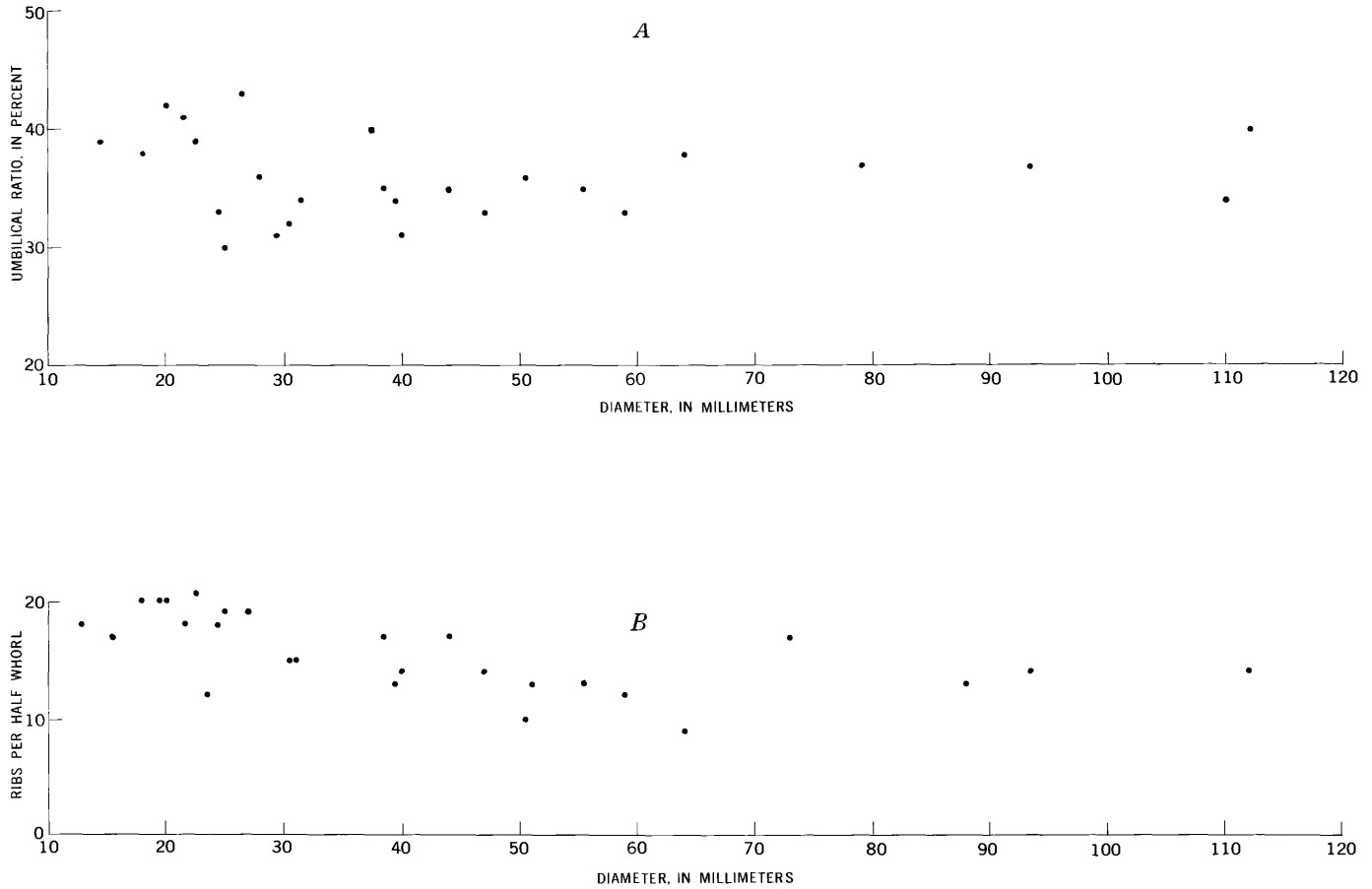


FIGURE 35.—Scatter diagrams showing umbilical ratios (*A*) and ribs per half a whorl (*B*) of *Watinoceras coloradoense* (Henderson) from bed 97 of the Rock Canyon section in the Pueblo area at USGS localities D3977, D6147, and D6478.

W. amudariense var. *horridum* Arkhangel'skii (1916, p. 49, pl. 8, figs. 8–10) from the lower Turonian of Turkestan seems to be *W. coloradoense*. The inner whorls have slightly fewer ribs than most comparable-sized specimens from Colorado, but considering the vast distance between the localities, the resemblances are most striking.

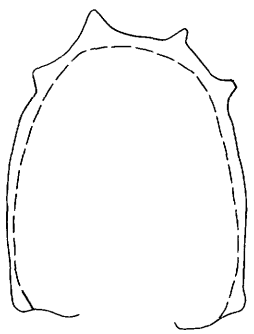


FIGURE 36.—Section, natural size, through the middle of the body chamber of a large adult *Watinoceras coloradoense* (Henderson) from the Greenhorn Limestone at USGS locality D6143 (fig. 16, loc. 36). USNM 164000 (pl. 27, figs. 17, 18).

Types.—Holotype, USNM 30877; hypotypes, USNM 163995–164006.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS locs. 15729, D3977, D4001, D4304, D4439, D4440, D6122, D6143, D6147, D6478); Hinkle Ranch section, bed 40 (USGS loc. D4876). *Watinoceras coloradoense* is also known from many localities in Colorado adjacent to the Front Range from the Fort Collins-Boulder area southward to the Canon City area and eastward along the Arkansas River valley to Kansas.

Genus MAMMITES Laube and Bruder, 1887

Type species.—*Ammonites nodosoides* Schlotheim in von Buch, 1829.

This is a stout genus that has strong but rather sparse umbilical, lower ventrolateral, and upper ventrolateral tubercles. The whorl section is typically rectangular to squarish, and the venter is flat-

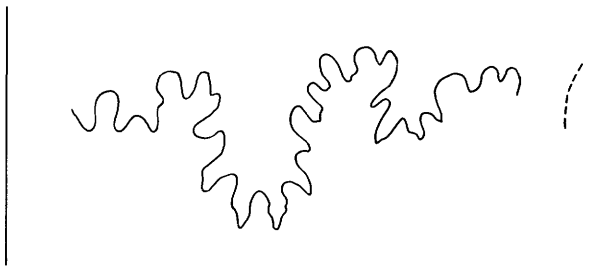


FIGURE 37.—Last external suture (× 2) of an adult *Watinoceras coloradoense* (Henderson) at a diameter of about 70 mm, from the Greenhorn Limestone at USGS locality 15729 (fig. 16, loc. 46). USNM 164006.

tened or slightly concave. The suture is only moderately incised and is similar to that of *Acanthoceras* and *Calycoceras*.

Reyment (1955, p. 49–50) presented a good summary concerning the genotype and scope of the genus.

Mammites nodosoides (Schlotheim)

1829. *Ammonites nodosoides* Schlotheim, *in* von Buch, Annales Sci. Nat., 1st ser., v. 18, p. 424.
1871. *Ammonites nodosoides* Schlotheim. Schlüter, Palaeontographica, v. 21, p. 19, pl. 8, figs. 1–4.
1887. *Mammites nodosoides* (Schlotheim). Laube and Bruder, Palaeontographica, v. 33, p. 229, pl. 25, figs. 1a, b; text fig. on p. 230.
1894. *Mammites nodosoides* (Schlotheim). de Grossouvre, Recherches sur le craie supérieure, Pt. 2, Carte Géol. Détaillée France Mém., p. 28, text fig. 14 [1893 imprint].
1902. *Mammites nodosoides* (Schlotheim). Petrascheck, Beitr. Paläontologie Oesterreich-Ungarns u. des Orients, v. 14, nos. 3–4, p. 142.
1907. *Mammites nodosoides* (Schlotheim). Pervinquière, Études de paléontologie tunisienne—Pt. 1, Céphalopodes des terrains secondaires, Carte Géol. Tunisie, p. 309, pl. 18, figs. 1a, b.
1907. *Mammites nodosoides* (Schlotheim) var. *afra* Pervinquière, Études de paléontologie tunisienne—Pt. 1, Céphalopodes des terrains secondaires, Carte Géol. Tunisie, p. 310, pl. 18, figs. 2–3; text. fig. 118.
1910. *Mammites nodosoides* (Schlotheim) var. *afra* Pervinquière. Brüggen, Neues Jahrb. Mineralogie, Geologie u. Paläontologie, Beil., v. 30, p. 736.
1916. *Mammites nodosoides* (Schlotheim) subsp. *chivensis* Arkhangel'skii, Comité Géol. Mém., new ser., no. 152, p. 51, pl. 8, figs. 1, 4–7; text fig. 18.
1929. *Mammites nodosoides* (Schlotheim) var. *afra* Pervinquière. Steinmann, Geologie von Perú, p. 147, text fig. 181.
?1935. *Mammites* cf. *M. nodosoides* (Schlotheim). Karrenberg, Palaeontographica, v. 82, pt. A, nos. 4–6, p. 136, pl. 31, fig. 10; pl. 33, fig. 6.
1935. *Mammites nodosoides* (Schlotheim) var. *armata* Karrenberg, Palaeontographica, v. 82, pt. A, nos. 4–6, p. 136, pl. 30, figs. 8, 8a; pl. 33, fig. 7.
1938. *Mammites nodosoides* (Schlotheim). Roman, Les ammonites Jurassiques et Crétacées—Essai de genera, p. 449, pl. 45, figs. 429, 429a.
1940. *Mammites nodosoides* (Schlotheim). Fabre, Marseille Univ. Fac. Sci. Annales ser. 2, v. 14, p. 285, pl. 9, fig. 1; pl. 10, fig. 1; text fig. 38.
1940. *Mammites nodosoides* (Schlotheim) var. *afra* Pervinquière. Fabre, Marseille Univ. Fac. Sci. Annales, ser. 2, v. 14, p. 286, pl. 9, fig. 2; text fig. 39.
1940. *Mammites nodosoides* (Schlotheim) var. *spinosa* Basse, Haut-Commissariat République Française, Syrie et Liban, Sec. Études Géol., Notes et Mém., v. 3, p. 458, pl. 7, fig. 2; pl. 9, fig. 2.
1956. *Mammites nodosoides* (Schlotheim) var. *afer* [sic] Pervinquière. Benavides-Cáceres, Am. Mus. Nat. History Bull., v. 108, art. 4, p. 468, pl. 55, figs. 5–8.
1957. *Mammites* aff. *M. nodosoides* (Schlotheim). Bürgl, Colombia Inst. Geol. Nac. Bol. Geol., v. 5, no. 2, pl. 13, figs. 2a, b.
1957. *Mammites nodosoides* (Schlotheim). Wright, *in* Arkell, Kummel, and Wright, Treatise on invertebrate paleontology, [Moore], Pt. L, Mollusca 4, p. L416, text figs. 535–4a, b, c.
1958. *Mammites nodosoides* (Schlotheim). Luppov and Drushchits, Principles of paleontology—Handbook for paleontologists and geologists of the U.S.S.R., v. 6, Mollusca; Cephalopoda 2, Ammonoidea, p. 120, text fig. 95 b.
1958. *Mammites nodosoides* (Schlotheim) var. *chivensis* Arkhangel'skii. Luppov and Drushchits, Principles of paleontology—Handbook for paleontologists and geologists of the U.S.S.R., v. 6, Mollusca,—Cephalopoda 2, Ammonoidea, pl. 58 figs. 4a, b.
1960. *Mammites nodosoides* (Schlotheim). Termier and Termier, Paléontologie stratigraphique, pt. 3, text figs. 2412, 2413.
1963. *Mammites nodosoides* (Schlotheim). Powell, Jour. Paleontology, v. 37, no. 2, p. 316, pl. 33, figs. 1, 3, 4, 6, 10, 11; text figs. 3m–o, t, u.
1966. *Mammites nodosoides* (Schlotheim). Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 39, p.. 20, figs. 11, 11a, b.
1966. *Mammites nodosoides* (Schlotheim) var. *spinosa* Basse. Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 40, pl. 20, figs. 12, 12a.
1966. *Mammites nodosoides* (Schlotheim) var. *afra* Pervinquière. Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 40, pl. 20, figs. 13, 13a.
1966. *Mammites nodosoides* (Schlotheim) var. *tassagdeltensis* Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 40, pl. 21, figs. 1, 1a, b.
1966. *Mammites nodosoides* (Schlotheim) var. *zeibaensis* Collignon, Service Géol. Maroc, Notes et Mém. 175, p. 41, pl. 21, fig. 2.
1966. *Mammites nodosoides* (Schlotheim)?. Willard, Lehigh Univ., The Harvey Bassler collection of Peruvian fossils, p. 41, fig. 1.
1969. *Mammites nodosoides* (Schlotheim). Freund and Raab, Palaenot. Assoc. London Spec. Paper 4, p. 12, pl. 1, fig. 7; text figs. 4g–i.

Schlüter (1871–72, pl. 8, figs. 1–4) was the first person to illustrate this species. He presented two

views each of two specimens about 120 and 295 mm in diameter from the "Labiatus-Mergel" of Westphalen, Germany. His excellent drawings were reproduced by Arkell, Kummel, and Wright (1957, figs. 535–4a, b, c) as typical examples of the genus. The smaller of Schlüter's specimens shows an umbilical ratio of about 22 percent, a rectangular whorl section having flattened flanks, and a flat to slightly concave venter. The larger example (an adult) has an umbilical ratio of about 36 percent, a squarish cross section, and a slightly concave venter. Both specimens have conspicuous nodate umbilical tubercles that number four to six per half whorl. The smaller specimen shows weak ribs that are straight, largely rectiradiate, and most conspicuous on the outer half of the whorls. Each rib bears a lower ventrolateral tubercle and terminates in an upper ventrolateral tubercle. According to Schlüter's drawing of the smaller specimen, 12 ventrolateral tubercles are present on a half whorl of about 88 mm diameter, whereas the number per half whorl decreases to 10 at a diameter of about 117 mm. The drawing of the larger specimen shows that the number of ventrolateral tubercles continues to decrease as the shell enlarges, and that at a diameter of about 276 mm, only five tubercles are present per half whorl. The end view of the larger specimen shows that the lower ventrolateral tubercles continue to increase in size and finally become horns, whereas the upper ventrolateral tubercles weaken and disappear at a diameter of about 170 mm.

A nearly complete external suture was illustrated by Laube and Bruder (1887, p. 230), and this drawing was reproduced later by de Grossouvre (1893, text fig. 14) and Luppov and Drushchits (1958, text fig. 95b). It is moderately incised and acanthoceratid in character. The lateral saddle is broad and deeply bifid, and the lateral lobe is as high but only half as wide. The next two saddles are about as wide as the lateral lobe, and the lobe separating them is about half as large as the lateral lobe.

Pervinquière (1907, p. 309, pl. 18, text fig. 118) described and illustrated some excellent specimens from the lower Turonian of Tunisia. He recognized two groups: (1) a typical form consisting of stout specimens having a few strong nodate umbilical tubercles, and (2) a variety *afra* consisting of more slender specimens having slightly more numerous but bullate umbilical tubercles. On both forms the upper ventrolateral tubercles were observed to be clavate, whereas the lower ventrolateral ones were nodate. Judging from Pervinquière's plate, the smallest specimens show a ventrolateral tubercle count of eight per half whorl at a diameter of about 40 mm for the typical form and nine to 10 at a diameter of about 55 mm for the variety *afra*.

Since Pervinquière's publication, many authors have presented descriptions and illustrations of *Mammites nodosoides* from several localities in the Mediterranean area and in South America. Three authors (Arkhangel'skii, 1916, p. 51; Karrenberg, 1935, p. 136; Basse, 1940, p. 458) proposed new varietal or subspecies names. Most illustrations of *M. nodosoides* and varieties show four or five umbilical tubercles per half whorl on all but the innermost whorls, and most show a gradual decrease in the ventrolateral tubercles from eight to 10 per half whorl at diameters from 30 to 90 mm to five to eight at diameters greater than 90 mm.

M. nodosoides is known from the lower Turonian of Germany (Schlüter, 1871–72, p. 19), Czechoslovakia (Laube and Bruder, 1887, p. 229), France (de Grossouvre, 1893, p. 28; Fabre, 1940, p. 285), England (Wright and Wright, 1951, p. 27), Russia (Arkhangel'skii, 1916, p. 51), Spain (Karrenberg, 1935, p. 136; Wiedmann, 1959, p. 712, 714, 720), Syria (Basse, 1940, p. 458), Israel (Freund and Raab, 1969, p. 12), Morocco (Collignon, 1966b, p. 39), Tunisia (Pervinquière, 1907, p. 309), Madagascar (Collignon, 1965a, p. 38), Peru (Brüggen, 1910, p. 736; Steinmann, 1929, p. 147; Benavides-Cáceres, 1956, p. 468), Colombia (Bürgl, 1957, p. 137), Mexico (Powell, 1965, p. 517, 518), and from several States in the western interior of the United States (Lawrence and others, 1966). The specimens of *Mammites* collected by us from Colorado and Kansas seem referable to *M. nodosoides*, but they differ enough from specimens outside North America to be regarded as a geographic subspecies that we are identifying as *M. nodosoides wingi* Morrow.

Mammites nodosoides (Schlotheim) subsp. wingi Morrow

Plate 26, figures 1–4, 9, 10; plates 31–33; text figure 38

1935. *Mammites wingi* Morrow, Jour. Paleontology, v. 9, no. 6, p. 467, pl. 51, fig. 2; pl. 52, figs. 2a–c; text fig. 2.

?1935. *Mammites rectangulus* Morrow, Jour. Paleontology, v. 9, no. 6, p. 468, pl. 53, fig. 6; text fig. 6.

1935. *Mammites* sp. Morrow, Jour. Paleontology, v. 9, no. 6, p. 468.

The holotype is an uncrushed phragmocone that has a diameter of 180 mm and an umbilical width of 51.5 mm (ratio of 29 percent). The last quarter of a whorl is worn on one side, but the thickness (costal) at the end of the phragmocone is estimated to have been about 76 mm. The whorls are very

stout, and the last whorl is as wide as high. The last half whorl has five strong bullate umbilical tubercles, nine strong nodate lower ventrolateral tubercles, and nine weak clavate upper ventrolateral tubercles. The umbilical and lower ventrolateral tubercles lie on poorly defined ribs that become very weak on the middle of the flank. The suture (Morrow, 1935, pl. 52, fig. 2a) differs from that on other forms of *Mammites nodosoides* in having a very broad lateral lobe. An unfigured paratype, 178 mm in diameter and having an umbilical ratio of 29 percent, has on the last half whorl five strong bullate umbilical tubercles, seven strong clavate lower ventrolateral tubercles, and seven very weak upper ventrolateral tubercles that almost disappear at the adoral end. A third specimen, described by Morrow (1935, p. 468) as *Mammites* sp., is chiefly part of a slightly distorted whorl that differs from the other two specimens in having a squarish cross section and nodate umbilical tubercles. Although this specimen is less than half a whorl, the full half whorl probably had nine ventrolateral tubercles at a diameter of 130 mm. Morrow's specimens, although few in number, differ from typical *M. nodosoides* in their slightly higher ventrolateral tubercle count and in their extraordinarily wide lateral lobe.

M. rectangulus Morrow (1935, p. 468, pl. 53, fig. 6; text fig. 6) is probably a large crushed *M. nodosoides wingi*. Its ventrolateral tubercle count is eight at a diameter of about 175 mm.

Specimens referable to *M. nodosoides wingi* are represented by 25 collections from nine beds of limestone in the middle third of the Bridge Creek Limestone Member in the Rock Canyon area near Pueblo and by one collection from a limestone bed near the middle of the Bridge Creek Limestone Member at its type locality. All specimens are internal molds, and most are distorted. They range in diameter from 32 to 300 mm.

Ribbing is distinct only on the inner whorls (pl. 26, figs. 9, 10). The ribs are straight, rectiradial, and strongest on the outer half of the whorl. On the smallest specimen, the ribs number 11 per half whorl at a diameter of 33 mm. On these early whorls the ribs are somewhat irregular in strength and unequal in length. Some extend to the umbilicus, others rise from umbilical tubercles, and a few are intercalated. All, however, bear nodate lower ventrolateral tubercles and clavate upper ventrolateral tubercles and cross the venter as broad swellings. Umbilical tubercles ordinarily number four per half whorl and are bullate on these early whorls. These specimens very closely resemble the illustrations of early whorls of *M. nodosoides* by Schlüter (1871–72, pl. 8, fig. 4), Pervinquière (1907, pl. 18, figs. 1a, b, 3a, b), Arkhangel'skii (1916, pl. 8, figs. 4–6), Steinmann (1929, text fig. 181), Benavides-Cáceres (1956, pl. 55, figs. 5, 6), and Bürgl (1957, pl. 13, figs. 2a, b).

On the later septate whorls, the ribs weaken or disappear, and the umbilical tubercles become nodate but remain sparse—four or five per half whorl. The ventrolateral tubercles, however, very gradually decrease in number as the shell enlarges, and they number about nine per half whorl at diameters of 150–160 mm. On the last septate whorl, the upper ventrolateral tubercles weaken, whereas the lower ventrolateral ones increase in size and become clavate; on the adult body chamber, the upper ventrolateral tubercles disappear, and the lower ventrolateral ones become clavate horns directed outward at a large angle from the plane of conch symmetry. The umbilical tubercles remain large, nodate, and sparse on these large shells. On the last half whorl, the ventrolateral tubercles may be no more numerous than the umbilical tubercles and may number five or six (pl. 33).

M. nodosoides wingi attains a diameter of about 360 mm. The tubercles decrease in size on the last quarter of a whorl, and the aperture is normal.

Only parts of sutures (fig. 38) can be seen, but wherever the lateral lobe is visible, it is very broad, much like that of Morrow's holotype. The next lobe is very small in contrast to the lateral lobe. The su-

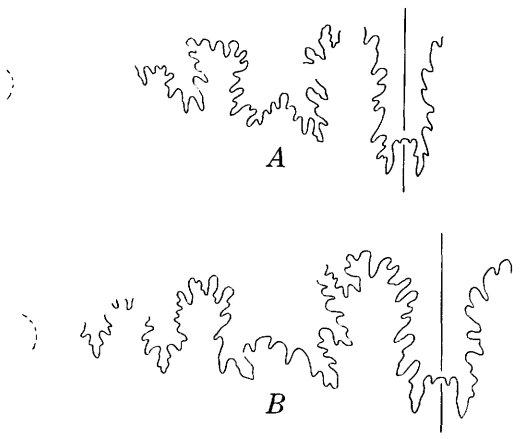


FIGURE 38.—Sutures, natural size, of *Mammites nodosoides wingi* Morrow from USGS locality D4879 (fig. 16, loc. 163). *A*, Composite of two adjacent sutures at a diameter of about 50 mm of the specimen (USNM 164009) shown on plate 26, figures 2, 3. *B*, Penultimate suture at a diameter of about 60 mm of a small adult USNM 164010).

ture of *M. nodosoides wingi* closely resembles that of *M. dixeyi* Reyment (1955, text fig. 20).

Types.—Hypotypes, USNM 164007–164013.

Occurrences.—

Bed	USGS locality	Bed	USGS locality	Bed	USGS locality
Bridge Creek Limestone Member:					
Rock Canyon section:					
99	D6534	105	D3979	109	D6150
101	D3978		D4305		D6489
	D6144		D4442	110	D6533
	D4441		D6121	113	D4443
	D6148		D6124		D6483
102	D6134		D6146	118	D3981
	D6480		D6149		D6474
	D6482		D6479	120	D3982
103	D6476		D6535		
Hinkle Ranch section:					
51	D4879				

The subspecies is also known from other localities along the Front Range in Colorado as far north as Fort Collins.

Mammites? sp.

A few fragments of very large but extremely poorly preserved ammonites were found in limestone beds a little above the middle of the Bridge Creek Limestone Member in the Rock Canyon section. These ammonites attain diameters of at least 480 mm and are widely umbilicate (ratio of nearly 50 percent). The whorl section is squarish and has flattened flanks and a broadly rounded venter. The umbilical shoulder is well rounded, and the umbilical wall is moderately sloping. Nodate tubercles, spaced six per half whorl, are present on the umbilical shoulder. Each is matched by a clavate ventrolateral tubercle. The inner whorls and the suture are not preserved. The stout cross section, umbilical tubercles, and clavate ventrolateral tubercles suggest an adult *Mammites*, but the umbilicus is wider than that known for this genus.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 118 and 120 (USGS locs. D6474, D6475).

Genus AMPAKABITES Collignon, 1965

Type species.—*Kamerunoceras (Ampakabites) ariculatum* Collignon, 1965.

Collignon (1965a, p. 29) proposed *Ampakabites* as a subgenus of *Kamerunoceras* Reyment (1954, p. 250). *Ampakabites* has a large umbilicus whose wall is vertical and high rectangular whorls whose flanks are flat and whose venter is slightly arched; it is ornamented by looped ribs that rise in pairs from umbilical tubercles and terminate in clavate ventrolateral tubercles. The suture was described as having high lobes and saddles of which the first saddle lies on the ventrolateral shoulder and the fourth saddle lies on the umbilical wall.

The original description of *Kamerunoceras* Reyment (1954, p. 250) is as follows: "Evolute, whorl section subquadrate; median tubercles, upper and lower ventrolateral tubercles and variable umbilical tubercles. Weak, irregular ribs which become very numerous and dense on the body chamber. Suture simple." Arkell, Kummel, and Wright (1957, p. L416) added further that the siphonal tubercles are irregular, that the umbilical tubercles are present only in the middle growth stage, and that the inner ventrolateral tubercles are weak, whereas the outer ones are spinose.

Collignon did not mention siphonal tubercles in his definition of *Ampakabites*, and none are visible in the ventral view of the two specimens illustrated. The suture (Collignon, 1965a, pl. 389, fig. 1664) is more complex than that illustrated for *Kamerunoceras* by Reyment (1954, text fig. 2b). The lateral lobe is asymmetrically bifid because of a deep saddle that has the smaller part of the lobe on the ventral side. Because of these differences as well as differences in the whorl section and ribbing, we believe *Ampakabites* should be given full generic rank. Gén. Maurice Collignon (written commun., Feb. 2, 1968) no longer believes that *Ampakabites* should be assigned to *Kamerunoceras*, but he believes that it could be considered a subgenus of *Pseudaspidoceras*.

Ampakabites collignoni Cobban and Scott, n. sp.

Plate 29, figures 1–3; text figures 39, 40

This species is represented by a single well-preserved specimen from the Greenhorn Limestone near Pueblo. It probably represents most of an adult that lacks the adoral end of the body chamber and a small part of the last septate whorl. The inner whorls are not preserved. Its discovery is rather interesting; the upper half was collected by Cobban in 1950, and the lower half was found by Mr. William H. Birchby of Pueblo 17 years later.

The specimen is 165 mm in diameter, its umbilical diameter is 47.7 mm (29 percent). The body chamber is 73.2 mm high and 48.0 mm wide at its larger end. The umbilicus is sharply defined by its vertical wall. The whorls have a rectangular cross section; the flanks are flattened and the venter is arched (fig. 39).

The ornamentation consists of strong umbilical tubercles, weak upper flank tubercles, strong ventrolateral tubercles, and weak ribs. The umbilical tubercles are bullate, situated at the umbilical shoulder, and number about 20 per whorl. One clavate ventrolateral tubercle is present for each um-

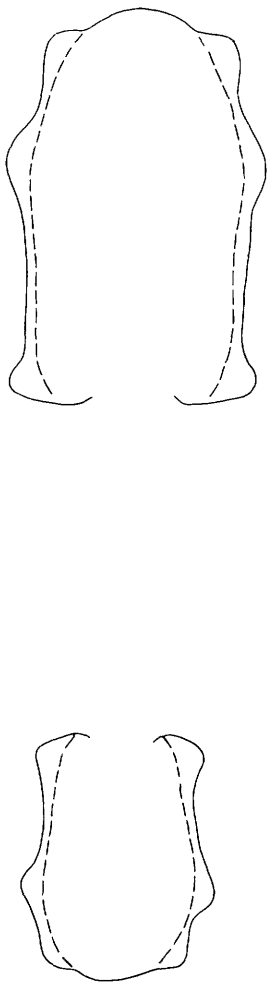


FIGURE 39.—Whorl sections, natural size, of *Ampakabites collignoni* Cobban and Scott, n. sp. USNM 164014.

bilical tubercle. On the phragmocone a pair of ribs rises from each umbilical tubercle and terminates at a ventrolateral tubercle. These looped ribs are prorsiradiate. The adapical rib of a pair is slightly stronger than the other rib and, high on the flank, a narrow bullate tubercle rises out of it. On the body chamber the ribbing becomes irregular and somewhat flexuous.

The external suture consists of lengthy elements that are moderately incised (fig. 40). The lateral lobe is large and asymmetrically divided by a deep saddle. The next two lobes are very much smaller.

Ampakabites collignoni differs from *A. auriculatus* Collignon (1965a, p. 29, pl. 388, fig. 1662; pl. 389, fig. 1664), the only other described species, in having a more arched venter, greater number of umbilical and ventrolateral tubercles, and a third row of tubercles on the flank. The sutures are of comparable complexity. The suture of an ammonite from Madagascar described as *Mammites conciliatus* (Stoliczka) by Basse (1931, p. 37, pl. 13, fig. 4) has a wide lateral lobe that is deeply bifid and asymmetric like *Ampakabites*.

The new species is named in honor of Gén. Maurice Collignon.

Type.—Holotype, USNM 164014.

Occurrence.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS loc. 22875).

Family BINNEYITIDAE Reeside, 1927

Genus BORISSIAKOCERAS Arkhangel'skii, 1916

Type species.—*Borissiakoceras mirabile* Arkhangel'skii, 1916.

Borissiakoceras is characterized by small shells that are laterally compressed and moderately evolute to moderately involute and have a rounded to flattened venter. The flanks are ordinarily smooth, but on some species they have thin closely spaced falcoid ribs. Tubercles may be present on the ventrolateral shoulder. The suture is slightly incised and is characterized by narrow bifid lobes and much broader bifid or trifid saddles.

The genus is known from the upper Cenomanian and lower Turonian of the western interior and gulf coastal areas of the United States (Cobban, 1961, p. 738–740), from the lower Turonian of the Arctic slope of Alaska (Cobban and Gryc, 1961, p. 178–179), from the lower Coniacian of west Greenland (Birkelund, 1965, p. 139–143), and from the lower Turonian of Turkestan (Arkhangel'skii, 1916, p. 55). It has been recorded with doubt from the Turonian-Coniacian of northern Russia (Bodylevsky, in Bodylevsky and Shulgina, 1958, p. 85–86), from the upper Cenomanian of British Columbia (Warren and Stelck, 1958, p. 45), and from the upper Cenomanian of northern Australia (Wright, 1963, p. 602–603, 612).

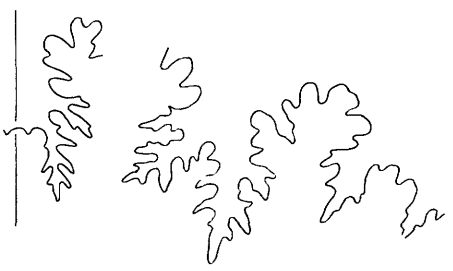


FIGURE 40.—Suture, natural size, of *Ampakabites collignoni* Cobban and Scott, n. sp., at a diameter of about 115 mm. USNM 164014.

Borissiakoceras compressum Cobban

Plate 2, figures 10, 11

1961. *Borissiakoceras compressum* Cobban, Jour. Paleontology, v. 35, no. 4, p. 747, pl. 87, figs. 19–33; pl. 89, figs. 1–9; text figs. 4a–k.

This species, which was originally described from the Frontier Formation of Wyoming, is large for the genus and attains diameters of nearly 45 mm. Its very narrow whorl section has nearly flat flanks and a broadly rounded venter. The umbilicus is very small. Most specimens are smooth, but a few have raised growth lines or very weak closely spaced thin falcoid ribs.

Borissiakoceras compressum is represented in the collections from the Thatcher Limestone Member of the Graneros Shale by a very few adults 30–40 mm in diameter. Most are smooth, but a few have some weak falcoid ribs on the outer part of the flank.

Type.—Hypotypes, USNM 164015, 164016.

Occurrences.—Graneros Shale: Rock Canyon section, bed 54 (USGS loc. D5150); Muldoon Hill section, bed 7 (USGS loc. 1323); and type section of Thatcher Limestone Member, bed 11 (USGS loc. D5733).

Borissiakoceras cf. B. orbiculatum Stephenson

Plate 2, figure 12

A few fragments of crushed ammonites from one concretion in the Graneros Shale may represent *Borissiakoceras orbiculatum* Stephenson (1955, p. 64, pl. 6, figs. 1–4). The fragments suggest that some individuals attained diameters of at least 23 mm. The two largest fragments are parts of venters that are crossed by widely spaced forwardly arched weak ribs much like those in the ventral view presented by Stephenson (1955, pl. 6, fig. 3) of the holotype. These ribs rise into low tubercles at the ventrolateral shoulder.

Figured specimen.—USNM 164017.

Occurrence.—Known only from a ferruginous concretion about 20 feet above the Thatcher Limestone Member at USGS locality D6726 (fig. 16, loc. 137).

Borissiakoceras sp.

Plate 14, figures 7, 8

The concretionary limestone bed at the top of the Graneros Shale in the Rock Canyon section contains flattened specimens of a small species of *Borissiakoceras*. None of the 15 specimens collected exceeds 24 mm in diameter. A few have faint falcoid growth lines; none has ribs or tubercles. The specimens resemble the nontuberculated forms of *B. reesidei* Morrow (1935, p. 463, pl. 49, figs. 7a, b; pl. 50, fig. 5; text fig. 8) and *B. orbiculatum* Stephenson (Cobban, 1961, p. 750–751, pl. 88, figs. 27–34).

Figured specimens.—USNM 164018, 164019.

Occurrence.—Graneros Shale: Rock Canyon section, bed 69 (22887).

Family VASCOCERATIDAE Spath, 1925

Genus VASCOCERAS Choffat, 1898

Type species.—*Vascoceras gamai* Choffat, 1898.

Choffat (1898, p. 53) included a wide variety of forms in his *Vascoceras*. Many of these have subsequently been assigned to new genera. *Vascoceras*, in a strict sense, was well defined by Barber (1957, p. 13) as follows:

> Shell discoidal, or subglobose to globose; whorls normally largely embracing. Venter subacute, rounded or flattened. Umbilicus steep sided. Early whorls ornamented with strong umbilical tubercles and fold-like costae which cross the venter. With age the ornament is lost and the last whorl is normally smooth. Suture line: three incised broad saddles and three bifid or denticulate lobes.

Vascoceras is confined to the lower Turonian. Arkell, Kummel, and Wright (1957, p. L419) recorded it from Portugal, Spain, France, north Africa, west Africa, and Mexico. It has also been recorded from Madagascar (Collignon, 1965a, p. 42, pl. 393), Colombia (Bürgl, 1957, p. 137, pl. 13, figs. 8a, b), Peru (Benavides-Cáceres, 1956, p. 471, pl. 56, fig. 7; Willard, 1966, pls. 41–42), and Brazil (White, 1887, p. 226, pl. 19).

Vascoceras sp.

Plate 36, figures 1–4; text figure 41

Two crushed and obliquely distorted ammonites from the Greenhorn Limestone at Pueblo seem referable to *Vascoceras*. Each has a diameter of 120 mm. The outer whorl, which greatly overlaps the inner ones, has a subtriangular section, the greatest width being at the umbilical shoulder (fig. 41). The umbilicus is rather wide and has a sharply rounded shoulder. The innermost whorls are not preserved. What may be weak umbilical tubercles are visible on the penultimate whorl of one specimen, but none are visible on the other. The last two whorls are apparently smooth.

The specimens are similar to *V. amieirensis* Choffat (1898, p. 61, pl. 12, figs. 1–2; pl. 13, figs. 1–2; pl. 21, figs. 17–21) from the lower Turonian of Portugal; *V. amieirensis* has a wide umbilicus, high triangular to subtriangular whorl section, and smooth shell and lacks visible umbilical tubercles.

Collignon (1957, p. 124) believed *V. amieirensis* could be included in his new subgenus *Discovascoceras* which was characterized by high subtriangular whorls, a deep umbilicus having vertical walls, and a lack of visible ornamentation. Collignon (1965b, p. 179) later emended his definition of *Discovascoceras* and raised it to full generic rank as the result of newer and better material from north Africa. He added to his original diagnosis the occurrence of umbilical tubercles in the earlier stages and the presence of three carinae that disappear with age. The two specimens from Pueblo show no signs of carinae but, otherwise, they closely resemble the genotype of *Discovascoceras, D. tesselitense* Collignon (1957, p. 125, pl. 16, figs. 1, 1a).

Types.—Figured specimens, USNM 164020, 164021.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 90 and 105 (USGS locs. D6142 and D6146).

Subgenus GREENHORNOCERAS Cobban and Scott, n. subgen.

Type species.—*Vascoceras (Greenhornoceras) birchbyi* Cobban and Scott, n. sp.

This new subgenus differs from *Vascoceras* in being more involute and in maintaining a squarish or rectangular whorl section. The whorl section of *V. gamai* Choffat varies from squarish (typical form) to subtriangular (var. *subtriangularis* Choffat). The subgenus *Greenhornoceras* is based on 120 specimens from the Greenhorn Limestone of the Pueblo–Canon City–Colorado Springs area and 40 specimens from other localities in eastern Colorado and southwestern Kansas. All specimens are inter-

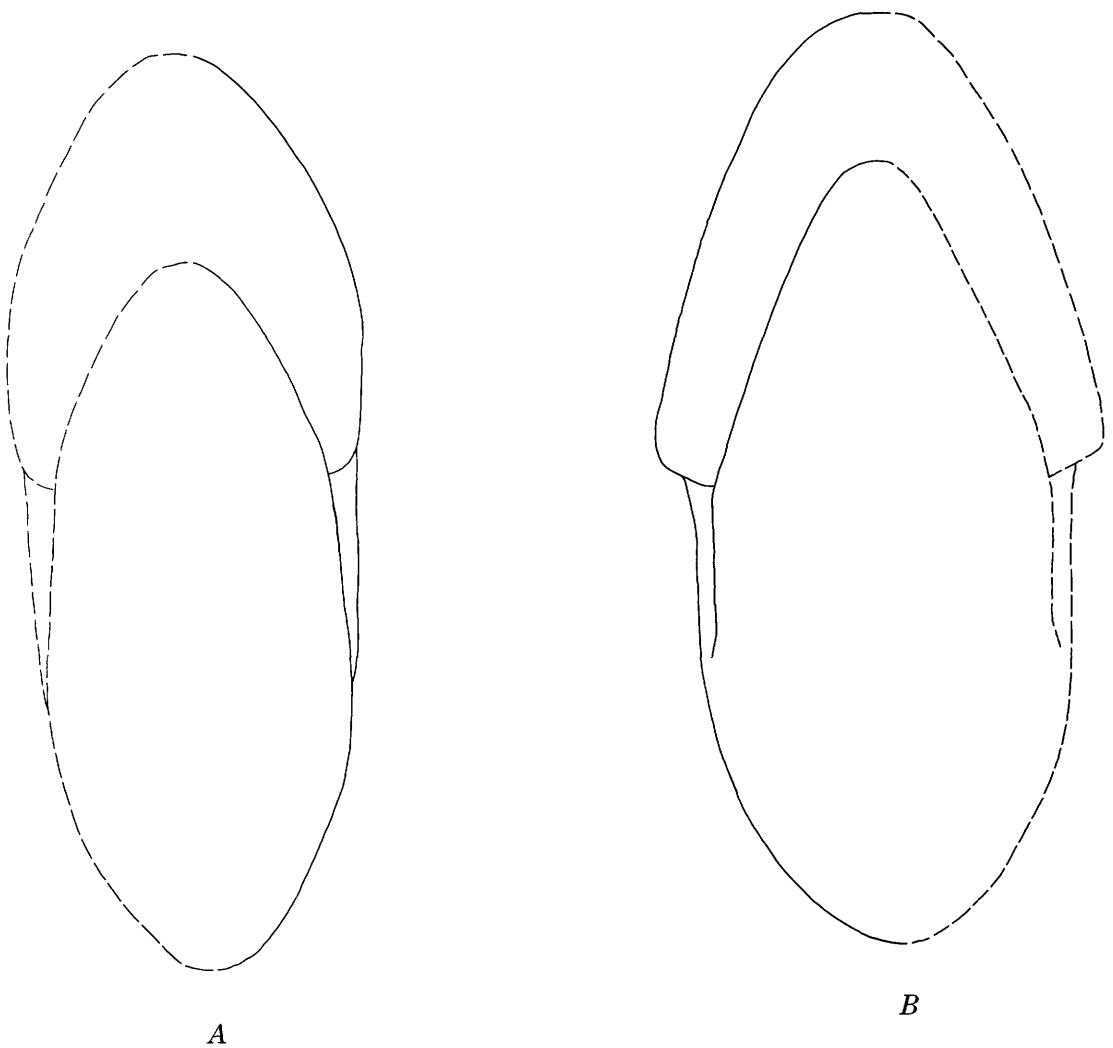


FIGURE 41.—Cross sections, natural size, of *Vascoceras* sp. from the Greenhorn Limestone. *A*, Specimen USNM 164021 from USGS locality D6146 (fig. 16, loc. 39). *B*, Specimen USNM 164020 from USGS locality D6142 (fig. 16, loc. 35).

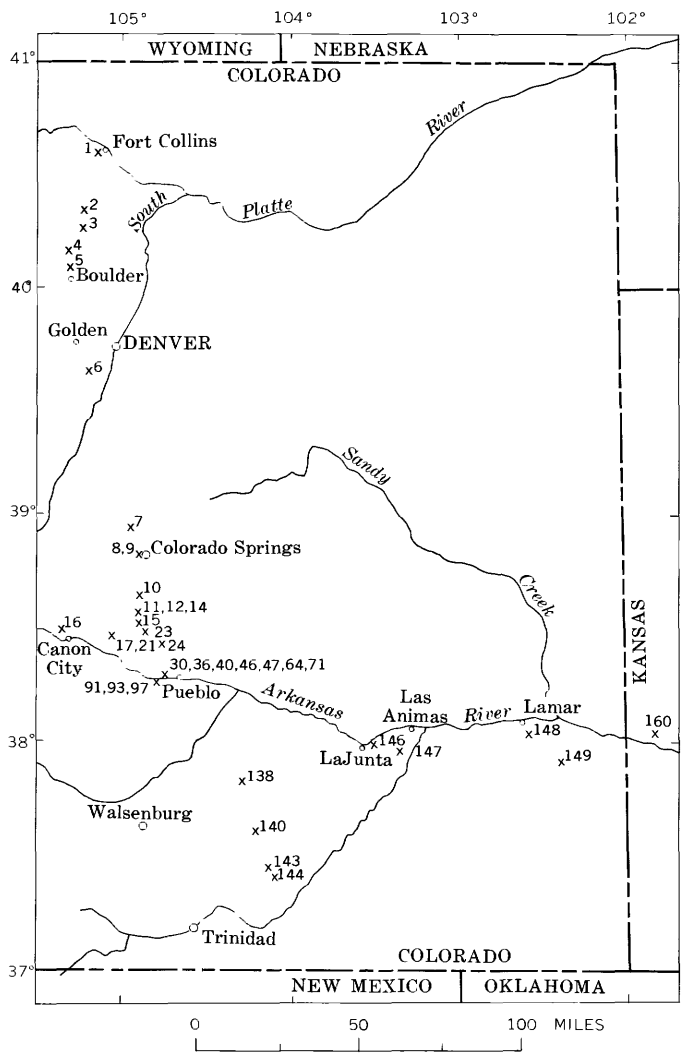


FIGURE 42.—Index map showing localities of *Vascoceras (Greenhornoceras) birchbyi* Cobban and Scott, n. sp. Numbers refer to the detailed descriptions of localities in table 5.

nal molds of which one side commonly shows the effects of subaqueous corrosion. The innermost whorls are not preserved, but the smallest observed have constrictions.

Vascoceras (Greenhornoceras) is known from 38 localities in the eastern half of Colorado and from one locality in southwestern Kansas. The general position of each locality is shown by map numbers in figure 42, and detailed data concerning the localities and collectors are given in table 5.

Vascoceras (Greenhornoceras) birchbyi Cobban and Scott, n. sp.

Plate 22; plate 23, figures 1–13; plate 24, figures 1–12; plate 25; plate 26, figures 5–8, 11, 12; plate 27, figures 1–6; text figures 43–47

This is a moderately stout and moderately involute species that has constrictions on the early whorls, strong ribs and umbilical tubercles on the later inner whorls, and a smooth to nearly smooth body chamber.

The umbilicus is deep and has steep walls and narrowly rounded shoulders. The umbilical ratio gradually increases as the shell enlarges (fig. 43*A*). Specimens 40–110 mm in diameter have ratios of 15–25 percent, whereas larger specimens have ratios of 20–30 percent.

The flanks are slightly flattened on the inner whorls and broadly rounded on the outer whorl. The venter is broad but well rounded and merges evenly into the flanks.

Constrictions, numbering four to six per half whorl, are present on the smallest specimens. The constrictions cross the entire venter and arch forward very slightly. They are present at the smallest diameter observed (9 mm) and disappear at some diameter between 18 and 50 mm. Most constrictions are bounded on one side or the other by a high rib which may or may not extend across the flank to the umbilicus.

The early ribs are prorsiradiate, and the longer or primary ones merge into conspicuous bullae at the umbilical shoulder. One to three secondary ribs of unequal height are present for each primary. As the shell enlarges and the constrictions disappear, all ribs become rectiradiate, equal in strength, highest on the venter, and not readily divisible into primaries and secondaries. They number 11–15 per half whorl (fig. 43) and greatly weaken or disappear at some diameter between 50 and 75 mm. On a very few specimens, the ribs are accentuated a little along the ventrolateral shoulder, and on one individual (pl. 24, figs. 11, 12) they are raised into incipient nodes. The ribs ordinarily disappear near the base of the body chamber, but they may persist well onto the body chamber of a few large adults where they form more or less poorly defined bulges that create an uneven venter (pl. 26, figs. 11, 12). The ribs on adults over 100 mm in diameter number 7–11 per half whorl (fig. 43).

Umbilical tubercles, commonly numbering three to five per half whorl, may persist to the orad end of the largest body chambers. The tubercles are usually bullate and conspicuous, but they may be conical on strongly ornamented inner whorls (pl. 23, figs. 4–6).

Vascoceras (Greenhornoceras) birchbyi varies greatly in size, form, and ornamentation. The diameter at the end of the phragmocone of the 25 best preserved specimens from the Rock Canyon anti-

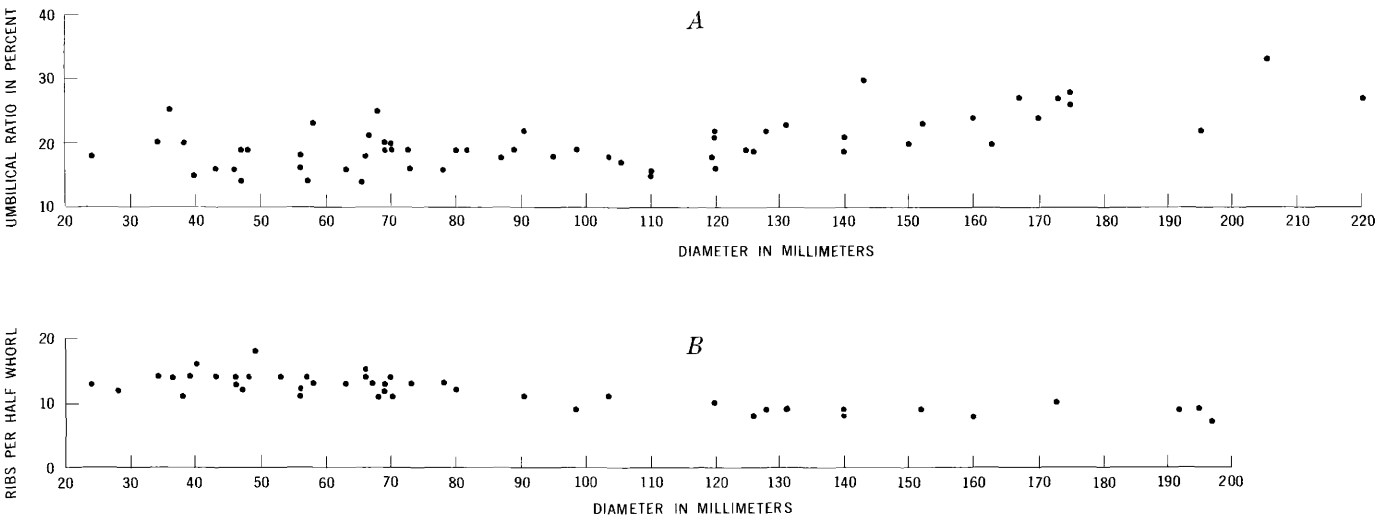


FIGURE 43.—Scatter diagrams showing umbilical ratios (*A*) and ribs per half whorl (*B*) of *Vascoceras* (*Greenhornoceras*) *birchbyi* from bed 97 of the Rock Canyon section in the Pueblo area at USGS localities 15393, 22875, 22876, D3977, D6143, and D6147.

cline (fig. 42, locs. 36, 40, 64, 97) ranges from 51 to 163 mm. These specimens do not fall into well-defined size groups (fig. 44) that might be indicative of sexual dimorphism. The complete body chamber occupies from one-half to two-thirds of a whorl, and the aperture is normal. The diameters of the specimens which we interpret as adults range from 85 to 246 mm.

Whorl sections are stout, and the height is usually a little greater than the width (fig. 45). Some whorl sections are as broad as high (fig. 46), and a very few are broader than high. The more slender sections characterize specimens that have smooth body chambers.

The ornamentation tends to vary depending on the stoutness of the shell. Very stout specimens have strongly ribbed inner whorls whose umbilical tubercles tend to be nodate (pl. 23, figs. 7, 8). On some large shells, the initial ribbed stage is followed by a smooth or nearly smooth stage, and that in turn is succeeded by a final adult ribbed stage.

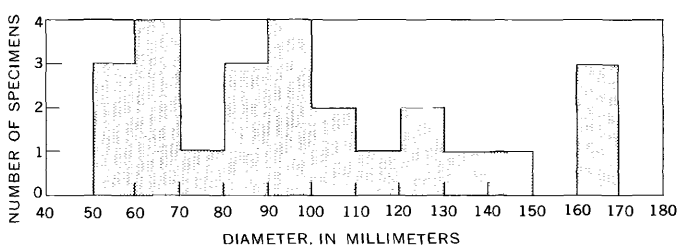


FIGURE 44.—Histogram showing size frequency of phragmocones at base of body chambers of *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp., from bed 97 of the Rock Canyon section at USGS localities D3977, D6143, D6147, and D6478.

The suture is not very distinct on these internal molds, and only parts of the external sutures are visible. Four incomplete sutures are shown in figure 47.

The holotype (pl. 22, text fig. 47*C*) is an adult 216 mm in diameter that is unusually slender and evolute (umbilical ratio of 33 percent). The inner whorls are crushed, but the last part of the phragmocone and the body chamber are uncrushed. The body chamber occupies half a whorl, and the aperture is normal. Poorly defined ribs are present on the last half of the phragmocone where they number 10 in half a whorl. The ribs weaken and disappear on the older part of the body chamber. Blunt nodate umbilical tubercles numbering four per half whorl are present on both the last chambered whorl and the body chamber. The suture is shown in figure 47*C*.

V. (G.) birchbyi perhaps most closely resembles the genoholotype, *V. gamai* Choffat (1898, p. 54, pl. 7, figs. 1–4; pl. 8, figs. 1a, b; pl. 10, fig. 2; pl. 21, figs. 1–3), in its rectangular whorl section and strongly ribbed inner whorls. *V. gamai*, which came from the lower Turonian of Portugal, is a more evolute species. Constrictions are not visible on the inner whorls of *V. gamai* illustrated by Choffat, and he did not mention them in his description. Constrictions, however, apparently are present on the inner whorls of some vascoceratids. They clearly show on two specimens from the lower Turonian of Nigeria that were assigned to *V. globosum* (Reyment) by Barber (1957, pl. 9, figs. 1–2) and on the inner whorls of specimens from northern Mexico

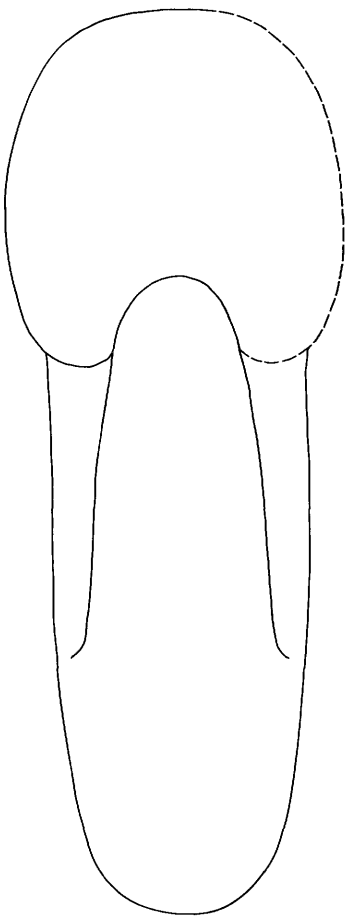


FIGURE 45.—Cross section, natural size, of the largest specimen collected of *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp., from USGS locality 22875. See plate 25 for lateral view. USNM 164037.

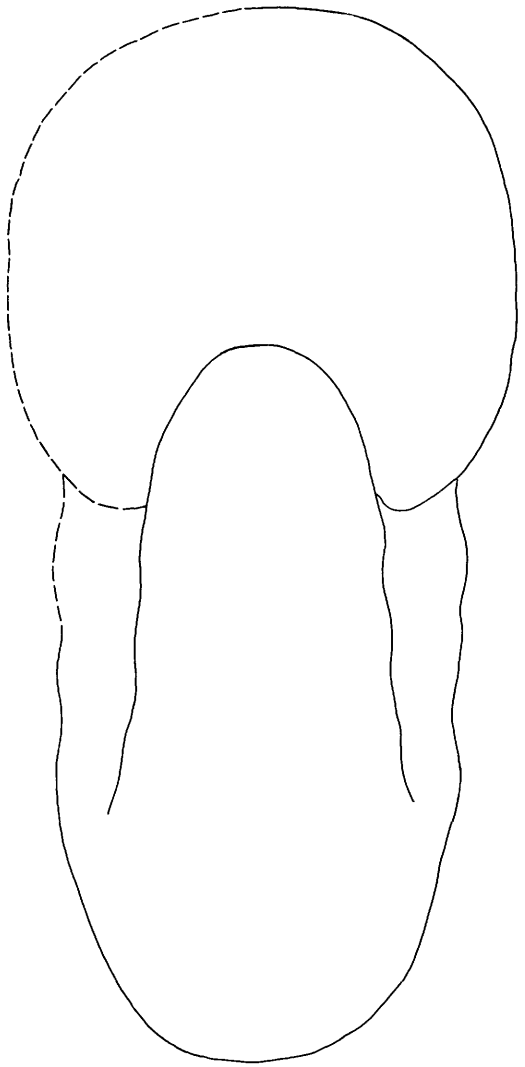


FIGURE 46.—Cross section, natural size, of a stout specimen of *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp., from USGS locality 22875. USNM 164039.

assigned to *Pachyvascoceras compressum* (Barber) by Powell (1963a, pl. 32, figs. 2–4). Adkins (1931, p. 56, pl. 2, figs. 16, 17) described the constricted specimen from western Texas as *Thomasites* sp.; Powell (1963a, p. 321) considered it to be another example of *P. compressum*. Some of the small adults of *V. (G.) birchbyi* closely resemble specimens from Colombia and Venezuela assigned to *Lewisiceras* by Leanza, especially *L. ubatense* Leanza (1967, p. 190, pl. 1, figs. 5, 6; pl. 2, figs. 1, 2; pl. 5, figs. 1, 2), but the inner whorls of *V. (G.) birchbyi* are not so stout and the constrictions are not so distinct.

Types.—Holotype, USNM 164022; figured paratypes, USNM 164023–164043.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS locs. 15729, 22875, 22876, D3977, D4001, D4439, D6122, D6143, D6147, D6478); Hinkle Ranch section, bed 40 (USGS loc. D4876). For localities of other occurrences, see figure 42.

Genus FAGESIA Pervinquière, 1907

Type species.—*Olcostephanus superstes* Kossmat, 1897.

Arkell, Kummel, and Wright (1957, p. L420) summarized the features of this genus as "Typically cadicones with strong blunt umbilical tubercles from which spring 2 or 3 strong rounded ribs which persist to a late stage, but in some species tubercles and ribs are lost at early stage. Suture regular, with deep narrow much-indented elements."

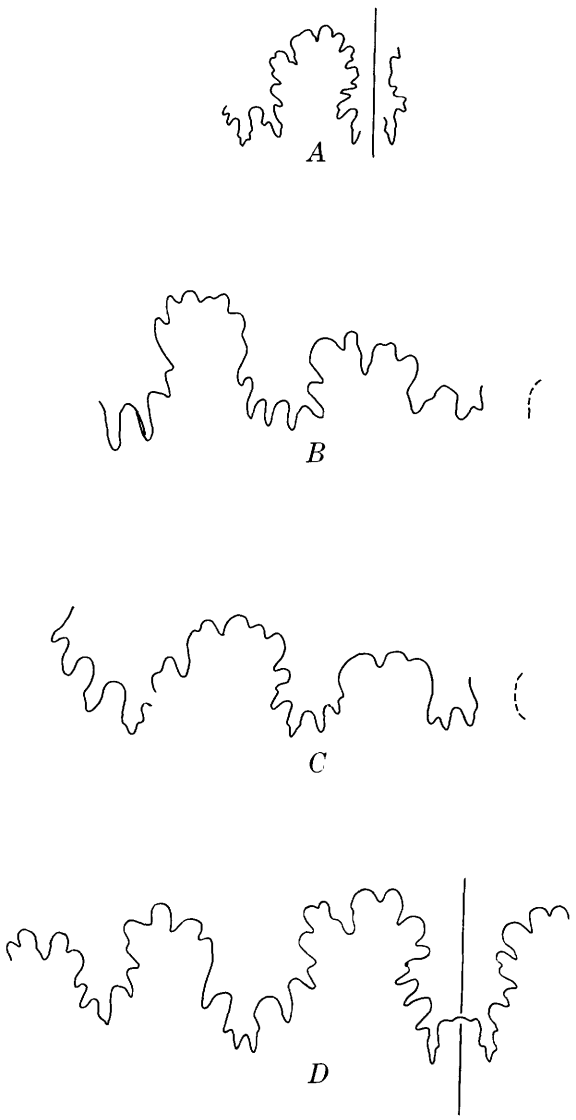


FIGURE 47.—Sutures, natural size, of *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. *A*, Part of the fifth from the last suture of a moderately stout individual, USNM 164031, from USGS locality 15393. *B*, Part of the last suture of an average-sized adult, USNM 164029, from USGS locality D6147. *C*, Part of the sixth from the last suture of the holotype, USNM 164022, from USGS locality D6147. *D*, Second from the last suture of a robust specimen, USNM 164043, from USGS locality 22916.

Fagesia is widely distributed geographically in lower Turonian strata. It is well documented from southern England (Sharpe, 1854, p. 29, as *Ammonites catinus* Mantell; Wright and Wright, 1951, p. 29), southern France (Coquand, 1859, p. 966–967, as *A. boucheroni* Coquand and *A. alphonsi* Coquand; Basse, 1939, p. 38; Fabre, 1940, p. 289; Faraud, 1951, p. 148–149), Portugal (Choffat, 1898, p. 69–70), Spain (Wiedmann, 1959, p. 715, 720, 726), Syria (Basse, 1940, p. 459), Israel (Freund, 1961, p. 80–81, table 1; Freund and Raab, 1969, p. 33–42), Egypt (Eck, 1909, p. 181; 1915, p. 197, 199), Tunisia (Pervinquière, 1907, p. 322–331), Algeria (Peron, 1896, p. 23, as *Mammites? tevesthensis* Peron), Nigeria (Barber, 1957, p. 27), Gabon (Furon, 1963, p. 270), Madagascar (Basse, 1931, p. 39; Collignon, 1965a, p. 46, 48), India (Stoliczka, 1865, p. 122, as *A. rudra* Stoliczka; Kossmat, 1897, p. 26 and 29, as *Olcostephanus superstes* and *O. rudra*), Japan (Yabe, 1904, p. 26 and 28, as *A. kotoi* Yabe; Matsumoto, 1959c, p. 359), New Caledonia (Kilian, 1910), Colombia (Fritzsche, 1921, p. 277; Petters, 1955, p. 214, 224), Mexico (Böse, 1918, p. 211–213; Powell, 1963a, p. 320), and Texas (Adkins, 1931, p. 55–56; Kummel and Decker, 1954, p. 313; Powell, 1965, p. 517). The genus was recorded from California by Anderson (1931; 1958, p. 248), but his species have since been assigned to other genera by Barber (1957, p. 15) and Matsumoto (1959e, p. 39, 102).

Fagesia sp.

Plate 34, figures 1, 2; plate 38, figure 4

The genus *Fagesia* is represented by two specimens from the Bridge Creek Limestone Member near Pueblo. The larger and better preserved specimen (pl. 34, figs. 1, 2) consists of less than half a whorl of an individual that was approximately 42 mm in diameter. The whorl section is very depressed, and its broadly rounded venter merges into gently sloping flanks. The greatest width is at the umbilical shoulder which is sharply rounded and contains conspicuous clavate tubercles. Only three of these tubercles are preserved on each side, but their spacing suggests as few as seven per whorl. About three strong ribs arise from each tubercle and trend straight across the venter without weakening. A strong intercalated rib lies between the groups of three. The smaller specimen (pl. 38, fig. 4) is badly crushed and shows only the ventral area.

These fragments of *Fagesia* could be *F. haarmanni* Böse (1918, p. 211, pl. 14, figs. 1–2; pl. 15, fig. 2), which was described from lower Turonian rocks of Coahuila, Mexico. This species is known also from Texas (Kummel and Decker, 1954, p. 313, text fig. 3; Powell, 1963a, p. 320, pl. 33, fig. 2, pl. 34, figs. 1–5, text figs. 2h–k).

Figured specimens.—USNM 164044, 164045.

Occurrences.—Bridge Creek Limestone Member:

Rock Canyon section, beds 97 and 105 (USGS locs. D3977, D6124).

Genus NEOPTYCHITES Kossmat, 1895

Type species.—*Ammonites telinga* Stoliczka, 1865 [=*Ammonites cephalotus* Courtiller, 1860].

Neoptychites is well defined by Arkell, Kummel, and Wright (1957, p. L421) as follows: "Very involute, high-whorled with minute umbilicus; whorl section widest at rounded umbilical edge; venter narrowly rounded; inner whorls *** constricted and nontuberculate; broad low ribs present in many shells at first disappear, leaving outer whorl smooth and compressed, with constricted aperture. Suture as in *Vascoceras*."

Shortly after Courtiller (1860, p. 248, pl. 2, figs. 1–4) described his *Ammonites cephalotus* from France, Stoliczka (1865, p. 125, pl. 62) described a very well preserved and complete adult ammonite from India which he named *A. telinga*. Kossmat (1895, p. 167, pl. 21, figs. 1a–c) refigured Stoliczka's specimen and made it the type for the new genus *Neoptychites*. In the following year, de Grossouvre (1896) and Peron (1896, p. 14, 20) suggested that Stoliczka's species was the same as that of Courtiller. This conclusion was accepted by such authorities as Pervinquière (1907, p. 393), Karrenberg (1935, p. 142), and Reyment (1955, p. 65). It was also accepted by Diener (1925, p. 102), whose synonomy was followed by Basse (1931, p. 34; 1940, p. 456).

Neoptychites seems to be confined to the Turonian, and most records are from the lower Turonian. The exceptions are occurrences from the middle Turonian in Mexico (Powell, 1963b, p. 1229–1231) and occurrences from the middle and upper Turonian in Madagascar (Collignon, 1965a, p. 54, 58, 69).

Neoptychites xetriformis Pervinquière

Plate 30, figures 2–6; text figure 48

1903. *Neoptychites* cf. *N. xetra* (Stoliczka). Pervinquière, Étude géol. de la Tunisie centrale (Docteur-es-Sciences Naturelles thèses, Fac. Sci. Paris), p. 101.

1907. *Neoptychites xetriformis* Pervinquière, Études de paléontologie tunisienne—Pt. 1, Carte Géol. Tunisie, p. 398, pl. 27, figs. 5–7; text figs. 153–154.

1920. *Neoptychites* aff. *N. xetriformis* Pervinquière. Böse, Texas Univ. Bull. 1856, p. 223, pl. 18, figs. 9, 11; text fig. 7 [1918 imprint].

1920. *Neoptychites xetriformis* Pervinquière. Taubenhaus, Deutschen Palästina-Vereins Zeitschr., v. 43, p. 45, pl. 5, fig. 1.

1925. *Neoptychites xetriformis* Pervinquière. Diener, Fossilium catalogus, I, Animalia, Pt. 29, p. 103.

1931. *Neoptychites xetriformis* Pervinquière. Basse, Monographie paléontologique du Crétacé de la Province de Maintirano, Madagascar, Service Mines, Govt. Gén. Madagascar et Dépendances, p. 35, pl. 12, fig. 1.

This species is represented by a single specimen from the Greenhorn Limestone at Wild Horse Park (fig. 16, loc. 24; probably the *Neoptychites*, n. sp., of Dane and others, 1937, p. 214). The specimen probably represents an adult that may have been 100 mm in diameter. Part of one side and much of the body chamber are missing (fig. 48). The end of the phragmocone is about 62 mm in diameter, and the width is estimated at 39 mm. The inner whorls up to a diameter of 32 mm are smooth except for narrow constrictions which number about four per whorl. Ribs become conspicuous at a diameter of 40 mm, and number 13 or 14 on the last half whorl of the phragmocone. They tend to be straight and rectiradial. The ribs weaken on the body chamber. The suture is too poorly preserved for reproduction.

The Greenhorn specimen closely resembles the holotype from Tunisia (Pervinquière, 1907, pl. 27, figs. 5a, b). The holotype seems to differ only in

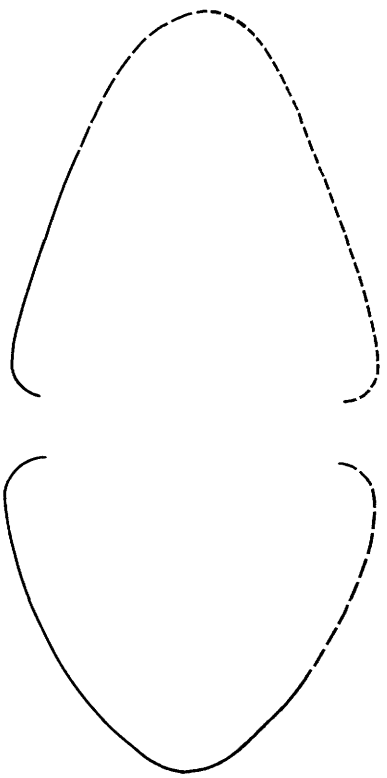


FIGURE 48.—Cross section, natural size, of *Neoptychites xetriformis* Pervinquière from USGS locality 15393 (fig. 16, loc. 24). USNM 164046.

having fewer ribs—about 11 on the last half whorl of the phragmocone. The specimen described from Mexico as *Neoptychites* aff. *xetriformis* Pervinquière by Böse (1918, p. 223, pl. 18, figs. 9, 11; text fig. 7), likewise, is more densely ribbed than the holotype and probably more closely resembles the Greenhorn specimen.

Powell (1963b, p. 1229, pl. 171, figs. 2–4, text fig. 5b) described some specimens from Mexico which he assigned to *N. xetriformis* Pervinquière. The adult whorl certainly resembles that of the African species, but the only inner whorl illustrated is well ribbed like the inner whorls of *N. xetra* (Stoliczka, 1865, p. 124, pl. 61, figs. 2–3). Powell's specimens came from the "*Spathites* zone" which is a little younger (middle Turonian) than the Greenhorn Limestone.

In addition to the Tunisian and Mexican occurrences, *N. xetriformis* has been recorded from the lower Turonian of Spain (Wiedmann, 1959, p. 714), Palestine (Taubenhaus, 1920, p. 45), Morocco (Basse de Ménorval and Choubert, 1959, p. 69), Cameroon (Belmonte, 1966, p. 11), and Madagascar (Basse, 1931, p. 35).

Type.—Hypotype, USNM 164046.

Occurrence.—Wild Horse Park northwest of Pueblo at USGS locality 15393 from same bed as bed 97 in the Bridge Creek Limestone Member of Rock Canyon section.

Neoptychites cf. N. cephalotus (Courtiller)

Plate 30, figure 9; text figures 49, 50

A single specimen from the type section of the Bridge Creek in Hamilton County, Kans., may represent *Neoptychites cephalotus* (Courtiller, 1860, p. 248, pl. 2, figs. 1–4). It consists of the younger part of the last septate whorl and the older part of the body chamber of a specimen that probably attained a diameter of 140 mm and a thickness of 50 mm (fig. 49). The inner whorls are not preserved. The outer whorl is entirely smooth, and this feature combined with its moderately narrow cross section suggests *N. cephalotus*. The suture (fig. 50), however, is much simpler than that of the genotype *Ammonites telinga* Stoliczka (1865, pl. 62, fig. 2) from India, which is considered by most authors to be the same as Courtiller's *Ammonites cephalotus*. The suture illustrated by Pervinquière (1907, text fig. 152) for *N. cephalotus* from Tunisia is much simpler than that of the Indian form: it is more like that of the Greenhorn specimen. The species from Cameroon, described as *Pulchellia perovalis* by von Koenen (1897, p. 10, pl. 1, fig. 3; pl. 2, fig. 6) and later assigned to *Neoptychites* by Solger (1904, p. 122), also has a slender section and a smooth outer whorl, but the suture has lobes that are more expanded than those on the Greenhorn specimen.

Neoptychites cephalotus has been recorded from the lower Turonian from several localities in France (Touraine, Courtiller, 1860, p. 248; Gard, Roman, 1912, p. 13; Corbières, Basse, 1939, p. 38), Spain (Karrenberg, 1935, p. 143; Wiedmann, 1959,

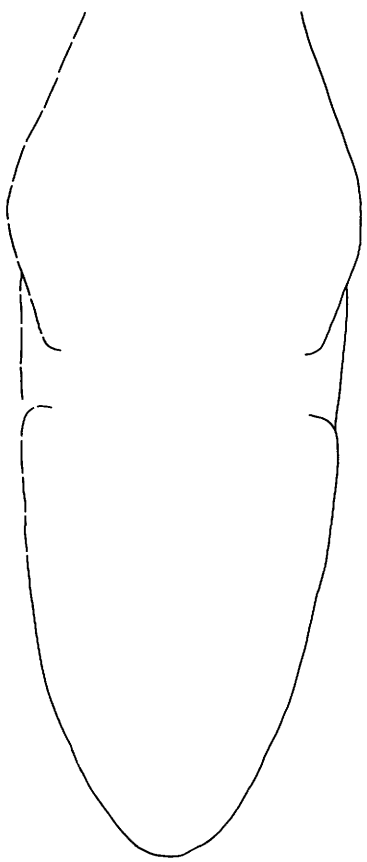


FIGURE 49.—Cross section, natural size, of *Neoptychites* cf. *N. cephalotus* (Courtiller) from the Greenhorn Limestone at USGS locality D4876 (fig. 16, loc. 160). USNM 164047.

FIGURE 50.—Seventh suture from the last, natural size, of *Neoptychites* cf. *N. cephalotus* (Courtiller) from USGS locality D4876. USNM 164047.

p. 711, 715, 719, 721), Syria (Basse, 1940, p. 456), Israel (Freund, 1961, p. 80–81, table 1; Freund and Raab, 1969, p. 48), Tunisia (Pervinquière, 1907, p. 393), Algeria (Peron, 1896, p. 14, 20), Morocco (Basse de Ménorval and Choubert, 1959, p. 69; Collignon, 1966b, p. 43), Cameroon (Pervinquière, 1907, p. 402), Madagascar (Basse, 1931, p. 34; Collignon, 1965a, p. 58), and India (Stoliczka, 1865, p. 125, as *Ammonites telinga*).

Figured specimen.—USNM 164047.

Occurrence.—Hinkle Ranch section, bed 40 (USGS loc. D4876).

Neoptychites sp.

Plate 30, figures 7, 8; text figure 51

Two somewhat crushed specimens from the Greenhorn Limestone of the Pueblo area have cross sections (fig. 51) comparable to the cross section of *N. cephalotus*, but the outer whorl is weakly ribbed. The specimens could be interpreted as slender variants of *N. xetriformis*.

Figured specimens.—USNM 164048, 164049.

Occurrence.—Bridge Creek Limestone Member: Rock Canyon section, bed 97 (USGS loc. D6122, D4439).

Family TISSOTIIDAE Hyatt, 1900

Genus CHOFFATICERAS Hyatt, 1903

Type species.—*Pseudotissotia meslei* Peron, 1897.

Hyatt (1903, p. 37) defined this genus as follows:

> This genus has sutures similar to those of *Pseudotissotia*, but the form is distinct. The species are more or less stout gibbous forms with more or less open and deep umbilici. The sides are heavily costated and nodose along the umbilical shoulders, but there are no external tubercles according to Peron. He also describes the venter as having a continuous keel and two ventro-lateral ridges. The form is more involute and more compressed than *Pseudotissotia*, and the outer parts of the volutions have a tendency to become concave in the involute species with broad volutions.

Peron (1896–97, p. 33; pl. 1, fig. 1; pl. 2, figs. 1, 2; pl. 3, fig. 2; pl. 17, fig. 1) illustrated two rather different specimens as *Pseudotissotia meslei*, but Hyatt (1903, p. 37, 38) restricted the species to the larger and more inflated one (Peron's pl. 1, fig. 1; pl. 2, fig. 1; pl. 17, fig. 1) and noted that the other specimen was "certainly distinct specifically and may be nearer to *Pseudotissotia* than to any species of this genus." The type specimen of *Choffaticeras meslei*, which comes from the lower Turonian of Algeria, is an adult shell 180 mm in diameter whose cordate cross section is thickest (80 mm) at the umbilical shoulder. The umbilicus is deep and has

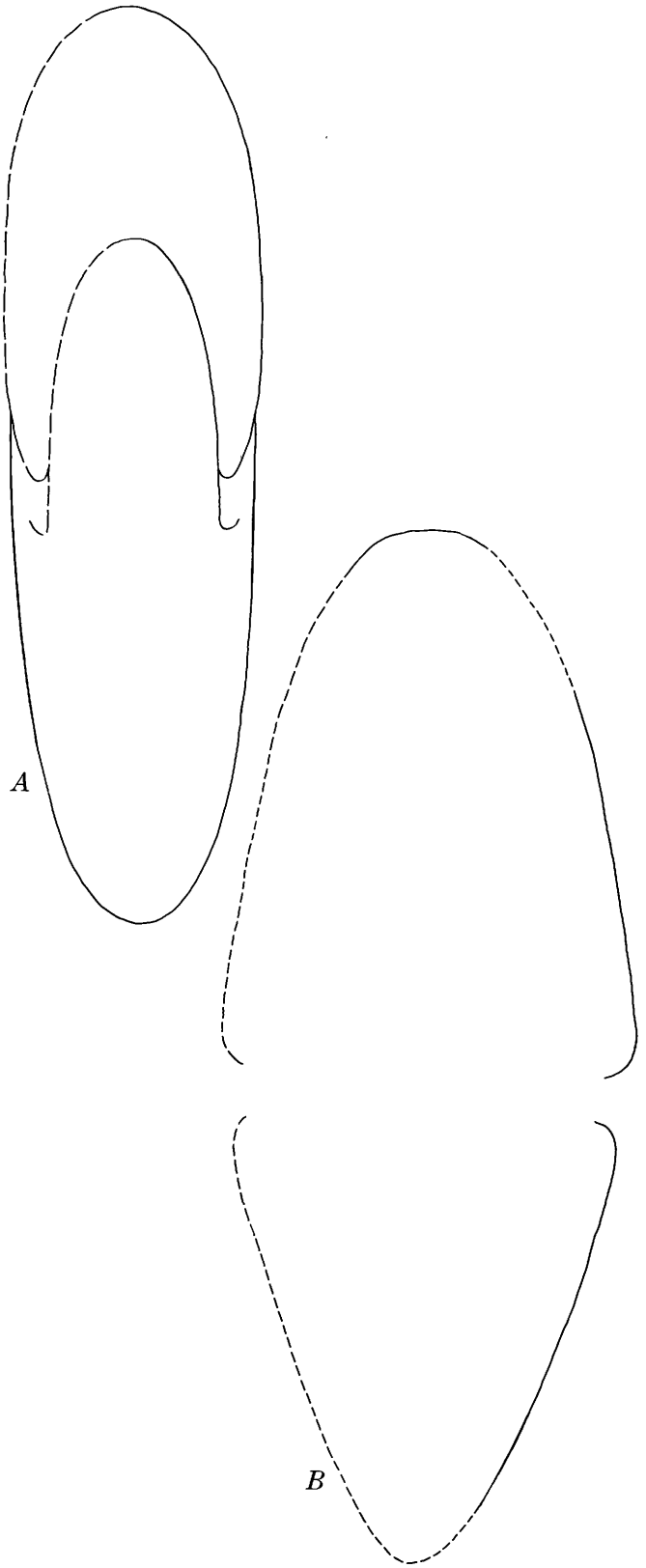


FIGURE 51.— Cross section, natural size, of *Neoptychites* sp. *A*, USNM 164048 from USGS locality D6122 (fig. 16, loc. 93). *B*, USNM 164049 from USGS locality D4439 (fig. 16, loc. 30).

sharply rounded shoulders and vertical to reentrant walls; the umbilical ratio ranges from 20 to 23 percent for the last whorl. A sharp median keel is closely bounded on each side by a lower ventrolateral ridge. Low inconspicuous ribs are present on the body chamber. They begin at the umbilical shoulder where they are hardly perceptible, curve back slightly on the lower half of the flank, and curve forward slightly on the upper half where they become strongest. There are no umbilical tubercles. The suture of the type specimen (Peron, 1897, pl. 17, fig. 1) is rather simple, and both lobes and saddles are incised. The lateral lobe on this specimen is nearly symmetrically bifid.

Pervinquière (1907, p. 349–350) considered *Choffaticeras* to be a subgenus of *Pseudotissotia* Peron (1897, p. 26). He distinguished two groups of forms within *Choffaticeras*: (1) a tricarinate group consisting of *P. meslei* Peron, *P. ganiveti* (Coquand), *P. segnis* Solger, and the new species *P. pavillieri* Pervinquière and (2) a monocarinate group consisting of *P. barjonai* Choffat, *P. philippii* Solger, the new species *P. luciae* Pervinquière and *P. massipiana* Pervinquière, and questionably *P. douvillei* Peron.

Douvillé (1911, p. 311) observed that the lateral lobe of *P. meslei* was symmetrical, whereas that lobe was very asymmetrical in *P. segnis, P. pavillieri, P. luciae,* and *P. douvillei.* Accordingly, he proposed the new generic name *Leoniceras* (type, *P. luciae* Pervinquière, 1907, p. 354, pl. 24, figs. 1, 2; text figs. 135–137) for those species having the asymmetric lobe. *Leoniceras* thus included species from both Pervinquière's tricarinate and monocarinate groups of *Choffaticeras. Leoniceras* has been accepted as an independent genus by several authors (for example, Basse, 1940, p. 459–461; Fabre, 1940, p. 295–298; Faraud, 1951; Collignon, 1957, p. 130; 1965b, p. 192, 199).

Reyment (1955, p. 72) and Arkell, Kummel, and Wright (1957, p. L423–424) interpreted *Choffaticeras* in a broad sense to include *Leoniceras* as a subgenus. Reyment's definition of *Choffaticeras* is as follows:

"Whorl section more or less cordate or lanceolate. Form involute, venter sharp with strong median keel and with subdued ventrolateral keels or rows of tubercles *(Choffaticeras)* or smooth *(Leoniceras)*. The early whorls may be costate."

According to this definition, Pervinquière's tricarinate group of *Choffaticeras* would be *Choffaticeras (Choffaticeras),* and his monocarinate group would be *Choffaticeras (Leoniceras)*; his interpretation is somewhat different from that of Douvillé, who separated the genera on the basis of the symmetry or asymmetry of the lateral lobe. Inasmuch as the only published illustration of the suture of the genotype of *Choffaticeras* seems to be that of Peron (1897, pl. 17, fig. 1), the question arises whether the symmetrical lateral lobe on that specimen is typical of the species. Until someone investigates the variation of *C. meslei* (Peron), we prefer the broad interpretation of the genus as presented by Reyment (1955, p. 72) and Arkell, Kummel, and Wright (1957, p. L423–L424).

Ammonites assigned to *Choffaticeras* or *Leoniceras* have been recorded from the Turonian at many places in the Mediterranean region. Examples of these occurrences are Portugal (Choffat, 1898, p. 73, as *Pseudotissotia barjonai;* Wiedmann, 1959, p. 723), Spain (Wiedmann, 1959, p. 712–723), southern France (Basse, 1939, p. 38, 51; Fabre, 1940, p. 295–298; Faraud, 1951), Syria (Taubenhaus, 1920, p. 41–44, 49; Basse, 1940, p. 459–461), Israel (Freund, 1961, p. 80, 81, 87, 88, tables 1, 2; Freund and Raab, 1969, p. 50–64), Egypt (Greco, 1915, p. 212–218; Douvillé, 1928, p. 20–28), Tunisia (Pervinquière, 1907, p. 351–358), and Algeria (Peron, 1897, p. 33; Collignon, 1957, p. 130, 131, 134). It has also been found in other parts of Africa—Nigeria (Reyment, 1955, p. 72, 73), Cameroon (Solger, 1904, p. 162, as *Pseudotissotia philippii*; Reyment, 1958, p. 53, 58), and Madagascar (Basse, 1931, p. 40).

Choffaticeras has not been recorded from North America except for a questionable small juvenile described by Reeside (1923, p. 30, pl. 12, figs. 3–6) from the lower Turonian of Montana. The Bridge Creek Limestone Member of the Greenhorn Limestone in the Pueblo area contains some tricarinate discoidal ammonites that are referable to *C. pavillieri* (Pervinquière).

Choffaticeras pavillieri (Pervinquière)

Plate 34, figures 3–6, 8, 9; plate 35, figures 1–3; text figure 52

1907. *Pseudotissotia (Choffaticeras) pavillieri* Pervinquière, Études de paléontologie tunisienne—Pt. 1, Céphalopodes des terrains secondaires, Carte Géol. Tunisie, p. 353, pl. 23, figs. 4–6; text fig. 134.

1912. *Leoniceras pavillieri* (Pervinquière). Douvillé, Soc. Géol. France Bull., 4th ser., v. 11, text fig. 50 [1911 imprint].

1925. *Pseudotissotia (Leoniceras) pavillieri* Pervinquière. Diener, Fossilium catalogus, I, Animalia, Pt. 29, p. 227.

1928. *Leoniceras carinifer* Douvillé, Acad. Sci. Inst. France Mém., 2d ser., v. 60, p. 25, pl. 4, fig. 3a.

1931. *Pseudotissotia (Choffaticeras) pavillieri* Pervinquière. Lombard, Soc. Géol. France Bull., 4th ser., v. 30, p. 289 [1930 imprint].
1931. *Pseudotissotia (Choffaticeras) pavillieri* Pervinquière. Basse, Monographie paléontologique du Crétacé de la Province de Maintirano, Madagascar, Service Mines, Govt. Gén., Madagascar et Dèpendances, p. 40, pl. 9, fig. 23; pl. 13, fig. 2.
1939. *Pseudotissotia (Leoniceras) pavillieri* Pervinquière. Basse, Soc. Géol. France Bull., 5th ser., v. 9, nos. 1–3, p. 51, pl. 3, fig. 13; text figs. 6a–c.
1951. *Leoniceras pavillieri* (Pervinquière). Lombard, Soc. Géol. France Bull., 6th ser., v. 1, p. 153, text fig. 4.
1957. *Leoniceras pavillieri* (Pervinquière). Collignon, Annales Paléontologie, v. 43, p. 130.
1965. *Leoniceras pavillieri* (Pervinquière). Collignon, Annales Paléontologie, v. 51, pt. 2, p. 190.
1969. *Choffaticeras pavillieri* (Pervinquière). Freund and Raab, Palaeont. Assoc. London Spec. Paper 4, p. 56, pl. 9, figs. 3–4; text figs. 11b–d.

This species differs from the other forms of *Choffaticeras* in its very small umbilicus and slender cross section. The holotype (Pervinquière, 1907, pl. 23, figs. 5a, b; text fig. 134), from the lower Turonian of Tunisia, has a diameter of 67 mm, a thickness of 21 mm, and an umbilical width of 5 mm (ratio of 7 percent). The cross section of *C. pavillieri* is lanceolate, and the greatest thickness is at the umbilical shoulder. The flanks are only slightly swollen. The median keel and ventrolateral ridge are conspicuous. Low closely spaced tubercles occur along the ventrolateral ridge out to about the base of the body chamber. Fine arcuate ribs are present on the inner whorls. They are very weak, hardly discernible except on the outer part of the flank, and disappear at a diameter of 50 or 60 mm. The body chamber is entirely smooth. The species is of moderate size; the largest specimen that Pervinquière (1907, p. 353, pl. 23, figs. 6a, b) reported was 190 mm in diameter.

Specimens that seem assignable to *C. pavillieri* are represented by 10 somewhat crushed internal molds from several beds of the Bridge Creek Limestone Member in the Pueblo area. None of the specimens reveals the innermost whorls. The largest individual (pl. 35, figs. 1–3) is 153 mm in diameter.

The umbilicus is very small on all the Pueblo specimens. The unbilical ratios of the four illustrated specimens are five (pl. 34, fig. 9), six (pl. 35), seven (pl. 34, fig. 8), and nine (pl. 34, fig. 3). Ratios ranged from six to 13 for the five Tunisian specimens reported by Pervinquière (1907, p. 353), eight to 11 for the four specimens measured by Faraud (1951, p. 154), and 12–14 for the three individuals reported by Lombard (1930, p. 289) and Collignon (1957, p. 131; 1965b, p. 190). The umbilical shoulder is abruptly rounded, and the umbilical wall is steep and undercut.

The flanks of the Pueblo specimens seem to be almost flat, a condition which is probably due in part to their being crushed. The venter is raised into a sharp keel having slightly excavated sides. On the inner whorls, the ventrolateral ridge is marked by low closely spaced clavate tubercles that number 15 or 16 for half a whorl at a diameter of 36 mm on one specimen (pl. 34, fig. 3) and probably more than 20 for half a whorl at a diameter of about 70 mm on another individual (pl. 34, fig. 8).

The tubercles disappear near the end of the phragmocone or on the older part of the body chamber, but the ventrolateral ridge continues part way out on the body chamber. Very weak broad arcuate ribs are present on the body chamber of some specimens, but the preservation of the inner whorls is too poor to reveal the faint ribs described by Pervinquière on the Tunisian material.

Only parts of the outer half of the external suture are visible on one specimen (pl. 34, figs. 3–6; text fig. 52). The lateral lobe is asymmetric and very similar to that of the holotype in degree of complexity.

Types.—Hypotypes, USNM 164050–164053.

Occurrences.—Bridge Creek Limestone Member: Rock Canyon section, beds 105 (USGS loc. D3979, D4305, D6149) and 113 (USGS loc. D6483).

Family COLLIGNONICERATIDAE Wright and Wright, 1951

Genus COLLIGNONICERAS Breistroffer, 1947

Type species.—*Ammonites woollgari* Mantell, 1822.

The genus has been well defined by Matsumoto (1965, p. 9):

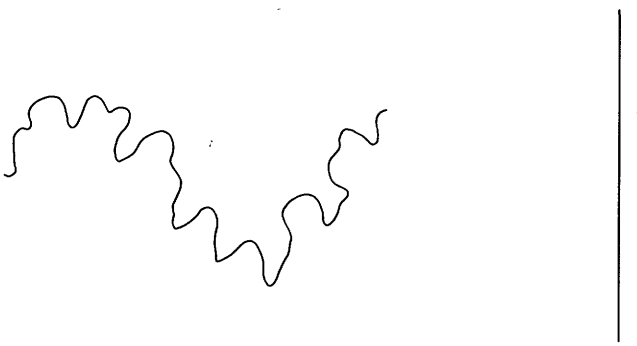


FIGURE 52.—Lateral lobe of the last suture (× 3) of *Choffaticeras pavillieri* (Pervinquière) from USGS locality 15393 (fig. 16, loc. 24). The middle of the venter is indicated by the line on the right. This specimen is illustrated on plate 34, figures 3–6 (USNM 164050).

The shell is small to moderately large and rather evolute. The whorl is compressed in early growth-stages and less so or even squarish in late growth-stages. The midventral clavi form or tend to form a serrated keel; the serrations correspond in number with the ribs.

The ribs in the young stages are crowded, mostly simple, of nearly equal length, with occasional shorter ones, more or less prorsiradiate, provided at first with outer ventrolateral tubercles and then with both outer and inner ventrolateral ones; weak umbilical tubercles or bullae are developed variably at each second to fifth ribs or may be seen at every rib.

In more or less late growth stages the ribs are coarse and widely spaced, more or less prorsiradiate and have prominent outer and inner ventrolateral tubercles which are finally united to form strong horns. The umbilical tubercles are removed upward from the umbilical margin and may be finally absorbed by the horned or flared ribs. A few secondary ribs may remain in some adult shells.

The suture consists of E, L, U_2, U_3 [$=S$], U_1 and I. The elements are less deeply incised and the saddles are rather massive.

Collignoniceras is confined to the Turonian and has a worldwide distribution. The genus is sparsely present in the upper part of the Bridge Creek Limestone Member of the Greenhorn Limestone, and all specimens are referable to *C. woollgari* (Mantell).

Collignoniceras woollgari (Mantell)

Plate 14, figure 5; plate 30, figure 1; plate 37, figures 9, 10

1822. *Ammonites woollgari* Mantell, The fossils of the South Downs, p. 197, pl. 21, fig. 16; pl. 22, fig. 7.
1828. *Ammonites woollgari* Mantell. Sowerby, J. De C., The mineral conchology of Great Britain, v. 6, p. 165, pl. 587, fig. 1.
1849. *Ammonites woolgari* [sic] Mantell. Brown illustrations of the fossil conchology of Great Britain and Ireland, p. 19, pl. 14, figs. 6, 7.
1855. *Ammonites woollgari* Mantell. Sharpe, Description of the fossil remains of Mollusca found in the Chalk of England, Palaeont. Soc. [Mon.], p. 27, pl. 11, figs. 1a, b, 2a, b [1854 imprint].
1856. *Ammonites percarinatus* Hall and Meek, Am. Acad. Arts and Sci. Mem., new ser., v. 5, p. 396, pl. 4, figs. 2a, b.
1872. *Ammonites woolgari* [sic] Mantell. Schlüter, Palaeontographica, v. 21, p. 25, pl. 9, figs. 1–4, 6.
1872. *Ammonites woollgari* Mantell. Geinitz, Palaeontographica, v. 20, pt. 2, p. 184, pl. 33, figs. 1, 3a, b, 4.
1876. *Prionocyclus (Prionotropis) woolgari* [sic] (Mantell). Meek, U.S. Geol. Survey Terr. (Hayden) Rept. 9, p. 455, pl. 6, fig. 2; pl. 7, figs. 1a–h, 3.
1878. *Ammonites woollgari* Mantell. Dixon, The geology of Sussex, pl. 21, fig. 16.
1887. *Acanthoceras woollgari* (Mantell). Laube and Bruder, Palaeontographica, v. 33, p. 235, text fig. on p. 235.
1894. *Prionotropis woolgari* (Mantell). Stanton, U.S. Geol. Survey Bull. 106, p. 174, pl. 42, figs. 1–4 [1893 imprint].
1898. *Prionotropis woolgari* (Mantell). Logan, Kansas Univ. Geol. Survey, v. 4, pt. 8, p. 466, pl. 102, figs. 1–4.
1902. *Acanthoceras woollgari* (Mantell). Petrascheck, Beitr. Paläontologie Oesterreich-Ungarns u. des Orients, v. 14, nos. 3–4, p. 149 text figs. 7, 8.
1906. *Prionotropis woolgari* (Mantell). Chamberlin and Salisbury, Geology, v. 3, Earth history, text figs. 417b, c.
1910. *Prionotropis woolgari* (Mantell). Grabau and Shimer, North American index fossils, v. 2, p. 227, figs. 1509a–d.
1916. *Prionotropis woolgari* (Mantell). Arkhangel'skii, Comité Géol. Mém., new ser., no. 152, p. 46, pl. 6, figs. 3, 4.
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1925. *Prionotropis woollgari* (Mantell). Diener, Fossilium catalogus, I, Animalia, Pt. 29, Ammonoidea neocretacea, p. 157.
1938. *Prionotropis woolgari* (Mantell). Roman, Les ammonites jurassiques et crétacées—Essai de genera, p. 455, pl. 56, figs. 434, a, b.
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1958. *Collignoniceras woolgari* (Mantell). Matsumoto and Miller, Jour. Paleontology, v. 32, no. 2, p. 353, pl. 44, figs. 1–6; pl. 45, fig. 1.
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Collignoniceras woollgari is represented in the collections from the Rock Canyon and Bridge Creek sections by 30 crushed internal molds and impressions from 20 to 120 mm in diameter. The specimens fall within the range of variation described and illustrated by Haas (1946) and Matsumoto (1965). A few irregularities in the ribbing and tuberculation on the venter are present on some of the large adults.

Types.—Hypotypes, USNM 164054–164056.

Occurrences.—

Bed	USGS locality	Bed	USGS locality	Bed	USGS locality
Bridge Creek Limestone Member:					
Rock Canyon section:					
120	D6475, D6486	131	D3983, D6487	135	D3985, D3986
Hinkle Ranch section:					
94	D4896	102	D4898	104	D4899
98	D4897				

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PLATES 1–39

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

PLATE 1

Calycoceras (*Conlinoceras*) *gilberti* Cobban and Scott, n. sp. (p. 61). Side view (× 1) of an adult from the Thatcher Limestone Member of the Graneros Shale at USGS locality 1323 (text fig. 16, loc. 115). USNM 163908.

AMMONITE FROM THE GRANEROS SHALE

PLATE 2

[All figures natural size except as indicated]

FIGURES 1–4. *Acanthoceras granerosense* Cobban and Scott, n. sp. (p. 68).

1, 2. Rear and side views of part of a juvenile whorl from 11 feet above the Thatcher Limestone Member at USGS locality D5124 (text fig. 16, loc. 130). USNM 163954.

3, 4. Rear and side views of part of a larger whorl from 14 feet above the Thatcher Limestone Member at USGS locality D5292 (text fig. 16, loc. 135). USNM 163960.

5–9, 13–18. *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott, n. sp. (p. 61).

5, 6. Side and rear views (× 2) of a stout juvenile whorl from 1½ feet above the Thatcher Limestone Member at USGS locality D3964 (text fig. 16, loc. 53). USNM 163912.

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13, 14. Rear and side views of part of a larger whorl from the same locality. USNM 163914.

15, 18. Rear and side views of the holotype from the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115). USNM 163907.

16, 17. Rear and side views of part of a septate whorl from the same locality as figures 15 and 18. See text figure 24 for the suture. USNM 163911.

10, 11. *Borissiakoceras compressum* Cobban (p. 83).

From the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115).

10. Latex cast of two adult specimens showing raised falcoid growth lines. USNM 164015.

11. Five adults, uncoated, in piece of dark-gray limestone. USNM 164016.

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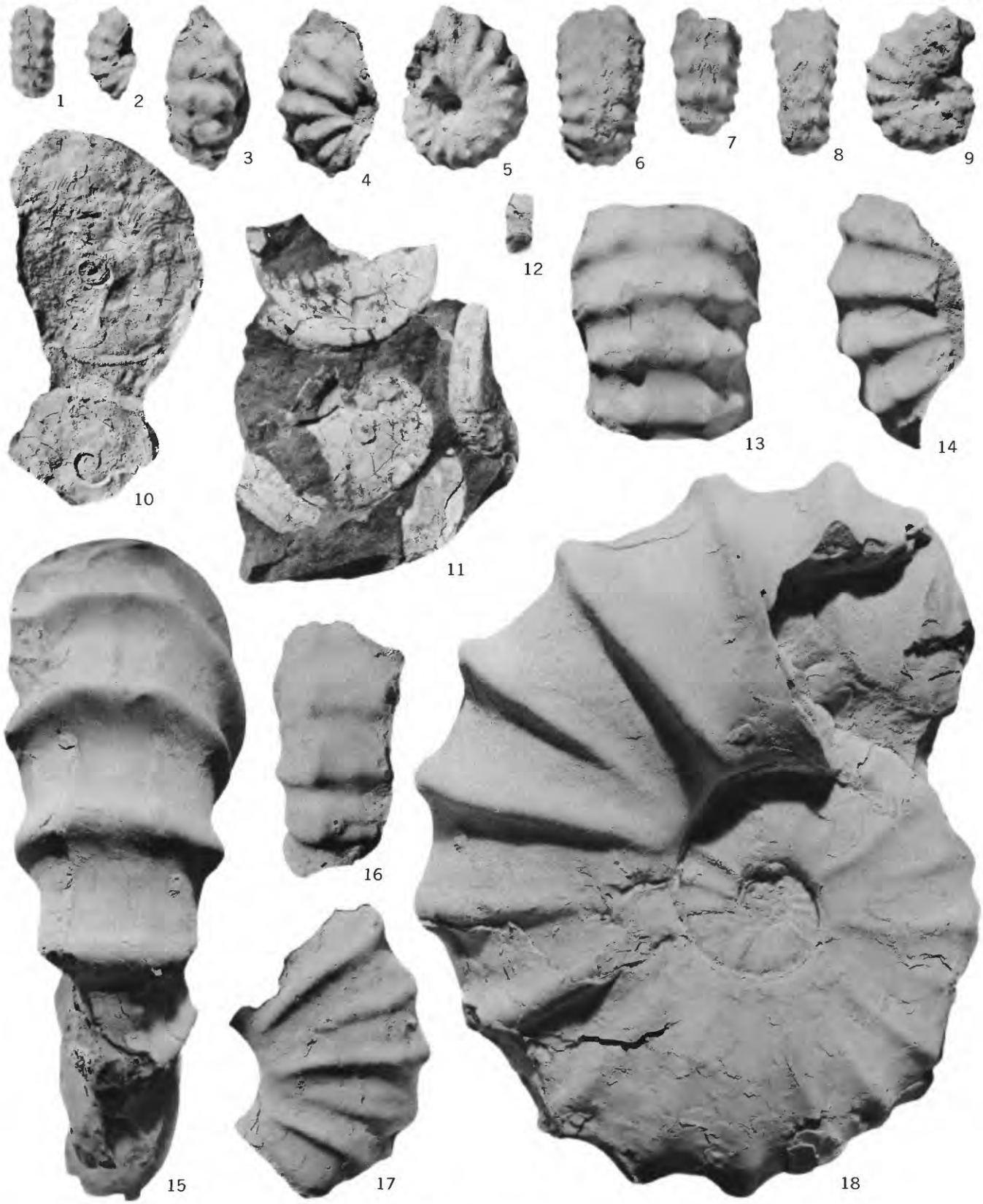
Ventral view of a fragment showing weak forwardly arched ribs and low ventrolateral tubercles. From about 20 feet above the Thatcher Limestone Member at USGS locality D6726 (text fig. 16, loc. 137). USNM 164017.



AMMONITES FROM THE GRANEROS SHALE

PLATE 3

[All figures natural size except as indicated]

FIGURES 1–4. *Calycoceras leonense* (Adkins) (p. 60).

From the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115).

1, 2. Rear and side views of a specimen showing part of the body chamber as well as part of the phragmocone. USNM 163903.

3, 4. Rear and side views of most of a large body chamber. USNM 163904.

5–7, 11. *Calycoceras* (*Conlinoceras*) *gilberti* Cobban and Scott, n. sp. (p. 61).

From the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115).

5, 6. Side and rear views of an unusually slender inner whorl. USNM 163909.

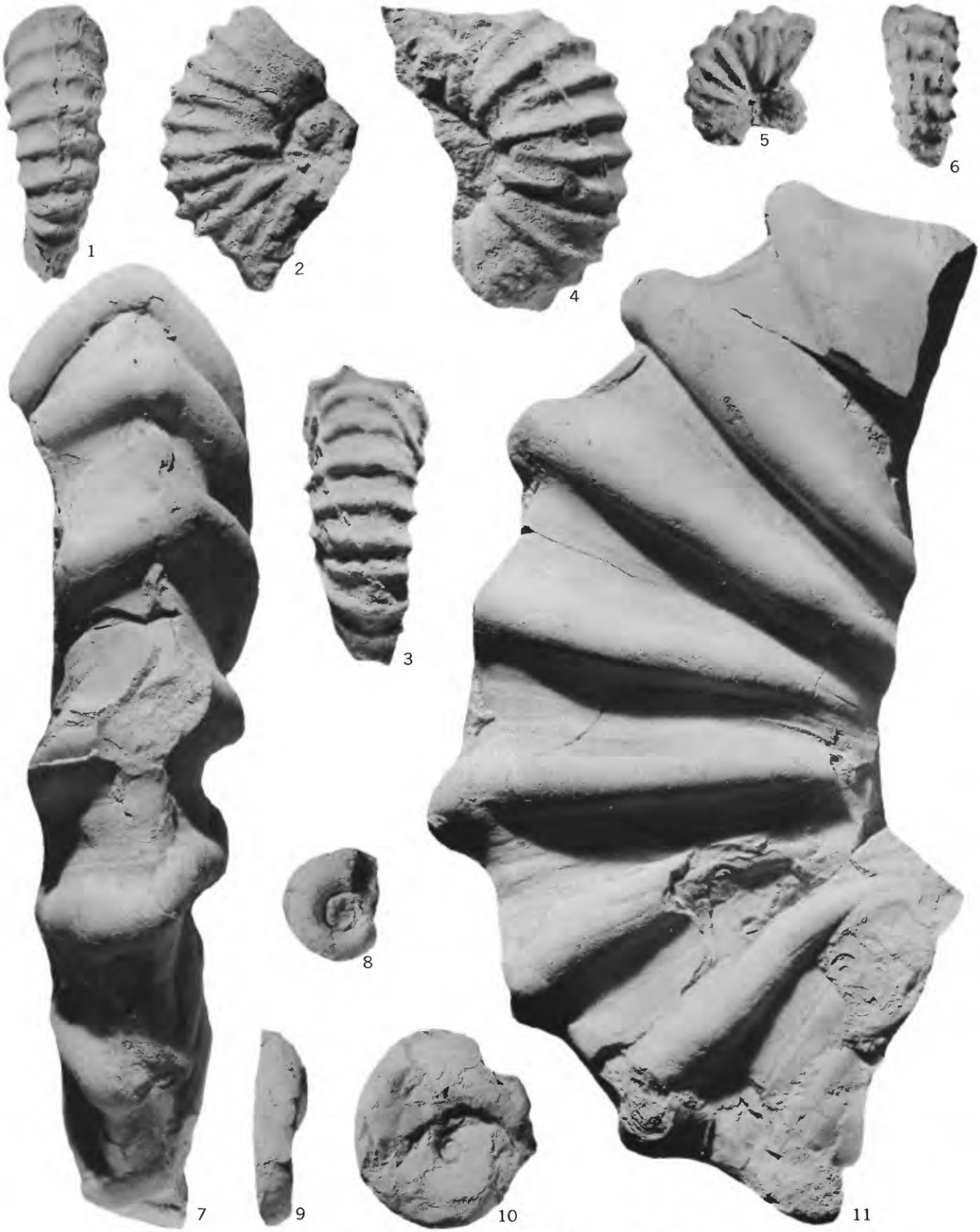
7, 11. Rear and side views of a crushed adult body chamber retaining its shell material. USNM 163910

8–10. *Desmoceras* (*Pseudoughligella*) sp. (p. 56).

From near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48).

8. Side view (× 3) of a juvenile specimen. USNM 163889.

9, 10. Rear and side views of a septate specimen. The suture is shown in text figure 23. USNM 163890.



AMMONITES FROM THE GRANEROS SHALE

PLATE 4

[All figures natural size]

FIGURES 1, 3. *Acanthoceras muldoonense* Cobban and Scott, n. sp. (p. 67).

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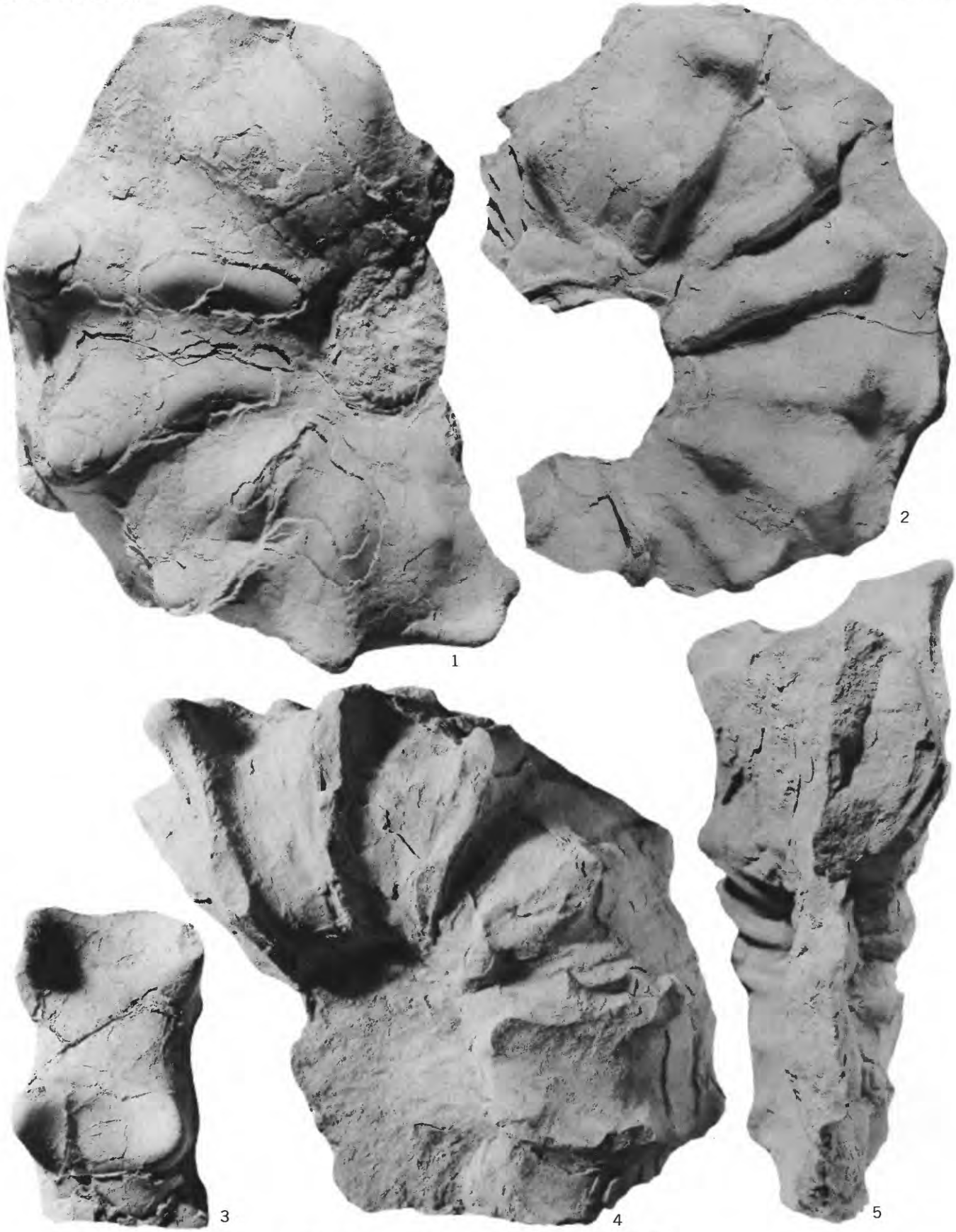
3. Ventral view of an adult from about 20 feet above the Thatcher Limestone Member at USGS locality D3000 (text fig. 16, loc. 124). USNM 163944.

2. *Acanthoceras granerosense* Cobban and Scott, n. sp. (p. 68).

Side view of a crushed adult showing the conspicuous lower and upper ventrolateral tubercles. From 11 feet above the Thatcher Limestone Member at USGS locality D5124 (text fig. 16, loc. 130). USNM 163955.

4, 5. *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) (p. 70).

Side and front views of a specimen from the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115). USNM 163961.



AMMONITES FROM THE GRANEROS SHALE

PLATE 5

[All figures natural size]

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3. *Acanthoceras granerosense* Cobban and Scott, n. sp. (p. 68).

Ventral view of fragment showing persistence of the siphonal tubercles and the lower and upper ventrolateral tubercles to a large diameter. From 11 feet above the Thatcher Limestone Member at USGS locality D5124 (text fig. 16, loc. 130). USNM 163956.

5. *Calycoceras*? sp. (p. 61).

Side view of latex cast of a specimen from about 13 feet above the Thatcher Limestone Member at USGS locality D5145 (text fig. 16, loc. 118). USNM 163906.

6–8. *Euomphaloceras* cf. *E. cunningtoni* (Sharpe) (p. 70).

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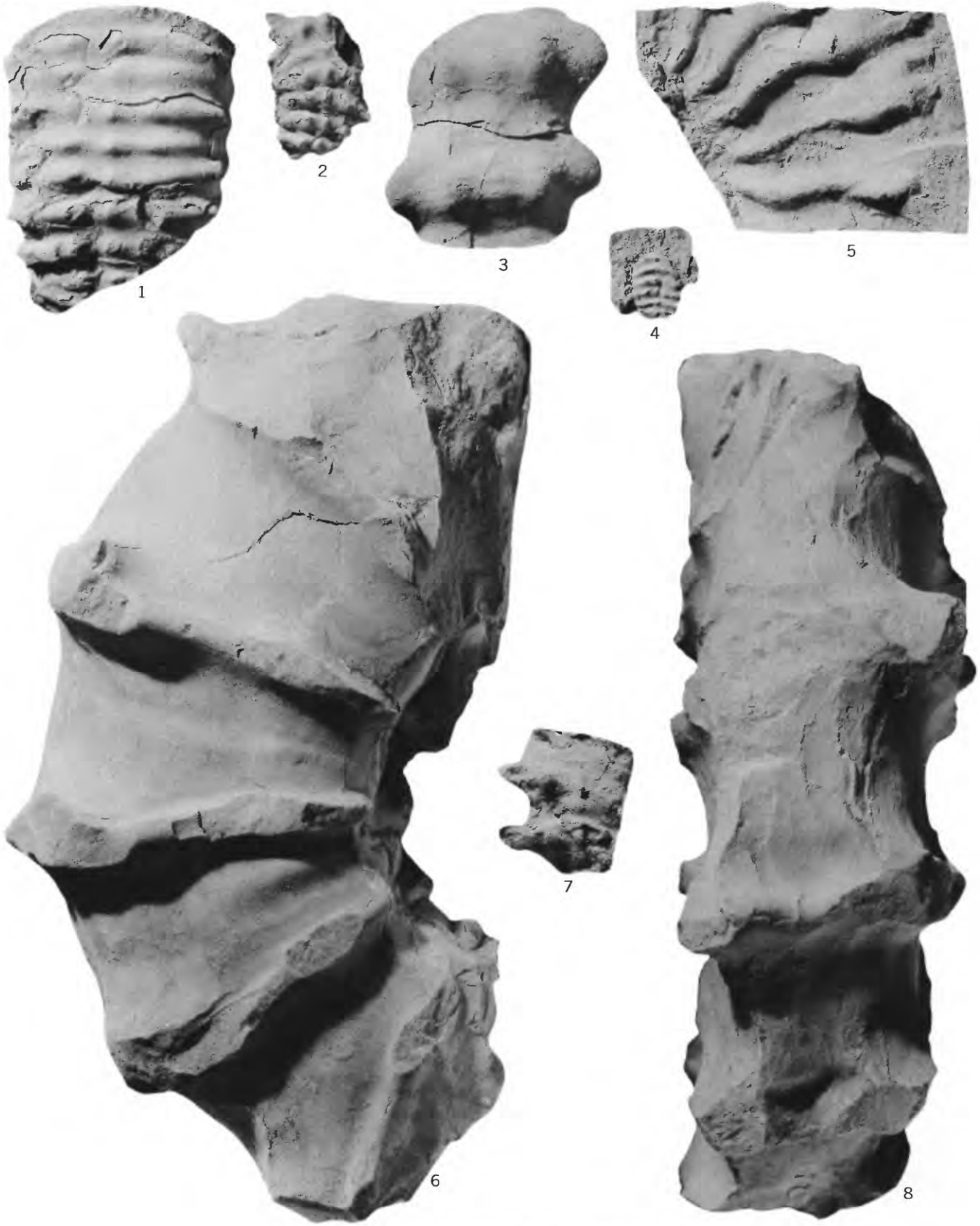
7. Latex cast showing the ventral surface of an inner whorl of the specimen whose suture is shown in text figure 33. From the same locality as figures 6 and 8. USNM 163963.



AMMONITES FROM THE GRANEROS SHALE

PLATE 6

[All figures natural size]

FIGURES 1–3. *Acanthoceras granerosense* Cobban and Scott, n. sp. (p. 68).

1, 2. Side and upper rear views of the holotype from 9 feet above the Thatcher Limestone Member at USGS locality D5291 (text fig. 16, loc. 134). The specimen, which has retained its shell material, has a calcareous worm tube attached to its ventral surface. USNM 163953.

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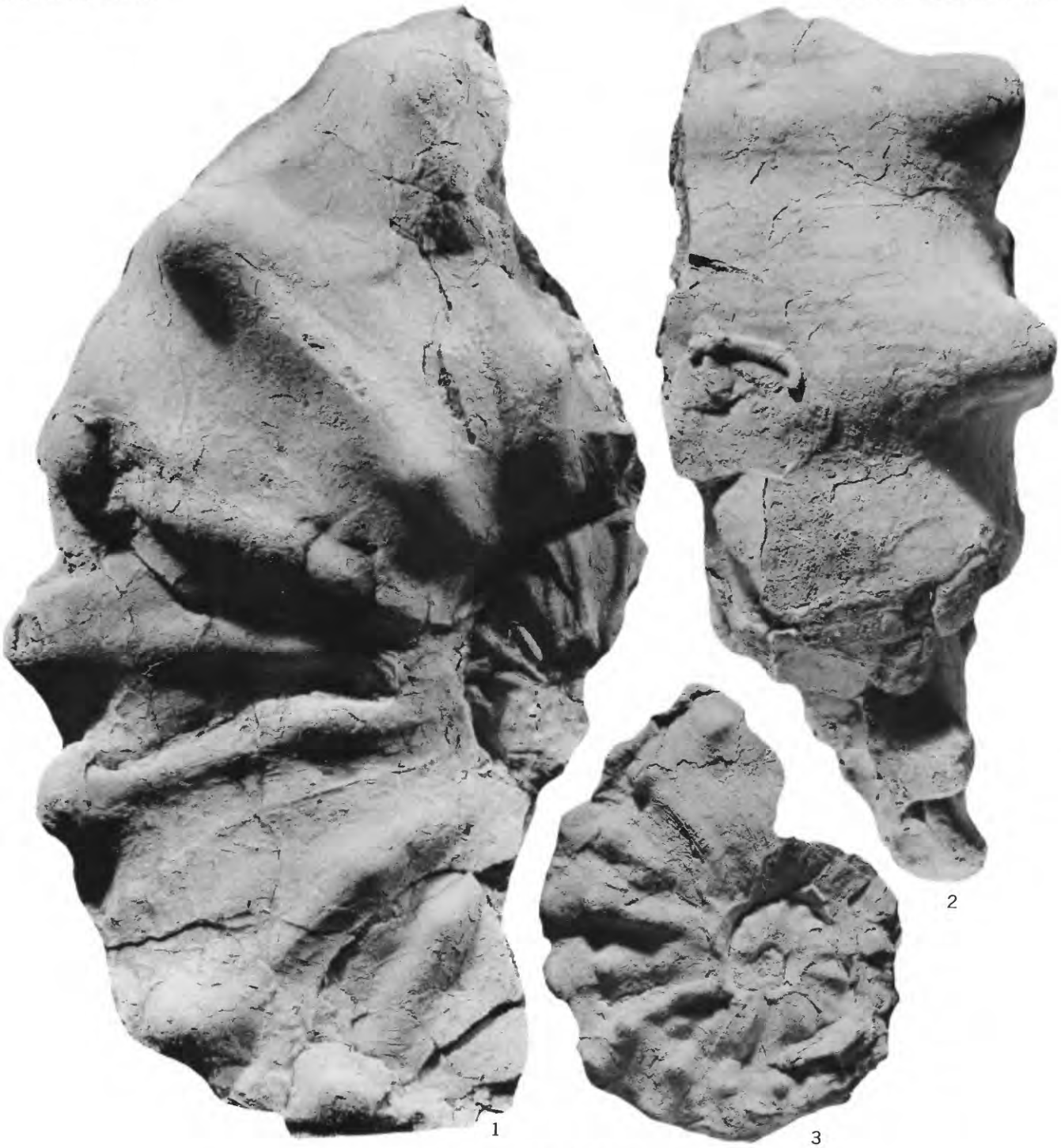

AMMONITES FROM THE GRANEROS SHALE

PLATE 7

[All figures natural size]

FIGURES 1–13. *Acanthoceras muldoonense* Cobban and Scott, n. sp. (p. 67).

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10, 13. Side and rear views of an adult body chamber from 16 feet above the Thatcher Limestone Member at USGS locality D5294 (text fig. 16, loc. 79). USNM 163949.

11, 12. Rear and side views of a specimen from 13 feet above the Thatcher Limestone Member at USGS locality D5145 (text fig. 16, loc. 118). USNM 163950.

AMMONITES FROM THE GRANEROS SHALE

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PLATE 8

Epengonoceras dumbli (Cragin)? (p. 59).

Side view (× ¾) of a large crushed specimen retaining much of its shell material from 11 feet above the Thatcher Limestone Member at USGS locality D3963 (text fig. 16, loc. 52). USNM 163900.

AMMONITE FROM THE GRANEROS SHALE

PLATE 9

Acanthoceras amphibolum Morrow (p. 65).

Side view (× 1) of an adult from the top of the Graneros Shale at USGS locality D3966 (text fig. 16, loc. 25). USNM 163935.

AMMONITE FROM THE GRANEROS SHALE

PLATE 10

[All figures natural size except as indicated]

FIGURES 1–11. *Tarrantoceras rotatile* Stephenson (p. 64).

From near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48).

1. Side view (× 2) of a crushed juvenile. USNM 163927.
2, 3. Side and rear views of a septate specimen. See text figure 25 for the suture. USNM 163928.
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5, 6. Rear and side views of part of a crushed body chamber. USNM 163930.
7, 8. Side and rear views of a more coarsely ribbed specimen. USNM 163931.
9. Side view of another coarsely ribbed specimen. USNM 163932.
10. Latex cast of the side of an adult body chamber. USNM 163933.
11. Latex cast of a crushed specimen showing conspicuous umbilical tubercles. USNM 163934.

12–16. *Acanthoceras amphibolum* Morrow (p. 65).

From near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48).

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13. Latex cast of a larger specimen. USNM 163937.
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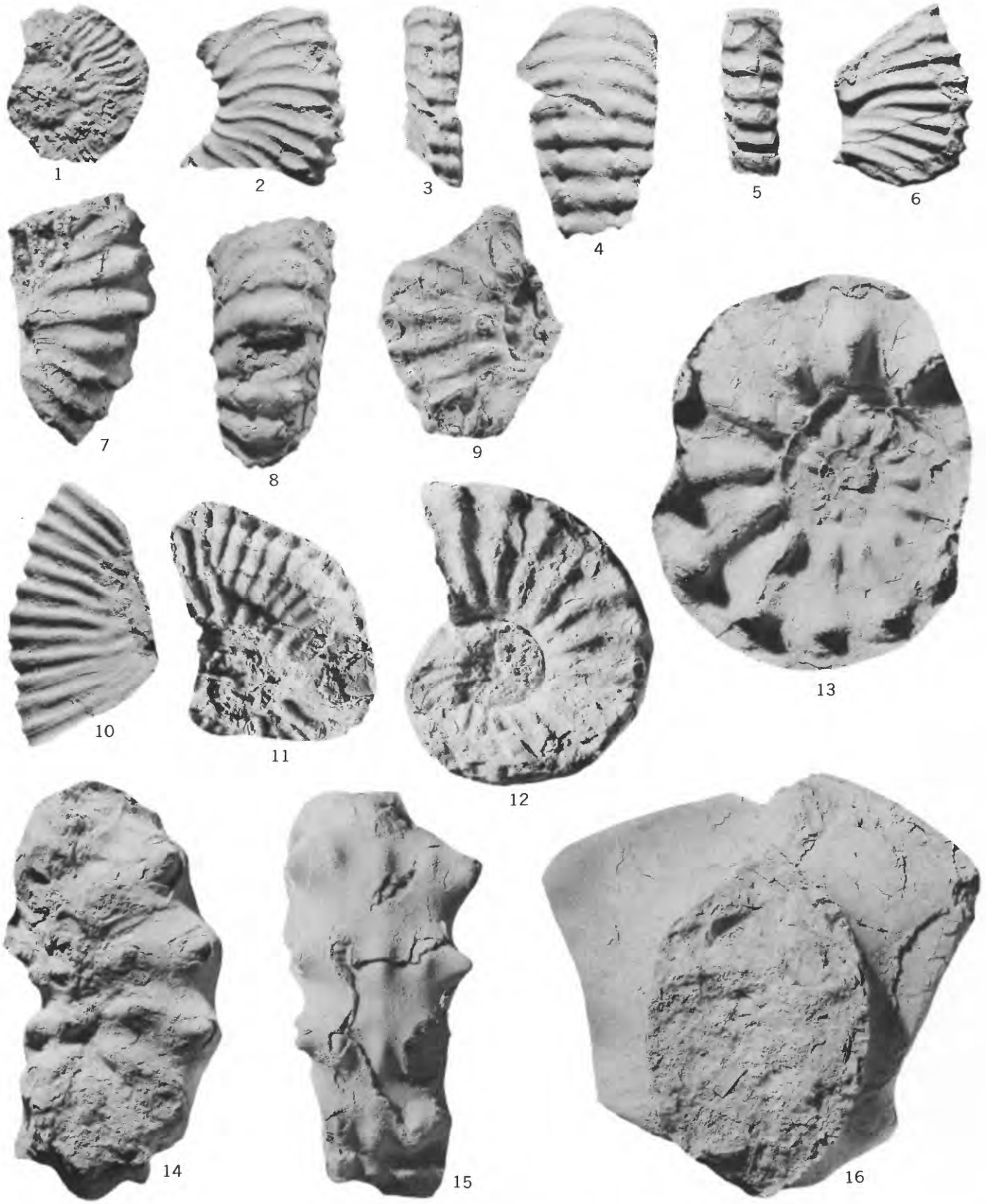
16. Front view near the end of a body chamber showing the presence of a flange-like rib. USNM 163939.



AMMONITES FROM THE GRANEROS SHALE

PLATE 11

[All figures natural size except as indicated]

FIGURES 1–11. *Turrilites* (*Turrilites*) *acutus* Passy *americanus* Cobban and Scott, n. subsp. (p. 53).

From near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48).

1–6. Side views of paratypes USNM 163873–163878. Figure 1 is a latex cast.

7. Basal view of the holotype. USNM 163872.

8. Latex cast of a specimen consisting of 10 whorls. USNM 163879.

9. Side view (× 2) of a specimen that has low whorls. USNM 163880.

10, 11. Side views of paratypes. USNM 163881, 163882.

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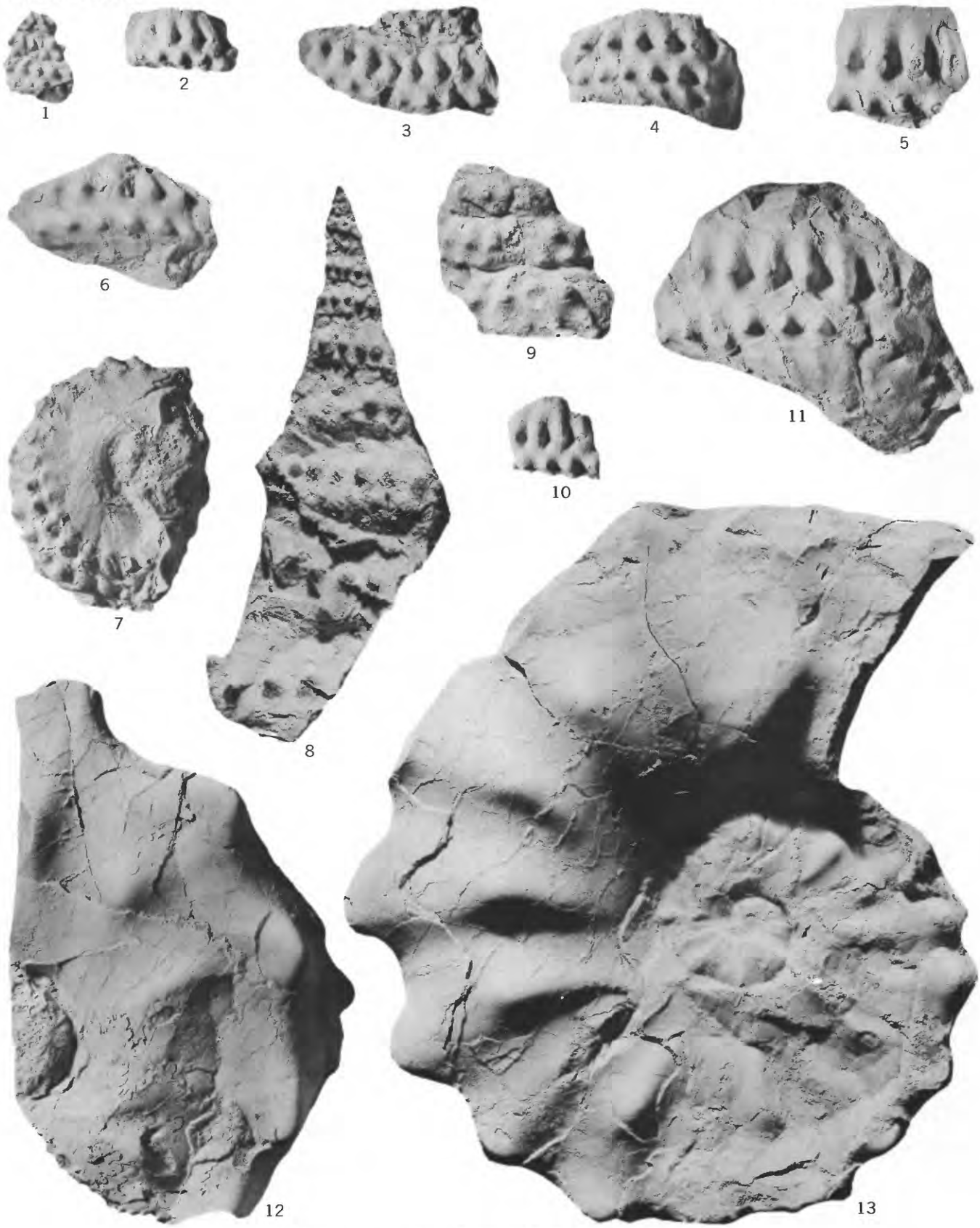
13. Side view of the holotype from 17 feet above the Thatcher Limestone Member at USGS locality D3965 (text fig. 16, loc. 54). USNM 163941.



AMMONITES FROM THE GRANEROS SHALE

PLATE 12

[All figures natural size except as indicated]

FIGURE 1. *Turrilites* (*Euturrilites*) sp. (p. 55).
Latex cast of a specimen from the Thatcher Limestone Member at USGS locality 1323 (text fig. 16, loc. 115). USNM 163887.

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17, 18. Rear and side views of a slender specimen from the same locality as figures 11 and 12. USNM 163971.
19, 20. Rear and side views of a larger specimen from the same locality as figures 13 and 14. USNM 163973.
21, 22. Side and rear views of another specimen from the same locality. USNM 163974.
23. Rear view of a specimen that has tubercles of irregular shape and strength. From the same locality as figures 15 and 16. USNM 163976.
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AMMONITES FROM THE GRANEROS SHALE AND GREENHORN LIMESTONE

PLATE 13

[All figures natural size]

FIGURES 1–4. *Idiohamites* sp. (p. 50).

From 20 feet above the Thatcher Limestone Member at USGS locality D6726 (text fig. 16, loc. 137).

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2. Side view of a densely ribbed fragment. USNM 163863.
3. Side view of a small specimen. USNM 163864.
4. Side view of a crushed specimen. USNM 163865.

5–10. *Stomohamites* cf. *S. simplex* (d'Orbigny) (p. 44).

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15–17. Rear, side, and front views of a small adult from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). USNM 163916.

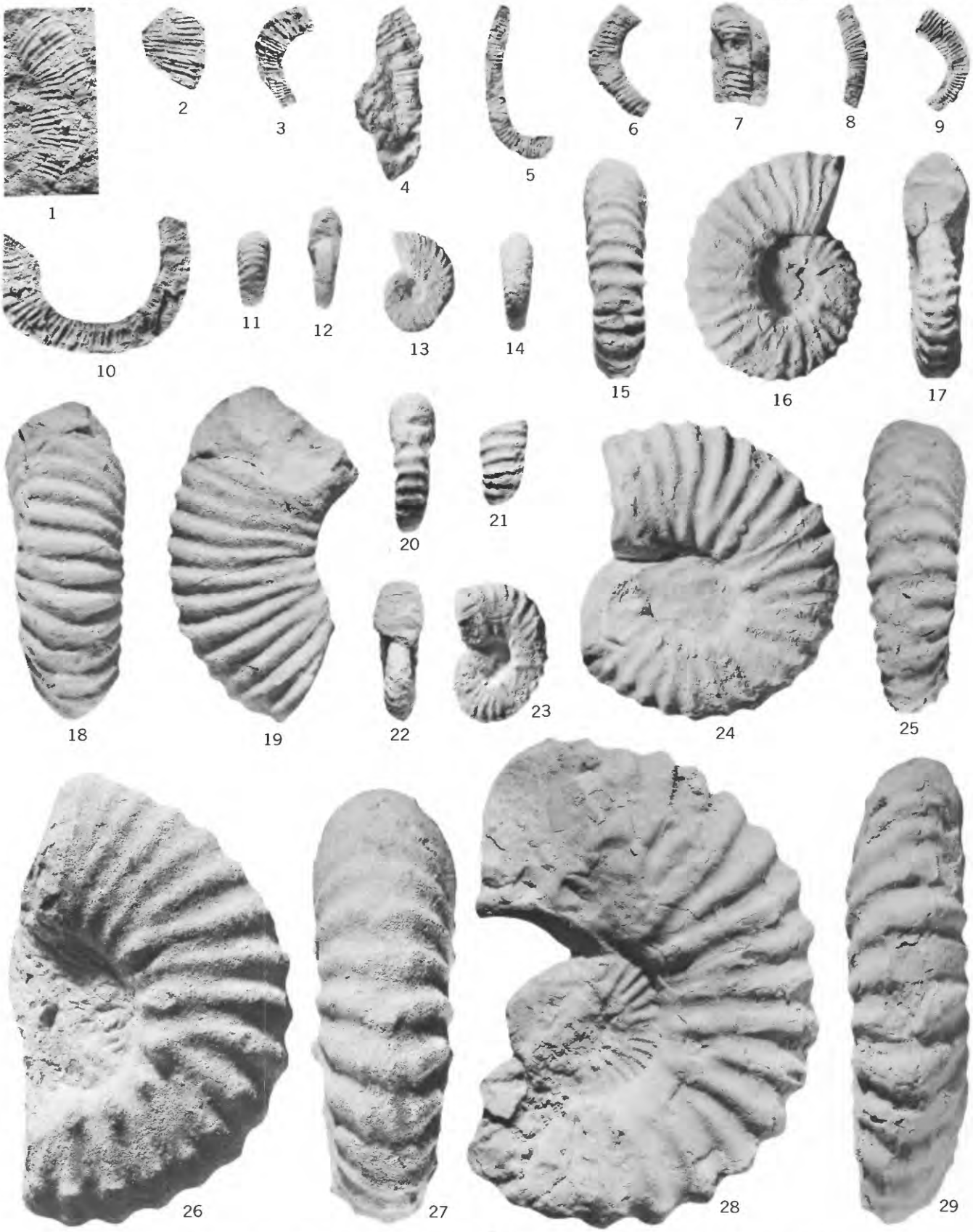
18, 19. Rear and side views of part of an adult body chamber showing the loss of tubercles. From 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D3973 (text fig. 16, loc. 60). USNM 163918.

20–23. Rear, top, front, and side views of a small adult from the same locality as figures 15–17. USNM 163917.

24, 25. Side and rear views of a larger adult from near the base of the Bridge Creek Member at USGS locality D5127 (text fig. 16, loc. 22). USNM 163919.

26, 27. Side and rear views of an adult body chamber from 8 feet above the base of the Bridge Creek Limestone Member at USGS locality D6572 (text fig. 16, loc. 19). USNM 163921.

28, 29. Side and rear views of a large adult from the same locality as figures 24 and 25. USNM 163920.



AMMONITES FROM THE GRANEROS SHALE AND GREENHORN LIMESTONE

PLATE 14

[All figures natural size]

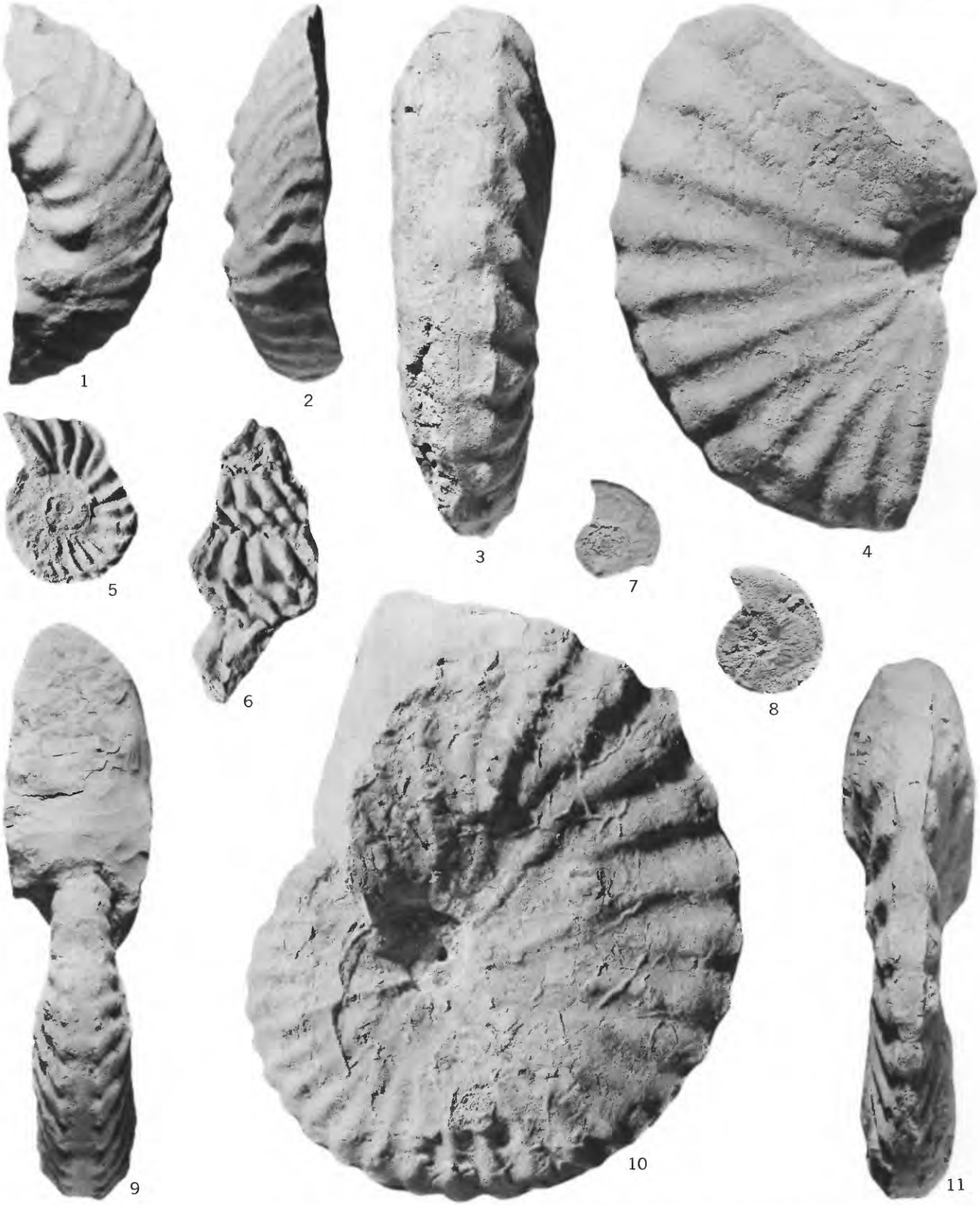
FIGURES 1, 2. *Tragodesmoceras* sp. (p. 58).
Side and rear views of a specimen from the Bridge Creek Limestone Member at USGS locality D3979 (text fig. 16, loc. 66). USNM 163899.

3, 4, 9–11. *Metoicoceras whitei* Hyatt (p. 74).
3, 4. Rear and side views of a phragmocone from near the base of the Bridge Creek Limestone Member at USGS locality D5127 (text fig. 16, loc. 22). USNM 163986.
9–11. Front, side and rear views of a phragmocone from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). USNM 163988.

5. *Collignoniceras woollgari* (Mantell) (p. 94).
Latex cast of a small specimen from the top of the Bridge Creek Limestone Member at USGS locality D4897 (text fig. 16, loc. 181). USNM 164054.

6. *Turrilites (Turrilites) acutus* Passy (p. 52).
Side view of a crushed specimen from the Thatcher Limestone Member at USGS locality D3002 (text fig. 16, loc. 85). USNM 163871.

7, 8. *Borissiakoceras* sp. (p. 83).
Side views of two crushed specimens from near the top of the Graneros Shale at USGS locality 22887 (text fig. 16, loc. 48) USNM 164018, 164019.



AMMONITES FROM THE GRANEROS SHALE AND GREENHORN LIMESTONE

PLATE 15

[All figures natural size]

FIGURES 1–7, 10–13. *Pseudocalycoceras dentonense* (Moreman) (p. 63).

1–3. Front, side, and rear views of a phragmocone and part of the adult body chamber from near the base of the Bridge Creek Limestone Member at USGS locality 15393 (text fig. 16, loc. 24). USNM 163922.

4–6. Front, rear, and side views of an adult from 5 feet above the base of the Bridge Creek Limestone Member at USGS locality D6571 (text fig. 16, loc. 18). USNM 163923.

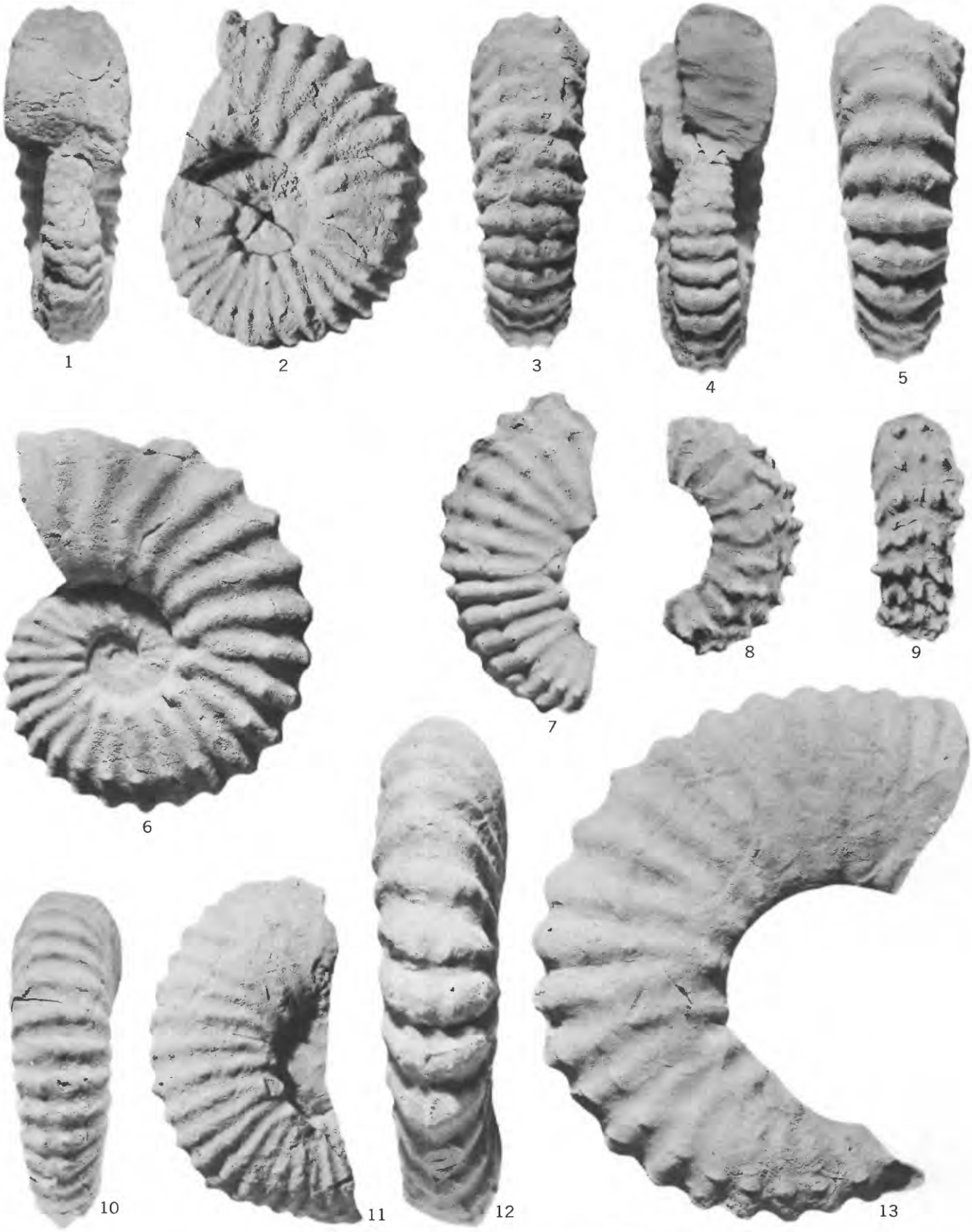
7. Side view of a latex cast of a specimen from near the base of the Bridge Creek Limestone Member at USGS locality D1308 (text fig. 16, loc. 20). USNM 163924.

10, 11. Rear and side views of a moderately small adult from near the base of the Bridge Creek Limestone Member at USGS locality 22876 (text fig. 16, loc. 47). USNM 163925.

12, 13. Rear and side views of an adult body chamber from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). USNM 163926.

8, 9. *Kanabiceras puebloense* Cobban and Scott, n. sp. (p. 73).

Side and rear views of half of an outer whorl from the Bridge Creek Limestone Member at USGS locality D4442 (text fig. 16, loc. 33). USNM 163979.



AMMONITES FROM THE GREENHORN LIMESTONE

487-487 O - 72 - 10

PLATE 16

FIGURES 1, 2. *Metoicoceras whitei* Hyatt (p. 74).
Side and front views (× 1) of an adult from near the base of the Bridge Creek Limestone Member at USGS locality 1394 (text fig. 16, loc. 139). USNM 163991.

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AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 17

[All figures natural size except as indicated]

FIGURE 1. *Scaphites* sp. (p. 56).
Lateral view of a specimen from 4½ feet above the base of the Bridge Creek Limestone Member at USGS locality D4870 (text fig. 16, loc. 154). USNM 163888.

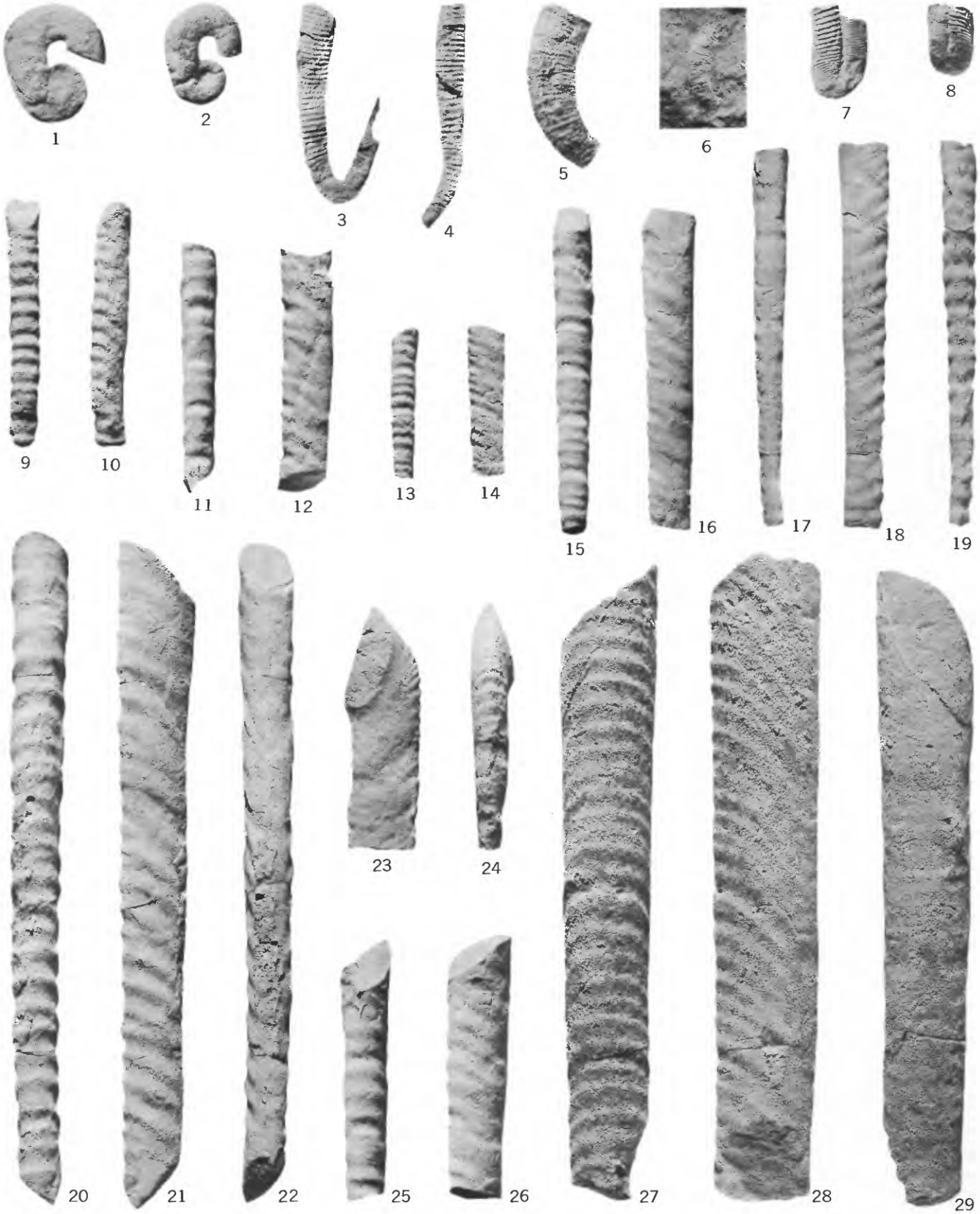
2. *Worthoceras gibbosum* Moreman (p. 43).
Lateral view of a specimen from 8 feet above the base of the Bridge Creek Limestone Member at USGS locality D6572 (text fig. 16, loc. 19). USNM 163822.

3, 4. *Stomohamites* cf. *S. simplex* (d'Orbigny) (p. 44).
Lateral views of two crushed specimens from the Bridge Creek Limestone Member at USGS locality D4888 (text fig. 16, loc. 172). USNM 163814, 163815.

5, 6. *Anisoceras* sp. (p. 49).
Lateral view (× 2 and × 1) of a specimen from the Bridge Creek Limestone Member at USGS locality D3975 (text fig. 16, loc. 62). USNM 163861.

7, 8. *Hemiptychoceras reesidei* Cobban and Scott, n. sp. (p. 45).
7. Lateral view of the holotype from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). USNM 163823.
8. Lateral view of a slightly smaller specimen from near the base of the Bridge Creek Limestone Member at USGS locality 15402 (text fig. 16, loc. 10). USNM 163824.

9–29. *Sciponoceras gracile* (Shumard) (p. 47).
9, 10. Ventral and lateral views of a small coarsely ribbed specimen from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D3973 (text fig. 16, loc. 60). USNM 163847.
11, 12. Ventral and lateral views of a larger specimen from the same locality as figure 7. USNM 163849.
13, 14. Ventral and lateral views of a small specimen from the same locality as figures 9 and 10. USNM 163848.
15, 16. Ventral and lateral views of a specimen that has well-defined constrictions from the same locality as figure 7. USNM 163850.
17–19. Dorsal, lateral, and ventral views of a specimen from near the base of the Bridge Creek Limestone Member at USGS locality D5127 (text fig. 16, loc. 22). USNM 163852.
20–22. Ventral, lateral, and dorsal views of a larger specimen from the same locality as figures 17–19. USNM 163853.
23, 24. Lateral and ventral views of a small adult showing the complete aperture from near the base of the Bridge Creek Limestone Member at USGS locality 22915 (text fig. 16, loc. 13). USNM 163854.
25, 26. Ventral and lateral views of a specimen from the same locality as figure 7. USNM 163851.
27–29. Ventral, lateral, and dorsal views of a very large specimen from 5 feet above the base of the Bridge Creek Limestone Member at USGS locality D6571 (text fig. 16, loc. 18). USNM 163855.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 18

[All figures natural size]

FIGURES 1–5. *Puebloites spiralis* Cobban and Scott, n. sp. (p. 46).

From 20 feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone at USGS locality D6147 (text fig. 16, loc. 97).

1–3. Two lateral views and the ventral view of part of a large whorl. USNM 163831.

4, 5. Ventral and lateral views of the holotype. USNM 163830.

6–19. *Puebloites corrugatus* (Stanton) (p. 45).

6. Lateral view of a specimen from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). See text figure 17 for the suture. USNM 163825.

7–9. Two lateral views and the ventral view of a slender specimen from near the base of the Bridge Creek Limestone Member at USGS locality 22915 (text fig. 16, loc. 13). USNM 163826.

10–13. Four views of a small specimen from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D3973 (text fig. 16, loc. 60). USNM 163827.

14. Lateral view of a smaller specimen from the same locality. USNM 163828.

15, 16. Ventral and lateral views of a plaster cast of the holotype. USNM 22934.

17–19. Dorsal, lateral, and ventral views of a very large specimen from 8 feet above the base of the Bridge Creek Limestone Member at USGS locality D6572 (text fig. 16, loc. 19). USNM 163829.

AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 19

[All figures natural size]

FIGURES 1–6. *Puebloites spiralis* Cobban and Scott, n. sp. (p. 46).

From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6147 (text fig. 16, loc. 97).

1, 2. Lateral and ventral views of a small specimen. USNM 163832.

3, 4. Ventral and lateral views of a slightly larger specimen. USNM 163833.

5, 6. Ventral and lateral views of a large, finely ribbed whorl. USNM 163834.

7–28. *Puebloites greenhornensis* Cobban and Scott, n. sp. (p. 46).

From 25½ feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 105 of the Rock Canyon section).

7. Latex cast of juvenile limbs from USGS locality D4442. USNM 163836.

8, 9. Ventral and lateral views of part of a densely ribbed whorl from USGS locality D6121. USNM 163838.

10, 11. Lateral and ventral views of a sharply ribbed specimen from the same locality as figure 7. USNM 163837.

12, 13. Ventral and lateral views of a fragment from USGS locality D3979. USNM 163840.

14–16. Ventral, lateral, and dorsal views of the holotype from the same locality as figures 12 and 13. USNM 163835.

17–19. Ventral, lateral, and dorsal views of a specimen showing the coarsely ribbed adult stage. From USGS locality D4305. USNM 163841.

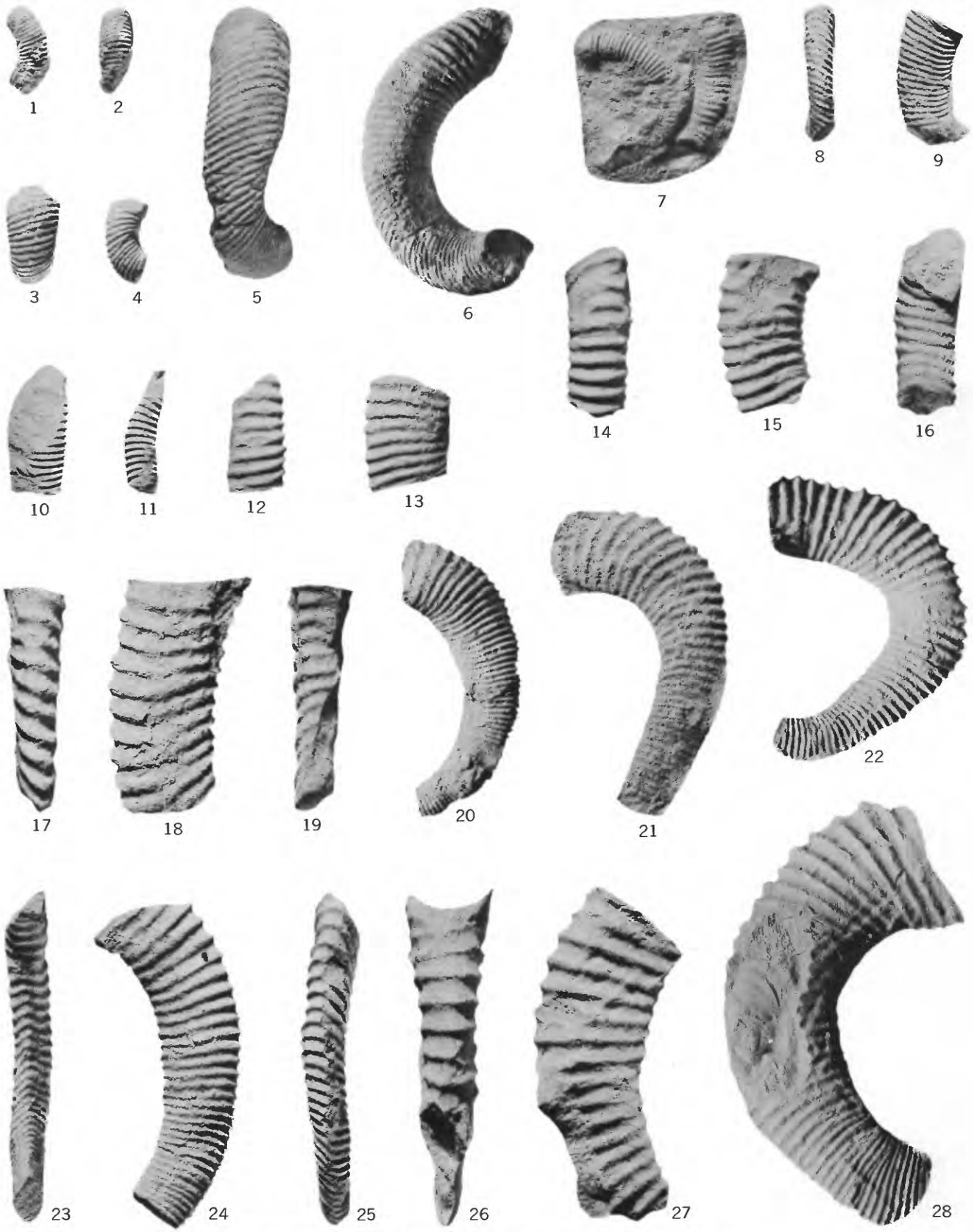
20, 21. Latex casts of two specimens from the same locality showing the change from fine to coarse ribbing, USNM 163842, 163843.

22. Latex cast of a specimen showing changes in form of coiling and in density of ribbing. From USGS locality D6479. USNM 163846.

23–25. Dorsal, lateral, and ventral views of a specimen from the same locality as figures 8 and 9. USNM 163839.

26, 27. Ventral and lateral views of a specimen showing the coarsely ribbed adult stage. From the same locality as figures 17–19. USNM 163844.

28. Lateral view of a large specimen from the same locality showing the change from dense to sparse ribbing. USNM 163845.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 20

[All figures natural size]

FIGURES 1–14. *Allocrioceras annulatum* (Shumard) (p. 51).

1–3. Ventral, lateral, and dorsal views of a plaster cast of the holotype of White's *Helicoceras pariense*. USNM 8638.

4–6. Dorsal, lateral, and ventral views of a specimen from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D4438 (text fig. 16, loc. 29). USNM 163866.

7, 8. Lateral and ventral views of a specimen from near the base of the Bridge Creek Limestone Member at USGS locality D5127 (text fig. 16, loc. 22). USNM 163867.

9, 10. Lateral and ventral views of a large specimen from near the base of the Bridge Creek Limestone Member at USGS locality D1308 (text fig. 16, loc. 20). USNM 163869.

11, 12. Lateral and ventral views of a large specimen from the same locality as figures 7 and 8. USNM 163868.

13, 14. Ventral and lateral views of a stout specimen from 2½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6472 (text fig. 16, loc. 102). USNM 163870.

15–21. *Baculites* cf. *B. yokoyamai* Tokunaga and Shimizu (p. 48).

From 30 feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 113 of the Rock Canyon section).

15–17. Dorsal, lateral, and ventral views of a specimen from USGS locality D6483. USNM 163856.

18, 19. Lateral and ventral views of a very large adult from USGS locality D3980. USNM 163858.

20, 21. Lateral and ventral views of a specimen from the same locality as figures 15–17. USNM 163857.

AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 21

[All figures natural size except as indicated]

FIGURES 1, 3, 4. *Calycoceras* cf. *C. naviculare* (Mantell) (p. 60).

1. Fragment showing the conspicuous ventrolateral tubercles. From the basal bed of the Bridge Creek Limestone Member in the Rock Canyon reference section at USGS locality D6473 (text fig. 16, loc. 103). USNM 163901.

3, 4. Rear and side views of a crushed specimen from 3$\frac{3}{10}$ feet above the base of the Bridge Creek Limestone Member at USGS locality D4870 (text fig. 16, loc. 154). USNM 163902.

2. *Calycoceras*? *canitaurinum* (Haas) (p. 60).

Side view (× ½) of a crushed specimen from the Lincoln Limestone Member at USGS locality D2547 (text fig. 16, loc. 136). USNM 163905.

AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 22

Vascoceras (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

Side view (× 1) of the holotype from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6147 (text fig. 16, loc. 97). USNM 164022.

AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 23

[All figures natural size]

FIGURES 1–13. *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

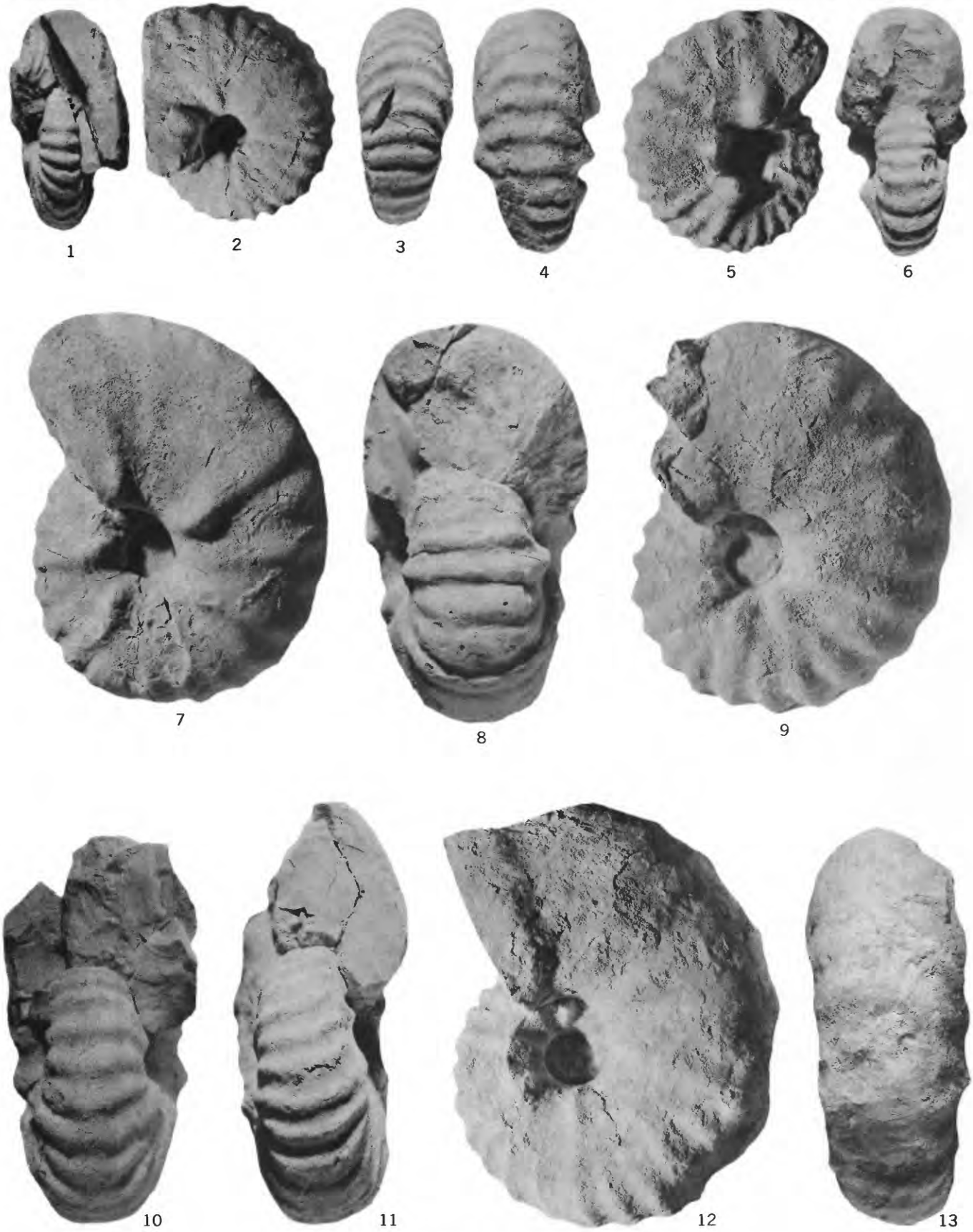
1–3. Front, side, and rear views of a slender phragmocone from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality 22876 (text fig. 16, loc. 47). USNM 164023.

4–6. Rear, side, and front views of a stouter phragmocone that has very strong umbilical tubercles. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6147 (text fig. 16, loc. 97). USNM 164025.

7, 8. Side and front views of a very stout specimen from the same locality. USNM 164026.

9, 10. Side and front views of a slender but strongly ribbed specimen from the Bridge Creek Limestone Member at USGS locality 15393 (text fig. 16, loc. 24). USNM 164030.

11–13. Front, side, and rear views of a slender specimen from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6143 (text fig. 16, loc. 36). USNM 164032.



AMMONITES FROM THE GREENHORN LIMESTONE

487-487 O - 72 - 11

PLATE 24

[All figures natural size]

FIGURES 1–12. *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

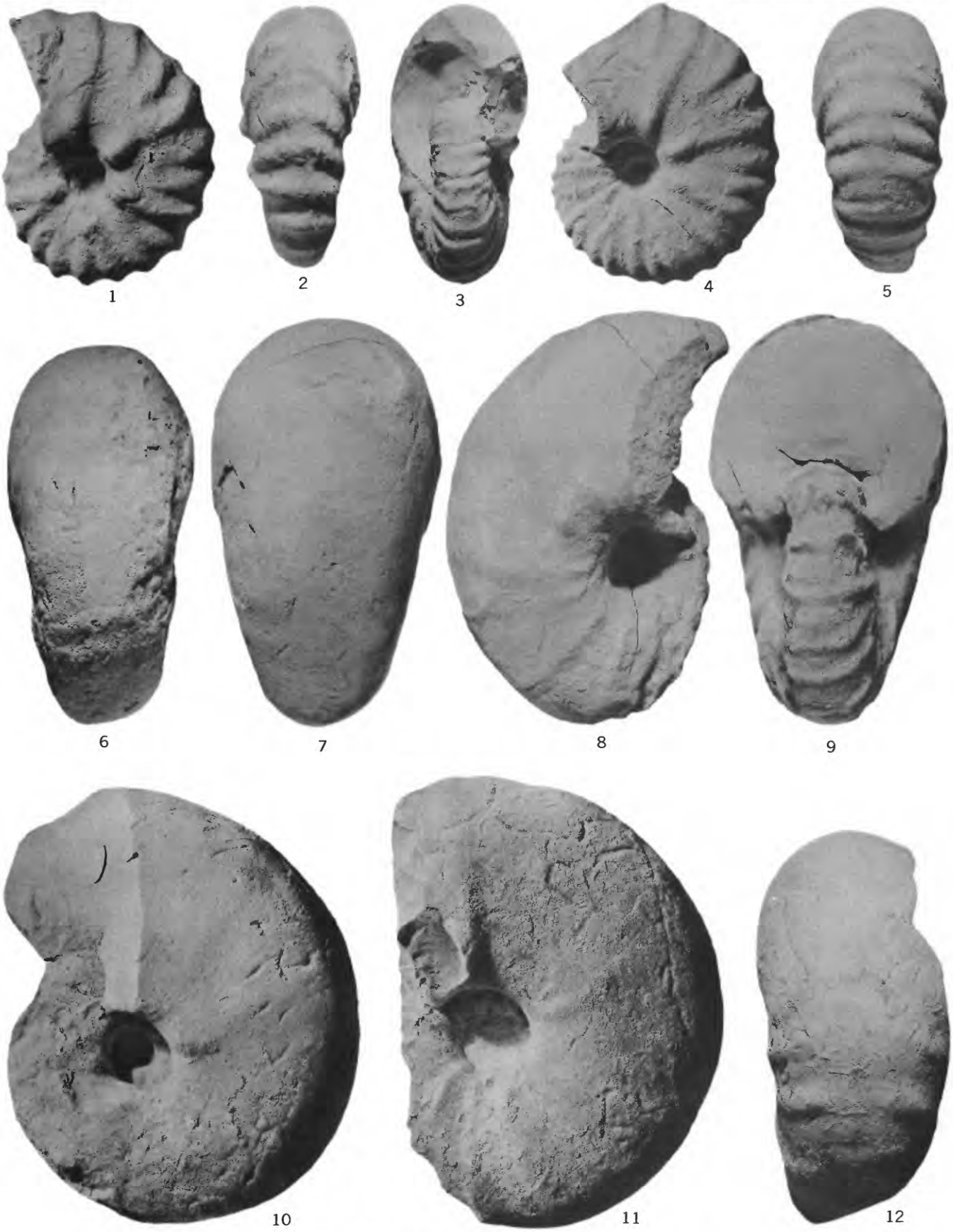
1, 2. Side and rear views of a coarsely ribbed slender phragmocone from the Bridge Creek Limestone Member at USGS locality 15402 (text fig. 16, loc. 10). USNM 164034.

3–5. Front, side, and rear views of the inner whorls of a specimen showing the constrictions. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6143 (text fig. 16, loc. 36). USNM 164033.

6, 10. Rear and side views of a very small and nearly smooth adult from the Bridge Creek Limestone Member at USGS locality 15729 (text fig. 16, loc. 46). USNM 164035.

7–9. Rear, side, and front views of a very small adult from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality 22875 (text fig. 16, loc. 91). USNM 164036.

11, 12. Side and rear view of another small adult that has incipient ventrolateral tubercles. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D3977 (text fig. 16, loc. 64). USNM 164040.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 25

Vascoceras (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

Side view (× ⅞) of the largest specimen collected. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality 22875 (text fig. 16, loc. 91). See text figure 45 for cross section. USNM 164037.

AMMONITE FROM THE GREENHORN LIMESTONE

487-487 O - 72 - 12

PLATE 26

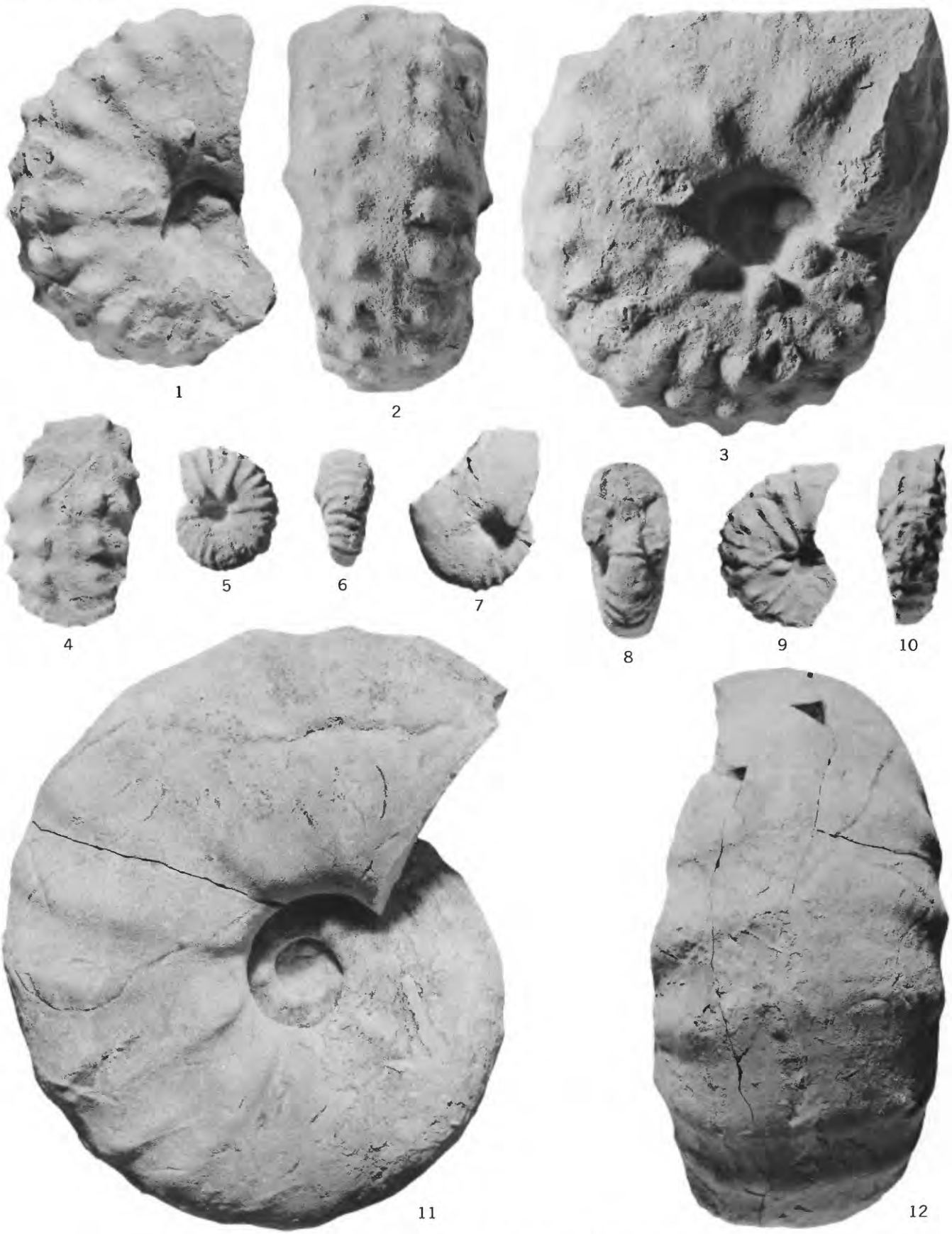
[All figures natural size]

FIGURES 1–4, 9, 10. *Mammites nodosoides* (Schlotheim) subsp. *wingi* Morrow (p. 79).

1. Side view of the inner whorls of a specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D4305 (text fig. 16, loc. 28). USNM 164007.
2, 3. Rear and side views of a specimen from the Bridge Creek Limestone Member at USGS locality D4879 (text fig. 16, loc. 163). USNM 164009.
4. Rear view of a small stout specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D4442 (text fig. 16, loc. 33). USNM 164011.
9, 10. Side and rear views of a very slender variant from the same locality as figure 1. USNM 164008.

5–8, 11, 12. *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

5, 6. Side and rear views of the inner whorls showing the constrictions. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6147 (text fig. 16, loc. 97). USNM 164027.
7, 8. Side and front views of a small specimen showing constrictions and raised ribs. From the Bridge Creek Limestone Member at USGS locality 22919 (text fig. 16, loc. 15). USNM 164042.
11, 12. Side and rear views of a rather small stout adult from the same locality as figures 5 and 6. USNM 164028.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 27

[All figures natural size]

FIGURES 1–6. *Vascoceras* (*Greenhornoceras*) *birchbyi* Cobban and Scott, n. sp. (p. 85).

From 20 feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 97 of the Rock Canyon section).

1. Side view of an unusually finely ribbed specimen from USGS locality 22876. USNM 164024.

2, 3. Side and rear views of a very slender specimen that has constrictions persisting to a large diameter. From USGS locality 22875. USNM 164038.

4–6. Rear, side, and front views of strongly ribbed inner whorls showing constrictions. From USGS locality D3977. USNM 164041.

7–10. *Watinoceras reesidei* Warren? (p. 75).

From 20 feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 97 of the Rock Canyon section).

7, 8. Rear and side views of a specimen from USGS locality D6147. USNM 163992.

9, 10. Rear and side views of a larger specimen from USGS locality D3977. USNM 163994.

11–19. *Watinoceras coloradoense* (Henderson) (p. 76).

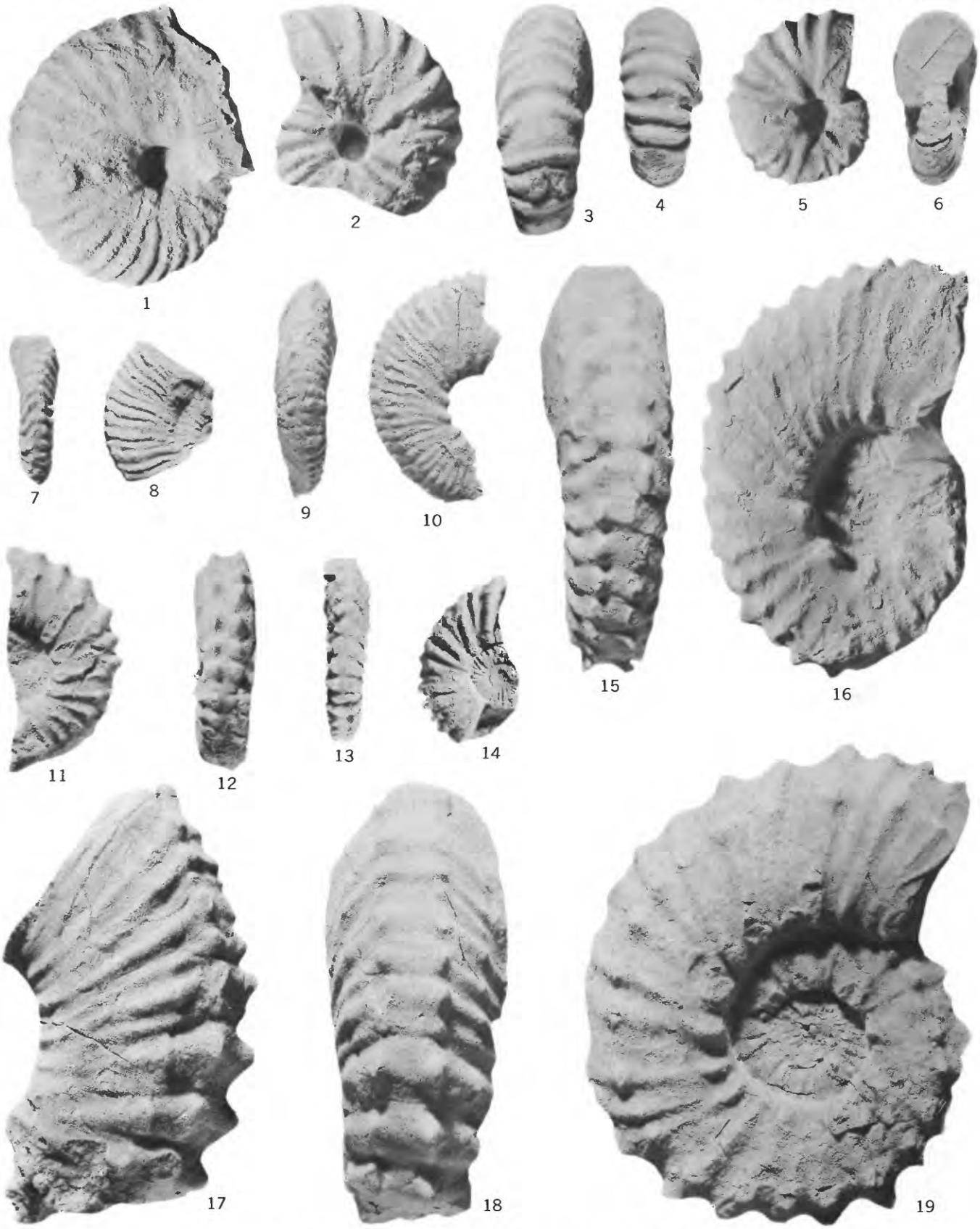
11, 12. Side and rear views of a young specimen from the Bridge Creek Limestone Member at USGS locality D4876 (text fig. 16, loc. 160). USNM 163995.

13, 14. Rear and side views of a smaller specimen from the same locality showing the inner whorls. USNM 163996.

15, 16. Rear and side views of an adult from 20 feet above base of the Bridge Creek Limestone Member at the same locality as figures 7 and 8. USNM 163997.

17, 18. Side and rear views of the orad end of an adult body chamber showing the decline in tuberculation toward the aperture. From 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6143 (text fig. 16, loc. 36). USNM 164000.

19. Side view of an adult from the same locality as figures 15 and 16. USNM 163998.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 28

[All figures natural size]

FIGURES 1–3, 5–9. *Watinoceras coloradoense* (Henderson) (p. 76).

From 20 feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 97 of the Rock Canyon section).

1, 3. Rear and side views of an adult from USGS locality D6478. USNM 164001.

2. Latex cast of a juvenile from the same locality. USNM 164002.

5, 7. Rear and side views of a very large adult body chamber from USGS locality D6147. USNM 163999.

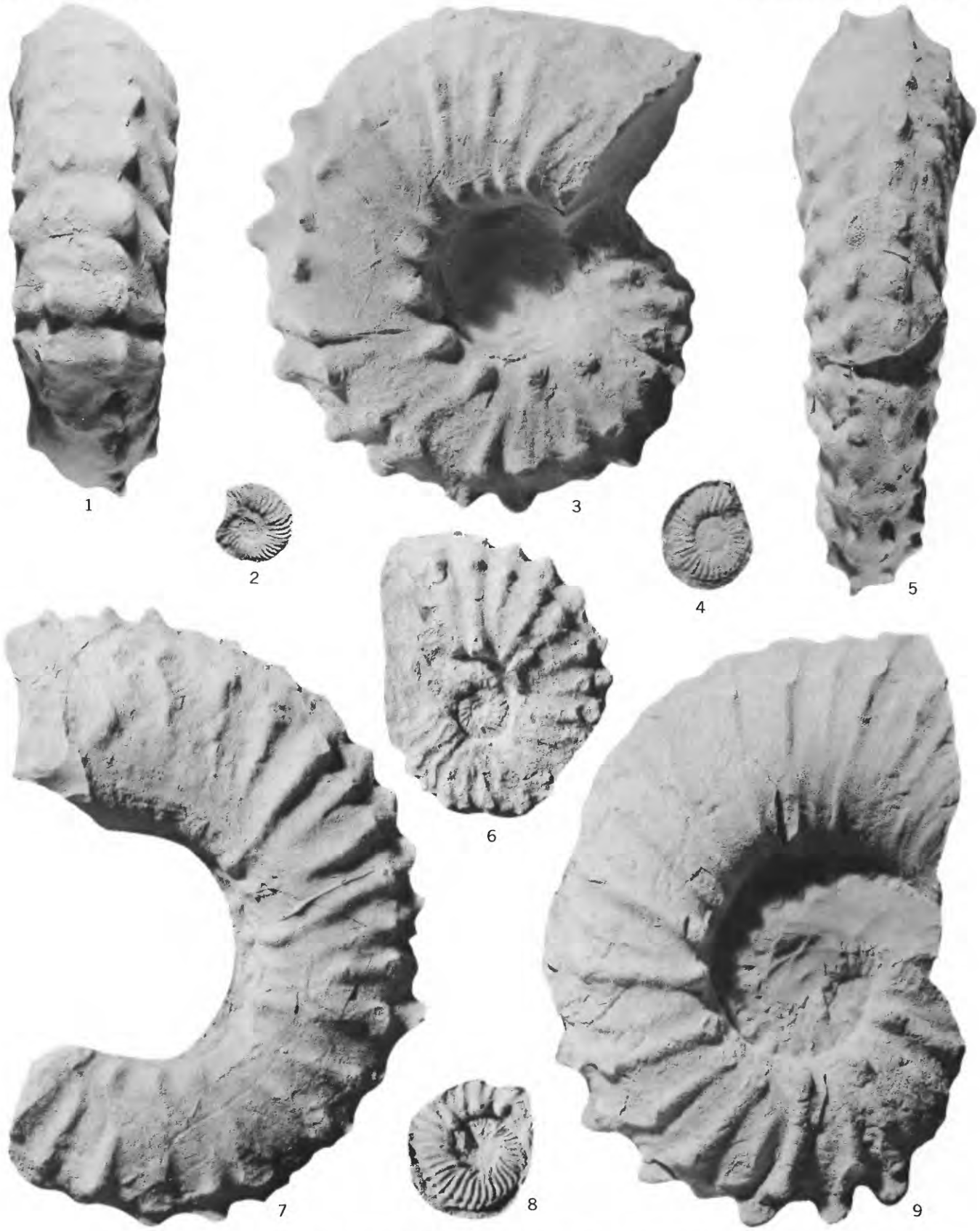
6. Side view of a specimen showing the contrast between the densely ribbed inner whorls and the more sparsely ribbed outer whorl. From USGS locality D6122. USNM 164004.

8. Latex cast of a small specimen from USGS locality D3977. USNM 164005.

9. Side view of a large adult from USGS locality D6478. USNM 164003.

4. *Watinoceras reesidei* Warren? (p. 75).

Latex cast of a juvenile from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6147 (text fig. 16, loc. 97). USNM 163993.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 29

FIGURES 1–3. *Ampakabites collignoni* Cobban and Scott, n. sp. (p. 81).
Rear, side, and front views (× 1) of the holotype from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality 22875 (text fig. 16, loc. 91). USNM 164014.

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AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 30

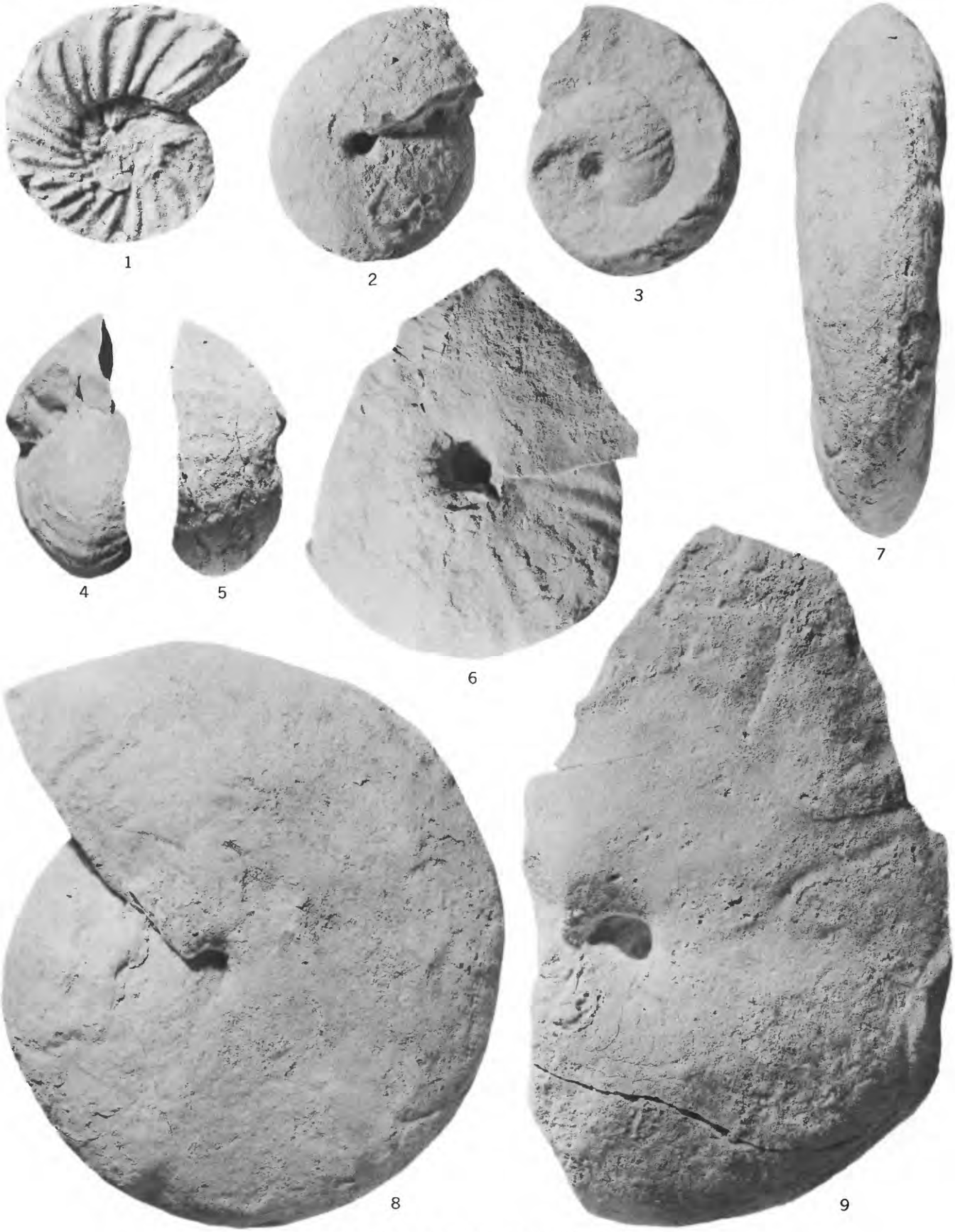
[All figures natural size]

FIGURE 1. *Collignoniceras woollgari* (Mantell) (p. 94).
Side view of a crushed juvenile from 10½ feet below the top of the Bridge Creek Limestone Member at USGS locality D6487 (text fig. 16, loc. 44). USNM 164055.

2–6. *Neoptychites xetriformis* Pervinquière (p. 89).
From the Bridge Creek Limestone at USGS locality 15393 (text fig. 16, loc. 24). USNM 164046.
2–5. Two side views and front and rear views of the inner whorls.
6. Side view of the outer whorl.

7, 8. *Neoptychites* sp. (p. 91).
Rear and side views of an adult from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D6122 (text fig. 16, loc. 93). USNM 164048.

9. *Neoptychites* cf. *N. cephalotus* (Courtiller) (p. 90).
Side view of part of an adult from the Bridge Creek Limestone Member at USGS locality D4876 (text fig. 16, loc. 160). See text figure 50 for the suture. USNM 164047.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 31

FIGURES 1, 2. *Mammites nodosoides* (Schlotheim) subsp. *wingi* Morrow (p. 79).
Side and front views (× 1) of the holotype from the Jetmore Chalk Member of the Greenhorn Limestone of Cloud County, Kans.

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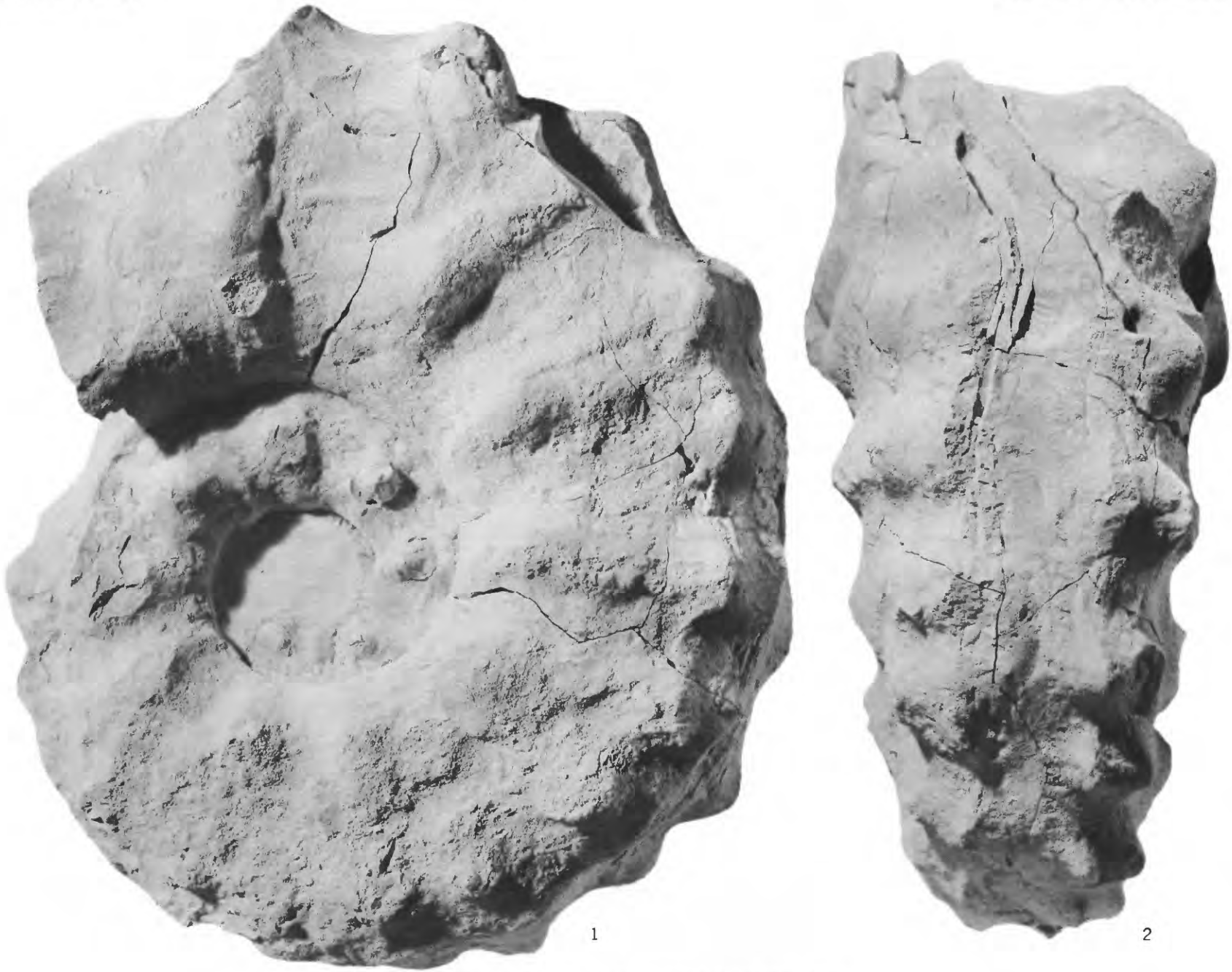
AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 32

FIGURES 1, 2. *Mammites nodosoides* (Schlotheim) subsp. *wingi* Morrow (p. 79).
Side and rear views (× 1) of a specimen from the Bridge Creek Limestone Member at USGS locality 22876 (text fig. 16, loc. 47). USNM 164012.



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AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 33

Mammites nodosoides (Schlotheim) subsp. *wingi* Morrow (p. 79).

Side view of a large specimen (× 6/10) from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6149 (text fig. 16, loc. 99). USNM 164013.

AMMONITE FROM THE GREENHORN LIMESTONE

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PLATE 34

[All figures natural size]

FIGURES 1, 2. *Fagesia* sp. (p. 88).

Rear and side views of a specimen from 20 feet above the base of the Bridge Creek Limestone Member at USGS locality D3977 (text fig. 16, loc. 64). USNM 164044.

3–6, 8, 9. *Choffaticeras pavillieri* (Pervinquière) (p. 92).

3, 4. Side and front views of the inner whorls of a specimen showing the low tubercles along the ventrolateral ridge. From the Bridge Creek Limestone Member at USGS locality 15393 (text fig. 16, loc. 24). USNM 164050.

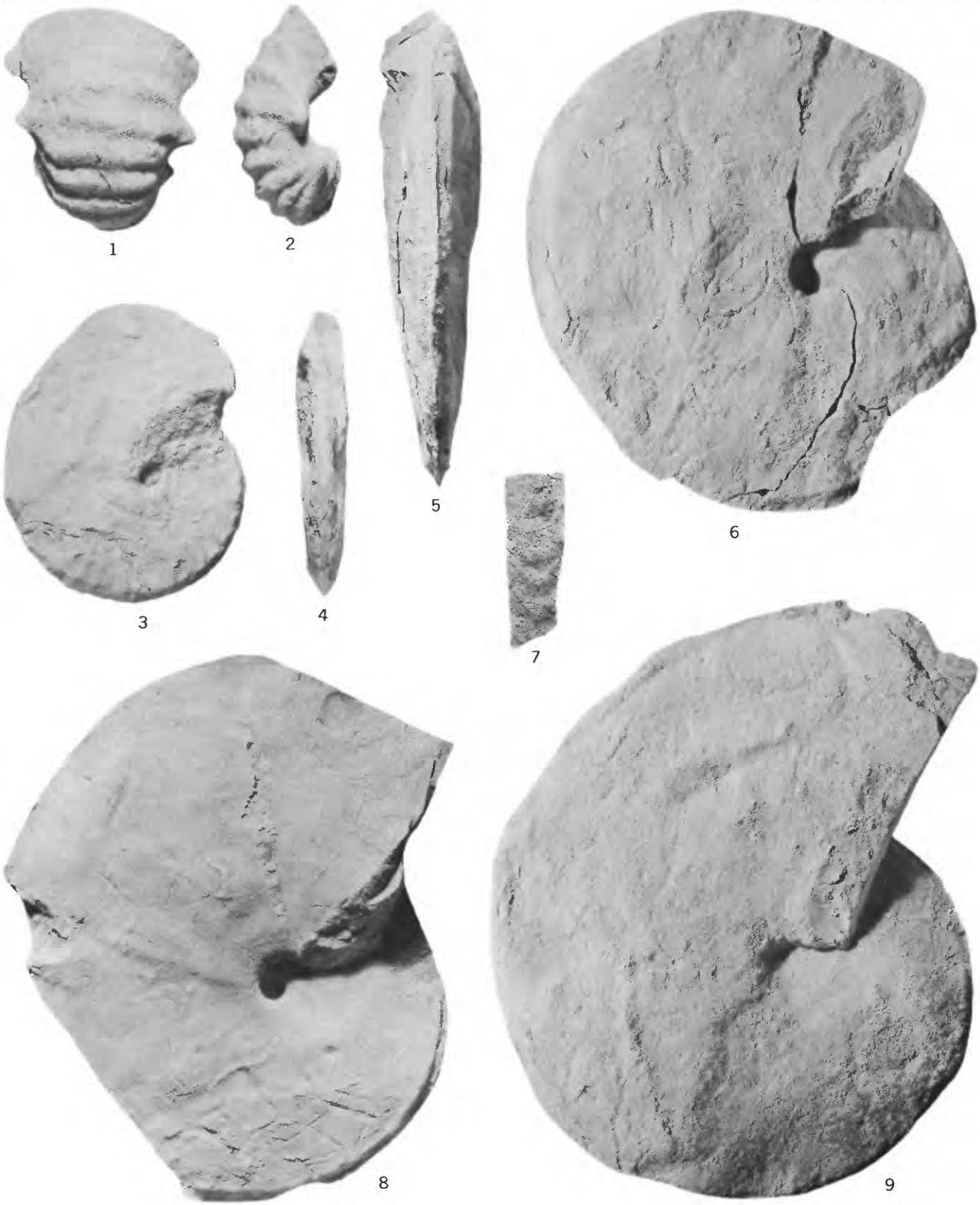
5, 6. Rear and side views of the outer whorl of the specimen shown in figures 3 and 4.

8. Side view of an adult from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D3979 (text fig. 16, loc. 66). USNM 164051.

9. Side view of a slightly larger adult from 30 feet above the base of the Bridge Creek Limestone Member at USGS locality D6483 (text fig. 16, loc. 108). USNM 164052.

7. *Baculites calamus* Morrow (p. 49).

Side view of a crushed specimen from the top of the Bridge Creek Limestone Member at USGS locality D4897 (text fig. 16, loc. 181). USNM 163859.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 35

FIGURES 1–3. *Choffaticeras pavillieri* (Pervinquière) (p. 92).
Rear, side, and front views (× 1) of a large crushed specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6149 (text fig. 16, loc. 99). USNM 164053.

1

2

3

AMMONITE FROM THE GREENHORN LIMESTONE

PLATE 36

[All figures natural size]

FIGURES 1–4. *Vascoceras* sp. (p. 83).

1, 2. Front and sides views of a specimen from 18 feet above the base of the Bridge Creek Limestone Member at USGS locality D6142 (text fig. 16, loc. 35). USNM 164020.

3, 4. Side and front views of a specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6146 (text fig. 16, loc. 39). USNM 164021.

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PLATE 37

[All figures natural size]

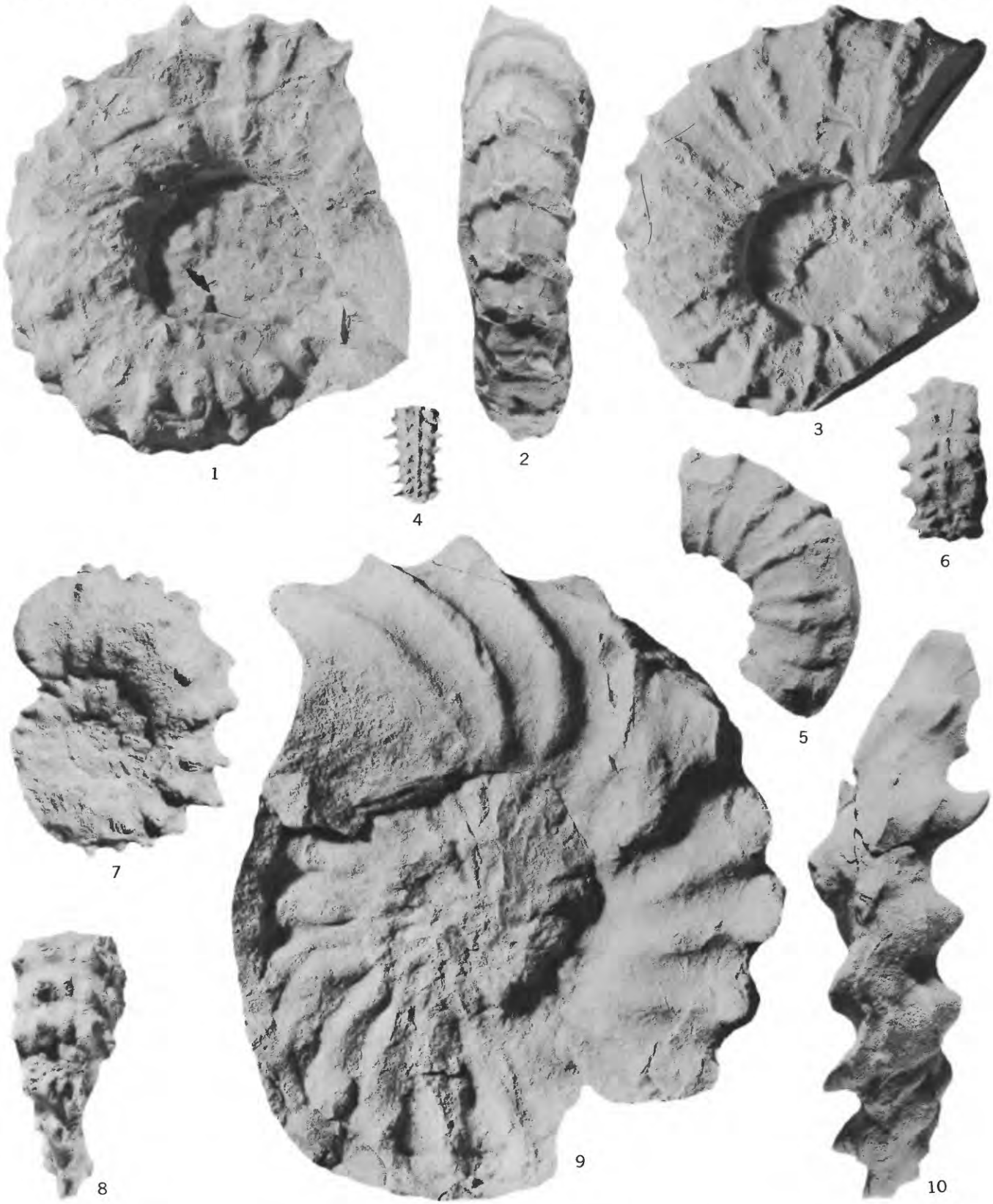
FIGURES 1–8. *Kanabiceras puebloense* Cobban and Scott, n. sp. (p. 73).

From 25½ feet above the base of the Bridge Creek Limestone Member of the Greenhorn Limestone (bed 105 of the Rock Canyon section).

1. Side view of an adult from USGS locality D6124. USNM 163982.
2, 3. Rear and side views of an adult from USGS locality D6479. USNM 163984.
4. Latex cast of the ventral area preserved on the dorsum of the next larger whorl of a specimen from USGS locality D4442. USNM 163980.
5. Side view of part of a whorl from USGS locality D6124. USNM 163983.
6. Rear view of a smaller specimen from USGS locality D4442. USNM 163981.
7, 8. Side and rear views of the holotype from USGS locality D4305. USNM 163978.

9, 10. *Collignoniceras woollgari* (Mantell) (p. 94).

Side and rear views of a distorted specimen from 5½ feet below the top of the Bridge Creek Limestone Member at USGS locality D3985 (text fig. 16, loc. 114). USNM 164056.



AMMONITES FROM THE GREENHORN LIMESTONE

PLATE 38

[All figures natural size]

FIGURE 1. *Kanabiceras puebloense* Cobban and Scott, n. sp. (p. 73).
Side view of a spinose specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6479 (text fig. 16, loc. 41). USNM 163985.

2, 3, 5–13. *Tragodesmoceras bassi* Morrow (p. 58).
2, 3. Rear and side views of Morrow's paratype from the Bridge Creek Limestone Member at USGS locality 12768 (text fig. 16, loc. 150). USNM 163892.
5. Side view of a specimen from the Bridge Creek Limestone Member at USGS locality 22875 (text fig. 16, loc. 91). USNM 163893.
6, 7. Rear and side views of a specimen from 30 feet above the base of the Bridge Creek Limestone Member at USGS locality D4443 (text figs. 16, loc. 34). USNM 163894.
8, 9. Side and rear views of part of a whorl from 30 feet above the base of the Bridge Creek Limestone Member at USGS locality D6483 (text fig. 16, loc. 108). USNM 163895.
10, 11. Rear and side views of a specimen from the Bridge Creek Limestone Member at USGS locality D4880 (text fig. 16, loc. 164). USNM 163896.
12, 13. Rear and side views of a larger specimen from the same locality as figures 8 and 9. USNM 163897.

4. *Fagesia* sp. (p. 88).
Rear view of a crushed specimen from 25½ feet above the base of the Bridge Creek Limestone Member at USGS locality D6124 (text fig. 16, loc. 95). USNM 164045.

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PLATE 39

Tragodesmoceras bassi Morrow (p. 58).

Side view (× 7/10) of a specimen 310 mm in diameter from the Bridge Creek Limestone Member at USGS locality 15393 (text fig. 16, loc. 24). USNM 163898.

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