Callovian (Jurassic) Ammonites from the United States and Alaska

Part 1. Western Interior United States

GEOLOGICAL SURVEY PROFESSIONAL PAPER 249-A

DEPARTMENT OF THE INTERIOR
March 3, 1849

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By RALPH W. IMLAY

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Descriptions and illustrations of
cephalopods of Late Jurassic age

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CALLOVIAN (JURASSIC) AMMONITES FROM THE UNITED STATES AND ALASKA

PART 1. WESTERN INTERIOR UNITED STATES

By **Ralph W. Imlay**

ABSTRACT

Early Late Jurassic ammonites have been obtained from the Rierdon formation of Montana and the lower part of the Sundance formation of Wyoming and South Dakota. These ammonites represent only the lower part of the Callovian stage and correspond with the northwest European zones of *Macrocephalites macrocephalus, Proplanulites koenigi* and *Sigaloceras calloviense.* Possibly the highest ammonite-bearing beds are as young as the *Cosmoceras jason* zone, although most of the evidence is against such a correlation.

Careful stratigraphic collecting has demonstrated the existence of five ammonite zones and their positions with respect to various lithologic units. The basal zone, characterized by *Arcticoceras codyense,* has been identified at many localities in the basal oölitic beds of the Sundance formation in Wyoming and South Dakota and in the lowermost beds of the Rierdon formation in Montana. It is correlated with the European zone of *Macrocephalites macrocephalus* on the basis of its stratigraphic position beneath beds containing abundant *Gowericeras* and because it contains numerous *Cadoceras* that are not older than the Callovian. The immediately overlying beds in central and nothwestern Montana have furnished a densely ribbed ammonite, called *Gowericeras costidensum.* Above, near the middle of the Rierdon formation, follow beds containing abundant *Gowericeras* and *Cadoceras* and characterized by the species *Gowericeras subitum.* These beds containing *Gowericeras* are correlated with the northwest European zone of *Proplanulites koenigi* because of the abundance of *Gowericeras* and the highest occurrence of *Procerites.* The overlying beds which contain *Kepplerites tychonis,* are correlated with the lower part of the *Sigaloceras calloviense* zone of Europe because the same species occurs in Alaska and East Greenland in association with *Cosmoceras (Gulielmiceras).* The highest beds of the Rierdon formation in Montana contain many *Kepplerites,* of which *K. mclearni* has been designated the zonal index. Correlation with the *Sigaloceras calloviense* zone of northwest Europe is indicated by the presence of *Cosmoceras (Gulielmiceras)* and *C. (Gulielmites),* by the abundance of *Kepplerites* with flattened venters, and by the occurrence of similar forms in Alaska in beds containing *Gowericeras* and *Paracadoceras.*

The Callovian ammonites of the western interior sea show greater resemblances to those of East Greenland than to those of southwestern Alaska. This probably reflects differences in depth of water, as all available evidence shows that the sea in the area of southwestern Alaska was fairly deep and bordered mountainous shores, whereas the seas of the western interior and of Greenland were very shallow and bordered low shores.

INTRODUCTION

Studies of the Callovian ammonites of the western interior region were begun by the writer in the summer of 1944 and were nearly completed the following year except for photographic work. The delay in publication was beneficial in several ways: important collections and valuable field data were added in Montana and Wyoming, the Callovian ammonites of Alaska were studied thoroughly, and a much better understanding was obtained of comparable faunas of Europe, Asia, and South America. In particular, the many months spent in the field measuring sections, tracing lithologic units, and collecting fossils made possible definite conclusions concerning faunal zones and stratigraphic correlations that should be useful to mapping parties.

Most of the fossils described herein have been collected since 1938, but some were collected as early as 1885 in the Yellowstone National Park area. The principal collectors were T. W. Stanton in 1911 and 1921, A. J. Collier in 1921 and 1923, D. A. Andrews and W. G. Pierce in 1935, J. B. Reeside, M. M. Knechtel and S. W. Hobbs in 1938, C. F. Deiss and R. M. Garrells in 1940, Josiah Bridge in 1941, William Cobban in 1944 and 1946, R. W. Imlay from 1944 to 1951, Oscar Mueller in 1944 and 1946, and J. D. Love, Theodore Botinelly and George Pipiringos in 1946.

BIOLOGIC ANALYSIS

The Callovian ammonites from the western interior of the United States include 482 specimens that are specifically identifiable. Among these the Macrocephalitidae is represented by 11, the Cardioceratidae by 230, the Cosmoceratidae by 221, and the Perisphinctidae by 20. In the Cardioceratidae, *Arcticoceras* comprises 20 percent and *Cadoceras* 28 percent of the total number of ammonites present. In the Cosmoceratidae, *Kepplerites* comprises 15 percent, *Gowericeras* 23 percent, and *Cosmoceras* 8 percent of the total. In number of species the Macrocephalitidae is represented by 4, the Cardioceratidae by 10, the Cosmoceratidae by 17, and the Perisphinctidae by 7. The ammonites are distributed among 10 genera and subgenera, and 37 species and varieties. Nineteen species and 1 variety are described as new, 5 have been described previously from western interior collections, 1 is identified with a common boreal species, 1 is compared with a boreal species, 1 is compared with a Mexican species, 2 are compared with European species, and 7 are not named because they are poorly preserved.

The Macrocephalitidae is represented by *Lilloettia* and *Xenocephalites.* These have been found only in the *Kepplerites mclearni* zone at the top of the Rierdon formation in Montana. *Lilloettia* has been reported previously from Alaska and British Columbia (Crickmay, 1930, pp. 60, 62). In Alaska *Lilloettia* is associated with other ammonites that indicate correlation with the middle Callovian zones of *Sigaloceras calloviense* and *Cosmoceras jason* in northwest Europe. *Xenocephalites* occurs in southwestern Alaska, in East Greenland (Spath, 1932, p. 44, pl. 14, figs. 4 a-d), in southern Mexico (Burckhardt, 1927, p. 33, pl. 16, figs. 4-9), and South America (Stehn, 1924, pp. 86-92, pl. 1, figs. 3-6). It ranges from the Bathonian into the Callovian, but probably not higher than the *S. calloviense* zone. Both of these genera are migrants from the Pacific region and are unknown in Europe. Their morphologic characteristics and generic relationships are discussed in detail by the writer in a paper dealing with the Callovian ammonites from Alaska (U. S. Geol. Survey Prof. Paper 249-B) and need not be repeated here.

The Cardioceratidae is represented by *Arcticoceras* and *Cadoceras. Arcticoceras* includes at least six species that show considerable range in ornamentation and in whorl shape. All species are characterized by a narrowly rounded to subtrigonal venter, by an extremely small umbilicus without an umbilical edge, and in the immature forms by forwardly inclined ribs that bifurcate near the middle of the flanks and arch forward noticeably on the venter. Most species develop a nearly smooth body chamber and some become smooth at an early age. The aperture is prolonged ventrally in a long lappet. There is very slight or no umbilical enlargement at the anterior end of the adult body chamber. On some specimens the suture line of the last septate whorl develops broad lobes and saddles and the second lateral lobe may become bifid.

The genus is represented by the following species:

A. ishmae (Keyserling), 1846, p. 331, pl. 20, figs. 8-10; Sokolov, 1912, pp. 15, 49, pl. 1, fig. 1, pl. 3, fig. 12, text. fig. 2; Spath, 1932, pl. 15, figs. 7a, b.
A. kochi Spath, 1932, p. 53, pl. 12, fig. 1, pl. 13, figs. 4, 5, pl. 14, figs. 1-3, pl. 15, figs. 1, 4-6.
A. michaelis Spath, 1932, p. 56, pl. 13, figs. 3a, b.
A. ishmae Madsen (not Keyserling), 1904, p. 191, pl. 8, fig. 7.
A. codyense Imlay, 1948, p. 20, pl. 6, figs. 4, 6, 8.
A. henryi (Meek and Hayden), 1865, p. 128, pl. 5, figs. 9 a-c.
A. rierdonense Imlay.
A. n. sp. ind. (see pl. 3, figs. 13, 15, 17).
A. crassicostatum Imlay.
A. loveanum Imlay.

Possibly the list should include *Cadoceras subpatruum* Nikitin (1885a, p. 58, pl. 11 (13), figs. 58), whose adult whorl greatly resembles that of the adult *A. henryi* (Meek and Hayden). Of the species listed, *A. codyense* and *A. henryi* lose their ribbing earliest; *A. ishmae, A. kochi,* and *A. crassicostatum* have the coarsest ribbing; *A. codyense* has the most nearly trigonal whorl section. The whorl shape of *A. codyense* suggests a relationship to the keeled *Chamoussetia* R. Douville (1912, p. 19), of the lower Callovian, or to the middle and upper Callovian *Longaeviceras* Buckman (1919, p. 121b, pl. 121a), which has keeled inner whorls. However, most species of *Arcticoceras* show greater resemblances to the slightly older *Arctocephalites,* as pointed out by Spath (1932, p. 52). The latter genus is distinguished from *Arcticoceras* by having a wider umbilicus, lower and more rounded whorl sections, and nearly radial ribbing. *Arcticoceras* is placed in the Cardioceratidae rather than in the Macrocephalitidae because of its compressed form, narrowed venter, and forwardly inclined ribbing of its inner and intermediate whorls. The stratigraphic position of *Arcticoceras* at the very base of the Callovian in the western interior and boreal regions suggests the possibility that it is ancestral to the similar but slightly younger *Pseudocadoceras, Longaeviceras,* and certain compressed forms of *Cadoceras* of which *C. stenolobum* (Keyserling) (1846, p. 329, pl. 20, fig. 7, pl. 22, figs. 13, 14) is typical.

The genus *Cadoceras* will be discussed by the writer in detail in a paper dealing with the Callovian ammonites of southwestern Alaska and will be subdivided into seven groups or subgenera based mainly on the varied and prolific Alaskan forms. It is of considerable interest therefore that all the species of *Cadoceras* from the western interior of the United States belong to a group that has not been found in Alaska but occurs in East Greenland and central

Russia in beds that probably correspond to the European zone of *Sigaloceras calloviense*. This group is characterized by a narrow tubular umbilicus, moderately to broadly rounded whorls, an evenly rounded umbilical edge, a lack of tubercles or tubercles weakly developed on inner whorls only, and a globose, smooth body chamber. The adults are much larger than in any other group of *Cadoceras* (see pls. 7, 10, 12). This group is represented by the following species:

C. franciscus Spath, 1932, p. 74, pl. 20, figs. 2a-c.
C. freboldi Spath, 1932, p. 65, pl. 18, figs. 2a, b.
C. surense Nikitin, 1885a, p. 57, pl. 12, figs. 53-55, text fig. 4 on p. 58.
C. shoshonense Imlay, 1948, p. 22, pl. 7, figs. 13, 16, 17.
C. muelleri Imlay.
C. tetonense Imlay.
C. piperense Imlay.

Of these species, *C. franciscus* and *C. piperense* are the most compressed, *C. shoshonense* and *C. tetonense* are the stoutest, *C. tetonense* has the finest ribbing, *C. shoshonense* has the coarsest ribbing, and *C. muelleri* attains the largest size. The inner whorls of *C. surense* Nikitin are more evolute than those of the other species included in the group, but the deep, corkscrew-shaped umbilicus is quite typical. *C. subpatruum* Nikitin (1885a, p. 58, pl. 13, fig. 58, text fig. 5 on p. 59) is described as having ribbing on its inner whorls similar to that of *C. surense* Nikitin and may therefore belong in the same group, but its characteristics are more similar to those of *Arcticoceras* than of *Cadoceras*.

It is astounding that of all the seven groups of *Cadoceras* that can be recognized in the Callovian deposits of the Boreal sea and associated waters, only one occurs in the Callovian of the western interior of the United States and this particular group has not yet been found in the *Cadoceras*-rich Callovian of southwestern Alaska. The explanation is evidently partly stratigraphic but is probably also partly ecologic. In the western interior *Cadoceras* is associated with ammonites that indicate a Callovian age corresponding with the European zones of *Macrocephalites macrocephalus*, *Proplanulites koenigi* and *Sigaloceras calloviense*. In contrast, in the Alaskan Peninsula and the Cook Inlet regions the bulk of the Callovian beds are equivalent to the European *Cosmoceras jason* and *Erymnoceras coronatum* zones of the middle Callovian. Only the basal fourth or fifth contain ammonites, such as *Gowericeras* and *Gulielmiceras*, representing the *Proplanulites koenigi* and *Sigaloceras calloviense* zones, and this basal part is not nearly so rich in ammonites as the overlying beds. Furthermore, in this part of Alaska there is as yet no faunal evidence for the presence of beds corresponding to the *Macrocephalites macrocephalus* zone.

This stratigraphic explanation for the occurrence of groups of *Cadoceras* in Alaska different from those in the western interior is not completely satisfactory because the basal Callovian beds in Alaska can be correlated with the Callovian in the western interior on the basis of similar or identical species of *Gowericeras, Kepplerites, Gulielmiceras,* and *Xenocephalites,* and yet they contain quite different groups of *Cadoceras*. Furthermore the Alaskan beds contain such genera as *Phylloceras, Oppelia* (*Oxycerites*), *Kheraiceras* and *Reineckeia* that are not known in the western interior, and they lack nautiloids, which are fairly common in the Callovian of the western interior. These differences suggest that ecological factors influenced considerably the distribution of genera and subgenera of ammonites.

The Cosmoceratidae is represented abundantly by *Gowericeras, Kepplerites* (*Seymourites*), *Cosmoceras* (*Gulielmiceras*) and *Cosmoceras* (*Gulielmites*). *Gowericeras* is represented by six species and varieties. Of these *G. subitum* Imlay is the most different from the described European species. The genus is characterized by a rounded whorl section, evolute coiling and persistence of lateral tubercles. The venter in the western interior species is flattened in the young but not runcinate as in some European species. The species described herein are all from the middle part of the Rierdon formation of Montana, directly above the *Arcticoceras* beds and below the *Kepplerites tychonis* beds. *G. costidensum* Imlay occurs slightly lower than the other species.

Kepplerites is represented by six species, referred to the subgenus *Seymourites*. The genus may be distinguished from *Gowericeras* by its shorter primary ribs, less persistent tuberculation, more tightly coiled inner whorls, more persistent runcination, larger size, and more complicated suture. The subgenus, *Seymourites,* is retained by Spath (1932, p. 83) for the Boreal forms of *Kepplerites* because they differ from the typical *Kepplerites* in central Europe by their larger size, earlier loss of runcination, finer ribbing in the young, and by the tendency of the aperture to become flared. The only conspicuous difference is in size. Of the species from the western interior, one is identified with *K. tychonis* Ravn (1911, p. 490, pl. 37, fig. 1), from east Greenland and Alaska. The other five species occur higher stratigraphically than *K. tychonis* and resemble species from Greenland more than species from Alaska. Two of them, *K. mclearni* Imlay and *K. rockymontanus*

Imlay, attain a larger size and have more evolute outer whorls than any described species of *Kepplerites*. In the western interior *Kepplerites* has been found mainly in the upper part of the Rierdon formation, in beds that probably correspond to the *Sigaloceras calloviense* zone of northwest Europe. In Alaska *Kepplerites* ranges through the lower two-thirds of the Callovian beds that correspond to the *Proplanulites koenigi* to *Cosmoceras jason* zones of northwest Europe. Some of the species from the lower third show ventral flattening, as in the species from Montana, but those from the middle third show scarcely any ventral flattening, even in immature forms.

Gulielmiceras is represented in the western interior by three species from the *Kepplerites mclearni* beds at the top of the Rierdon formation in central Montana. The subgenus is characterized by persistent runcination, coarse ribbing on the body chamber, long lateral lappets, and presence of lateral and ventral tubercles. Most described European species of *Gulielmiceras* have a smooth or nearly smooth venter and a row of umbilical tubercles. All the species from the western interior have strong ribbing on the venter and lack distinct umbilical tubercles, although the ribs are swollen on the umbilical edge. Similar species are known from Alaska, East Greenland (Spath 1932, p. 96, pl. 24, figs. 3a, b, pl. 26, fig. 5), central Russia (Nikitin, 1881a, p. 70, pl. 4, fig. 31; Lahusen, 1883, p. 55, pl. 6, fig. 9), and England (Brinkman, 1929, pl. 1, fig. 1; Spath, 1932, p. 97). *Gulielmiceras* is distinguished from *Kepplerites* by its lateral lappets, greater compression, and more flexuous ribbing. *Sigaloceras* develops a smooth body chamber, has denser ribbing, and is generaly untuberculate. *Gulielmites* is distinguished by a smooth body whorl and an absence of lappets.

Gulielmites is represented only by three fragments of two species from the *Kepplerites mclearni* beds in Montana. One species is similar to *C. obductum* (Buckman) (1925, pl. 559) from England and the other to a form described by D'Orbigny (1845, p. 442, pl. 36, figs. 9-15) from Russia. The presence of three rows of tubercles on the finely-ribbed species shows that it belongs in *Gulielmites* rather than in *Sigaloceras*.

The Perisphinctidae is represented by several species each of *Procerites* and *Grossouvria*. Although most of the specimens are fragments, they may be compared readily with species in the lower Callovian beds of Europe. *Procerites* occurs both in the *Arcticoceras* and *Gowericeras* beds in central Montana and in the underlying beds in association with *Arctocephalites*. *Grossouvria* has been found only in the beds with *Gowericeras* and *Kepplerites*.

STRATIGRAPHIC SUMMARY

Callovian ammonites have been found in the western interior of the United States only in Montana, northern, central, and east-central Wyoming, and northwestern South Dakota. The Callovian beds in this area consist mainly of soft, calcareous gray shale that becomes sandier southeastward and more calcareous northwestward. In Montana they comprise the Rierdon formation, and in Wyoming and South Dakota are included in the lower part of the Sundance formation. Thin sandstone members occur at both the base and near the top of the sequence in central and eastern Wyoming and in western South Dakota. The basal sandstone, called the Canyon Springs sandstone member of the Sundance formation, fills the irregularities of an erosion surface, is medium-grained and partly oölitic, and greatly resembles the Nugget sandstone. It passes northwestward from the Hartville Uplift and the northern part of the Black Hills to the western margin of the Big Horn Mountains, where it grades into a sandy oölitic limestone that persists westward as oölitic limestone into Idaho and southwestern Montana. The upper sandstone, called the Hulett sandstone member of the Sundance formation, is fine-grained, gray, calcareous, thin- to thick-bedded, and is characterized by oscillation ripple marks. It thickens eastward at the expense of the underlying Stockade Beaver shale member of the Sundance formation. It extends westward as far as Cody in northwestern Wyoming and northward into southeastern Montana and most of North Dakota. In northwestern Wyoming west of Cody and Dubois and in southern Montana west of the Pryor Mountains it passes into dark-gray shale. Northwestward from southeastern Montana it becomes oölitic and then passes into a chalky limestone in central Montana. This limestone persists into Saskatchewan and marks the top of the Rierdon formation over a large area. The Rierdon formation of Montana west of the wedge of the Hulett sandstone member consists mainly of calcareous gray shale and gray limestone. Limestone predominates in the Little Rocky Mountains and in the subsurface in central Montana, but shale predominates in the Sweetgrass Arch area. The lower Callovian beds in Wyoming west of the wedge of the Hulett sandstone member consists mostly of soft gray shale but include a few thin beds of limestone. In extreme western Wyoming and southeastern Idaho the shale passes into a much thicker, dense limestone in the upper part of the Twin Creek limestone. This is overlain at the top of the Twin Creek limestone by ripple-marked sandstone and sandy limestone very similar to the Hulett sandstone member of the Sundance formation. More extended discussions of these stratigraphic units may be found in other publications (Imlay, 1947, 1948, 1950; Imlay, Gardner, Rogers, and Hadley, 1948).

FAUNAL ZONES AND CORRELATIONS

ARCTICOCERAS CODYENSE ZONE

The ammonite *Arcticoceras* characterizes the basal beds of the Rierdon formation in Montana and of the Sundance formation in Wyoming and South Dakota. As *A. codyense* Imlay is by far the most abundant and widespread species of the genus throughout this area, it is herein designated the zonal index for the beds containing *Arcticoceras.* It seems probable that future field work will demonstrate the existence of three subzones characterized from the base upward by *A. rierdonense* Imlay, *A. loveanum* Imlay, and *A. henryi* (Meek and Hayden). This is suggested by the distribution of these forms. *A. rierdonense* and *A.* n. sp. ind. have been found only in the western parts of Montana and Wyoming, *A. loveanum* and *A. crassicostatum* Imlay have been found only in eastern Wyoming, and *A. henryi* has been found in the United States only in the Black Hills area of easternmost Wyoming and westernmost South Dakota. *A. codyense* occurs throughout the entire area but is most common in central Wyoming and central Montana. This distribution might be explained by ecological differences, which are not obvious, or by assuming that the Callovian sea transgressed from west to east across the area in question and that the transgression involved sufficient time for several species of *Arcticoceras* to develop or to enter the sea from the polar region. The latter explanation is supported by the fact that the Callovian deposits of the western interior are the thickest and most calcareous in western Montana and southeastern Idaho and become thinner and more clastic eastward. Also, *A. henryi* in the Black Hills is distinctly at the top of the *Arcticoceras* beds. Failure to find *A. henryi* with *A. codyense* may have stratigraphic significance.

Arcticoceras occurs with abundant *Cadoceras* and rare *Procerites* in the western part of Wyoming and Montana. All the species of *Cadoceras* range into the overlying beds characterized by *Gowericeras.* Locally *Arcticoceras* is associated with many pelecypods, but mostly with species that range beyond the *Arcticoceras* beds. *Gryphaea impressimarginata* McLearn attains its greatest development in the *Arcticoceras* beds in western Montana and does not range higher. A fairly large species of naticoid gastropod is a common associate in central Wyoming.

Arcticoceras appears to be widespread in the western interior of Canada as shown by collections at the University of Alberta that were examined by me at the request of P. S. Warren. One collection contains single specimens of *A. henryi* (Meek and Hayden) and *Gowericeras* from a locality near the top of the Fernie shale on the Cascade River near Banff, Alberta. Another collection contains *Arcticoceras* and *Arctocephalites* from a locality between Bell River and Old Crow River near Porcupine River, Yukon Territory. In addition the U. S. Geological Survey has collections from about the same place near Porcupine River that contain *Arcticoceras kochi* Spath and *Cadoceras calyx* Spath.

In the Boreal region *Arcticoceras* has been found in the Petchora Basin of northern Russia (Keyserling, 1846, p. 331; Sokolov, 1912, p. 15, 49), in East Greenland (Spath, 1932, pp. 50-58, 138, 142, 145), and in northern Alaska on the Canning and Sadlerochit Rivers.

The age of the *Arcticoceras* beds of Greenland and Russia was determined by Spath (1932, pp. 131, 141, 142, 145) as lower Callovian. In Greenland *Arcticoceras* is associated with *Cadoceras* and probably with *Pleurocephalites.* In the Petchora Basin *Arcticoceras* is associated with *Pleurocephalites krylowi* (Milachewitch) (1879, p. 14; Sokolov, 1912, pp. 14, 19), which in central Russia near Sergatsch is associated with *Cadoceras elatmae* Nikitin (Milachewitch, 1879, p. 8). At several places in central Russia *C. elatmae* occurs with species of *Gowericeras, Chamoussetia,* and *Macrocephalites* (Nikitin, 1885b, p. 84), which are distinctly early Callovian in age. Arkell (1946, p. 25) shows that the zone of *Cadoceras elatmae* in Russia is equivalent to the zones of *Macrocephalites macrocephalus* and *Proplanulites koenigi* in northwest Europe.

The age of the *Arcticoceras* beds in the western interior of the United States is determined as basal Callovian because of their position at the base of a sequence that has furnished a succession of ammonites closely similar to that in the *Proplanulites koenigi* and *Sigaloceras calloviense* zones of northwest Europe. The abundance of *Gowericeras* immediately above the *Arcticoceras* beds is by itself strong evidence for correlating the latter with the zone of *Macrocephalites macrocephalus.* The presence of abundant *Cadoceras* in the *Arcticoceras* beds shows that they are not older than the *macrocephalus* zone.

Table 1.—Stratigraphic distribution of Callovian ammonite species in the western interior of the United States.

	Rierdon formation of Montana					Lower part of Sundance formation, Wyoming and South Dakota			
Genus and species	*Arcticoceras codyense* beds	*Gowericeras costidensum* beds	*Gowericeras subitum* beds	*Kepplerites tychonis* beds	*Kepplerites mclearni* beds	Canyon Springs sandstone member	Stockade Beaver shale member	Hulett sandstone member	Lak member
Lilloettia sp. ind.					—				
Xenocephalites phillipsi Imlay, n. sp.					—				
X. bearpawensis Imlay, n. sp.					—				
X. cf. *X. nikitini* (Burckhardt)					—				
Arcticoceras rierdonense Imlay, n. sp.	— ?								
A. n. sp. ind.	— ?								
A. crassicostatum Imlay, n. sp.						? —			
A. loveanum Imlay, n. sp.						? —			
A. codyense Imlay	—								
A. henryi (Meek and Hayden)							—		
Cadoceras shoshonense Imlay		—	—				—		
C. muelleri Imlay, n. sp.		—	—				—		
C. tetonense Imlay, n. sp.	—	—	—				—		
C. piperense Imlay, n. sp.	? —	—	—			? —			
Kepplerites (Seymourites) mclearni Imlay					—				
K. (Seymourites) rockymontanus Imlay, n. sp.					—				
K. (Seymourites) cf. *K. rosenkrantzi* Spath					—				
K. (Seymourites) tychonis Ravn				—					
K. (Seymourites) landuskiensis Imlay, n. sp.					—				
K. (Seymourites) planiventralis Imlay, n. sp.					—				
Gowericeras subitum Imlay			—						
G. subitum var. *distinctum* Imlay, n. var.			—						
G. costihians Imlay n. sp.			—						
G. costimedium Imlay n. sp.		—	—						
G. costicrassum Imlay, n. sp.		—	—						
G. costidensum Imlay, n. sp.		—							
Cosmoceras (Gulielmiceras) knechteli Imlay, n. sp					—				
C. (Gulielmiceras) zortmanense Imlay, n. sp.					—				
C. (Gulielmiceras) vigorosum Imlay, n. sp.					—				
C. (Gulielmites) cf. *C. obductum* (Buckman)					—				
C. (Gulielmites) cf. *C. jason* (Reinecke)					—				
Procerites spp.	—	—	—						
Grossouvria warmdomensis Imlay, n. sp.		—							
Grossouvria spp.			—	—					

GOWERICERAS COSTIDENSUM ZONE

In central and northwestern Montana from 10 to 15 feet of the Rierdon formation directly overlying the basal *Arcticoceras* beds is characterized by a densely ribbed species of *Gowericeras* that is herein described as *G. costidensum* Imlay. This species has not been found with *G. subitum* but immediately underlies it at several localities. Associated with *G. costidensum* are numerous *Cadoceras,* rare specimens of *Procerites* and *Grossouvria,* and an abundance of *Gryphaea nebrascensis* Meek and Hayden, which species is exceedingly rare in the underlying beds. Other pelecypods are abundant locally. None of the species of *Cadoceras* is restricted to the *G. costidensum* zone.

Gowericeras costidensum has not been found with any species of *Arcticoceras,* although conceivably it may have lived at the same time as *Arcticoceras henryi* (Meek and Hayden), which has not been found in Montana. This possibility is suggested by their occurrence directly above beds containing *Arcticoceras codyense.* If *G. costidensum* and *A. henryi* coexisted, their apparent nonassociation would have to be explained by collecting failure or by ecological differences, which are not obvious. It seems more probable that *A. henryi* is slightly older than *G. costidensum,* especially considering that *A. henryi* in the Black Hills area is associated with *A. loveanum* Imlay, which is a common associate of *A. codyense.* The matter can be settled only by more field work.

The presence of *Gowericeras* is by itself excellent evidence for correlation with the *Proplanulites koenigi* zone of northwest Europe, although the genus occurs rarely in the *Sigaloceras calloviense* zone. Also, *Procerites,* typical of the Bathonian stage, is not recorded above the lower Callovian. The position of *G. costidensum* immediately below beds containing abundant *Gowericeras* suggests correlation with only the lower part of the *Proplanulites koenigi* zone.

GOWERICERAS SUBITUM ZONE

This zone is characterized by many species and individuals of *Gowericeras* and *Cadoceras.* Many of the latter exceed a foot in diameter. Much less common are *Procerites* and *Grossouvria.* The reported occurrence of *Arcticoceras* in this zone (Imlay, 1948, p. 15) was based on a misidentification of a specimen of *Quenstedtoceras,* which later collecting showed was derived from the basal beds of the Swift formation along with specimens of *Cardioceras.* Associated with the *Gowericeras* and *Cadoceras* in the *G. subitum* zone are abundant pelecypods, many large naticoid gastropods, and locally many brachiopods. *Gryphaea nebrascensis* Meek and Hayden occurs in great abundance in calcareous shales and shaly limestones. Several nautiloid cephalopods have been found in this zone.

The beds characterized by *Gowericeras subitum* are correlated with the *Proplanulites koenigi* zone of northwest Europe on the basis of the abundance of *Gowericeras,* the resemblance of several species of *Gowericeras* to those in the Kellaways beds of Great Britain, the highest occurrence of *Procerites,* and the stratigraphic position of the *G. subitum* beds, about 90 ft. below beds containing *Kepplerites, Gulielmiceras,* and *Gulielmites.*

KEPPLERITES TYCHONIS ZONE

The presence of finely ribbed *Kepplerites tychonis* Ravn in the middle part of the Rierdon formation of Montana and near the base of the Chinitna siltstone in the Cook Inlet region of Alaska furnishes a correlation with the *Kepplerites tychonis* beds of East Greenland. These were tentatively correlated by Spath (1932, pp. 138, 139, 145, 146) with the *Sigaloceras calloviense* zone of northwest Europe, but he discussed the possibility that the beds may be younger. He was influenced by the presence of *Gulielmiceras,* which ranges from the *Sigaloceras calloviense* to the *Erymnoceras coronatum* zone. In Alaska the basal beds of the Chinitna contain such ammonites as *Gowericeras, Paracadoceras, Gulielmiceras,* and *Procerites,* which indicate correlation with the *Proplanulites koenigi* and *Sigaloceras calloviense* zones. In Montana the beds containing *Kepplerites tychonis* are correlated with the lower part of the *calloviense* zone because of their position above beds containing *Gowericeras* and beneath beds containing *Gulielmiceras* and *Gulielmites.*

KEPPLERITES MCLEARNI ZONE

This zone has been identified in Montana at the top of the Rierdon formation in the Little Rocky Mountains, the Bearpaw Mountains, the East Butte of the Sweetgrass Hills, and the south edge of Glacier National Park. It is absent in the Little Belt Mountains, the Big Snowy Mountains, the Judith Mountains, most of the Sawtooth Range south of Glacier Park, and much of southwestern Montana, owing to erosion or nondeposition in late Callovian time. Probable equivalent beds exist in a littoral sandstone facies, called the Hulett sandstone member of the Sundance formation, throughout much of eastern Wyoming, western South Dakota, North Dakota, and eastern Montana. A similar sandstone exists at the top of the Twin Creek limestone of southeastern Idaho and westernmost Wyoming.

The zone is characterized by an abundance of species and individuals of *Kepplerites* and *Cosmoceras* (*Gulielmiceras*). In addition there are a few specimens of *Cosmoceras* (*Gulielmites*), *Lilloettia, Xenocephalites,* and *Grossouvria.* Nautiloid cephalopods are rare. The zone also contains many pelecypods, including *Gryphaea nebrascensis* Meek and Hayden, and locally some brachipods. Among the peculiarities of this zone is the apparent absence of the Cadoceratinae and the resemblance of some of the species of *Kepplerites* to species of the ammonite *Sigaloceras.*

Formerly, Imlay (1948, p. 16) referred the ammonites herein called *Lilloettia* to *Macrocephalites* and those now called *Xenocephalites* to *Kamptokephalites.* The changes are based on studies of the Callovian ammonites of Alaska. The ammonites called *Sigaloceras* in the 1948 paper are now considered species of *Kepplerites* that have unusually persistent ventral flattening and flexuous ribbing.

The *Kepplerites mclearni* zone in the western interior of the United States corresponds either to the upper part of the *Sigaloceras calloviense* zone or to the *Cosmoceras* (*Gulielmites*) *jason* zone of northwest Europe. Both *Gulielmiceras* and *Gulielmites* range from the upper part of the *Sigaloceras calloviense* zone to the *Erymnoceras coronatum* zones, but are most common above the *S. calloviense* zone. *Kepplerites* ranges from the *Macrocephalites macrocephalus* zone to the *Sigaloceras calloviense* zone in England and apparently into the *Erymnoceras coronatum* zone in northern Russia. In Alaska it occurs in beds which correspond to the *Proplanulites koenigi, Sigaloceras calloviense,* and *Cosmoceras jason* zones. *Lilloettia* in Alaska occurs in beds that are correlated with the *S. calloviense* and *C. jason* zones. *Xenocephalites* is characteristic of the Bathonian and lower Callovian of the Pacific Province. In Alaska the highest *Xenocephalites* is at the top of the local range of *Gowericeras* and *Paracadoceras,* which genera in Europe range as high as the *S. calloviense* zone but are more common in the underlying Callovian.

All things considered, correlation with the upper part of the *S. calloviense* zone rather than with the *C. jason* zone is favored by the first appearance of *Gulielmiceras* and *Gulielmites,* the abundance of *Kepplerites,* the occurrence of *Xenocephalites,* and the stratigraphic position above beds containing *Kepplerites tychonis* (which species in Alaska is associated with *Gulielmiceras* and is below the top of the local range of *Gowericeras* and *Paradoceras*). Also, the species of *Kepplerites* in the *K. mclearni* zone characteristically have flattened venters. This feature in Alaska is common only in the beds containing *Gowericeras* and *Paracadoceras,* which are considered to be older than the *C. jason* zone of Europe.

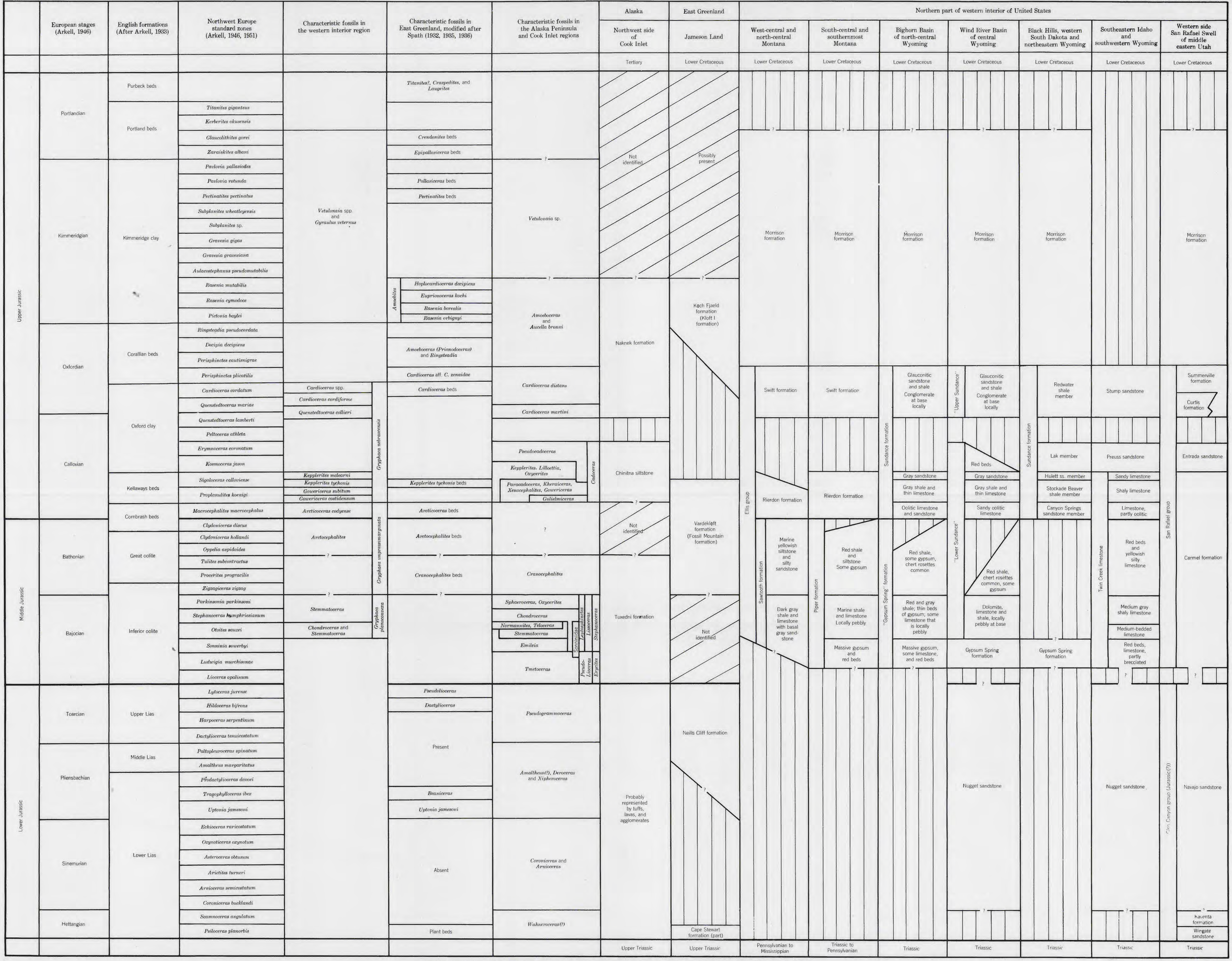
COMPARISONS WITH OTHER FAUNAS

Rather detailed comparisons of the Callovian ammonite assemblages of North America, the Barents Sea area, northwest Europe, and central Russia will be made by the writer in Professional Paper 249-B, which deals with the Callovian ammonites of the Alaska Peninsula and Cook Inlet regions of Alaska. Most of these comparisons need not be repeated. However, it is interesting that the Callovian ammonites of the western interior are more similar to those of East Greenland than to those of southwestern Alaska. This applies particularly to the genera *Cadoceras* and *Kepplerites.* None of the subgenera of *Cadoceras* found in Alaska occur in the western interior and all the species of *Cadoceras* in the western interior belong to a subgenus that is unknown in Alaska but present in Greenland. Such ammonites as *Gowericeras* and *Gulielmiceras* are much more common in the western interior than in Alaska. Such genera as *Paracadoceras, Pseudocadoceras, Phylloceras,* and *Kheraiceras* are very common in Alaska and unknown in the western interior. Also, nautiloid cephalopods occur in the Callovian of the western interior and not in Alaska. These differences cannot be ascribed to land barriers because such typical Pacific elements as *Lilloettia* and *Xenocephalities* have been found in central Montana. Part of the differences may be explained by the fact that the lowest Callovian in southwestern Alaska is not rich in ammonites, but most of the differences appear to be ecological. Thus the lithologic and faunal characteristics of the marine Callovian deposits of the western interior and of East Greenland indicate that the seas were very shallow and bordered lowlands, whereas the characteristics of the Callovian deposits of southwestern Alaska indicate that fairly deep waters bordered mountainous shores.

ECOLOGIC CONSIDERATIONS

SOURCES OF SEDIMENT

During the early Callovian the marine sediments deposited in the western interior of the United States were derived from both east and west. East of a line drawn from the Sweetgrass Arch in north-central Montana to the San Rafael Swell in east-central Utah



CORRELATION OF JURASSIC FORMATIONS IN PARTS OF THE WESTERN INTERIOR OF THE UNITED STATES the dominant source of sand was to the east or southeast. West of this line the dominant source of sand was to the west. Apparently most of the clay came from the east, as nearly all shaly units become more calcareous westward. However, in the Sawtooth Range in western Montana the lower Callovian sediments become shalier northward toward the Glacier Park area and equivalent beds in the front ranges of Alberta are essentially all shale. Locally some islands in central Montana and north-central Wyoming furnished sand and pebbles at the beginning of the Callovian transgression.

CONDITIONS OF DEPOSITION

CONGLOMERATE

Small pebbles of limestone occur at the base of the Rierdon formation on the East Butte of the Sweetgrass Hills in north-central Montana. It is probable that the pebbles were derived from outcrops of Mississippian limestone exposed on the Sweetgrass Arch at the beginning of the Callovian.

Pebbles of dark-gray chert, quartz, and quartzite characterize the base of the Sundance formation in areas adjoining the Big Horn Mountains and the Black Hills. Most of the pebbles are less than an inch in diameter, and consist of irregularly pitted, highly polished, dark-gray chert identical with chert pebbles in the Middle Jurassic beds of north-central Wyoming. Some pieces of the quartz and quartzite exceed three inches in diameter. In both areas the pebbles occur as thin layers in soft, gray, calcareous shale, or sandstone, or are disseminated through several feet of gray shale. On the west side of the Big Horn Mountains near Tensleep, a basal conglomerate contains some pebbles and cobbles of dolomitic limestone and of rounded siliceous rosettes identical with material in the underlying Middle Jurassic beds. Judging from the distribution of these pebbly beds, the sources of the pebbles were landmasses in the Big Horn area and the Black Hills area. The identity of the pitted and polished chert pebbles with some in the Middle Jurassic of north-central Wyoming suggests that they came from the same source and were residual pebbles, swept basinward by an advancing sea. The presence of siliceous rosettes in the pebbly beds indicates that the Middle Jurassic beds, adjoining the Big Horn Mountain area, underwent erosion before the Callovian transgression.

A third occurrence of pebbles in the Callovian is in the basal coarse-grained sandstone of the Sundance formation in the Bison Basin area in northwestern Sweetwater County, south-central Wyoming (Love and others 1945). The pebbles evidently were derived from the south or southeast, as the area is near the southeastern margin of marine Callovian deposits.

SAND

Lower Callovian sandy material occurs mainly in the eastern part of the western interior seaway north of Colorado. A thin mantle of sand, called the Canyon Springs sandstone member of the Sundance formation, lies at the base of the Callovian in southern and eastern Wyoming and parts of adjoining states (Imlay, 1947, pp. 232, 233, 247-251; Love, 1948, p. 103), fills in the irregularities of an erosion surface, and locally attains 60 ft. in thickness. It consists mostly of medium to coarse grains, of which many are well-rounded and frosted, but contains some oölites and beds of oölitic limestone and passes northward in southern Montana and westward in central Wyoming into oölitic limestone and shale. It greatly resembles the Nugget sandstone, from which it was probably derived either early in the Callovian transgression or immediately preceding it. In the latter case, this basal sand may have been deposited first by winds or streams and later reworked by the sea. The latter possibility is suggested by the abrupt contact with the overlying Stockade Beaver shale member in most places.

Equivalent oölitic limestones at the base of the Callovian in southeastern Idaho contain some sand and become sandier westward. The degree of sandiness is comparable to that of the Canyon Springs sandstone member of the Sundance formation at the south end of the Big Horn Mountains, where the source area of the sand was at least 150 miles to the southeast.

Another mantle of sand, called the Hulett sandstone member of the Sundance formation, occurs at the top of the lower Callovian sequence and is a little thicker and more widespread in Wyoming and eastern Montana than the basal sand. It ranges in thickness from a few feet to 12 ft. and thickens to the southeast. It is grayish, thin- to thick-bedded, fine-grained, calcareous, glauconitic, ripple-marked, and fairly hard (Imlay, 1947, pp. 255-257). It passes westward in northwestern Wyoming into calcareous shale and northward in central Montana into oölitic to chalky limestone. It differs from the basal sand by its smaller grain size, presence of glauconite, and numerous oscillation ripple marks. It must have been derived from rocks older than the Nugget sandstone, because that formation was nearly covered by the end of the lower Callovian. It must have been deposited in fairly shallow water, as indicated by ripple marks. The absence of current ripple marks and scarcity of cross bedding suggests deposition some distance from shore. Bottom conditions were evidently unfavorable for life or for its preservation, as fossils are rare in the sandstone and consist generally of free-swimming or free-floating forms, such as *Pentacrinus* and *Camptonectes.* The latter are generally fragmentary. Deposition of the Hulett sandstone member in the littoral zone is indicated by the abundance of ripple marks, the scarcity and fragmentary conditions of the fossils within it, and superposition directly on the Stockade Beaver shale member, whose shallow-water origin is attested by an abundance of Lingulas. Judging by the extent of the Hulett sandstone member, sand flats were widely exposed during low tide along the eastern margin of the lower Callovian sea.

A similar glauconitic sand was deposited in southeastern Idaho near the end of the early Callovian. It was derived from the west, as it passes eastward into sandy to silty, ripple-marked limestone at the top of the Twin Creek limestone. Evidently the sea became very shallow at the end of the early Callovian just prior to the deposition of the red Preuss sand.

MARINE SILTSTONE AND SHALE

Lower Callovian calcareous gray shale and siltstone, known as the Stockade Beaver shale member of the Sundance formation in Wyoming and the Dakotas, grade northwestward from a featheredge in southwestern Wyoming and western South Dakota into a shale and limestone sequence (Rierdon formation), locally more than 200 ft. thick in northwestern Wyoming and western Montana. To the southeast, the shale and siltstone of the Stockade Beaver shale member are underlain and overlain by sandstones of early Callovian age. Silt decreases northwestward as the adjoining sandstones thin, and does not occur much farther west than the western margin of the overlying Hulett sandstone member of the Sundance formation, except locally near Belt Island in west-central Montana. In westernmost Wyoming the shale and limestone sequence passes into as much as 1500 ft. of shaly limestone in the upper part of the Twin Creek limestone. The Stockade Beaver shale member contains many ostracodes and some Foraminifera, and Lingulas. Pelecypods, and ammonites have been found associated with calcareous concretions near its base. The Rierdon formation likewise has many ostracodes, but also many Foraminifera, mollusks, and brachiopods. It is especially characterized by an abundance of *Gryphaea,* which is uncommon in the more silty facies, such as the type Stockade Beaver member, or in the equivalent limestone facies in the upper part of the Twin Creek limestone. Very shallow water deposition is indicated for the Rierdon formation by the abundance of *Gryphaea* and by numerous pelecypods, and for the Stockade Beaver shale member by the presence of linguloid brachiopods (Twenhofel and others, 1932, p. 175; Allan, 1936, pp. 383-385).

LIMESTONE

Most of the limestone of Callovian age was formed in the western part of the Jurassic seaway and the main area of deposition was in southeastern Idaho and north-central Utah. This limestone, representing the upper two-thirds of the Twin Creek limestone, is mostly shaly to thin-bedded, dense to porcelaneous, and poorly fossiliferous. The most abundant fossils are free-swimming or free-floating forms such as belemnites, crinoids, and *Camptonectes.* Bottom-dwelling pelecypods, such as *Astarte, Trigonia,* and *Pinna* occur in a few beds. *Gryphaea* occurs only in the basal beds and along the eastern margin of the facies, where it is becoming shalier. Such features as fine texture and scarcity of organic matter and fossils suggest a chemical origin for the limestone.

Most of the lower Callovian limestone in Montana and northwestern Wyoming consists of thin beds in a dominantly shale facies, except for an area in central Montana centering around the Little Rocky Mountains and lying immediately east of Belt Island. These limestones generally contain many mollusks, including *Gryphaea* and *Ostrea,* that prove deposition in fairly shallow water.

OTHER TYPES OF SEDIMENT

Bedded gypsum of probable early Callovian age occurs in the upper part of the Carmel formation in Utah associated with gray, greenish, and reddish shale and with limestone. The gypsiferous beds pass eastward and southward into thinner red shale and sandstone and westward into thicker limestone and gray shale. The thin red beds cover large areas in eastern Utah and adjoining parts of Colorado, New Mexico, and Arizona. They are considered to be marginal deposits formed at the southern end of a seaway. Their early Callovian age is based entirely on stratigraphic position and on lateral tracing of units northwestward into the Twin Creek limestone.

Siliceous material in lower Callovian beds has been observed by the writer only near the top of the Hulett sandstone member of the Sundance formation along the southern base of the Pryor Mountains in southern Montana. The material consists of light gray rosettes or irregular rounded masses, some as much as a foot in diameter. One of the most accessible localities to observe these is along Gypsum Creek in the SE ¼ of Sec. 33, T. 9 S., R. 27 E., Carbon County. Similar siliceous rosettes are widespread in Wyoming in the upper part of the Middle Jurassic. In both cases the siliceous masses lie in the upper parts of lithologic units whose upper surfaces are cut by minor disconformities. This relationship suggests that the presence of these siliceous masses may be related to times of erosion.

Minor amounts of glauconite have been found in the Hulett sandstone member of the Sundance formation in eastern Wyoming and western South Dakota and at the top of the Rierdon formation in northwestern Montana. Some of the ripple-marked sandy beds at the top of the Twin Creek limestone in southeastern Idaho contain an abundance of glauconite. The presence of glauconite appears to be related to shallowing of the sea during its withdrawal north of Montana just before deposition of red beds.

Oölites were formed widely in the western interior at the begining and end of the Callovian marine transgression. They are interpreted as indicating very shallow water and saturation of the water with calcium carbonate.

AMMONITE DISTRIBUTION AND ASSOCIATIONS

The writer has discussed the faunal assemblages in the Callovian sea of the western interior region and presented evidence that the limestones and shales were deposited in the upper part of the neritic zone and that the sandstone members were probably deposited partly in the littoral zone (Imlay, 1950, pp. 94-99). The littoral character is suggested by the abundance of ripple marks, a scarcity of benthonic mollusks, the fragmentary character of specimens of *Camptonectes*, and the presence of oysters and *Mytilus* locally. General deepening of the sea westward across Wyoming and Montana, except where islands occurred, is indicated by an increase in the number of Gryphaeas and foraminifers and a decrease in the number of ostracodes and Lingulas.

The ammonites are most abundant in thin limestones that are interbedded with calcareous shale and contain many benthonic pelecypods. Many of these thin limestones are slightly silty or sandy. Some of the associated beds may be oölitic. Ammonites are extremely rare in thick-bedded or ripple-marked sandstones, especially in beds that contain *Ostrea* or *Mytilus*. The absence of ammonites in the dense, shaly limestone forming the upper two-thirds of the Twin Creek limestone is possibly related to the scarcity of pelecypods on which they fed and may perhaps be explained by unfavorable bottom conditions induced by rapid subsidence and equally rapid sedimentation and perhaps, also, by abnormally high salinity of the sea water. Evidently the ammonites favored those parts of the sea beyond the littoral zone in which there was an abundance of bottom-dwelling mollusks, fairly hard bottoms, and slow deposition of sediments. These parts were most widespread in the areas now included in northwestern Wyoming and central and northwestern Montana.

Certain features in the distribution and associations of the ammonite genera in the western interior sea during early Callovian time indicate that their presence was controlled or influenced greatly by depth of water and perhaps by temperature. For example, *Arcticoceras* is the most widespread of all the genera, specimens being found in eastern Wyoming in oölitic sandstones, in central Wyoming in oölitic limestones, and in western Montana in thin-bedded limestones interbedded with shales. It is associated with ammonites such as *Cadoceras, Procerites,* and *Grossouvria* only in sequences that contain some shales and were presumably formed in deeper water than the sequences that are dominantly oölitic. As another example, specimens of the genus *Gowericeras* have been found in central and western Montana in thin-bedded limestones that may be slightly silty, sandy, or oölitic. It is associated with many specimens of *Cadoceras* and some of *Procerites, Grossouvria,* and nautiloid cephalopods. It has not been found with *Kepplerites* except possibly at one locality on Rierdon Gulch in western Montana where two fragments of a single specimen of *Kepplerites* (U. S. G. S. Mes. loc. 22650) were obtained as float about 40 ft. apart on a steep slope near the top of the *Arcticoceras* beds. It seems likely that this specimen was derived from the *Gowericeras subitum* zone which forms the top of the Rierdon formation at Rierdon Gulch. The scarcity of *Kepplerites* in the *Gowericeras* beds is striking because in the overlying beds of the *Kepplerites tychonis* zone the genera *Cadoceras* and *Kepplerites* are commonly associated. Also, in Alaska and in the Boreal region *Gowericeras, Kepplerites,* and *Cadoceras* are associated.

The most peculiar cephalopod association is that represented by the *Kepplerites mclearni* zone, which includes *Kepplerites, Cosmoceras* (*Gulielmiceras*), *C.* (*Gulielmites*), *Grossouvria, Xenocephalites, Lilloettia,* and a few nautiloids, but not a single *Cadoceras*. In contrast, equivalent beds in Alaska and the Boreal region contain numerous *Cadoceras*. Peculiar also is the absence from the western interior of such ammonites as *Paracadoceras, Pseudocadoceras, Phylloceras,* and *Kheraiceras* (which are so abundant in Alaska), and the occurrence of only one of the several subgenera of *Cadoceras* present in the Boreal region. That the seas were connected is shown by the presence of such typical Pacific elements as *Xenocephalites* and *Lilloettia* as far south as Montana. It is also shown by the occurrence of *Kepplerites tychonis* in Alaska, Montana, and the Boreal region.

Judging from these occurrences, it seems probable that *Arcticoceras* could live in shallow waters of various depths nearly to the strand line, that *Gowericeras, Cadoceras, Procerites,* and *Grossouvria* could not live in as shallow waters as *Arcticoceras,* and that *Kepplerites* preferred still deeper waters than *Gowericeras.* The absence of *Cadoceras* in the *Kep-*

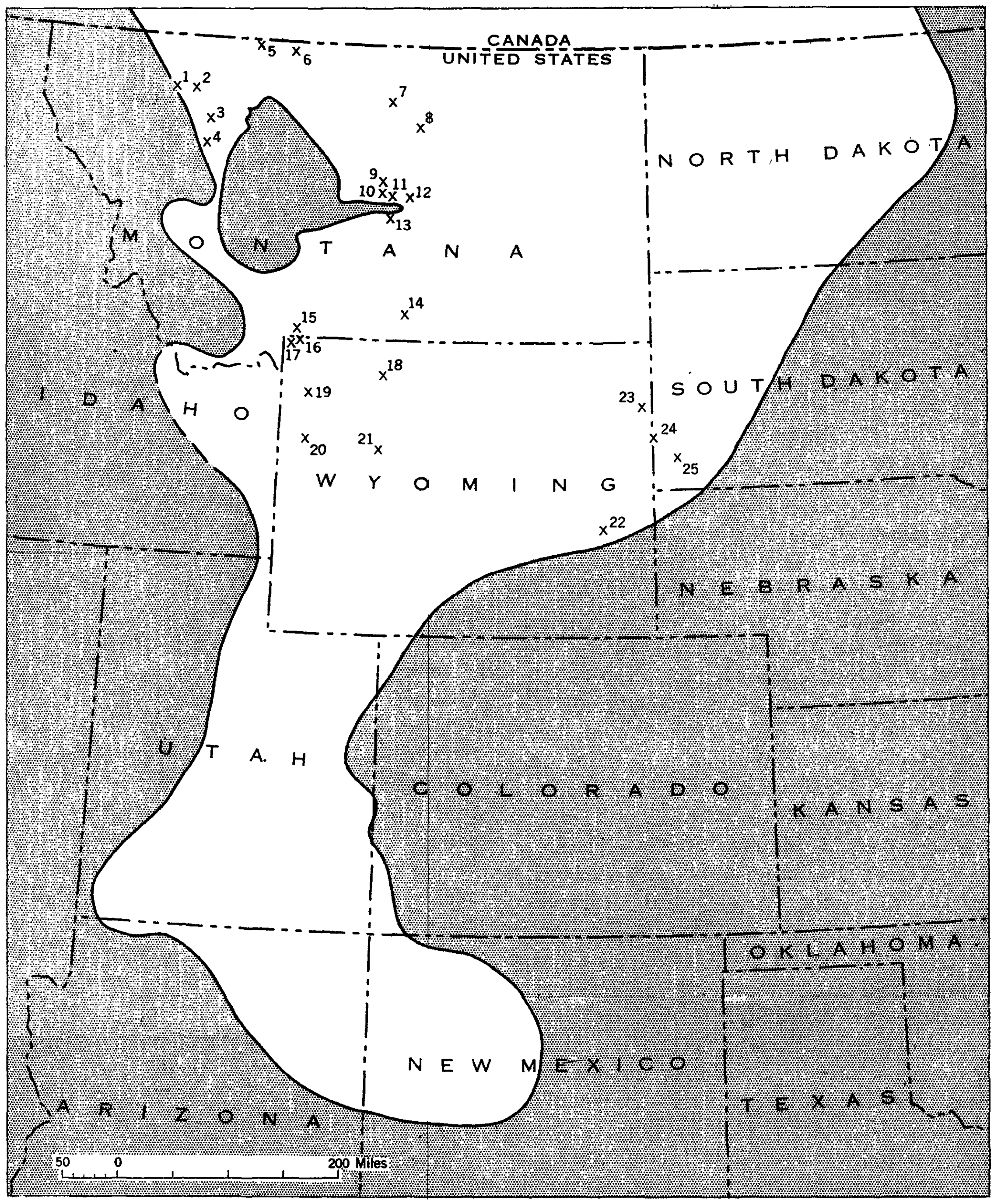


FIGURE 1.—Index map showing Callovian localities in the western interior United States.

Table 3.—Geographic distribution of the Callovian Ammonites of the western interior of the United States

	Montana																																																															Wyoming												South Dakota		
	Rierdon formation																																																																	Sundance formation												
	1		2	3																4	5	6			7		8																						9	10						11			12	13	14			15	16	17	18			19	20	21	22			23	24		25
	7124	19194	20390	18718	19397	19590	19591	19593	19594	19596	19597	19599	19600	19602	19603	19605	19607	20365	22651	18610	20391	11973	19196	21467	18758	19202	10729	10730	10732	18726	18735	18737	18738	18742	18750	18753	18754	19203	19211	19212	19572	19576	19583	19584	19585	19587	19588	19589	19176	19169	19179	19180	19181	19213	19616	19170	19175	19182	11312	19628	19629	20360	20363	19618	1163	1130	17106	17179	19632	21522	20974	21635	20496	20497	20503	20337	19560	19561	19556
Lilloettia sp. ind.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Xenocephalites phillipsi Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X. bearpawensis Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X. cf. *X. nikitini* (Burckhardt)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arcticoceras rierdonense Imlay, n. sp.	—	—	—	—	X	—	—	X	—	—	—	—	—	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
A. n. sp. ind.	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—
A. crassicostatum Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—
A. loveanum Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	X	—	X	X
A. codyense Imlay	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	X	X	X	X	—	—	—
A. henryi (Meek and Hayden)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X
Cadoceras shoshonense Imlay	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	X	X	X	X	—	—	X	—	X	X	X	—	—	—	—	—	—	—	X	X	X	—	—	—	—	—	—	—	—	—
C. muelleri Imlay, n. sp.	—	—	—	—	—	—	X	—	—	X	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	X	X	X	X	—	—	X	X	X	—	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
C. tetonense Imlay, n. sp.	..	..	..	X	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
C. piperense Imlay, n. sp.	—	—	—	X	—	X	—	—	—	X	—	X	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	X	X	X	—	X	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	X	—	—	—	—	—	—	—
Kepplerites (Seymourites) mclearni Imlay	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	—	X	X	—	X	—	—	X	X	—	X	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. (Seymourites) rockymontanus Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. (Seymourites] cf *K. rosenkrantzi* Spath	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. (Seymourites) tychonis Ravn	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. (Seymourites) landuskiensis Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. (Seymourites) planiventralis Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gowericeras subitum Imlay	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	X	—	X	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
G. subitum var. *distinctum* Imlay, n. Var.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
G. costihians Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
G. costimedium Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
G. costicrassum Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
G. costidensum Imlay, n. sp.	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cosmoceras (Gulielmiceras) knechteli Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	X	X	—	X	—	—	—	—	—	X	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. (Gulielmiceras) zortmanense Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	X	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. (Gulielmiceras) vigorosum Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. (Gulielmites) cf. *C. obductum* (Buckman)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. (Gulielmites) cf. *C. jason* (Reinecke)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Procerites spp.	—	—	—	X	—	—	—	—	—	—	X	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Grossouria warmdomensis Imlay, n. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Grossouvria spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

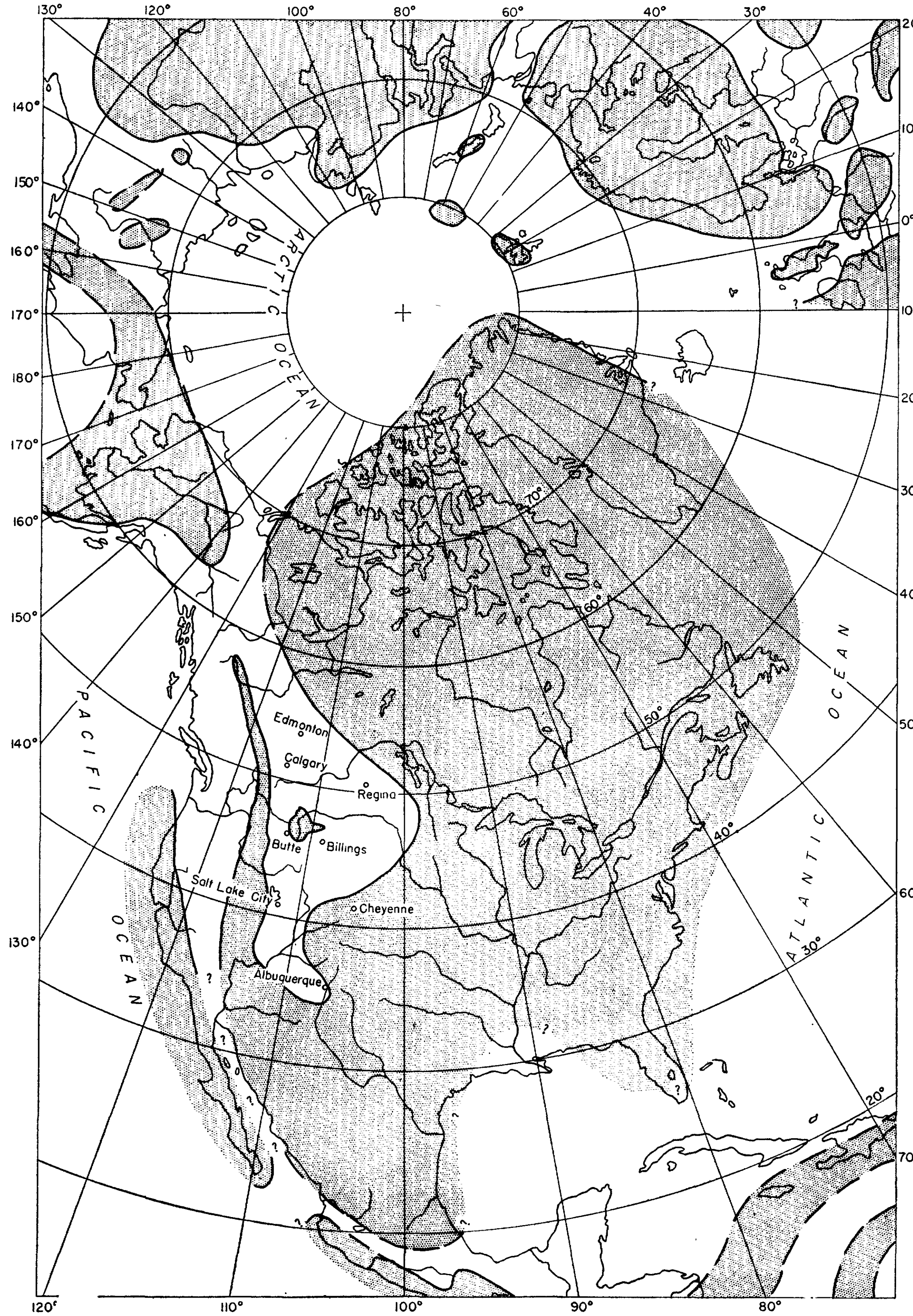


FIGURE 2.—Lower Callovian paleogeography of the Boreal region.

plerites mclearni zone may be due to a shallowing and possible warming of the early Callovian sea during its withdrawal northward or to the extinction of the single subgenus that managed to migrate into the western interior from the Boreal region. The absence of many ammonite genera in the Callovian beds of the western interior that are present in the Callovian of southwestern Alaska is likely to be related to greater shallowness and warmth of the western interior sea. Some of these puzzling faunal relationships will probably be solved when the Callovian faunas of the western interior of Canada have been more fully studied.

GEOGRAPHIC DISTRIBUTION

The occurrence by area and locality of the 38 species described herein is shown in the table facing p. 12. The general position of each locality is shown on figure 1. Detailed descriptions of the individual localities are given in the following list to avoid repetition in the text:

Localities at which ammonites were collected from Callovian beds in the western interior of the United States

No. on fig. 1	Geological Survey Mesozoic locality	Collector, year of collection, description of locality, and stratigraphic assignment
1	7124	M. R. Campbell and T. W. Stanton, 1911. On Great Northern Ry, from ½ to ¾ mile west of Skyland, in the NW¼ of sec. 8, T. 29 N., R. 14 W., Flathead County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
1	19194	R. W. Imlay and Hal C. Yingling, Jr., 1944. One mile east of Autumn Creek on north side of U. S. Highway 2, in the NW¼ of sec. 9, T. 29 N., R. 14 W., Flathead County, Mont. Rierdon formation, *Kepplerites tychonis* zone.
2	20390	W. A. Cobban and R. W. Imlay, 1946. North slope of Sawmill Creek, ½ mile above mouth, in sec. 3, T. 29 N., R. 11 W., Pondera County, Mont. About 19 ft. below top of Rierdon formation, *Kepplerites tychonis* zone.
3	18718	Josiah Bridge and C. F. Deiss, 1941. Lonesome ridge, west side of sec. 34, T. 25 N., R. 9 W., Teton County, Mont. Rierdon formation.
3	19397	W. A. Cobban, 1944. Head of Rierdon Gulch, sec. 23, T. 24 N., R. 9 W., Teton County, Mont. Twenty feet above base of Rierdon formation, *Arcticoceras codyense* zone.
3	19590	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Sawtooth Range, Teton County, Mont. About 36 ft. below top of Rierdon formation, *Gowericeras* beds.
3	19591	William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. Float from Rierdon formation.
3	19593	William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. About 55 ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
3	19594	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. Ten ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
3	19596	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. About 16 ft. below top of Rierdon formation. *Gowericeras* beds.
3	19597	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. W., Teton County, Mont. About 40 ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
3	19599	R. W. Imlay, 1945. Line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. From upper third of Rierdon formation.
3	19600	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. From lower 40 ft. of Rierdon formation, *Arcticoceras codyense* zone.
3	19602	R. W. Imlay and William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. About 8 ft. below top of Rierdon formation, *Gowericeras subitum* zone.
3	19603	A. G. Alpha, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. About 20 ft. below top of Rierdon formation, *Gowericeras* beds.
3	19605	William Saalfrank, 1945. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. About 30 ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
3	19607	R. W. Imlay and William Saalfrank, 1945. Sec. 21, T. 25 N., R. 9 W., Teton County, Mont. From 25 to 30 ft. below top of Rierdon formation, *Gowericeras* beds.
3	20365	William Cobban and R. W. Imlay, 1946. Near line of secs. 33 and 34, T. 25 N., R. 9 W., Teton County, Mont. Upper 15 ft. of Rierdon formation, *Gowericeras subitum* zone.
3	22651	R. W. Imlay, 1951. South central part of sec. 23, T. 24 N., R. 9 W., Teton County, Mont. Rierdon formation, about 38 ft. below top.
4	18610	C. F. Deiss and R. M. Garrells, 1940. Ridge east of head of East Fork of Lange Creek, in the SE¼, sec. 35, T. 21 N., R. 9 W., Lewis and Clark County, Mont. Rierdon formation, *Arcticoceras codyense* zone.

Localities at which ammonites were collected from Callovian beds in the western interior of the United States—Continued

No. on fig. 1	Geological Survey Mesozoic locality	Collector, year of collection, description of locality, and stratigraphic assignment
5	20391	Bert Brush, 1946. Northern Ordnance Inc. Holtz No. 1 well, sec. 23, T. 37 N., R. 2 W., Toole County, Mont. Top of Rierdon formation, *Kepplerites tychonis* zone.
6	11973	A. J. Collier, 1923. East side of East Butte of Sweetgrass Hills, sec. 28, T. 36 N., R. 5 E., Liberty County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
6	19196	C. E. Erdmann, 1930. North side of East Butte of Sweetgrass Hills, SE¼ of sec. 8, T. 36 N., R. 5 E., Liberty County, Mont. Upper 33 ft. of Rierdon formation, *Kepplerites mclearni* zone.
6	21467	A. R. Loeblich and R. W. Imlay, 1948. North side of East Butte of Sweetgrass Hills, SE¼ of sec. 8, T. 36 N., R. 5 E., Liberty County, Mont. About 20 ft. below top of Rierdon formation, *Kepplerites mclearni* zone.
7	18758	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside,, Jr. 1938. Section Creek, sec. 1, T, 28 N., R. 20 E., east end of Bearpaw Mountains, Blaine County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
7	19202	R. W. Imlay and Hal C. Yingling, Jr., 1944. Sec. 1, T. 28 N., R. 20 E., at east end of Bearpaw Mountains, Blaine County, Mont. From 25 to 35 ft. above base of Rierdon formation, *Gowericeras subitum* zone.
8	10729	A. J. Collier, T. W. Stanton, 1921. One mile a little north of east of the St. Paul Mission, Little Rocky Mountains, Blaine County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	10730	T. W. Stanton and L. Horton, 1921. One mile S. 65° W. of Landusky, Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	10732	T. W. Stanton, 1921. East slope of mountain south of Zortman, Phillips County, Mont Rierdon formation, *Kepplerites mclearni* zone.
8	18726	J. B. Reeside, Jr., and S. W. Hobbs, 1938. In the W½ of sec. 7, T. 24 N., R. 25 E., on Morrison Butte, Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18735	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. In the SE¼ of sec. 12, T. 25 N., R. 25 E., Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18737	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. In the NW¼ of sec. 3, T. 25 N., R. 26 E., Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18738	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. In the SE¼ of sec. 15, T. 25 N., R. 25 E., Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18742	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. In the SE¼ of sec. 32, T. 24 N., R. 24 E. Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18750	M. M. Knechtel, S. W. Hobbs, 1938. Middle of S½ of sec. 5, T. 24 N., R. 26 E., Little Rocky Mountains, Phillips County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	18753	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. Small dome just south of Camp Creek dome in the S½ of sec. 5, T. 24 N., R. 26 E., Phillips County, Mont. Rierdon formation, lower 10 ft.
8	18754	M. M. Knechtel, S. W. Hobbs, and J. B. Reeside, Jr., 1938. East of Jim Brown's Creek, in the NE¼ of sec. T. 26 N., R. 24 E., Little Rocky Mountains, Blaine County, Mont. Rierdon formation, *Kepplerites mclearni* zone.
8	19203	R. W. Imlay and Hal C. Yingling, Jr., 1944, Sec. 7, T. 25 N., R. 26 E., Chalk Butte dome, Phillips County, Mont. Upper 10 ft. of Rierdon formation, *Kepplerites mclearni* zone.
8	19211	R. W. Imlay and Hal C. Yingling, Jr., 1944. Sec. 32, T. 25 N., R. 24 E., one mile southwest of Landusky, Phillips County, Mont. Upper 10 ft. of Rierdon formation, *Kepplerites mclearni* zone.
8	19212	R. W. Imlay and Hal C. Yingling, Jr., 1944. Sec. 7, T. 25 N., R. 26 E., Chalk Butte dome, Phillips County, Mont. From 11 ft. of nodular limestone which is 13 ft. above base of Rierdon formation, *Gowericeras costidensum* zone.
8	19572	William Saalfrank, 1945. Sec 7, T. 25 N., R. 26 E., Chalk Butte dome, Phillips County, Mont. Upper 10 ft. of Rierdon formation, *Kepplerites mclearni* zone.
8	19576	R. W. Imlay and William Saalfrank, 1945. NW corner of sec. 6, T. 24 N., R. 26 E., Little Rocky Mountains, Phillips County, Mont. Rierdon formation, lower 10 ft. just above a bed of yellow sandy limestone, *Gowericeras costidensum* zone.
8	19583	R. W. Imlay and William Saalfrank, 1945. NW corner of sec. 6, T. 24 N., R. 26 E., South side of Camp Creek dome, Phillips County, Mont. Upper 10 ft, of Rierdon formation, *kepplerites mclearni* zone.
8	19584	R. W. Imlay and William Saalfrank, 1945. Sec. 3, T. 25 N., R. 26 E., east side of Matador dome, Phillips County, Mont. Upper 10 ft. of Rierdon formation, *Kepplerites mclearni* zone.
8	19585	R. W. Imlay and William Saalfrank, 1945. Sec. 32, T. 26 N., R. 26 E., northeast end of Little Warm dome, Phillips County, Mont. From 10 to 15 ft. above base of Rierdon formation, *Gowericeras costidensum* zone.

Localities at which ammonites were collected from Callovian beds in the western interior of the United States—Continued

No. on fig. 1	Geological Survey Mesozoic locality	Collector, year of collection, description of locality, and stratigraphic assignment
8	19587	R. W. Imlay and William Saalfrank, 1945. Sec. 3, T. 25 N., R. 26 E., east side of Matador dome, Phillips County, Mont. Rierdon formation, about 20 ft. above base.
8	19588	R. W. Imlay, 1945. Sec. 7, T. 25 N., R. 26 E., Chalk Butte Dome, Phillips County, Mont. From base of nodular limestone, 13 ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
8	19589	R. W. Imlay and William Saalfrank, 1945. Sec. 32, T. 26 N., R. 26 E., northeast end of Little Warm dome, Phillips County, Mont. From 1 ft. of sandy limestone from 3 to 4 ft. above base of Rierdon formation, *Arcticoceras codyense* zone.
9	19176	R. W. Imlay and Hal C. Yingling, Jr., 1944. Directly east of Giltedge Mine, in the SW¼ of sec. 17, T. 16 N., R. 20 E., Fergus County, Mont. Rierdon formation, lower 30 ft.
10	19169	R. W. Imlay, Hal C. Yingling, Jr., and Roland Brown, 1944. Sec. 15, T. 14 N., R. 20 E., Fergus County, Mont. Rierdon formation, from 15 to 30 ft. above base, *Gowericeras subitum* zone.
10	19179	R. W. Imlay and Hal C. Yingling, Jr., 1944. In the SE¼ of sec. 17, T. 14 N., R. 20 E., Fergus County, Mont. From 10 to 30 ft. above base of Rierdon formation, *Gowericeras subitum* zone.
10	19180	J. B. Reeside, Jr., Oscar Mueller, and R. W. Imlay, 1944. In the SE¼ of sec. 9 and NE¼ of sec. 16, T. 14 N., R. 20 E., Fergus County, Mont. From 10 to 30 ft. above base of Rierdon formation, *Gowericeras subitum* beds.
10	19181	J. B. Reeside, Jr., Oscar Mueller, and R. W. Imlay, 1944. North side of road in north central part of sec. 14, T. 14 N., R. 20 E., Fergus County, Mont. From lower 25 ft. of Rierdon formation, *Gowericeras subitum* zone.
10	19213	Oscar Mueller, 1946. Sec. 16, T. 14 N., R. 20 E., Fergus County, Mont. Rierdon formation, *Gowericeras subitum* zone.
10	19616	R. W. Imlay and William Saalfrank, 1945. Near middle of sec. 12, T. 14 N., R. 19 E., Fergus County, Mont. Lower 30 ft. of Rierdon formation, *Gowericeras subitum* zone.
11	19170	R. W. Imlay and Hal C. Yingling, Jr., 1944. Near center of sec. 15, T. 14 N., R. 21 E., Fergus County, Mont. From lower 15 ft. of Rierdon formation, *Gowericeras costidensum* zone.
11	19175	R. W. Imlay and Hal C. Yingling, Jr., 1944. East side of road in north central part of sec. 14, T. 14 N., R. 21 E., Fergus County, Mont. From lower 22 ft. of Rierdon formation, *Gowericeras subitum* zone.
11	19182	J. B. Reeside, Jr., Oscar Mueller, and R. W. Imlay, 1944. NW¼ of sec. 16, T. 14 N., R. 21 E., Fergus County, Mont. From 8 ft. of sandy limestone 14 ft. above base of Rierdon formation, *Gowericeras subitum* beds.
12	11312	Frank Reeves, 1922. North side of Button Butte, Sec. 18, T. 14 N., R. 24 E., Fergus County, Mont Rierdon formation, *Gowericeras subitum* zone.
13	19628	William Saalfrank and Carl Rogers, 1945. Near line of secs. 28 and 33, T. 11 N., R. 21 E., Golden Valley County, Mont. Rierdon formation, 15 to 20 ft. above base, *Gowericeras* beds.
14	19629	Carl Rogers, William Saalfrank, and R. W. Imlay, 1945. Sec. 36 T. 5 S., R. 24 E., Carbon County, Mont. Rierdon formation, 23 ft. above base, *Kepplerites tychonis* zone.
14	20360	J. B. Reeside, Jr., and R. W. Imlay, 1946. Sec. 3, T. 24 E., R. 6 S., Carbon County, Mont. About 100 ft. below top of Rierdon formation, *Kepplerites tychonis* zone.
14	20363	J. B. Reeside, Jr., and R. W. Imlay, 1946. In the SE¼ of sec. 4, T. 24 E., R. 6 S., Carbon County, Mont. About 100 ft. below top of Rierdon formation, *Kepplerites tychonis* zone.
15	19618	R. W. Imlay and William Saalfrank, 1945. Sec. 36, T. 8 S., R. 7 E., Cinnabar Mountain, Park County, Mont. Eight feet above base of Rierdon formation, *Arcticoceras codyense* zone.
16	1163	W. H. Weed, Summit of Wagon road between Sentinel Butte and Terrace Mountain, Mammoth Hot Springs, Yellowstone National Park. Rierdon formation, *Arcticoceras codyense* zone.
17	1130	J. P. Iddings. Divide between Fawn Creek and Gallatin Valley, Yellowstone National Park. Rierdon formation, *Arcticoceras codyense* zone.
18	17106	D. A. Andrews, 1935. South side of Shoshone River 2 miles west of Cody, Wyo. Base of Sundance formation directly above red beds. *Arcticoceras codyense* zone.
18	17179	W. G. Pierce, 1935. South side of Shoshone River 2 miles west of Cody, Wyo. About 15 ft. above 48 ft. of gypsiferous red beds that underlie the Sundance formation.
18	19632	R. W. Imlay and William Saalfrank, 1945. South side of Shoshone River, 2 miles west of Cody, in the NE¼ of sec. 4, T. 52 N., R. 102 W., Park County, Wyo. From 15 to 20 ft. above base of Sundance formation.
19	21522	R. K. Hose and J. L. Weitz, 1949. Long. 110°32'24", Lat. 44°14'28", 2½ miles SW of Heart Lake, Yellowstone National Park. "Lower Sundance" 30 ft. below top.
20	20974	R. W. Imlay, 1947. North side of lower lake on the Gros Ventre River, sec. 4, T. 42 N., R. 114 W., Teton County, Wyoming. "Lower Sundance" about 200 ft. below top, or about 30 ft. below lowest appearance of numerous *Gryphaea nebrascensis* Meek and Hayden.

Localities at which ammonites were collected from Callovian beds in the western interior of the United States—Continued

No. on fig. 1	Geological Survey Mesozoic locality	Collector, year of collection, description of locality, and stratigraphic assignment
21	21635	R. W. Imlay and G. Pipiringos, 1949. East side of Red Creek, in the NE¼ of sec. 7 and SE¼ of sec. 6, T. 6 N., R. 3 W., Fremont County, Wyo. From 12 to 18 feet below top of Canyon Springs sandstone member of the Sundance formation, *Arcticoceras codyense* zone.
22	20496	J. D. Love et al, 1946. Center of E½ of sec. 11, T. 29 N., R. 68 W., Platte County, Wyo. Sundance formation, Canyon Springs sandstone member, *Arcticoceras codyense* zone.
22	20497	J. D. Love et al, 1946. In the SE¼ of sec. 11, T. 29 N., R. 68 W., Platte County, Wyo. Sundance formation, Canyon Springs sandstone member, *Arcticoceras codyense* zone.
22	20503	J. D. Love et al, 1946. Center of E½ of sec. 11, T. 29 N., R. 68 W., Platte County, Wyo. Sundance formation, Canyon Springs sandstone member, *Arcticoceras codyense* zone.
23	20337	J. B. Reeside, Jr., T. Botinelly, R. W. Imlay, and G. Pipiringos, 1946. On butte in sec. 23, T. 48 N., R. 62 W., Weston County, Wyo. From Canyon Springs sandstone member of Sundance formation just above massive gypsum. *Arcticoceras codyense* zone.
24	19560	R. W. Imlay and William Saalfrank, 1945. In the S½ of sec. 19, T. 4 S., R. 1 E., Custer County, Dak. Basal 5 feet of Stockade Beaver shale member of the Sundance formation, *Arcticoceras henryi* beds.
24	19561	R. W. Imlay and William Saalfrank, 1945. In the NW¼ of sec. 8, T. 4 S., R. 1 E., Custer County, Dak. Basal 5 feet of Stockade Beaver shale member of the Sundance formation, *Arcticoceras henryi* beds.
25	19556	R. W. Imlay and William Saalfrank, 1945. In the S½ of sec. 21, T. 7 S., R. 4 E., Fall River County, Dak. From (feet of shale containing nodular limestone about 48 feet below top of Stockade Beaver shale member of the Sundance formation, *Arcticoceras henryi* beds.

SUMMARY OF RESULTS

1. The described Callovian ammonites from the western interior of the United States include 10 genera and 38 species and varieties. Of these, 19 species and 1 variety are described as new. Of the total number of ammonite specimens, *Arcticoceras* comprises 20 percent, *Cadoceras* 28 percent, *Kepplerites* 15 percent, *Gowericeras* 23 percent, *Cosmoceras* 8 percent, and *Xenocephalites, Procerites,* and *Grossouvria* each about 2 percent. Only two specimens of *Lilloettia* have been found.
2. Most of the fossil collections made in recent years have been located closely stratigraphically. This has been facilitated by the presence of several thin distinctive lithologic units that persist for scores or even hundreds of miles and change gradually in a predictable manner. These lithologic units have been discussed in detail in other publications by the writer and are merely summarized in this paper.
3. As a result of careful stratigraphic collecting, it has been possible to demonstrate the presence of five distinct ammonite zones in the marine Callovian, to show the positions of these zones with respect to the various lithologic units, and by considering both faunal and lithologic relationships to determine fairly accurately the history of Callovian time in the western interior region. The zones from the base upward are named after the characteristic species *Arcticoceras codyense* Imlay, *Gowericeras costidensum* Imlay, *Gowericeras subitum* Imlay, *Kepplerites tychonis* Ravn, and *Kepplerites mclearni* Imlay.
4. Comparisons of the ammonites in these zones with European ammonites show that the zones represent only about half of the Callovian stage. The basal zone of *Arcticoceras codyense* is correlated with the European zone of *Macrocephalites macrocephalus* mainly because of stratigraphic position. The *Gowericeras costidensum* and *Gowericeras subitum* zones are correlated with the European zone of *Proplanulites koenigi* because of the abundance of *Gowericeras,* the highest occurrence of *Procerites,* and the resemblance of several species to *Gowericeras* in the Kellaways beds of Great Britain. The overlying *Kepplerites tychonis* zone has been identified elsewhere in Alaska and East Greenland where associated species of *Cosmoceras* (*Gulielmiceras*) indicate an age not older than the European *Sigaloceras calloviense* zone. The highest zone of *Kepplerites mclearni* is correlated with the upper part of the European *Sigaloceras calloviense* zone because of the first appearance of *Gulielmiceras* and *Gulielmites,* the presence of *Xenocephalites,* the abundance of *Kepplerites,* and the characteristically flattened venters of the species of *Kepplerites.* This feature in Alaska is common in *Kepplerites* occurring in beds containing *Gowericeras* and

Paracadoceras, which are considered to be older than the *Cosmoceras jason* zone of Europe.

5. The Callovian ammonites of the western interior of the United States bear much greater resemblance to those of East Greenland than to those of southwestern Alaska. None of the subgenera of *Cadoceras* found in Alaska occur in the western interior and all the species of *Cadoceras* in the western interior belong to a subgenus that is unknown in Alaska but present in Greenland. *Gowericeras* and *Gulielmiceras* are much more common in the western interior than in Alaska. *Lilloettia* and *Xenocephalites* are fairly common in Alaska and are rare in the western interior. *Paradoceras, Pseudocadoceras, Phylloceras,* and *Kheraiceras* are very common in Alaska and unknown in the western interior. Nautiloid cephalopods occur in the Callovian of the western interior and not in Alaska. *Arcticoceras* is common at the base of the Callovian deposits of the western interior of North America, in northern Alaska, and in the Boreal region in general, but has not yet been found in the Alaska Peninsula or Cook Inlet regions of Alaska. Most of these differences appear to be ecological. Lithologic and faunal evidence indicates that the Callovian seas of the western interior and of East Greenland were very shallow and bordered lowlands, whereas the Callovian sea in the area of southwestern Alaska was fairly deep and bordered mountainous shores. Evidently only part of the ammonite genera that inhabited the deeper waters of the Boreal sea managed to become adapted to the shallower and probably warmer waters covering the interior of North America.
6. The distribution and associations of the Callovian ammonites in the western interior sea indicates that certain genera could live in much shallower water than others. It appears that *Arcticoceras* could live in shallow waters nearly to the strand line, that *Gowericeras, Cadoceras, Procerites,* and *Grossouvria* could not live in as shallow waters as *Arcticoceras,* and that *Kepplerites* preferred still deeper waters than *Gowericeras.* The absence of *Cadoceras* in the *Kepplerites mclearni* zone may be related to a shallowing and possible warming of the early Callovian sea during its withdrawal northward or due to the extinction of the single subgenus that managed to migrate into the western interior sea from the Boreal region. That no part of the western interior sea was deeper than the upper part of the neritic zone, and probably not deeper than 300 feet, is shown by the general association of the ammonites with abundant Gryphaeas and a few Lingulas.

SYSTEMATIC DESCRIPTIONS

Genus **LILLOETTIA** Crickmay 1930

Lilloettia sp. ind.

Plate 1, figures 10–13

The genus *Lilloettia* is represented in the Geological Survey collections from Montana by two septate specimens of vastly different sizes. Assignment to *Lilloettia* is based on the extremely small umbilicus, and the characteristics of the ribs, which thicken considerably ventrally and disappear anteriorly on the body whorl. Both specimens are compressed and have a narrowly rounded venter similar to that of *L. lilloetensis* Crickmay (1930, p. 62, pl. 18, figs. 1-4) but are much more coarsely ribbed than that species.

On the small specimen the ribbing is strong, gently flexuous and inclined slightly forward. The primary ribs are sharp, and bifurcate near the top of the lower third of the flanks. Many of the furcation points are indistinct. Most pairs of forked ribs are separated by short intercalated ribs. The secondary ribs are stronger and rounder than the primary ribs and attain their greatest strength on the venter. They arch forward distinctly on the venter. The suture line is poorly preserved but is similar to that on specimens of *Lilloettia* of comparable size from Alaska.

The large specimen, which probably represents the penultimate whorl, bears thick, low, widely spaced ribs on its venter on the posterior part only. These ribs fade out dorsally near the middle of the flank. The entire anterior half of the septate whorl appears to be completely smooth. The suture line cannot be traced with certainty.

Probably the two specimens represent the same species, but this cannot be proven until better specimens are obtained. The ribbing on the small specimen resembles that of the coarsest ribbed species of *Lilloettia* from Alaska. The ribbing on the large specimen is much coarser than that of any known species from Alaska or British Columbia.

Figured specimens, U.S.N.M. 108236, 108237.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 19583 and 19584.

Genus **XENOCEPHALITES** Spath 1928

Xenocephalites phillipsi Imlay, n. sp.

Plate 1, figures 1, 2, 5, 9

The two available specimens of this species show the characteristics of only the body whorl and part of the penultimate whorl. Whorl section subovate, wider than high, widest below the middle of the flanks, embracing nearly completely; flanks gently convex, rounding rather abruptly into umbilicus, venter broadly rounded. Umbilicus very narrow, enlarging somewhat at anterior end of body whorl; wall low and steep. Body chamber incomplete but represented by at least five-sixths of a whorl.

The ribs on the penultimate whorl are fairly sharp, low, a little narrower than the interspaces, strongly flexuous, and generally bifurcate on the lower third of the flanks. Most pairs of forked ribs are separated by short, intercalated ribs. On the body whorl the ribbing rapidly becomes higher and more widely spaced anteriorly and intercalated ribs become less common.

The suture line illustrated is the next to the last preceding the body chamber and is very similar to that of some forms of *Cranocephalites* figured by Spath (1932, pl. 5, figs. 7, 8). The first lateral lobe is as long as the external lobe, the second lateral lobe is much shorter, and the greatest thickness of the shell coincides with the inner part of the first lateral saddle. Comparisons with the suture line of *Xenocephalites borealis* Spath (1932, p. 44, pl. 14, figs. 4a-d) are not useful because of the differences in the sizes of the specimens. The simple suture contrasts markedly with that of *Kheraiceras,* whose ornamentation and form resembles *Xenocephalites.*

The holotype at a diameter of 56 mm has a whorl height of 28 mm and a whorl thickness of 34 mm. These measurements were made just back of the crushed anterior end of the body chamber.

This species has much denser, finer ribbing than *X. bearpawensis* Imlay and is rather similar to species in the Chinitna formation of the Cook Inlet region, Alaska. *X. nikitini* (Burckhardt) (1927, p. 33, pl. 16, figs. 4–9), from southern Mexico, has sparser but weaker ribbing. *X. parvus* var. *angustumbilicata* (Stehn) (1924, p. 92, pl. 1, fig. 6, text. fig. 13) appears to have finer ribbing on the body chamber and higher points of rib branching.

Holotype, U.S.N.M. 108238; paratype, U.S.N.M. 108239.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. loc. 10730.

Xenocephalites bearpawensis Imlay, n. sp.

Plate 1, figures 3, 4, 6, 8

Six specimens of this species are at hand. The holotype has been crushed laterally but the two figured paratypes appear to be undeformed. Whorls ovate in section, higher than wide, widest a little below the middle of the flanks, embracing nearly completely; flanks gently convex; venter evenly arched. Umbilicus very narrow, enlarging slightly at anterior end of body whorl; wall low and rounding evenly into flanks. Body chamber represented by about three-fifths of a whorl. The aperture is probably complete in the specimen shown on pl. 1, fig. 6.

The ribbing, exposed only on the body whorl, is high, sharp ventrally, very widely spaced, flexuous, inclined forward on the flanks, and arched forward gently on the venter. Nearly all the primary ribs bifurcate slightly below the middle of the flanks into sharper and narrower secondary ribs. Intercalated ribs are uncommon.

The suture line cannot be traced.

The largest paratype (pl. 1, fig. 6) at a diameter of about 64 mm has a whorl height of 29 mm and an umbilical width of 8 mm.

This species has the strongest and most widely spaced ribs of any known form of *Xenocephalites. X. neuquensis* (Stehn) (1924, pp. 86-88, pl. 1, fig. 3, text fig. 11) has the most similar ribbing but has a lower whorl section and an umbilicus that enlarges rapidly at the anterior end of the body whorl.

Holotype, U.S.N.M. 108240; paratypes, U.S.N.M. 108241, 108242.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 10730, 10732, and 18758.

Xenocephalites cf. X. nikitini (Burckhardt)

Plate 1, figure 7

One small fragment has blunter ribbing than any of the known species of *Xenocephalites* from the western interior or from Alaska but is rather similar to *X. nikitini* (Burckhardt) (1927, p. 33, pl. 16, figs. 7–9) from the Callovian of southern Mexico. It does not show thickening of the ribs on the venter as in *Lilloettia.* In *Kheraiceras* rib-branching occurs higher on the flanks, and specimens of comparable size are much more densely ribbed.

Figured specimen, U.S.N.M. 108243.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. loc. 18737.

Genus ARCTICOCERAS Spath 1932

Arcticoceras rierdonense Imlay, n. sp.

Plate 2, figures 1, 2; plate 3, figures 16, 18, 21, 22

This species is represented in the Survey collections by eleven specimens, and probably also by several large fragments and several immature specimens. Form lenticular, compressed. Whorls elliptical, much higher than wide, thickest near the umbilicus. Flanks flattened, converging gently to rather narrowly rounded venter. Umbilicus nearly closed. Body chamber represented by about three-fifths of a whorl. Aperture on internal mold slightly constricted, inclined forward in a gently sinuous manner, preceded near umbilicus by a broad, shallow constriction.

Certain small specimens shown on pl. 3, figs. 19, 20, are interpreted as the immature forms of *A. rierdonense* as they were obtained from the same localities as some of the larger specimens. These small specimens have flexuous ribbing that curves forward on the upper part of the flanks and on the venter. The primary ribs are fairly sharp and bifurcate at about the top of the lower third of the flanks into weaker secondaries. Most pairs of forked ribs are separated by single intercalated ribs that begin along the zone of furcation.

During growth, effacement of the ribs takes place on the lower parts of the flanks and gradually spreads ventrally. The ribs on the upper parts of the flanks and on the venter are moderately strong, strongly curved forward, and extend to the anterior end of the septate shell. The body chamber is nearly smooth except for faint, broad undulations on the venter.

The suture line, well exposed on several specimens, has fairly slender lobes and saddles on the immature forms, but these sutural elements become broad and shallow on the last septate whorl (pl. 3, fig. 1). The second lateral lobe is irregularly trifid.

Most of the specimens have been compressed or distorted. However, the anterior half of the paratype shown on plate 3, figures 21, 22, appears to be nearly undeformed. At a diameter of 94 mm, it has a whorl height of 55 mm and a whorl thickness of 38 mm.

Compared with *Arcticoceras kochi* Spath (1932, p. 53, pl. 12, fig. 1; pl. 13; figs. 4, 5; pl. 14, figs. 1–3; pl. 15, fig. 1) from Greenland, the present species has finer ribbing that begins to disappear much earlier and is curved forward less strongly on the upper part of the flanks. Adult specimens are very similar, but *A. kochi* has a deep constriction near the aperture. *A. ishmae* (Keyserling) (Sokolov, 1912, pp. 15, 49, pl. 1, fig. 1, pl. 3, fig. 12; Spath, 1932, pl. 15, figs. 7a, b; Roman, 1938, pl. 20, fig. 204) from Petchora land has finer and less projected ribbing than *A. kochi* but much coarser ribbing than *A. rierdonense.* Both of the Boreal species appear to have a more robust form and a wider umbilicus than *A. rierdonense. A. codyense* Imlay has a more trigonal-shaped whorl section, finer ribbing that disappears at an earlier growth stage, and a bifid second lateral lobe. *A. henryi* (Meek and Hayden) (1865, pp. 123, 124, pl. 5, figs. 9a-c) has a much stouter form and loses its ribbing at a much smaller size.

Holotype, U.S.N.M. 108244; paratypes, U.S.N.M. 108245a, b, 108246.

Ellis group, Rierdon formation, *Arcticoceras* beds, U.S.G.S. Mes. localities 1130, 18610, 19397, 19593, and 19605.

Arcticoceras n. sp. ind.

Plate 3, figures 13, 15, 17

One species is represented by six fragmentary specimens, none sufficiently well preserved to merit designation as a type. The species is characterized by a trigonal whorl section and by very broad, low, widely-spaced ribs. The ribs disappear from the lower part of the flanks at a small diameter but persist on the venter as broad swells to diameters of at least four inches. The ribbing is as widely spaced as in *A. crassicostatum* Imlay but much weaker. *A. codyensis* Imlay has a similar whorl section but much finer ribbing.

Figured specimens, U.S.N.M. 108248, 108249.

Ellis group, Rierdon formation, *Arcticoceras* beds, U.S.G.S. Mes. locs. 1163, 18610, 19600, 19605, 20974, and probably 19618.

Arcticoceras crassicostatum Imlay, n. sp.

Plate 3, figures 1–6

Four specimens of this species are known and these appear to be nearly undeformed. It seems unlikely that they represent adults. Form compressed. Whorls subovate, higher than wide, thickest on the lower third of flanks. Flanks slightly convex, converging above into narrowly rounded venter. Umbilicus narrow but wider than in most species of *Arcticoceras;* wall low, vertical at base, rounding evenly into flanks. Body chamber incomplete, but represented by at least half a whorl.

The ribs, known only from the body whorl, are very prominent, widely spaced, and flexuous. The primary ribs are radial on the umbilical wall and incline forward on the lower part of the flank. About half of them bifurcate at or just below the top of the lower third of the flank. Some of the furcation points are so indistinct as to give the appearance of alternation of long and short ribs. The secondary ribs bend backward slightly near the middle of the flanks and then strongly forward on the upper part of the flanks and on the venter. Along the midventral line the anterior slope of the ribs is appreciably steeper than the posterior slope.

The suture line is barely visible.

The holotype at a diameter of 56 mm has a whorl height of 25 mm, a whorl thickness of 19 mm, and an umbilical width of 10 mm. As the specimen has been deformed by lateral compression, the dimensions should be considered only as approximate.

This species has coarser ornamentation and a wider umbilicus than any other species of *Arcticoceras.* When first examined it was thought to represent the inner whorls of some coarsely-ribbed *Arctocephalites,* such as figured by Imlay (1948, p. 19, pl. 6, figs. 2, 5). However, its venter is more narrowly rounded than in *Arctocephalites* and the pronounced forward arching of the ribs on the venter contrasts with the transverse ribbing on *Arctocephalites.* Also, this species resembles both *Arcticoceras ishmae* (Keyserling) (see Spath, 1932, pl. 15, figs. 7a, b) from the Boreal region and *A. loveanum* Imlay with which it is associated, differing from them mainly in its more compressed form and stronger ribbing.

Holotype, U.S.N.M. 108250; paratypes, U.S.N.M. 108251a, b.

Sundance formation, Canyon Springs sandstone member, *Arcticoceras* beds, U.S.G.S. Mes. locs. 20496 and 20497.

Arcticoceras loveanum Imlay, n. sp.

Plate 3, figures 7–12, 14

Ten specimens of this species are available, but probably none is an adult. Most of them are slightly crushed. Whorls ovate, probably a little higher than wide before crushing. Flanks gently convex, rounding evenly into umbilicus, converging to narrowed venter. Umbilicus very narrow. Body chamber incomplete, represented by at least half a whorl.

The ribs are moderately strong, incline forward gently on the lower half of the flanks, curve forward strongly on the upper half of the flank, and form a distinct forward arch on the venter. The primary ribs bifurcate between the tops of the lower fourth and lower third of the flanks. Some of the furcation points are indistinct and there are a few intercalated ribs that begin along the zone of furcation. Anteriorly on the body chamber the ribbing coarsens rapidly and becomes widely spaced. The ribs along the midventral line have steeper anterior than posterior slopes.

The suture line is barely visible in a few places and cannot be traced. Owing to crushing, measurements of dimensions are useless.

This species differs from *Arcticoceras crassicostatum* Imlay in its considerably finer ornamentation and more inflated shape. The strength and spacing of its ribbing resemble that of the septate shell of the much larger *Arcticoceras ishmae* (Keyserling) (Pompeckj, 1899, p. 72; Sokolov, 1912, pp. 15, 49, pl. 1, fig. 1; Spath, 1932, pl. 15, figs. 7a, b; Roman, 1938, pl. 20, fig. 204), which becomes smooth on the body whorl. This species is named in honor of J. D. Love of the Geological Survey, who was in charge of the field party that collected most of the specimens.

Holotype, U.S.N.M. 108252; paratypes, U.S.N.M. 108253a, b, 108254.

Sundance formation, Canyon Springs sandstone member, *Arcticoceras* beds, U.S.G.S. Mes. locs. 20337, 20496, and 20497; Sundance formation, Stockade Beaver shale member, basal 15 ft., Mes. loc. 19556.

Arcticoceras codyense Imlay

Plate 4, figures 1–13

Arcticoceras codyense Imlay, U. S. Geol. Survey Prof. Paper 214–B, pp. 20, 21, pl. 6, figs. 4, 6, 8, 1948.

This species is the most common representative of *Arcticoceras* in the western interior, being represented by about forty specimens of various sizes. Most of the specimens have been deformed. Some, including the holotype, have been compressed laterally, thereby producing a high, thin whorl section. Others have been depressed, resulting in a fairly thick whorl section. The specimens from the Little Rocky Mountains of central Montana appear to be least deformed and are herein illustrated to show the changes in whorl shape.

Shell lenticular, flattened in young, stout in adult. Whorls trigonal in section, much higher than wide, becoming stouter during growth, thickest near the umbilicus. Flanks flattened; venter narrowly rounded; umbilicus nearly closed. Body chamber incomplete but represented by at least half a whorl.

The small immature specimens have many low, flexous ribs separated by interspaces of about equal width. These ribs are indistinct on the lower parts of the flanks at diameters of about 25 mm. During growth effacement of the ribs spreads ventrally, resulting in a nearly smooth mold at diameters of about 60 mm. The secondary ribs curve forward strongly on the upper parts of the flanks, arch forward distinctly on the venter, and are thickest and most persistent on the venter. The body whorl of adult specimens shows no trace of ribbing.

The suture line, well exposed on the holotype and on several larger specimens, is characterized by a bifid second lateral lobe that contrasts with the suture of *A. rierdonense* Imlay. The general sutural pattern is similar to that of *A. henryi* (Meek and Hayden), differing mainly in its broader saddles.

The dimensions of the types in millimeters and in ratios of whorl height and thickness to the diameter are as follows:[1]

Specimen	Diameter	Whorl height	Whorl thickness
Holotype (pl. 4 , figs. 1, 4)	85	51 (0.60)	36 (0.42)
Paratype (pl. 4 , figs. 9, 12)	88	52 (0.59)	36 (0.40)
Paratype (pl. 4 , fig. 13)	181	110 (0.60)	91 (0.50)

The largest specimen, collected from Chalk Butte dome in the Little Rocky Mountains, is about 280 mm in diameter. It has only half the whorl of body chamber and lacks the aperture. However, a weak constriction similar to that near the aperture of the adult of *A. rierdonense* (pl. 2, fig. 2) suggests that the body chamber is nearly complete. This specimen of *Arcticoceras codyense* maintains its trigonal shape on the body chamber and is thus readily differentiated from the similar large adult specimens of *A. rierdonense.*

Arcticoceras codyense is characterized by its trigonal whorl shape, bifid second lateral lobe, rather fine ribbing, and by its loss of ribbing at a smaller growth stage than any of the described species of *Arcticoceras* except *A. henryi* (Meek and Hayden). The latter has a much thicker, rounder whorl section and finer, sparser ribbing. The other species are not closely comparable.

Holotype, U.S.N.M. 104132; paratypes, U.S.N.M. 104133 a–c; plesiotypes, U.S.N.M. 108255, 108256, 108257 a, b.

Ellis group, Rierdon formation, *Arcticoceras* beds, U.S.G.S. Mes. locs. 18718, 19588, 19589, and 19600; Sundance formation, basal limestone at Mes. locs. 17106 and 21635; Sundance formation, Canyon Springs sandstone member at Mes. locs. 20337, 20496, 20497, and 20503.

Arcticoceras henryi (Meek and Hayden)

Plate 5, figures 6–15

Ammonites henryi Meek and Hayden, Smithsonian Contr. Knowledge, vol. 14, Art. 5, pp. 123, 124, pl. 5, figs. 9 a–c, 1865.

Arcticoceras henryi (Meek and Hayden), Imlay, U. S. Geol. Survey Prof. Paper 214–B, p. 21, 1948.

The Survey collections contain twenty-two specimens of this species. Most of these are undeformed. Shell lenticular, fairly stout. Whorls ovate in section, higher than wide, thickest at the top of the lower third of the flanks. Flanks gently convex, becoming more convex on body chamber. Venter highly arched. Umbilicus nearly closed; wall low, vertical at base, rounding evenly into flanks. Body chamber represented by three-fourths of a whorl. Aperture sinuous, inclined strongly forward, and produced ventrally in a long lappet.

The smallest specimens, ranging from 35 to 50 mm in diameter, have striae on the lower parts of the flanks and weak, widely-spaced ribs on the ventral region. These incline forward on the lower third of the flank, then recurve slightly, curve forward strongly on the upper parts of the flanks, and arch forward on the venter. This ornamentation weakens rapidly anteriorly and at diameters greater than 50 mm the internal molds are nearly smooth. Viewed under oblique lighting the larger specimens show faint, sparse undulations and even fainter striae that project forward on the ventral region.

The suture line, well preserved on many specimens, has rather broad saddles and lobes. Its most interesting feature is the second lateral lobe, which is trifid on immature specimens but becomes bifid on most adults by diminution of the innermost lobule. On the holotype the second lateral lobe is broad and bifid on one side of the shell, but narrower and trifid at the same position on the other side of the shell.

Dimensions in millimeters and in ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness
Holotype (pl. 5 , fig. 11)	79	44 (0.55)	?
Plesiotype (pl. 5 , figs. 13, 15)	93	53 (0.57)	45 (0.48)
Plesiotype (pl. 5 , figs. 8, 9)	54	32 (0.59)	28 (0.52)

This species has the weakest ribbing of any known species of *Arcticoceras.* Its venter is considerably broader than *A. rierdonense* Imlay and is comparable with that of *A. ishmae* (Keyserling), as figured by Spath (1932, pl. 15, fig. 7b). Its smooth lateral aspect resembles that of the adult of *Cadoceras subpatruum* Nikitin (1885a, p. 58, pl. 11 (13), fig. 58), whose inner whorls are reported to be ribbed as in *C. surense* Nikitin (1885a, p. 57, pl. 10 (12), figs. 53, 54a, b, 55) and to have comma-shaped tubercles. However, on *C. subpatruum* the trigonal whorl section, the very narrow umbilicus; the forward arching of the ribs on the ventral region, the thickening of the ribs along the midventral line, and the complete disappearance of ornamentation except for fine striae on the body chamber are all characteristics

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[1] In the following pages this statement will be abbreviated to "Dimensions in millimeters and ratios are as follows:"

of *Arcticoceras*. Also, the occurrence of *C. subpatruum* in the *Macrocephalites* beds of Russia agrees with the stratigraphic occurrence of *Arcticoceras*, whereas similarly compressed forms of *Cadoceras* are characteristic of higher beds in the middle part of the Callovian.

Holotype, U.S.N.M. 314; plesiotypes, U.S.N.M. 108258a–f, 108259.

Sundance formation, Stockade Beaver shale member, basal 15 feet, top of *Arcticoceras* beds, U.S.G.S. Mes. locs. 19556, 19560 and 19561.

Genus Cadoceras Fischer 1882

Cadoceras shoshonense Imlay

Plate 6, figures 1–14

Cadoceras shoshonense Imlay, U. S. Geol. Survey Prof. Paper 214–B, p. 22, pl. 7, figs. 13, 16, 17, 1948.

The species is represented in the collections by at least 46 specimens. It probably includes two large, globose specimens measuring about 8 inches in diameter, but the ornamentation of their inner whorls could not be determined. The species was originally described as follows:

> Form globose, tending to become broader and more spherical during growth. Whorl semicircular in section, wider than high, becoming wider during growth, and embracing most of the preceding whorl. Flanks rounding evenly into the broadly rounded venter. Umbilicus rather narrow; wall vertical at base, steep above, and rounding rather abruptly into flanks. Body chamber apparently nearly complete on the holotype where it comprises three-fourths of a whorl.
>
> The ribs are coarse and high. On the inner whorls they are as wide as the inner spaces, but during growth become narrower than the inner spaces. The primary ribs are faint on the upper part of the umbilical wall and are weak on the edge of the umbilicus, but become strong ventrally. They curve forward considerably on the lower fourth of the flank and give rise to pairs of secondary ribs that incline forward slightly on the flanks and arch forward gently on the venter. Occasional intercalary ribs begin just above the zone of furcation.
>
> The last suture line of the holotype is characterized by the shortness of its lobes and saddles. This may reflect the proximity of the body chamber, although a smaller specimen (paratype, U.S.N.M. 104144) has several suture lines that are similarly short, and which contrast with those of the other species of *Cadoceras* in the *Gowericeras* beds. Comparable short sutural elements occur on *C. tschernyschewi* Sokolov (1912, pp. 19, 51, pl. 1, figs. 2a, b, pl. 2, fig. 1).

Cadoceras shoshonense is distinguished by its globose form, coarse ribbing and small umbilicus. Among the associated species, *Cadoceras muelleri* Imlay has a similar form but its ribbing is considerably finer. *C. piperense* Imlay approaches it in coarseness of ribbing but has a much more compressed form. None of the described species from Alaska or Canada closely resemble it. *C. freboldi* Spath (1932, p. 65, pl. 18, figs. 2a, b) from East Greenland has a different whorl shape and finer ribbing. *Cadoceras?* sp. in. Spath (1932, p. 70, pl. 20, fig. 5) resembles *C. shoshonense* in whorl shape and umbilical width, but its ribbing is different. The rather blunt ribbing of *C. shoshonense*, especially in the young forms, clearly distinguishes it from *Pleurocephalites*.

Dimensions in millimeters and in ratios of the diameter are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 6, figs. 7, 11)	41	21 (0.51)	30 (0.73)	10 (0.24)
Paratype (pl. 6, figs. 3, 4)	53	29 (0.54)	37 (0.69)	12 (0.22)
Holotype (pl. 6, figs. 13, 14)	74	30 (0.40)	47 (0.63)	15 (0.20)
Paratype (pl. 6, fig. 12)	90	38 (0.42)	58 (0.64)	19 (0.21)
C. cf. *C. shoshonense*..	205	100 (0.48)	165 (0.80)	30 (0.14)

Types.—Holotype, U.S.N.M. 104143; paratypes, U.S.N.M. 104141, 104144a–c; plesiotypes, U.S.N.M. 104142, 104145a, b, 108260, 108261a, b.

Ellis group, Rierdon formation, *Gowericeras subitum* beds, U.S.G.S. Mes. localities 11312, 18718, 19169, 19179–19182, 19202, 19607, 19628, and 22651; *Gowericeras costidensum* beds, U.S.G.S. mes. localities 19170, 19212, and 19585; Sundance formation, lower part, Mes. localities 17179, 19632, 21522.

Cadoceras muelleri Imlay, n. sp.

Plate 7; plate 8, figures 2, 7, 9; plate 9, figures 1–3, 6–8, 10

Forty-five specimens, representing most stages of growth, are at hand. Form globose. Whorls semicircular in section, much wider than high, embracing most of the preceding whorl. Flanks rounding evenly into the broadly rounded venter. Umbilicus fairly narrow and deep; wall vertical, rounding rather abruptly into flanks. Adult body chamber represented by at least five-sixths of a whorl, slightly contracted at anterior end. Aperture not preserved.

The ribs are moderate in height, fairly thick, as wide as the interspaces on the inner whorls, becoming weaker and more widely separated anteriorly. On the smallest specimen (pl. 9, figs. 2, 6) the ribs are faint on the lower fourth of the flanks, but there are indications of rib branching at about the top of the lower fourth. On the upper three-fourths of the flanks the ribs incline forward slightly and then cross the venter with a gentle forward arch. Effacement of the ribs spreads ventrally during growth, resulting in a completely smooth body whorl on the largest adults.

The suture line has moderately long lobes and saddles. On one small specimen (pl. 9, fig. 7) the first lateral lobe is shorter than the external lobe and the second lateral saddle is not entirely outside the umbilical edge. On some large specimens the first lateral lobe is as long as the external lobe and the second lateral saddle is removed from the umbilical edge.

Dimensions in millimeters and ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 9, figs. 2, 6)	54	32 (0.59)	42 (0.78)	10 (0.18)
Paratype (pl. 9, figs. 1, 3)	82	48 (0.58)	73 (0.89)	16 (0.19)
Holotype (pl. 8, fig. 7)	124	65 (0.52)	?	19 (0.13)
Holotype (pl. 8, fig. 7).	190	81 (0.42)	?	40 (0.21)

The species attains a larger size than the above dimensions show as the smooth body whorl of the holotype is about 290 mm in diameter and there are fragments suggesting even larger specimens.

This species differs from *Cadoceras shoshonense* Imlay mainly in its much finer, closer-spaced ribbing that begins to disappear at an earlier growth stage and by the longer elements of its suture line. The effacement of the primary ribs contrasts with the rather strong primaries on *C. freboldi* Spath (1932, p. 65, pl. 18, figs. 2a, b) and *Cadoceras?* sp. ind. Spath (1932, p. 70, pl. 20, fig. 5), which are otherwise rather similar to *C. muelleri*. This species is named in honor of Oscar O. Mueller, a lawyer and ardent amateur collector, of Lewistown, Montana.

Holotype, U.S.N.M. 108262; paratypes, U.S.N.M. 108263–108266.

Ellis group, Rierdon formation, *Gowericeras* beds, U.S.G.S. Mes. locs. 19169, 19170, 19175, 19179-19182, 19202, 19585, 19587, 19591, 19596, 19607, 19629 and 20365; Sundance formation, near base, Mes. loc. 19632.

Cadoceras tetonense Imlay, n. sp.

Plate 10, figures 1, 2; plate 11, figures 1–10

Twelve specimens of this species are available. Shell stout in young, globose in adult forms. Whorls semicircular in section, much wider than high, embracing most of the preceding whorl. Flanks rounding evenly into the broadly rounded venter. Umbilicus fairly narrow and deep; wall vertical, rounding rather abruptly into flanks. Adult body chamber represented on holotype by a complete whorl whose anterior end is somewhat contracted. Aperture not perfectly preserved but showing a swelling that is preceded by a broad, weak constriction.

The ribs on the smallest specimens (pl. 11, figs. 1, 3, 9) are fairly high and narrow on the venter and widely separated. They incline forward on the flanks and arch forward gently on the venter. The primary ribs are much broader and lower than the secondary ribs and pass into two or three secondary ribs at about the top of the lower fourth of the flanks. There are a few intercalated ribs.

At diameters greater than about 60 mm effacement of the ribs begins on the lower parts of the flanks and gradually spreads ventrally. Concomitantly the ribbing on the ventral region becomes lower, broader, and about as wide as the interspaces. The last half whorl of the body chamber is nearly smooth except for faint undulations on the venter.

The suture line is characterized by broad, short elements. The first lateral lobe is slightly shorter than the external lobe and the second lateral saddle is considerably outside of the umbilical edge.

Dimensions in millimeters and ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 11, figs. 1, 3, 9).	36	18 (0.50)	21.5 (0.59)	5.5 (0.15)
Paratype (pl. 11, figs. 5, 6).	56	25 (0.44)	32? (0.57)	7 (0.12)
Paratype (pl. 11, figs. 8, 10).	89	53 (0.55)	68? (0.71)	18 (0.18)
Holotype (pl. 10, figs. 1, 2).	130	59 (0.45)	104 (0.80)	23 (0.17)
Holotype (pl. 10, figs. 1, 2).	160	79 (0.49)	134? (0.83)	31 (0.19)

This species differs from the associated *C. muelleri* Imlay in its weaker, denser ribbing and by its less globose small and intermediate sized whorls. *C. piperense* Imlay is more compressed and its ventral ribbing is higher and more sparse. *C. shoshonense* has a similar suture line but has much coarser ribbing. *C. franciscus* Spath (1932, p. 74, pl. 20, figs. 2 a–c) resembles the immature forms of *C. tetonense* in ribbing and whorl shape, although it appears to have a wider umbilicus and sharper primary ribs.

Holotype, U.S.N.M. 108267; paratypes, U.S.N.M. 108268, 108269–108271.

Ellis group, Rierdon formation. *Arcticoceras* beds at U.S.G.S. Mes. locs. 19593 and 19594; *Gowericeras* beds at Mes. locs. 19169, 19179, and 19202; not localized stratigraphically at Mes. loc. 18718; Sundance formation, near base at Mes. loc. 19632.

Cadoceras piperense Imlay, n. sp.

Plate 12; plate 13, figures 1–12; plate 14, figure 7

This species is represented by thirty specimens, including nine adults. Many of these are contorted. Shell compressed in young, stout in adult. Whorls ovate in section, a little higher than wide in immature specimens, becoming wider than high in adult, embracing most of the preceding whorl. Flanks gently convex, rounding evenly into moderately broad venter. Umbilicus fairly narrow but enlarging on anterior third of body whorl. Wall vertical, rounding rather abruptly into flanks. Body chamber represented by five-sixths of a whorl, contracted somewhat at anterior end. Aperture inclined forward, preceded on internal mold by a weak constriction.

The smallest known whorls at diameters of about 25 mm have broad, fairly strong ribs on the venter and upper half of the flanks, but are nearly smooth on the lower fourth of the flanks. Some specimens bear faint indications of rib branching at about the top of the smooth area. During growth the ribs become much broader but at all growth stages are slightly narrower than the interspaces. The ribs incline forward slightly on the flanks and arch forward gently on the venter. Effacement of the ornamentation in the ventral area occurs gradually on the body whorl.

The suture line has fairly long lobes and saddles. The first lateral lobe is deeper than the external lobe and the second lateral saddle is barely outside of the umbilical edge.

Dimensions in millimeters and ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 13, figs. 5, 6).	33	16.5 (0.50)	15.5 (0.47)	4.5 (0.14)
Paratype (pl. 13, figs. 1, 2).	51	29.5 (0.58)	29 (0.57)	5.5 (0.11)
Paratype (pl. 13, figs. 3, 4).	60	30 (0.50)	32 (0.53)	8 (0.13)
Holotype (pl. 14, fig. 7).	145	81 (0.56)	98 (0.67)	26 (0.18)

This species is the most compressed of any *Cadoceras* in the collections from the western interior. Its ventral ribbing is a little broader, lower and sparser than that of *C. muelleri* Imlay. The immature shells have dimensions similar to that of *C. franciscus* Spath (1932, p. 74, pl. 20, figs. 2 a–c), which is distinguished by a wider umbilicus and by stronger ribbing on the lower parts of the flanks. None of the Alaskan species is very similar.

Holotype, U.S.N.M. 108272; paratypes, U.S.N.M. 108273–108278.

Ellis group, Rierdon formation, U.S.G.S. Mes. locs. 18610, 18718, 19169, 19170, 19176, 19179–19181, 19213, 19590, 19596, 19599, 19602, 19628; Sundance formation, lower part, Mes. locs. 19632 and 21635. The species occurs mainly in the zone of *Gowericeras subitum.* At Mes. loc. 21635, it is associated with *Arcticoceras.* Some of the collections from the Sawtooth Range, such as 18610 and 18718, are not localized and may be from the *Arcticoceras* zone.

Genus Kepplerites Neumayr 1892

Kepplerites (Seymourites) mclearni Imlay

Plate 15; plate 16; plate 17, figures 1–8

Kepplerites (Seymourites) mclearni Imlay, U. S. Geol. Survey Prof. Paper 214–B, pp. 24, 25, pl. 8, figs. 1, 2, 5, 7, 10; pl. 9, fig. 1, 1948.

This is the most common species in the Little Rocky Mountains. It is represented by 45 specimens, most of them fragmentary and compressed, although the various growth stages are well shown. The immature specimens have a subquadrate whorl section about two-thirds as wide as high. During growth the whorls become relatively stouter, and in the adult the width is about five-sixths the height. The flanks are somewhat flattened, becoming less so during growth. The venter is runcinate and slightly concave up to a diameter of 1½ in. (38 mm), and some flattening is visible up to a diameter of 2¼ in. (60 mm). Thereafter, it changes to narrowly rounded, and, on the outer whorl is moderately rounded. The umbilical wall is low, rounds evenly into the flanks, is steeply inclined on the inner whorls, and is very gently inclined on the outer whorls. The umbilicus is narrow on the smallest whorls but widens rapidly at diameters of 4½ to 5½ in. and thereafter is wide. The body chamber is completely preserved on the largest specimen (see pl. 16) and is represented by one and one-quarter volutions.

The ornamentation changes little up to the body chamber. On the smaller whorls (pl. 17, figs. 1, 4, 5) the ribs are sharp and moderately spaced. The primary ribs are strong, elevated, and nearly radial, or curve backward slightly on the umbilical wall then curve forward on the lower fourth of the flanks and terminate in prominent, conical tubercles. The secondary ribs incline gently forward, are slightly flexuous at diameters of less than 1½ in., and cross the venter transversely. Bifurcation is the common mode of branching at all growth stages, but some trifurcation occurs at diameters greater than 2 inches. Most rib branches are separated by single intercalary ribs which begin at or slightly above the line of tubercles. On the intermediate whorls the ribbing gradually becomes coarse, and the tubercles remain fairly conspicuous as far as the body whorl. On the body whorl the ornamentation gradually changes. The tubercles disappear, single ribs become more common, and effacement of the ribbing occurs, especially on the lower part of the flanks. The specimen shown on pl. 17, figs. 3, 6, has at a diameter of about 2½ in. (60 mm) 25 primary ribs and about 85 secondary ribs. The holotype (pl. 15) at a diameter of about 8 in. (125 mm) has 36 primary ribs and about 106 secondary ribs. At a diameter of 12 in. (300 mm) it has 68 primary ribs and 142 secondary ribs.

The suture line is deeply dissected. Ventral lobe longer than wide; first lateral lobe a little longer than ventral lobe but narrower; second lateral lobe shorter than first lateral lobe. Saddles slightly wider than lobes; ventral saddle longer than wide and divided by a lobule, which is shorter than the saddle, into a small inner branch and a large outer branch; first lateral saddle bifid, a little smaller than ventral saddle, longer than wide; second lateral saddle smaller than first lateral saddle, nearly as wide as long, and has its inner branch on the umbilical margin. The tubercle is in the outer branch of the second lateral saddle.

The holotype is slightly compressed. Another specimen (U.S.N.M. 104124) that appears to be undistorted at a diameter of about 9 in. (230 mm) has a whorl height of 60 mm., a whorl thickness of 49 mm., and an umbilical width of about 175 millimeters. The small specimen shown on pl. 17, figs. 3, 6, has corresponding dimensions of 60 mm., 26 mm., 20 mm., and 17 mm.

The species is somewhat similar to *K. gitinsi* McLearn (1929, p. 8, pl. 3, fig. 1, pl. 4, fig. 1, pl. 8, fig. 5) but has much coarser ribbing, fewer secondaries, more prominent tubercles, and more complicated sutures, and a longer first lateral lobe. *K. plenus* (McLearn) (1929, p. 5, pls. 1, 2) and *K. loganianus* (Whiteaves) (1876, p. 27, pl. 8, fig. 2) have less similar ornamentation and thicker whorl sections. The ornamentation is similar to that in *Gowericeras*, but the primaries are shorter, the inner whorls are much more tightly coiled, the adults attain a much larger size, and the suture is somewhat different. It has much coarser ribbing and stronger tubercles than *K. rockymontanus* Imlay.

Holotype, U.S.N.M. 104125, paratypes, U.S.N.M. 104122–104124, 104126–104130.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 7124, 10730, 10732, 18726, 18737, 18738, 18750, 19203, 19211, 19572, 19583, and 19584.

Kepplerites (Seymourites) rockymontanus Imlay, n. sp.

Plate 18; plate 19, figures 1, 2

This species is represented in collections from Montana by 2 fairly well preserved specimens and by 10 fragments of which most have been crushed laterally. The adult whorls before compression were probably broadly rounded and wider than high. On the inner whorls the flanks are fairly flat, round abruptly into a low, vertical umbilical wall, and converge slightly above to the nearly flat venter. During growth the flanks become more convex and on the adult whorls round evenly into a low, gently inclined umbilical wall and an evenly rounded venter. The umbilicus is fairly narrow on the inner whorls but becomes wide on the adult. Most of the widening occurs at diameters between 4 and 5 in. On the largest specimen (pl. 18) the body chamber is incomplete, and is represented by slightly more than one complete volution.

On the inner whorls the ribs are sharp and moderately spaced. The primary ribs curve backward on the umbilical wall, curve forward on the lower third of the flanks, and terminate in small, acute, radially elongated tubercles. The secondary ribs incline gently forward, are slightly flexuous, and cross the venter transversely. Trifurcation is the common mode of branching posterior to the body whorl. Most rib branches are separated by single intercalated ribs which begin at or slightly above the line of tubercles. During growth the ribs gradually become more widely spaced and more elevated but the tubercles remain only moderately conspicuous. On the adult body chamber the ornamentation changes considerably. The tubercles disappear, the ribs become broader and lower, many ribs are single, branching occurs only in pairs, and intercalary ribs become uncommon.

The suture line is fairly deeply cut. Ventral lobe a little longer than wide; first lateral lobe about same length as ventral lobe but narrower; second lateral lobe shorter and relatively wider than first lateral lobe. Saddles are wider than lobes; ventral saddle longer than wide and divided by a lobule, which is shorter than the saddle, into a small inner branch and a large outer branch; first lateral saddle bifid, much smaller than ventral saddle, not as long as wide; second lateral saddle smaller than first lateral saddle, much wider than long, and has its inner branch on the umbilical margin. The tubercle is on the outer border of the second lateral saddle.

Most of the specimens are so distorted that accurate measurements cannot be made. The largest specimen must have had a diameter of 11 in. before compression.

This species differs from *K. mclearni* Imlay (1948, p. 24, pl. 8, figs. 1, 2, 5, 7–10, pl. 9, fig. 1) by having much weaker ornamentation, and more secondary ribs. The evolute coiling of its outer two whorls is in marked contrast to that of the described Canadian species, although the ribbing on its penultimate whorl resembles that in *K. gitinsi* McLearn (1927, p. 72, pl. 1, fig. 2; 1929, p. 8; pl. 3, fig. 1; pl. 4, fig. 1: pl. 8, fig. 5). Among the somewhat similar species from East Greenland, *K. rosenkrantzi* Spath (1932, p. 89, pl. 26, figs. 1a, b) may be distinguished by its weaker ribbing, and *K. peramplus* Spath (1932, p. 88, pl. 24, figs. 1a, b) by its weaker tubercles and greater involution.

Types.—Holotype, U.S.N.M. 104131; paratypes, U.S.N.M. 104146 a-c.

Occurrence.—Ellis group, Rierdon formation. *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 10730, 19203 and 19211, in the Little Rocky Mountains, Montana.

Kepplerites (Seymourites) cf. K. rosenkrantzi Spath

Plate 14, figure 9

Two crushed specimens belong to a species whose penultimate whorl bears vigorous ornamentation similar to that of *K. ingrahami* (McLearn) (1929, p. 9, pl. 7, figs. 1, 2) from British Columbia or that of *K. rosenkrantzi* Spath (1932, pl. 19, fig. 3, pl. 26, fig. 1) from East Greenland. Particularly conspicuous are the conical tubercles at the ends of the short, prominent primary ribs. From these pass three or four sharp, nearly straight secondaries that incline slightly forward. Between most rib-bundles are one or two intercalated ribs. This ornamentation changes completely on the body whorl where tuberculation is lacking and the ribbing consists of striae or of bundles of striae. The fading of the ribs is similar to that in *K. rosenkrantzi* but apparently has gone one step farther. The manner of coiling is likewise similar to that of *K. rosenkrantzi.* Comparisons of the whorl sections cannot be made because of defective preservation.

Figured specimen: U.S.N.M. 108279.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. loc. 7124.

Kepplerites (Seymourites) tychonis Ravn

Plate 20, figure 1–3

Macrocephalites sp. cf. *compressus* (Quenstedt) Madsen, Meddelelser om Grønland. Bind 29, p. 192, 1904.

Kepplerites tychonis Ravn, Meddelelser om Grønland, Bind 45, p. 490, pl. 37, fig. 1, 1911.

Kepplerites (Seymourites) tychonis Ravn, Spath, Meddelelser om Grønland, Bind 87, pp. 83–87, pl. 23, figs. 1–3, pl. 24, fig. 6, pl. 25, figs. 1–3, pl. 26, figs. 3, 6, 1932.

Kepplerites (Seymourites) cf. *K. tychonis* Ravn, Imlay, U. S. Geol. Survey Prof. Paper 214–B, p. 25, pl. 8, figs. 3, 4, 6, 1948.

The presence of this distinctive, finely ribbed species of Kepplerites in both Montana and Alaska has been confirmed by recent collections. In Montana it characterizes beds lying between the zones of *Gowericeras subitum* and *Kepplerites mclearni.* In Alaska it is associated with *Paracadoceras* and *Gulielmiceras* and occurs near beds that have furnished *Gowericeras.* It appears to be a useful stratigraphic marker for beds equivalent to the lower part of the *Sigaloceras calloviense* zone.

Figured specimens: U.S.N.M. 104172, 104173.

Ellis group, Rierdon formation. *Kepplerites tychonis* beds, U.S.G.S. Mes. locs. 19194, 19629, 20360, 20363, 20390, and 20391.

Kepplerites (Seymourites) landuskiensis Imlay, n. sp.

Plate 19, figure 3, 6–8

Four specimens of this species are at hand. Of these, two are fragments of the penultimate whorl. The holotype appears to be nearly undeformed, although one side is much corroded and its inner whorls are not preserved. Whorls ovate, higher than wide, becoming lower on the anterior third of the body whorl. Flanks somewhat flattened, converging toward venter, rounding evenly into umbilicus. Venter flattened on penultimate whorl, narrowly arched on body whorl. Umbilicus narrow at posterior end of penultimate whorl, becoming wide anteriorly: umbilical wall low and vertical on penultimate whorl, becoming gently inclined on body whorl. Body chamber represented by about five-sixths of a whorl. Aperture marked by a weak, forwardly inclined constriction.

The ribbing on the penultimate whorl is sharp and fairly widely spaced. The primary ribs are radial on the umbilical wall, curve forward on the lower third of the flanks, and terminate in small, conical tubercles. From these pass two or three weaker secondary ribs that incline forward in a gently flexuous manner but cross the venter transversely. Most rib bundles are separated by single intercalated ribs. Anteriorly on the body whorl the ribs become fairly thick, closely-spaced, and more inclined on the flanks, bifurcation becomes the common mode of branching, and the point of furcation becomes lower. Tiny, conical tubercles persist as far as the aperture. The body whorl of the holotype has 47 primary ribs and 146 secondary ribs.

The suture line is poorly preserved. The holotype at a diameter of 140 mm has a whorl height of 50 mm. At the anterior end the diameter is 161 mm, the whorl height 48 mm, and the whorl thickness about 39 mm.

Compared with *K. rockymontanus* Imlay, this species becomes evolute much more quickly, has fewer secondary ribs, and more persistent tuberculation. Its lateral aspect is similar to that of *K. rosenkrantzi* Spath (1932, p. 89, pl. 19, fig. 3, pl. 26, fig. 1), but it is more compressed, has weaker tubercles, and fewer secondary ribs. *K. peramplus* Spath (1932, p. 88, pl. 24, figs. 1a, b) is much stouter, has more flexuous ribbing, and weaker tubercles.

Holotype, U.S.N.M. 108280; paratype, U.S.N.M. 108281.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 18735 and 18726.

Kepplerites (Seymourites) planiventralis Imlay, n. sp.

Plate 20, figures 4–9

The three specimens illustrated are the only known representatives of the species. Whorl section elliptical, much higher than wide. Flanks flattened, rounding rather abruptly into umbilical wall. Venter highly arched, and marked by a persistent narrow, flattened area along the mid-ventral line. Umbilicus narrow at posterior end of penultimate whorl but widening fairly rapidly anteriorly; wall low and vertical on penultimate whorl, becoming steeply inclined on body whorl. Body chamber incomplete, represented by at least half a whorl.

The ribbing is sharp, widely spaced and decidedly flexuous. The primary ribs are radial on the umbilical wall, curve forward on the lower two-fifths of the flanks, and terminate in small, conical tubercles. From these on the penultimate whorl pass bundles of two or three secondary ribs that tend to curve forward near the middle of the flanks but cross the venter transversely. On the body chamber the furcation points become indistinct. Some intercalated ribs arise at or just above the zone of tuberculation. Others occur only on the upper third of the flanks. Forward arching of the ribs on the flanks is not nearly as conspicuous as on the penultimate whorl.

The suture line is not well preserved.

The holotype at a diameter of 111 mm has a whorl height of 47 mm and a whorl thickness of 37 mm. At a diameter of 150 mm, the whorl height is 61 mm and the whorl thickness 41 mm.

This species most resembles *K. landuskiensis* of any of the associated species in the Rierdon formation. Its ribbing is coarser on the penultimate whorl, more widely spaced on the body whorl, and much more flexuous on the flanks; its form is much more compressed; and the persistent ventral flattening is quite distinctive. It is much more compressed than *K. rosenkrantzi* Spath (1932, p. 89, pl. 19, fig. 3, pl. 26, fig. 1), which has similar ribbing.

Holotype, U.S.N.M. 108282; paratypes, U.S.N.M. 108283, 108284.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 18754 and 19211.

Genus Gowericeras Buckman 1921

Gowericeras subitum Imlay

Plate 21, figures 1–18; plate 22, figure 9

Cadoceras subitum Imlay, U. S. Geol. Survey Prof. Paper 214–B, pp. 22–24, pl. 7, figs. 1–11, 1948.

This species is represented in collections in hand by about 80 specimens and is much more common than any of the associated species of *Gowericeras*.

The inner whorls are subquadrate, higher than wide, embrace about four-fifths, have flattened flanks that round rather abruptly into a flattened venter, and have a low, steep umbilical wall. During growth the whorls become subovate, wider than high, thickest near the umbilicus, and considerably more evolute; the flanks become gently convex and round evenly into a moderately broad venter; the umbilicus changes from fairly narrow to moderately wide; the umbilical wall becomes moderately high, nearly vertical, and rounds rapidly into the flanks. The body chamber is represented by about five-sixths of a whorl. The aperture is inclined forward in a slightly sinuous manner. It is preceded by two weak ribs behind which is a broad shallow constriction that is not evident on the venter (pl. 21, figs. 11, 12).

The character of the ribbing changes fairly abruptly several times during growth following a constriction and then an abrupt thickening of the whorl section, but the greatest change occurs at the beginning of the adult body chamber. The smallest whorls (pl. 21, figs. 5, 8, 9) up to a diameter of about 30 mm have moderately strong primary ribs that are widely spaced, incline backward slightly on the umbilical wall, incline forward on the lower third of the flank, and terminate abruptly in weak, radially elongated tubercles. From the tubercles arise pairs of secondary ribs that are considerably weaker than the primary ribs. Between successive rib pairs are two or three intercalary ribs that begin between the tubercles and the middle of the flank and are as strong as the paired ribs. The paired and intercalary ribs incline forward on the flanks and cross the venter transversely or with a slight forward bend.

At a diameter of about 30 mm the shell has a rather pronounced constriction that is followed by an abrupt thickening of the whorl section (pl. 21, figs. 2, 3). Several other constrictions are generally present in the next three-fourths whorl up to a diameter of about 45 mm. The thickening is accompanied by coarsening of the primary ribs which become relatively much stronger than the secondaries. The primaries terminate in weak radially elongate tubercles from which pass two or three secondaries. Intercalary ribs become less common anteriorly and generally only one is present between successive groups of branched ribs. The forward inclination of the ribs is very marked, and the secondaries bend forward gently on the venter.

On the body chamber the primary ribs abruptly become much stronger and more widely spaced. The weak radially elongate tubercles persist, but branching occurs well above the tubercles at or above the middle of the flanks. For most primary ribs there are generally three secondaries, of which two are connected with the primary and the other begins high on the flank. Near the aperture there are only two secondaries for each primary. All secondary ribs bend forward considerably on the venter and are slightly weaker there than on the flanks.

The suture line (pl. 21, fig. 10) is rather simple. Ventral lobe longer than wide; first lateral lobe trifid, slightly longer than wide, a little shorter than ventral lobe; second lateral lobe trifid, much smaller than first lateral lobe. Saddles wider than lobes; ventral saddle bifid with largest branch on outer side, as long as wide; first lateral saddle broad and bifid, much smaller than ventral saddle. The tubercle is in the outer branch of the first lateral saddle.

This species is characterized by the abrupt coarsening of the ribbing at the beginning of the body chamber and by the ribs becoming widely spaced on the anterior half of the body whorl.

Dimensions in millimeters and in ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 21, figs. 8, 9).	25	11.5 (0.46)	8.5 (0.34)	6 (0.24)
Paratype (pl. 21, figs. 2, 3).	42	19. (0.45)	20. (0.48)	11 (0.26)
Holotype (pl. 21, figs. 13, 14).	56	24. (0.43)	25. (0.45)	16 (0.29)
Paratype (pl. 21, fig. 4).	61	23. (0.38)	?	19 (0.31)
Paratype (pl. 21, figs. 17, 18).	71	26. (0.37)	26. (0.37)	24 (0.34)

Holotype, U.S.N.M. 104155; paratypes, U.S.N.M. 104153, 104154, 104156a–c; plesiotypes, U.S.N.M. 108285a–c, 108286, 108287a, b.

Ellis group, Rierdon formation, *Gowericeras subitum* beds, U.S.G.S. Mes. locs. 19169, 19175, 19179–19182, 19602, 19616, and 20365.

Gowericeras subitum var. distinctum Imlay, n. var.

Plate 22, figures 5, 6

One adult specimen having a well-preserved aperture differs from the typical form of *G. subitum* by the more gradual coarsening of the ribbing on the body whorl, closer spacing of the primary ribs, and fewer secondary ribs for each primary. The ribbing on the body whorl is much weaker and denser than in *Gowericeras costihians* Imlay. *Gowericeras approximatum* (Buckman) (1922, pl. 336) has similar ornamentation and shape, but bears distinct ventral tubercles bordering a flattened mid-ventral area.

Holotype, U.S.N.M. 108288.

Ellis group, Rierdon formation, *Gowericeras subitum* beds, U.S.G.S. Mes. locs. 19179.

Gowericeras costihians Imlay, n. sp.

Plate 22, figures 1–4, 7, 8

This species is represented by 8 specimens that show only the outer two whorls. Whorls subovate, wider than high, embracing about three-fourths. Anterior part of body whorl contracting somewhat from remainder of shell. Flanks gently convex. Venter broadly rounded. Umbilicus changes from fairly narrow to moderately wide; wall vertical at base, rounds rapidly into flanks. Body chamber incomplete, represented by nearly three-fourths of a whorl.

The ribbing is strong, rather widely spaced, and coarsens gradually on the outer two whorls. The primary ribs are prominent, widely separated, nearly radial, and terminate at the top of the lower two-fifths of the flanks in small, acute tubercles. From these pass two slightly weaker secondary ribs that incline forward on the flanks, arch forward gently on the venter, and are not reduced in strength along the mid-ventral line. The pairs of forked ribs are separated by single short ribs which pass across the venter into paired ribs.

The first lateral lobe is slightly longer than the ventral lobe. The second lateral lobe is much shorter than the first. The saddles are broader than the lobes. The tubercle is in the inner branch of the first lateral saddle.

The specimens are either too distorted or too incomplete for accurate measurements.

This species bears considerable resemblance to *G. subitum* Imlay. It differs by having a thicker whorl section and stronger, sharper, more widely-spaced ribbing that is particularly stronger on the venter of the adult body chamber.

Holotype, U.S.N.M. 108289; paratypes, U.S.N.M. 108290, 108314.

Ellis group, Rierdon formation, *Gowericeras subitum* beds, U.S.G.S. Mes. locs. 19169, 19179, 19180, and 19182.

Gowericeras costimedium Imlay, n. sp.

Plate 23, figures 14–16

This species is represented by three specimens, of which two are fragments of the body whorl. Shell stout for genus. Whorls semicircular in section, wider than high, embracing about three-fifths. Flanks and venter evenly rounded. Umbilicus moderately wide, widening rapidly near end of body whorl; wall fairly low, steeply inclined, rounding evenly into flanks. Body chamber incomplete but represented by at least three-fourths of a whorl.

The ribs on the body whorl are low, moderately spaced, incline forward slightly on the flanks, and cross the venter transversely. The primary ribs are nearly twice as strong as the secondary ribs and terminate in radially elongate tubercles at about the top of the lower two-fifths of the flanks. From these tubercles pass three or four secondary ribs. Single, short ribs are intercalated between most rib bundles. The body whorl bears 23 primary ribs and about 80 secondary ribs.

The suture line is characterized by broad saddles and narrow lobes. The first lateral lobe is about the same length as the ventral lobe. The tubercle is in the outer branch of the first lateral saddle.

The holotype at a diameter of 64 mm has a whorl height of 25 mm, a whorl thickness of 28.5 mm, and an umbilical width of 24 mm.

This species differs from *G. subitum* and its varieties by having weaker, denser ribbing that does not coarsen rapidly on the body whorl. Its ribbing is similar to that on *G. planum* Buckman (1922, pl. 287), although probably not as dense. In this respect it is intermediate between *G. planum* and *G. metorchum* Buckman (1921, pl. 254).

Holotype, U.S.N.M. 108291.

Ellis group, Rierdon formation, *Gowericeras* beds, U.S.G.S. Mes. locs. 19179, 19180, 19585.

Gowericeras costicrassum Imlay, n. sp.

Plate 23, figures 1–12, 18

This species is represented by 10 specimens. Shell very stout, coronate. Whorls semicircular in section, much wider than high, embracing about three-fifths. Flanks convex. Venter broadly rounded, faintly flattened at diameters less than 20 mm. Umbilicus moderately narrow, widening slightly at anterior end of body whorl; wall high, vertical at base, steeply inclined above and rounding rather abruptly into flanks. Body chamber represented by about four-fifths of a whorl. Aperture inclined forward, abruptly truncated, preceded by a single, strong rib.

The ribbing is vigorous and the lateral spines are prominent. The primary ribs are high and narrow, trend radially on the umbilical wall, and curve forward on the lower two-fifths of the flanks where they terminate in acute tubercles. From the tubercles pass two- or rarely three, narrow but weaker secondary ribs that incline forward on the flanks and arch forward gently on the venter. Most sets of branched ribs are separated by single, short ribs. A marked diminution in strength of the secondary ribbing occurs on half a whorl between diameters of about 22 to 27 mm. This diminution does not affect the primary ribs or the tubercles and is not related to changes in whorl shape. Anteriorly all ornamentation becomes more prominent and more widely spaced. The small specimen shown on pl. 23, figs. 5–7, has 78 secondary ribs and 21 primary ribs. The much larger holotype has 68 secondary ribs and 21 primary ribs.

The suture line has broad saddles and narrow lobes. The first lateral lobe is shorter than the ventral lobe. The tubercle is in the inner branch of the first lateral saddle.

This species is characterized by its stout form and coarse ornamentation. It is more coronate than any described species of *Gowericeras*.

Holotype, U.S.N.M. 108294; paratypes, U.S.N.M. 108292, 108293a, b, 108295a, b.

Ellis group, Rierdon formation, *Gowericeras sub-*

itum beds, U.S.G.S. Mes. locs. 19169, 19170, 19180, 19182, and 19602.

Dimensions in millimeters and in ratios are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Paratype (pl. 23, figs. 12, 18).	21.5	9 (0.42)	11 (0.51)	6? (0.28)
Paratype (pl. 23, figs. 10, 11).	26	12 (0.46)	18 (0.69)	7 (0.27)
Paratype (pl. 23, figs. 5, 7).	35	17 (0.48)	21 (0.60)	9 (0.26)
Paratype (pl. 23, fig. 4).	43	19 (0.44)	26 (0.60)	12 (0.28)
Holotype (pl. 23, figs. 1, 3).	71	28 (0.39)	41 (0.57)	23 (0.32)

Gowericeras costidensum Imlay, n. sp.

Plate 22, figures 10–13

Seven specimens of this species are available. These show only the body whorl. Shell fairly stout. Whorls semicircular in section, wider than high, embracing preceding whorl about three-fifths. Flanks evenly convex. Venter broadly convex. Umbilicus moderately narrow; wall vertical at base, rounding evenly into flanks. Body chamber represented by three-fourths of a whorl. Aperture inclined forward, abruptly truncated, preceded by two weak single ribs.

The ribbing is fine and dense. The primary ribs are narrow, much stronger than the secondary ribs, trend backward on the umbilical wall, and curve forward on the lower two-fifths of the flanks, where they terminate in tiny, acute tubercles. From the tubercles pass bundles of 3 or 4 thread-like secondary ribs, between which lie 2 or 3 short ribs that begin a little higher than the zone of tuberculation. The secondary ribs incline forward on the flanks and arch forward gently on the venter. They are so fine that despite their large number they are separated by interspaces from 2 to 3 times their own width. Near the anterior end of the holotype there are about 25 secondary ribs in 25 mm and on the paratype at a comparable position about 21 ribs in 25 mm.

The suture line is poorly preserved and cannot be traced.

The holotype is too distorted for accurate measurements. The paratype at a diameter of 53 mm has a whorl height of 23 mm, a whorl thickness of 29 mm, and an umbilical width of 16 mm.

The species is characterized by its fine, dense ribbing and its fairly stout form. Among European species, *Gowericeras toricellii* (Oppel) (in Buckman, 1922, pl. 292) has nearly as dense ribbing but it is not as stout and its venter is flattened. None of the species of *Gowericeras* from Alaska or the western interior of the United States has comparable ribbing.

Holotype, U.S.N.M. 108297; paratype, U.S.N.M. 108296.

Ellis group, Rierdon formation, at base of *Gowericeras* beds, U.S.G.S. Mes. locs. 18718, 19170, 19212, 19576 and 19585. This species has been found associated with *Cadoceras shoshonense* Imlay but not with *Gowericeras subitum* Imlay. In the Little Rocky Mountains it was found at Chalk Butte dome only 1 foot above a specimen of *Arcticoceras codyense* Imlay and at Camp Creek dome only 5 ft. above *Arcticoceras codyense*. In the Big Snowy Mountains it was collected within 15 ft. of the base of the Rierdon formation. In the Sawtooth Range south of Glacier Park, it was obtained near the top of the Rierdon formation directly below beds containing *Gowericeras subitum* and directly above beds containing *Arcticoceras*.

Genus Cosmoceras Waagen 1869

Subgenus Gulielmiceras Buckman 1920

Cosmoceras (Gulielmiceras) knechteli Imlay, n. sp.

Plate 5, figures 1–5

This species is represented by 16 specimens. Whorls elliptical, much higher than wide, embracing about two-thirds. Flanks flattened below, converging slightly above, rounding abruptly into the umbilical wall. Venter narrow, truncated, slightly concave. Umbilicus fairly narrow, shallow, not enlarging on body whorl; wall low and vertical. Body chamber represented by three-fourths of a whorl. Aperture not perfectly preserved, but the posterior end of the lateral lappet is present on several specimens.

The ribbing is dense, fine, and flexuous. The primary ribs are narrow and a little higher than the secondary ribs. They trend backward on the upper part of the umbilical wall and trend forward on the lower third of the flanks where they terminate in small tubercles that are elongate radially. The primary ribs are slightly swollen on the umbilical edge without forming true tubercles. The secondary ribs bend forward near the middle of the flanks and then recurve slightly and cross the venter transversely. Near the lateral lappet the forward bending becomes pronounced. Bifurcation is the common mode of rib branching and most pairs of forked ribs are separated by single ribs that begin along the line of furcation. A few intercalated ribs arise higher on the flanks. Where the secondary ribs cross the ventro-lateral shoulders they give rise to tongue-shaped tubercles that are steepest on their anterior sides. The body whorl of the holotype has 42 primary ribs and 113 secondary ribs.

The suture line cannot be traced.

The holotype has been crushed laterally so that measurements are useless. The paratype shown on plate 5, figures 1 and 2, at a diameter of about 35 mm, has a whorl height of 17 mm a whorl thickness of 10.5 mm, and an umbilical width of 7.5 mm.

This species is characterized by its dense ribbing and compressed shape. Its ribbing is similar to that of a *Gulielmiceras* from England figured by Brinkman (1929, pl. 1, fig. 1), but it differs by having a ribbed venter and by lacking umbilical tubercles. *C.* (*G.*) *pauper* Spath (1932, p. 96, pl. 24, figs. 3a, b; pl. 26, fig. 5) has weaker ribbing and is less compressed.

This species is named in honor of Maxwell M. Knechtel of the Geological Survey who spent several summers studying the geology of the Little Rocky Mountains.

Holotype, U.S.N.M. 104152; paratypes, U.S.N.M. 104151 and 108298.

Ellis group, Rierdon formation, *Kepperites mclearni* beds, U.S.G.S. Mes. localities 10730, 10732, 11973, 18726, 18737, 19203, 19211, 19584.

Cosmoceras (Gulielmiceras) zortmanense Imlay, n. sp.

Plate 14, figures 1–6, 8

This species is represented by 18 specimens, of which most are fragmentary. Whorls subovate, a little higher than wide, embracing about two-thirds. Flanks rather flattened in their lower parts, converging gently in upper parts, rounding abruptly into umbilical wall. Venter narrow, truncated, slightly concave. Umbilicus fairly narrow, shallow, not enlarging on body whorl; wall low and vertical. Body chamber represented by three-fifths of a whorl. Posterior end of lateral lappet preserved on five specimens.

The ribbing is fine, fairly closely spaced, and moderately flexuous. The primary ribs are high and narrow, trend nearly radially on the umbilical wall, curve forward on the lower third of the flanks, and terminate in weak radially elongate tubercles. From these pass pairs of secondary ribs that bend forward near the middle of the flanks but cross the venter transversely. Between most of the pairs are single ribs that begin at or just above the zone of furcation. Near the lateral lappet the secondary ribs bulge forward considerably. On the ventro-lateral angles the ribs are produced in tongue-shaped tubercles that are steepest on their anterior sides.

The suture line is poorly preserved. The paratype shown on pl. 14, figs. 3, 4, at a diameter of 35 mm has a whorl height of 13.5 mm, a whorl thickness of 9 mm, and an umbilical width of 10 mm.

This species differs from *C.* (*Gulielmiceras*) *knechteli* Imlay in its sparser, coarser ribbing, lower whorl section, broader venter, and slightly wider umbilicus. Its ribbing is nearly the same as in a species occurring in the lower part of the Chinitna siltstone in Alaska, but it is more compressed and its venter narrower.

Holotype, U.S.N.M. 108299; paratypes, U.S.N.M. 108300–108302.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 10729, 18735, 18742, and 18750.

Cosmoceras (Gulielmiceras) vigorosum Imlay, n. sp.

Plate 9, figures 4, 5, 9

One nearly complete adult specimen has much coarser ribbing than any of the associated forms of *Gulielmiceras*. Whorls elliptical, much higher than wide, embracing about two-thirds. Flanks flattened in lower two-thirds, converging slightly above into a narrow, truncated venter. Umbilicus fairly narrow, shallow, not enlarging on body whorl; wall low and vertical. Body chamber occupies about three-fourths of a whorl. Aperture not perfectly preserved, but there are remnants of a lateral lappet extending about 6 mm beyond the most anterior rib.

The ribbing is prominent and fairly widely spaced. The primary ribs curve forward on the lower third of the flanks and terminate in small radially elongate tubercles. From these pass pairs of secondary ribs, of which one rib is commonly indistinctly connected. In addition, most rib pairs are separated by single intercalated ribs that begin along the zone of furcation. All the secondary ribs bend forward near the middle of the flanks, then recurve slightly, curve forward again near the venter, and cross the venter transversely. The forward bending becomes accentuated near the aperture. Small tongue-shaped tubercles arise from the ribs along the ventro-lateral shoulders.

The suture line is poorly preserved.

The holotype at a diameter of 46 mm has a whorl height of 19 mm, a whorl thickness of 11 mm, and an umbilical width of 13 mm. The specimen has been slightly crushed laterally.

The species has coarser ribbing than *C.* (*G.*) *zortmanense* Imlay. Compared with *C.* (*G.*) *stutchburii*

(Pratt) (Buckman, 1924, pl. 531), from England, its ribbing is less sharp, its involution is greater, and it lacks umbilical tubercles. It is finer ribbed and less tuberculate than a species from Russia described by Nikitin (1881a, p. 70, pl. 4, fig. 31), but resembles it in the absence of umbilical tubercles. Its shape, and its ribbing are similar to that of *Sigaloceras enodatum* of Lahusen (1883, p. 55, pl. 6, fig. 9), which does not appear to be the same species as described by Nikitin (1881b, p. 112, pl. 3, figs. 12, 13).

Holotype, U.S.N.M. 108303.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. loc. 18754.

Subgenus Gulielmites Buckman 1923

Cosmoceras (Gulielmites) cf. C. obductum (Buckman)

Plate 8, figures 3–5

Two fragments have weak umbilical, lateral and ventral tubercles and fine, flexuous, ribbing that is indistinct on the lower part of the flanks but sharp on the ventral region. The venter is distinctly flattened. The ornamentation closely resembles that of *C.* (*Gulielmites*) *obductum* (Buckman) (1925, pl. 559) and is a little coarser than that of *C.* (*Gulielmites*) *delicatus* (Buckman) (1924, pl. 521).

Figured specimens, U.S.N.M. 108304, 108305.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. locs. 10729, 18735.

Cosmoceras (Gulielmites) cf. C. jason (Reinecke)

Plate 8, figures 1, 6, 8

One small fragment has three rows of tubercles, flexuous ribbing, indistinct furcation, and continuous ribbing across a flattened venter. The ventral tubercles are larger than the others, and elongated spirally. In several places two ribs unite in a ventral tubercle. The umbilicus is narrow.

The ribbing is coarser than that of most species of *Gulielmites,* but is not much coarser than some specimens from France assigned to *Cosmoceras* (*Gulielmites*) *jason* (Reinecke) by Douvillé (1915, pl. 10, figs. 6-8), or from Russia assigned to *C. jason* by D'Orbigny (1845, p. 442, pl. 36, figs. 9-15). The narrow umbilicus is more similar to that of the Russian than of the French specimens.

Figured specimen, U.S.N.M. 108306.

Ellis group, Rierdon formation, *Kepplerites mclearni* beds, U.S.G.S. Mes. loc. 19196.

Genus Procerites Siemiradzki 1898

Procerites spp.

Plate 23, figures 13, 17; plate 24, figures 9–11

A few specimens of *Procerites* have been found in the *Arcticoceras* and *Gowericeras* beds of the lower part of the Rierdon formation in central and western Montana. Most of them are poorly preserved septate fragments that indicate adults ranging from 8 to 12 in. in diameter. Their preservation is generally too poor for illustration. Four fragments from U.S.G.S. Mes. loc. 18753 in the Little Rocky Mountains show some resemblance to *Procerites funatus* (Oppel) in Neumayr (1871, p. 40, pl. 14, figs. 1a, b), but have wider spaced ribs. Some specimens from U.S.G.S. Mes. localities 18718, 19597, and 19600 in the Sawtooth Range in Montana have rather weak ribbing similar to that of *Procerites tmetolobus* Buckman (1923, pl. 416). The specimens herein figured are from Mesozoic localities 18718 and 19603 in the Sawtooth Range and may be compared with *P. moorei* (Oppel) in Neumayr (1871, p. 39, pl. 13, figs. 1a, b, c). They differ in having weaker primary ribs and forwardly inclined secondary ribs.

Figured specimens, U.S.N.M. 108307, 108308.

Ellis group, Rierdon formation, *Arcticoceras* beds, U.S.G.S. Mes. localities 18718, 18753, 19597, and 19600; *Gowericeras subitum* beds at Mes. locality 19603.

Genus Grossouvria Siemiradzki 1898

Grossouvria warmdomensis Imlay, n. sp.

Plate 19, figures 4, 5

This species is represented by the holotype and by a small fragment of a septate whorl that is a little larger than the holotype. Whorl ovate in section, slightly wider than high, rather evolute; flanks gently convex, rounding gradually into umbilical wall and evenly arched venter. Umbilicus moderately narrow and deep; wall vertical at base, rounded above. Body chamber unknown.

The ribs are characterized by their width and by curving backward along the ventral margins. They trend radially on the umbilical wall, incline strongly forward on the flanks, recurve abruptly on the margins of the venter, and cross the venter transversely or with a slight backward arch. They are not reduced in strength along the venter. The primary ribs are fine on the umbilical wall, much broader than the interspaces on the flanks, and nearly half of them divide into two slightly weaker secondary ribs high on the flanks. Most pairs of forked ribs are separated by one unforked rib, but some are separated by two. Invariably a rib that is single on one flank passes across the venter into a branch of a forked rib.

The suture line is not preserved.

The holotype at a diameter of 43 mm has a whorl height of 17 mm, a whorl thickness of 16 mm, and an umbilical width of 13 mm. At a diameter of 35 mm the whorl width slightly exceeds the height. The specimen has been compressed slightly, mostly at its anterior end.

In lateral views the ribbing of this species resembles that of *G. retrocostatus* (Petitclerc) as figured by Corroy (1932, p. 148, pl. 20, figs. 9, 10), but the ribs are not interrupted along the midventral line and the coiling is less evolute. Most species of *Grossouvria* have narrower and more widely spaced ribs.

Holotype, U.S.N.M. 108309.

Ellis group, Rierdon formation, *Gowericeras costidensum* beds, U.S.G.S. Mes. loc. 19585.

Grossouvria spp.

Plate 24, figures 1–8

One weathered specimen (pl. 24, fig. 7) from the *Gowericeras subitum* zone in the Sawtooth Range of Montana differs from *G. warmdomensis* Imlay in its finer and more widely spaced ribbing and is possibly only a variety of that species. It appears to be more finely ribbed than most of the described species from Europe.

Several fragments (pl. 24, figs. 1, 3, 8) from the *Kepplerites mclearni* zone in the Sweetgrass Hills may be compared with *G. calloviense* (Loczy) (1915, p. 380, pl. 22 (10), figs. 1, 2) from Hungary. The backward curvature of the ventral ribbing is conspicuous and the ribs are reduced in strength along the mid-ventral line.

Three specimens (pl. 24, figs. 2, 4-6) from the *Gowericeras subitum* zone in the Big Snowy Mountains belong to a species that differs from *G. warmdomensis* Imlay in having a subquadrate whorl section, flattened flanks, lower points of rib branching, and finer ribbing. It is more involute than most species of *Grossouvria* but resembles a species described by Neumayr (1871, p. 34, pl. 12, figs. 4a, b) as *Perisphinctes aurigerus* Oppel. Likewise, its ribbing is weaker on the lower parts of the flanks than in most species of *Grossouvria.* However, a generic assignment to *Grossouvria,* or possibly to *Siemiradzkia* is indicated by the backward curvature of the secondary ribs and by the presence of many single ribs.

Figured specimens, U.S.N.M. 108310a–c, 108311–108313.

Ellis group, Rierdon formation, *Gowericeras subitum* beds at U.S.G.S. Mes. localities 19180, 19182, and 20365, and *Kepplerites mclearni* beds at Mes. localities 21467.

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[*Italic numbers indicated descriptions*]

☆ U. S. GOVERNMENT PRINTING OFFICE: 1953—209238

PLATES 1-24

PLATE 1

[Figures natural size unless otherwise indicated]

FIGURES 1, 2, 5, 9. *Xenocephalites phillipsi* Imlay, n. sp. (p. 18).
  1, 2, 9. Holotype, U.S.N.M. 108238. From U.S.G.S. Mes. loc. 10730, Rierdon formation. Suture line drawn near end of chambered shell.
  5. Paratype, U.S.N.M. 108239. From U.S.G.S. Mes. loc. 10730, Rierdon formation.

3, 4, 6, 8. *Xenocephalites bearpawensis* Imlay, n. sp. (p. 19).
  3, 4. Holotype, U.S.N.M. 108240. From U.S.G.S. Mes. loc. 10732, Rierdon formation.
  6. Paratype, U.S.N.M. 108242. From U.S.G.S. Mes. loc. 18758, Rierdon formation.
  8. Paratype, U.S.N.M. 108241. From U.S.G.S. Mes. loc. 10732, Rierdon formation.

7. *Xenocephalites* cf. *X. nikitini* (Burckhardt), (p. 19).
  U.S.N.M. 108243. From U.S.G.S. Mes. loc. 18737, Rierdon formation.

10–13. *Lilloettia* sp. ind. (p. 18).
  10, 12. Lateral view of specimen, U.S.N.M. 108236. From U.S.G.S. Mes. loc. 19583, Rierdon formation.
  11, 13. Lateral and apertural view of specimen, U.S.N.M. 108237. From U.S.G.S. Mes. loc. 19584, Rierdon formation.

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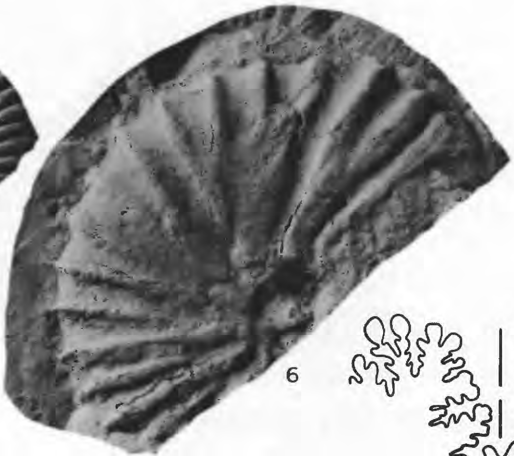

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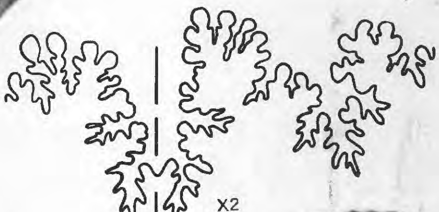

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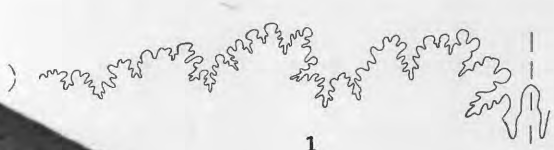
XENOCEPHALITES AND LILLOETTIA

PLATE 2

[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Arcticoceras rierdonense* Imlay, n. sp. (p. 19).
Lateral view and last suture line of holotype, U.S.N.M. 108244. From U.S.G.S. Mes. loc. 19593, Rierdon formation.



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ARCTICOCERAS

PLATE 3

[Figures natural size unless otherwise indicated]

FIGURES 1–6. *Arcticoceras crassicostatum* Imlay, n. sp. (p. 20).
- 1, 2. Holotype, U.S.N.M. 108250. From U.S.G.S. Mes. loc. 20496, Sundance formation, Canyon Springs sandstone member.
- 3, 4. Paratype, U.S.N.M. 108251a. From same locality as holotype.
- 5, 6. Paratype, U.S.N.M. 108251b. From same locality as holotype. Note that anterior end is directed downward.

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- 7, 8. Holotype, U.S.N.M. 108252. From U.S.G.S. Mes. loc. 20496, Sundance formation, Canyon Springs sandstone member.
- 9, 10. Paratype, U.S.N.M. 108253a. From same locality as holotype.
- 11, 12. Paratype, U.S.N.M. 108253b. From same locality as holotype.
- 14. Paratype, U.S.N.M. 108254. From U.S.G.S. Mes. loc. 19556, Sundance formation, Stockade Beaver shale member.

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- 13, 15. Specimen, U.S.N.M. 108248. From U.S.G.S. Mes. loc. 19600, Rierdon formation.
- 17. Lateral view of specimen, U.S.N.M. 108249. From U.S.G.S. Mes. loc. 18610, Rierdon formation.

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- 16. Suture line of paratype, U.S.N.M. 108245a. From U.S.G.S. Mes. loc. 18610, Rierdon formation. Suture line drawn at whorl height of 96 mm.
- 18. Paratype, U.S.N.M. 108246. From U.S.G.S. Mes. loc. 19397, Rierdon formation.
- 21, 22. Paratype, U.S.N.M. 108245b. From U.S.G.S. Mes. loc. 18610, Rierdon formation.

19, 20. *Arcticoceras* sp. juv. cf. *A. rierdonense* Imlay, n. sp. (p. 20).
- U.S.N.M. 108247a, b. From U.S.G.S. Mes. loc. 18610, Rierdon formation.


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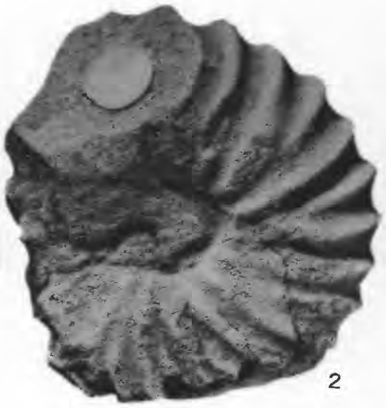
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ARCTICOCERAS

PLATE 4

[Figures natural size unless otherwise indicated]

Figures 1–13. *Arcticoceras codyense* Imlay (p. 21).

- 1, 4, 6. Holotype, U.S.N.M. 104132. From U.S.G.S. Mes. loc. 17106, Sundance formation.
- 2, 3. Plesiotype, U.S.N.M. 108257a. From U.S.G.S. Mes. loc. 20497, Sundance formation, Canyon Springs sandstone member.
- 5. Suture line of paratype 104133a. From U.S.G.S. Mes. loc. 19589, Rierdon formation. Suture line drawn at whorl height of 110 mm.
- 7, 8. Plesiotype, U.S.N.M. 108256. From U.S.G.S. Mes. loc. 20496, Sundance formation, Canyon Springs sandstone member.
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- 13. Sectional diagram of paratype, U.S.N.M. 104133c. From U.S.G.S. Mes. loc. 19589, Rierdon formation.


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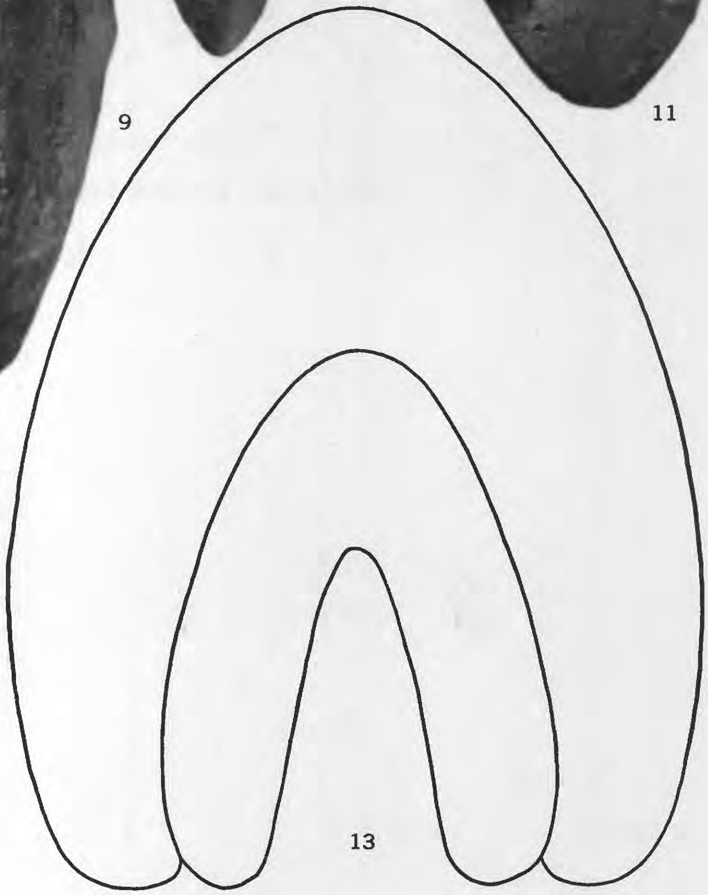
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ARCTICOCERAS

PLATE 5

[All figures natural size]

FIGURES 1–5. *Cosmoceras (Gulielmiceras) knechteli* Imlay, n. sp. (p. 31).
- 1, 2. Paratype, U.S.N.M. 104151. From U.S.G.S. Mes. loc. 19211, Rierdon formation.
- 3. Paratype, U.S.N.M. 108298. From U.S.G.S. Mes. loc. 19203, Rierdon formation.
- 4, 5. Holotype, U.S.N.M. 104152. From U.S.G.S. Mes. loc. 18726, Rierdon formation.

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- 8, 9. Plesiotype, U.S.N.M. 108259. From U.S.G.S. Mes. loc. 19556, Sundance formation, Stockade Beaver shale member.
- 11. Holotype, U.S.N.M. 314. From southwest base of Black Hills, South Dakota. Sundance formation.


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COSMOCERAS AND ARCTICOCERAS

PLATE 6

[All figures natural size]

FIGURES 1–14. *Cadoceras shoshonense* Imlay (p. 23).

1, 2. Plesiotype, U.S.N.M. 108261a; 3, 4, plesiotype, U.S.N.M. 104145a; 5, 6, plesiotype, U.S.N.M. 108261b; 7, 11, plesiotype, U.S.N.M. 104145b. All from U.S.G.S. Mes. loc. 19169, Rierdon formation.

8. Plesiotype, U.S.N.M. 104142. From U.S.G.S. Mes. loc. 19179.

9, 13, 14. Last suture line and ventral and lateral views of holotype, U.S.N.M. 104143. From U.S.G.S. Mes. loc. 17179, Sundance formation.

10, 12. Ventral views of paratypes, U.S.N.M. 104144a, b. From U.S.G.S. Mes. loc. 19180, Rierdon formation.


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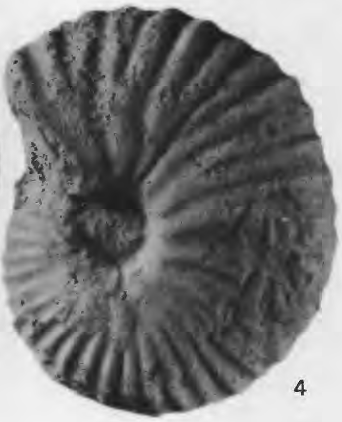
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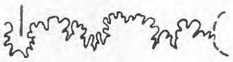
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CADOCERAS

PLATE 7

[Figure four-fifths natural size]

Cadoceras muelleri Imlay, n. sp. (p. 23).

Lateral view of holotype showing large smooth body chamber. U.S.N.M. 108262. From U.S.G.S. Mes. loc. 19182, Rierdon formation. Other views of holotype on pl. 8, figs. 2, 7, and pl. 9, figs. 8, 10.

CADOCERAS

PLATE 8

[Figures natural size unless otherwise indicated]

FIGURES 1, 6, 8. *Cosmoceras (Gulielmites)* cf. *C. jason* (Reinecke) (p. 33).
Lateral and ventral views of specimen, U.S.N.M. 108306. From U.S.G.S. Mes. loc. 19196, Rierdon formation.

2, 7. *Cadoceras muelleri* Imlay, n. sp. (p. 23).
Penultimate whorl and partial suture line of holotype, U.S.N.M. 108262. From U.S.G.S. Mes. loc. 19182, Rierdon formation. Other views of holotype on pl. 7, fig. 1, and pl. 9, figs. 8, 10.

3–5. *Cosmoceras (Gulielmites)* cf. C. obductum (Buckman) (p. 33).
3. Lateral view of part of body chamber, U.S.N.M. 108305. From U.S.G.S. Mes. loc. 10729, Rierdon formation.
4, 5. Ventral and lateral views of specimen, U.S.N.M. 108304. From U.S.G.S. Mes. loc. 18735, Rierdon formation.

9. *Cadoceras muelleri* Imlay, n. sp. (p. 23).
Paratype, U.S.N.M. 108265. From U.S.G.S. Mes. loc. 19170, Rierdon formation.

COSMOCERAS AND CADOCERAS

PLATE 9

[Figures natural size unless otherwise indicated]

Figures 1–3, 6–8, 10. *Cadoceras muelleri* Imlay, n. sp. (p. 23).

- 1, 3. Paratype, U.S.N.M. 108263. From U.S.G.S. Mes. loc. 19181, Rierdon formation.
- 2, 6. Paratype, U.S.N.M. 108264. From U.S.G.S. Mes. loc. 19179, Rierdon formation.
- 7. Suture line at whorl height of about 30 mm. on paratype, U.S.N.M. 108266. From U.S.G.S. Mes. loc. 19632.
- 8, 10. Inner whorls of holotype, U.S.N.M. 108262. From U.S.G.S. Mes. loc. 19182, Rierdon formation. Other views on pl. 7, fig. 1, and pl. 8, figs. 2, 7.

4, 5, 9. *Cosmoceras (Gulielmiceras) vigorosum* Imlay, n. sp. (p. 32).

Lateral and ventral views of holotype, U.S.N.M. 108303. From U.S.G.S. Mes. loc. 18754, Rierdon formation.


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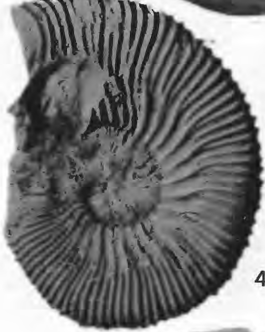
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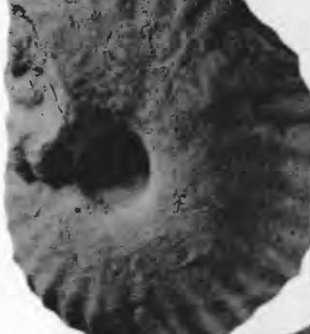
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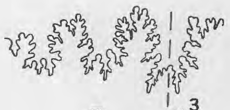
7 $\times\frac{3}{4}$


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CADOCERAS AND COSMOCERAS

PLATE 10

[All figures natural size]

FIGURES 1, 2. *Cadoceras tetonense* Imlay, n. sp. (p. 24).
Lateral and apertural views of holotype, U.S.N.M. 108267. From U.S.G.S. Mes. loc. 19593, Rierdon formation.

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CADOCERAS

PLATE 11

[Figures natural size unless otherwise indicated]

FIGURES 1–10. *Cadoceras tetonense* Imlay, n. sp. (p. 24).
- 1, 3, 9. Paratype, U.S.N.M. 108271. From U.S.G.S. Mes. loc. 19179, Rierdon formation.
- 2. Suture line at whorl height of 95 mm. near body chamber on paratype, U.S.N.M. 108268. From U.S.G.S. Mes. loc. 19594, Rierdon formation.
- 4, 7. Lateral and ventral views of paratype, U.S.N.M. 108269. From U.S.G.S. Mes. loc. 19202, Rierdon formation.
- 5, 6. Paratype, U.S.N.M. 108270a. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
- 8, 10. Paratype, U.S.N.M. 108270b. From U.S.G.S. Mes. loc. 19169, Rierdon formation.


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CADOCERAS

PLATE 12

[Nine-tenths natural size]

Cadoceras piperense Imlay, n. sp. (p. 25).
Paratype U.S.N.M. 108273. From U.S.G.S. Mes. loc. 19213, Rierdon formation. Note suture line on pl. 13, fig. 8.

x$\frac{9}{10}$

CADOCERAS

PLATE 13

[Figures natural size unless otherwise indicated]

FIGURES 1–12. *Cadoceras piperense* Imlay, n. sp. (p. 25).

1, 2. Paratype, U.S.N.M. 108275a. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
3, 4. Paratype, U.S.N.M. 108277. From U.S.G.S. Mes. loc. 19628, Rierdon formation.
5, 6. Paratype, U.S.N.M. 108276. From U.S.G.S. Mes. loc. 19170, Rierdon formation.
7, 9. Paratype, U.S.N.M. 108278. From U.S.G.S. Mes. loc. 19632, Sundance formation.
8. Suture line at diameter of 187 mm. on paratype, U.S.N.M. 108273. From U.S.G.S. Mes. loc. 19213, Rierdon formation. Same paratype shown on pl. 12.
10, 12. Paratype, U.S.N.M. 108275b. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
11. Paratype, U.S.N.M. 108274. From U.S.G.S. Mes. loc. 19180, Rierdon formation.


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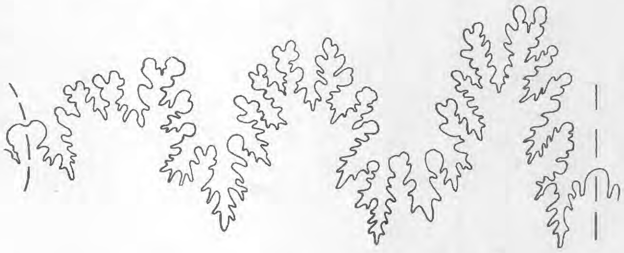
8 ×$\frac{3}{4}$


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CADOCERAS

PLATE 14

[All figures natural size]

FIGURES 1–6, 8. *Cosmoceras (Gulielmiceras) zortmanense* Imlay, n. sp. (p. 32).
1. Paratype, U.S.N.M. 108302a. From U.S.G.S. Mes. loc. 18750, Rierdon formation.
2. Paratype, U.S.N.M. 108301. From U.S.G.S. Mes. loc. 18742, Rierdon formation. Note lateral lappet.
3, 4. Paratype, U.S.N.M. 108300. From U.S.G.S. Mes. loc. 18737, Rierdon formation.
5. Rubber mold of holotype, U.S.N.M. 108299. From U.S.G.S. Mes. loc. 18737, Rierdon formation.
6, 8. Ventral and lateral views of paratype, U.S.N.M. 108302b. From U.S.G.S. Mes. loc. 18750, Rierdon formation.

7. *Cadoceras piperense* Imlay, n. sp. (p. 25).
Holotype, U.S.N.M. 108272. From U.S.G.S. Mes. loc. 19599, Rierdon formation. Note body chamber is nearly complete.

9. *Kepplerites (Seymourites)* cf. *K. rosenkrantzi* Spath (p. 27).
U.S.N.M. 108279. From U.S.G.S. Mes. loc. 7124, Rierdon formation.


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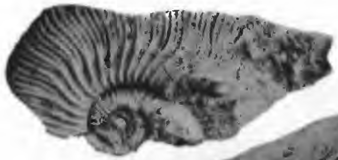
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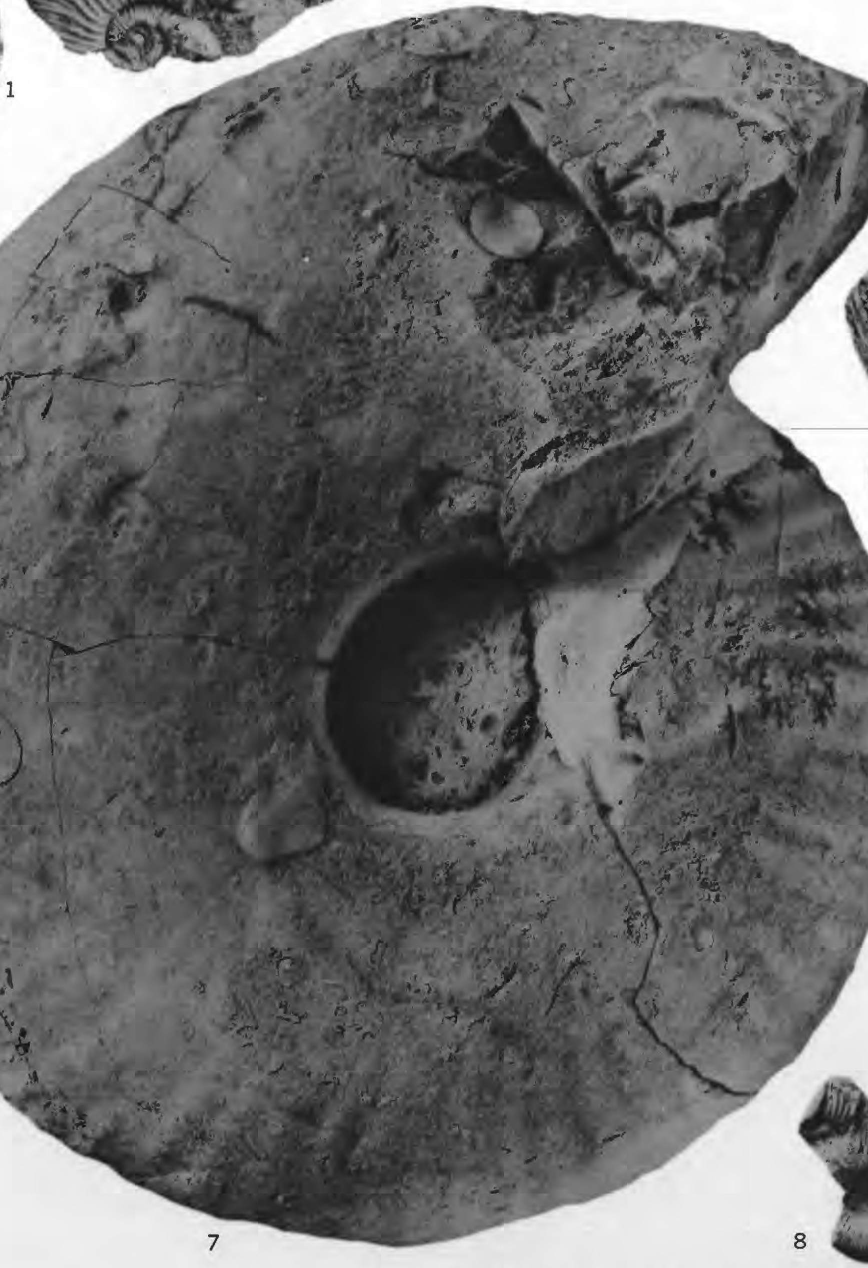
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COSMOCERAS, CADOCERAS, AND KEPPLERITES

PLATE 15

[Two-thirds natural size]

Kepplerites (Seymourites) mclearni Imlay (p. 25).
Holotype, U.S.N.M. 104125. From U.S.G.S. Mes. loc. 19211, Rierdon formation.

KEPPLERITES

PLATE 16

[Three-fifths natural size]

Kepplerites (Seymourites) mclearni Imlay (p. 25).

U.S.N.M. 104130. From U.S.G.S. Mes. loc. 19584, Rierdon formation. Note that body chamber is represented by 1¼ whorls.

KEPPLERITES

PLATE 17

[All figures natural size]

Figures 1–8. *Kepplerites mclearni* Imlay (p. 25).
1. Paratype, U.S.N.M. 104127. From U.S.G.S. Mes. loc. 19584, Rierdon formation.
2, 8. Paratype, U.S.N.M. 104122. From U.S.G.S. Mes. loc. 10732, Rierdon formation.
3, 6. Paratype, U.S.N.M. 104128. From U.S.G.S. Mes. loc. 18750, Rierdon formation.
4, 5. Paratype, U.S.N.M. 104126. From U.S.G.S. Mes. loc. 19583, Rierdon formation.
7. Paratype, U.S.N.M. 104123. From U.S.G.S. Mes. loc. 18737, Rierdon formation.


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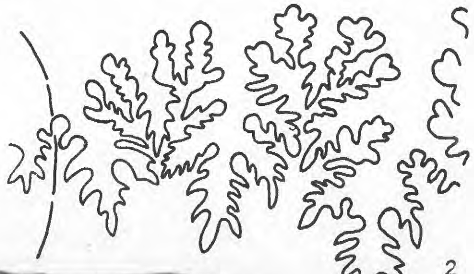
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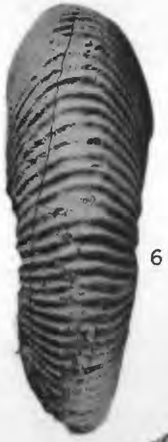
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KEPPLERITES

PLATE 18

[Four-fifths natural size]

Kepplerites (Seymourites) rockymontanus Imlay, n. sp. (p. 26).

Holotype, U.S.N.M. 104131. From U.S.G.S. Mes. loc. 19211, Rierdon formation. Note that incomplete body chamber is represented by a complete whorl.

KEPPLERITES

PLATE 19

[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Kepplerites (Seymourites) rockymontanus* Imlay, n. sp., (p. 26).

Lateral view and suture line of paratype, U.S.N.M. 104146. From U.S.G.S. Mes. loc. 10730, Rierdon formation. Suture line drawn from a fragment larger than the one figured.

3, 6–8. *Kepplerites (Seymourites) landuskiensis* Imlay, n. sp. (p. 27).

3, 8. Lateral views of the penultimate and body whorls of paratype, U.S.N.M. 108281. From U.S.G.S. Mes. loc. 18726, Rierdon formation. Note aperture is essentially complete.

6, 8. Holotype, U.S.N.M. 108280. From U.S.G.S. Mes. loc. 18726, Rierdon formation.

4, 5. *Grossouvria warmdomensis* Imlay, n. sp. (p. 33).

Lateral and ventral views of holotype, U.S.N.M. 108309. From U.S.G.S. Mes. loc. 19585, Rierdon formation.


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KEPPLERITES AND GROSSOUVRIA

PLATE 20

[All figures natural size]

FIGURES 1–3. *Kepplerites tychonis* Ravn (p. 27).
    1, 2. Plesiotype, U.S.N.M. 104173. From U.S.G.S. Mes. loc. 19629, Rierdon formation.
    3. Plesiotype, U.S.N.M. 104172. From U.S.G.S. Mes. loc. 20390, Rierdon formation. Aperture is nearly complete.
4–9. *Kepplerites (Seymourites) planiventralis* Imlay, n. sp. (p. 28).
    4, 5, 8. Ventral and lateral views of paratype, U.S.N.M. 108284. From U.S.G.S. Mes. loc. 18754, Rierdon formation. Note ventral flattening. Figure 4 is oriented with anterior end down.
    6. Paratype, U.S.N.M. 108283. From U.S.G.S. Mes. loc. 19211, Rierdon formation.
    7, 9. Holotype, U.S.N.M. 108282. From U.S.G.S. Mes. loc. 19211, Rierdon formation. Shows one-half whorl of body chamber.

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KEPPLERITES

PLATE 21

[All figures natural size]

FIGURES 1–18. *Gowericeras subitum* Imlay (p. 28).

1. Lateral view of plesiotype, U.S.N.M. 108287a. From U.S.G.S. Mes. loc. 19180, Rierdon formation.
2, 3. Paratype, U.S.N.M. 104156c; 5, paratype, U.S.N.M. 104156b; 8, 9, paratype, U.S.N.M. 104156a. All from U.S.G.S. Mes. loc. 19182, Rierdon formation.
4, 10. Paratypes, U.S.N.M. 104153a, b. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
6. Plesiotype, U.S.N.M. 108286. From U.S.G.S. Mes. loc. 19179, Rierdon formation.
7. Plesiotype, U.S.N.M. 108285a. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
11, 12. Plesiotype, U.S.N.M. 108285b. From U.S.G.S. Mes. loc. 19169, Rierdon formation.
13, 14. Holotype, U.S.N.M. 104155. From U.S.G.S. Mes. loc. 19182, Rierdon formation.
15, 16. Plesiotype, U.S.N.M. 108287b. From U.S.G.S. Mes. loc. 19180, Rierdon formation.
17, 18. Paratype, U.S.N.M. 104154. From U.S.G.S. Mes. loc. 19180, Rierdon formation.


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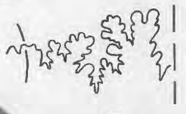
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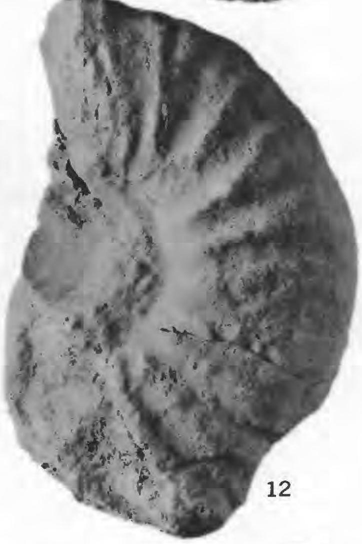
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GOWERICERAS

PLATE 22

[All figures natural size]

FIGURES 1–4, 7, 8. *Gowericeras costihians* Imlay, n. sp. (p. 29).
- 1, 2. Paratype, U.S.N.M. 108290. From U.S.G.S. Mes. loc. 19182, Rierdon formation.
- 3, 4, 7. Holotype, U.S.N.M. 108289. From U.S.G.S. Mes. loc. 19182, Rierdon formation. Suture lines drawn at whorl height of 19 mm immediately preceding body chamber.
- 8. Paratype, U.S.N.M. 108314. From U.S.G.S. Mes. loc. 19182, Rierdon formation.

5, 6. *Gowericeras subitum* var. *distinctum* Imlay, n. var. (p. 29).
- Holotype, U.S.N.M. 108288. From U.S.G.S. Mes. loc. 19179, Rierdon formation. Shows complete body chamber.

9. *Gowericeras subitum* Imlay (p. 28).
- Plesiotype, U.S.N.M. 108285c. From U.S.G.S. Mes. loc. 19169, Rierdon formation. Shows sparser, sharper ribbing than most immature forms of this species.

10–13. *Gowericeras costidensum* Imlay, n. sp. (p. 31).
- 10, 11. Holotype, U.S.N.M. 108297. From U.S.G.S. Mes. loc. 19212, Rierdon formation.
- 12, 13. Paratype, U.S.N.M. 108296. From U.S.G.S. Mes. loc. 19170, Rierdon formation.

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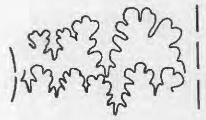

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GOWERICERAS

PLATE 23

[Figures natural size unless otherwise indicated]

FIGURES 1–12, 18. *Gowericeras costicrassum* Imlay, n. sp. (p. 30).

- 1–3. Holotype, U.S.N.M. 108294. From U.S.G.S. Mes. loc. 19170, Rierdon formation. Shows complete body chamber.
- 4. Paratype, U.S.N.M. 108292. From U.S.G.S. Mes. loc. 19180, Rierdon formation.
- 5–7. Paratype, U.S.N.M. 108295a. From U.S.G.S. Mes. loc. 19170, Rierdon formation.
- 8, 9. Paratype, U.S.N.M. 108293a. From U.S.G.S. Mes. loc. 19182, Rierdon formation. Suture line drawn at whorl height of 9 mm.
- 10, 11. Paratype, U.S.N.M. 108293b. From U.S.G.S. Mes. loc. 19182, Rierdon formation.
- 12, 18. Paratype, U.S.N.M. 108295b. From U.S.G.S. Mos. loc. 19170, Rierdon formation.

13, 17. *Procerites* sp. (p. 33).

Ventral and lateral views of specimen, U.S.N.M. 108307. From U.S.G.S. Mes. loc. 18718, Rierdon formation.

14–16. *Gowericeras costimedium* Imlay, n. sp. (p. 30).

Holotype, U.S.N.M. 108291. From U.S.G.S. Mes. loc. 19180, Rierdon formation. Suture line drawn at whorl height of 17 mm. near beginning of body chamber.


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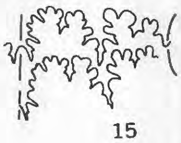
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GOWERICERAS AND PROCERITES

PLATE 24

[Figures natural size unless otherwise indicated]

FIGURES 1, 3, 8. *Grossouvria* sp. (p. 34).
Lateral views of specimens, U.S.N.M. 108310a–c. From U.S.G.S. Mes. loc. 21467, Rierdon formation.

2, 4–6. *Grossouvria* sp. (p. 34).
2, 6. Lateral and ventral views of specimen, U.S.N.M. 108312. From U.S.G.S. Mes. loc. 19182, Rierdon formation.
4, 5. Lateral and ventral views of specimen, U.S.N.M. 108313. From U.S.G.S. Mes. loc. 19180, Rierdon formation.

7. *Grossouvria* sp. (p. 34).
Specimen, U.S.N.M. 108311. From U.S.G.S. Mes. loc. 20365, Rierdon formation.

9–11. *Procerites* sp. (p. 33).
Specimen, U.S.N.M. 108308. From U.S.G.S. Mes. loc. 19603, Rierdon formation. Suture line drawn at whorl height of 64 mm.


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GROSSOUVRIA AND PROCERITES