Carboniferous Formations and Faunas of Central Montana

GEOLOGICAL SURVEY PROFESSIONAL PAPER 348

Carboniferous Formations and Faunas of Central Montana

By W. H. EASTON

GEOLOGICAL SURVEY PROFESSIONAL PAPER 348

A study of the stratigraphic and ecologic associations and significance of fossils from the Big Snowy group of Mississippian and Pennsylvanian rocks

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

Easton, William Heyden, 1916–

Carboniferous formations and faunas of central Montana. Washington, U.S. Govt. Print. Off., 1961.

iv, 126 p. illus., diagrs., tables. 29 cm. (U.S. Geological Survey. Professional paper 348)

Part of illustrative matter folded in pocket. Bibliography: p. 104–108.

1. Paleontology—Montana. 2. Paleontology—Carboniferous. 3. Geology, Stratigraphic—Carboniferous. I. Title. (Series)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[Plates 3–13 follow index]

TABLES

CARBONIFEROUS FORMATIONS AND FAUNAS OF CENTRAL MONTANA

By W. H. Easton

ABSTRACT

This report is mainly concerned with the paleontological recognition of stratigraphic units within the Big Snowy group of central Montana as revised and enlarged by Gardner. These outcrops are the nearest surface exposures of the oil-containing Carboniferous sequence of the subsurface Williston basin in eastern Montana and in western North Dakota. The study was confined to the outcrop sections in the Big Snowy Mountains and in the Little Belt Mountains. Stratigraphic units are well exposed and continuous, and structural relations are relatively orderly within that region. Therefore, the geology provides a local reference against which comparisons may be made of outcrop sections in the northern Rocky Mountains and in the subsurface of the northern Great Plains.

The Big Snowy group of this report consists, from oldest to youngest, of the Kibbey sandstone, Otter formation, Heath formation, Cameron Creek formation, Alaska Bench limestone, and Devils Pocket formation. It is underlain by evaporites and carbonate rocks of the Charles formation or by carbonate rocks of the Mission Canyon limestone which are middle Mississippian in age. It is overlain by unnamed clastic and carbonate strata of Pennsylvanian(?), Permian(?), or Triassic(?) age.

The Kibbey sandstone consists of about 240 feet of reddish sandstone from which no fossil has yet been collected. Inasmuch as the Kibbey sandstone is gradational to the overlying Otter formation of Chester age, it also is considered equivalent to some part of the Chester strata.

The Otter formation generally includes about 470 feet of green shale which contains a distinctive Chester fauna of megafossils and ostracodes.

The Heath formation consists of about 360 feet of black shale which contains a large assemblage of megafossils of Chester age. Some upper strata of the Heath with lenticular sandstones may be nonmarine and may be lithologic equivalents of the channel fillings seen in subsurface Williston basin.

The Cameron Creek formation consists of about 280 feet of reddish shales, sandstones, and carbonate rocks. These contain a fauna indicating Mississippian or Pennsylvanian age. Some elements of this fauna which are diagnostic of the reddish interval may be controlled by extraordinary ecologic conditions or are from an uncommon faunal realm, possibly Russian in origin.

The Alaska Bench limestone is a ridge-maker about 140 feet thick. It contains a rather abundant fauna of Mississippian or Pennsylvanian age.

The Devils Pocket formation consists mainly of 125 feet of reddish clastic sediments and interbedded cherty dolomite best exposed on the southeast flank of the Big Snowy Mountains. Although the only fossils found have post-Mississippian affinities, the unit intergrades stratigraphically with the Alaska Bench limestone and is considered probably of about the same age.

More than 4,000 specimens were studied and assigned to 187 faunal elements. Faunas are referred to beds in seven measured sections. Two new coral genera, *Fasciculiamplexus* and *Longiclava*, and two new chonetid and productid brachiopod genera, *Nix* and *Rugoclostus*, are proposed. The rugose coral genus *Bradyphyllum* Grabau, 1928, is emended. Fifty-seven distinct species of megafossils (excluding bryozoans) are recognized without qualification, including 30 species which are new. Sixty-four of all the faunal elements are significant in age determinations. Of these 53 are of Mississippian affinity and 11 are of Pennsylvanian affinity. Ten additional elements cross the Mississippian-Pennsylvanian boundary. The Big Snowy group contains faunules which are transitional between Mississippian and Pennsylvanian, with a recognizable increase in Pennsylvanian characteristics in progressively higher units, although the Mississippian element is numerically dominant (in all but the Devils Pocket formation which contains only two elements).

INTRODUCTION

PURPOSES OF THE STUDY[1]

This study of the fauna of the Big Snowy group was originally undertaken at the suggestion of the late James Steele Williams in connection with the mapping of some areas in central Montana by L. S. Gardner and associates, and as a possible aid to subsurface studies of these rocks in and near the Williston basin (fig. 1). Some of the results of that work have already been published in preliminary form (Gardner, 1959; Gardner, *in* Rader and others, 1951, p. 17) and stratigraphic sections measured during the mapping have also been published (Gardner and others, 1945; 1946, p. 1–6, 12–100). At the same time that the measured sections were released, L. L. Sloss (1946) published some faunal lists based on collections made under Gardner's direction, but an assembling of the entire fauna of the Big Snowy group and a description of it have not previously been attempted. The present report concerns the description of the fauna and the

[1] The preliminary and general results of this work were presented at the request of the American Association of Petroleum Geologists in public talks at the forum of that association in Los Angeles, Calif., on March 15, 1954; at the Annual Meeting of the Association in St. Louis, Mo., on April 15, 1954; and at other cities in the United States and Canada as part of the Distinguished Lecture Series of that body during March, 1955.

paleontological recognition of stratigraphic units in the area.

From their location near the western edge of the Williston basin, the well-exposed outcrops in the Big Snowy Mountains offer the best available evidence as to the nature of some of the subsurface units within the basin proper. The stratigraphic problems involved are not unique to the Williston basin proper, however. Recent oil discoveries in the Big Snowy group even closer to the Big Snowy Mountains (Hadley and Smith, 1952, p. 1016) are in the West Sumatra field in northwest Rosebud County and in the Ragged Point field in northeast Musselshell County, Mont. Both of these fields are now producing oil from the Heath formation in the Big Snowy group, as well as from other earlier discovered zones. In 1950 the Amsden formation was found to be productive in the Northwest Sumatra field in northwest Rosebud County, and Heath production was obtained from the West Sumatra field (Severy and McLarty, 1951, table IV on p. 1166). Before that, saturated zones in the Kibbey sandstone, Heath formation, and Amsden formation had variously produced oil in the Ragged Point, Big Wall, Melstone, Womans Pocket, Sumatra, Devils Pocket, Northwest Sumatra, and West Sumatra fields (Severy and McLarty, 1950, table IV on p. 1036; Severy and McLarty, 1951, table IV on p. 1166; Dorn, 1949, table II on p. 830; Rea, 1948, p. 888).

A partial result of this study is the use of paleontology to differentiate two separate sequences of sandstone units which might be confused on lithic grounds alone. Sandstones in the upper part of the Heath formation are associated with a typical Chester fauna, whereas sandstones in the Cameron Creek formation are associated with a fauna containing genera and species not typical of Chester fauna but seemingly of about the same age.

Extensive areal studies under way in the general region of the Northern Rocky Mountains depend in part upon paleontologic control. Although several partial studies have been made of Late Mississippian faunas of the Northern Rocky Mountains, a detailed account is needed. Shortcomings in or lack of paleontologic information for this interval in the Northern

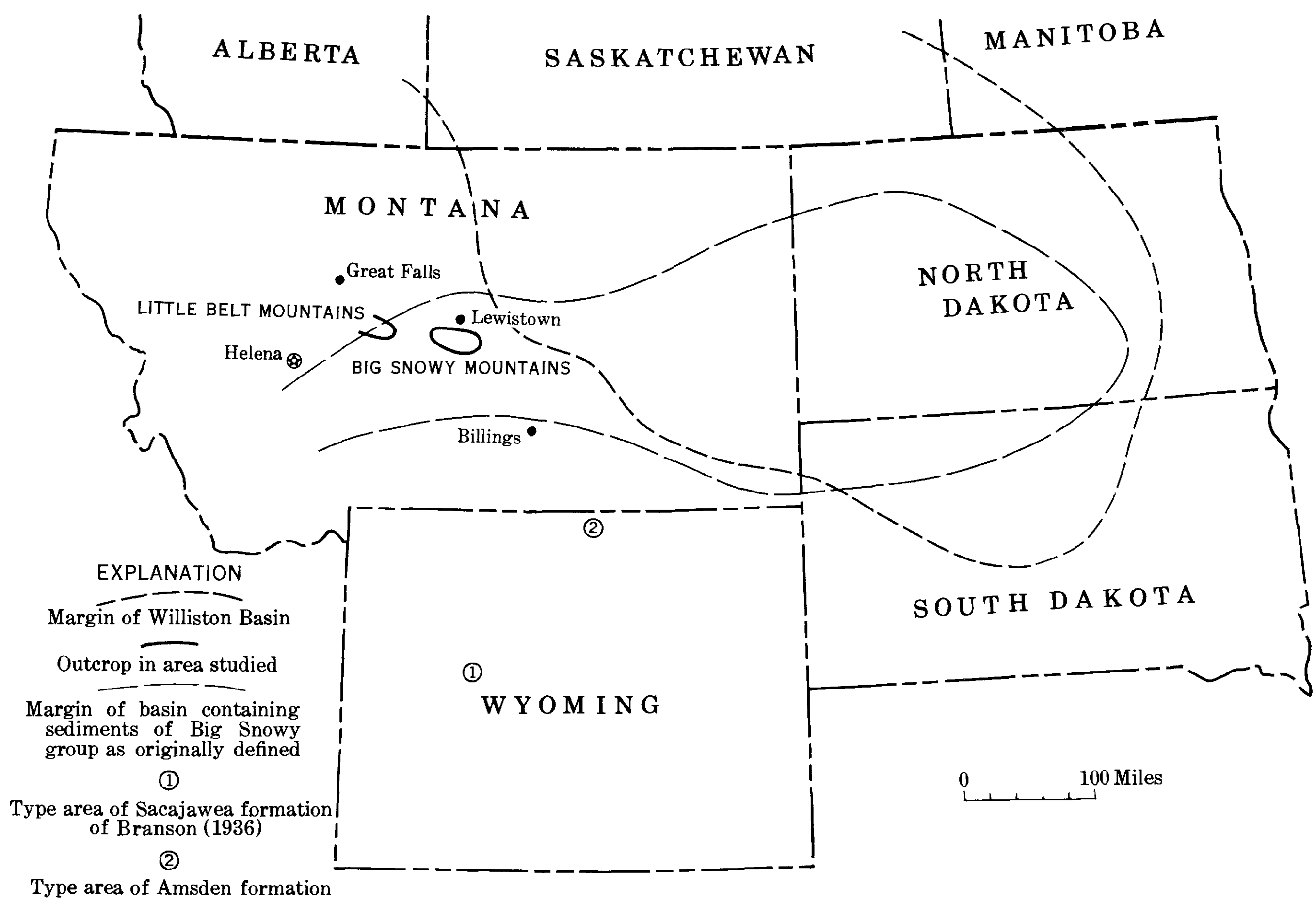


FIGURE 1.—Location of area studied with reference to Williston basin, areal extent of the Big Snowy group, and geographic boundaries. Partly after Barnes, 1952.

Rocky Mountains are indicated by Love (1939, p. 23, 24) in his comments on the inability of a field geologist to use existing stratigraphic names with confidence in the area he studied in Wyoming. Additional knowledge of the fauna of the Big Snowy group is needed to form a suitable paleontologic base on which more work in the West will be possible.

Evidence on which the Mississippian-Pennsylvanian boundary can be drawn is accumulating slowly, but little in the way of concrete and pertinent fact has been published for the area under consideration. Striking faunal distinctions exist between the stratigraphic sections of the Mississippi Valley and those of the far western States. Presumably the intermediate geographic and environmental relations of the faunas from Montana will contribute toward a solution of regional correlations, including the Mississippian-Pennsylvanian boundary problem.

ORGANIZATION OF PRESENT WORK

Fieldwork in Montana was principally carried out in the summer of 1952 in company with J. E. Smedley and Kasetre Phitaksphraivan. Early fieldwork was localized for us by L. S. Gardner who demonstrated the problems and circumscribed the area in which it was thought that operations should be carried forward. Measuring and checking of stratigraphic sections and fossil collecting were done by the three-man team.

Systematic work and report writing were done during 1952–53 at Survey offices in the U.S. National Museum in Washington, D.C., during a sabbatical leave from the University of Southern California. This provided access to technical facilities, files, and extensive earlier collections of the U.S. Geological Survey; to the systematic collections of the U.S. National Museum; and to superlative library facilities. Final writing was done at Los Angeles.

A short time in the summer of 1953 was spent in rechecking certain details in the field, assisted in part by Mr. Smedley and by Miss Phoebe Beall Easton.

Because Mr. Gardner was at work on a paper for publication (Gardner, 1959) in which his ideas on stratigraphy and correlation were to be presented, the writer restricted his efforts with regard to physical stratigraphy to accumulating such data as related to stratigraphic and geographic distribution of the faunas in central Montana.

Work was confined areally to the eastern Little Belt Mountains and to the Big Snowy Mountains because it was known that the formations under investigation were fairly persistent there, were of rather consistent lithology, and were easily accessible. In addition the area was strategically located not only to assist in solving problems of correlation between neighboring outcropping sections, but to provide the easiest comparisons with the subsurface sections of eastern Montana and the Williston basin (fig. 1).

By agreement with O. D. Blake of the Montana School of Mines, study of the Big Snowy bryozoans was reserved for him, and their description is, therefore, not undertaken in the present report.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the assistance received from many persons during the course of this investigation. L. S. Gardner, drawing upon his extensive background of work in the region, introduced the writer to the fieldwork and furnished him with a compelling interest in the problem. Mrs. C. L. Nieschmidt contributed invaluable information about lateral continuity of lithic units and about the various ways in which geologists were subdividing the section. J. E. Smedley and Kasetre Phitaksphraivan not only provided the writer with necessary field assistance, but also with professional suggestions which inestimably improved the work.

The writer is indebted to E. K. Beekly of the Northern Natural Gas Producing Co., O. D. Blake of the Montana School of Mines, H. D. Hadley of Northwest Geological Service, G. C. Mathis, who was formerly of the U.S. Gypsum Co., at Heath, O. O. Mueller of renown as an indefatigable collector in Lewistown, P. A. Mundt of Mobil Producing Co., G. H. Norton of Atlantic Refining Co., and Paul Richards of the U.S. Geological Survey in Billings for stimulating discussions of stratigraphic relations, for their cooperation and generosity in comparing results of their own investigations with those of the writer, or for assistance in the fieldwork by drawing upon their knowledge of the geological problems and localities.

Particular thanks go to erstwhile colleagues in the U.S. Geological Survey, whose interest in the writer's problems often transcended their own work, and who gave generously of information, advice, and constructive criticism. In acknowledgement of their good offices this report could well be studded with the names of Marjorie Arnold, P. E. Cloud, Jr., Helen Duncan, Mackenzie Gordon, Jr., L. G. Henbest, Doris Low, J. B. Reeside, Jr., N. W. Shupe, James Steele Williams, and Ellis Yochelson.

The systematic studies have benefitted equally from the generous and considerate cooperation of G. A. Cooper, D. H. Dunkle, and J. B. Knight of the U.S. National Museum.

Valuable assistance in providing comparative material and type specimens on loan was provided by A.

Myra Keen of Stanford University, R. Konizeski of the University of Chicago, H. W. Scott of the University of Illinois, A. G. Unklesbay of the University of Missouri, K. M. Waagé of Yale University, and J. Stewart Williams of Utah State Agricultural College.

The writer was enabled to undertake the work through leave of absence from his formal duties at the University of Southern California granted by agreement with Dean T. E. Strevey.

ANALYSIS OF PREVIOUS WORK

A vast amount of work has been done on the stratigraphy and paleontology of the Northern Rocky Mountains and on the northern Great Plains. The following roughly chronological account should acquaint the reader with the development of published thought on the region. However, many unpublished paleontologic data are available, as, for instance, in the collections of the U.S. Geological Survey and the U.S. National Museum in Washington, D.C. These collections commonly enable one to establish in current terms the identity of fossils published or merely studied by paleontologists who made age determinations contained in articles referred to herein.

PAPERS DEALING PRIMARILY WITH EQUIVALENTS OF THE BIG SNOWY GROUP IN MONTANA

The first mention of the fauna from beds now included in the Big Snowy group was by Dana and Grinnell (Ludlow, 1876, p. 113) with regard to the as yet unnamed outcrops in the canyon of the Musselshell River near what is now Delpine, Mont. They reported a fauna of 10 species, identified by R. P. Whitfield, only one of which is currently recognizable, but they did assign a Carboniferous age to the strata. A faunal list redetermined by the writer is published on this section. In the same paper, Whitfield (Ludlow, 1876, p. 143) described a new species from beds now assigned to the Big Snowy group of the Little Belt Mountains.

Davis (1886, p. 702) mentioned unnamed lower Carboniferous fossils as occuring in "shaly beds, with calcareous layers" in what is now called the Big Snowy group at a dome north of Barker on the north side of the Little Belt Mountains. These fossils are apparently those which Weed (1892, p. 309) listed and said were identified by Whitfield, who called them Spergen Hill types (Salem limestone of Indiana).

In 1892 Weed (1892, p. 307–309) published a section on Belt Creek in which he named his unit 4 the "Otter Creek shales." This unit corresponds to the Otter formation of this report. Fossils from unit 4 were said to have been called Carboniferous by C. A. White; a list of species was identified by C. D. Walcott and rather circuitously referred to by Weed as being from the upper part of the Carboniferous. He explained the presence of lower Carboniferous species by attributing modification of the fauna to ecologic influence.

Additional work by Weed became available in 1899 in the Fort Benton and Little Belt Mountains folios (Weed, 1899a, 1899b). He assigned the Otter formation and the Kibbey sandstone to the Quadrant formation and called it lower Carboniferous on unspecified information. More detailed data by Weed were released in the same year when he (1899c, p. 295, 296) published three faunal lists from the "Otter shale" which almost certainly included some species from higher in the Big Snowy group. Weed thought that the fossils from Riceville identified by C. D. Walcott indicated a "Spergen Hill facies." Other collections, from the Forks of the Judith River and from the Dry Fork of Belt Creek, identified by Charles Schuchert, were not inferred to indicate other than an early Carboniferous age. Weed referred the Kibbey and Otter to the Quadrant group.

Fisher (1909, p. 26, 27) published a section of the so-called Quadrant formation at Riceville and quoted Girty as saying that solving the problem of the age of the Quadrant formation involves three faunas of different ages—"a Madison fauna, a late Mississippian fauna, and a post-Mississippian fauna." Now, more than 40 years later, we are trying to refine data in order to proceed on just the basis Girty proposed; less difficulty is being met with recognized Madison faunas than with the others.

Additional faunas were identified by Girty from the so-called Quadrant formation on the south side of the Judith Basin (*in* Calvert, 1909 p. 18). Girty's uncertainty as to the Mississippian or Pennsylvanian age of some of these faunas is not only reflected in faunal lists in which choices of specific names signifying ages are offered for the same species, but his conclusions as to the ages of these faunas (p. 19) are equivocal. In explanation, it should be understood that the faunas with which he dealt had not been described and are considerably different from other Chester faunas.

An important detailed account of the Paleozoic formations of central Montana was published by Hammer and Lloyd (1926, p. 986–996). They reaffirmed the theory that part of the Quadrant formation is Pennsylvanian. An original copy of the description of the measured section and the collection of fossils are in the collections of the U.S. Geological Survey. Although the measured section (Hammer and Lloyd, 1926, p. 988, 989) was said to be located in secs. 2 and 11, T. 10 N., R. 22 E., data in the U.S. Geological Survey files indicate that beds 1–6 of the section actually were measured in sec. 36, T. 11 N., R. 20 E., and beds 7–48 were measured in sec. 29, T. 11 N., R. 21 E. These localities correspond to the southern end of State Road 25 and the headwaters of Stonehouse Canyon as published by Gardner and others (1946, p. 45–49, 51–54) and as published herein. Hammer and Lloyd report that Stanton and Girty identified fossils from beds 5 and 6 of their section (1926, p. 988) as being "Early Pennsylvanian, possibly Pottsville," but faunal lists were not published. These fossils, now filed under U.S. Geological Survey locality numbers 5847 (bed 5) and 5846 (bed 6), were reidentified by the author, with the following result:

Locality 5846:
- *Clionolithes* sp.
- *Chonetes pseudoliratus* Easton
- *Linoproductus nodosus* var.
- *Antiquatonia pernodosa* Easton
- *Composita* cf. *C. lateralis* (Girty)
  - *subquadrata* (Hall)
- *Spirorbis* sp.
- *Bellerophon* sp.

Locality 5847:
- *Linoproductus* sp.
- *Spirifer curvilateralis* Easton
- *Composita* cf. *C. sulcata* Weller

The whole assemblage is characteristic of the Cameron Creek formation and the Alaska Bench limestone, in which units it is associated with species which by themselves the writer would consider of Chester age.

Perhaps the first call for detailed work on the stratigraphy and paleontology of the Amsden and Quadrant formations in the Big Snowy Mountains was by Bauer and Robinson (1923, p. 176–178) who stressed the confusion then extant about those strata.

Reeves (1926, p. 53) first published the now well-known section at the aerial beacon on Alaska Bench south of Heath and referred the beds there to the Quadrant formation. Fossils which he listed from the very top few feet of what is now called the Heath shale (bed 5 of the writer's section at the beacon) were determined by Girty (Reeves, 1926, p. 51) as having definitely a "Mississippian facies."

Companion piece to Weed's work in the Little Belt Mountains is Reeves' report (1931) on the Big Snowy Mountains. Reeves recognized the Quadrant formation but did not subdivide it into formal named units as Weed did. Fossil collections studied by Girty were tentatively considered to be of Ste. Genevieve age, except for one lot consisting largely of mollusks from the present Alaska Bench limestone which Girty thought might be some obscure Chester or Pottsville phase.

Scott's work (1935b) gave impetus to stratigraphic investigations in central Montana by establishing the Big Snowy group as a distinct unit separable from the overlying Amsden formation. Scott considered both his Big Snowy group and his Amsden formation to be distinct Chester units separable from the old loosely construed "Quadrant formation" which wedges out to the eastward near Lombard, Mont. (Scott, 1935b, p. 1015) on the western border of the area studied herein. Subsequently Thompson and Scott (1941) demonstrated the Pennsylvanian age of part of the type Quadrant section in Yellowstone National Park and referred its basal 66 feet of Mississippian strata to the Sacajawea formation of Branson (1936). In central Montana Scott recognized as the Amsden formation those limestone and shale strata with a supposed Chester fauna which underlie the Ellis group (Jurassic) and overlie the Heath formation. Finally, Scott defined the Big Snowy group to include all these strata between the Madison limestone and the Amsden formation of central Montana. He included the Kibbey sandstone and Otter formations in the Big Snowy group and added a new formation at its top, the Heath formation. Scott tentatively assigned the age of his Big Snowy group as "not older than Warsaw nor younger than Upper Chester" (Scott, 1935b, p. 1031).

The first extension of the limits of the Big Snowy group was the addition of the Charles formation (Seager, 1942, p. 863–864) for the strata lying between the Madison limestone and the Kibbey sandstone. Seager considered the Amsden of Scott to be Mississippian on the basis of unspecified evidence. Freeman suggested (1922, p. 827) that the name Tyler be used for the sandstone lenses in the upper part of the Heath formation, but this did not alter the limits of the Big Snowy group.

By 1943 enough additional information was available for Perry and Sloss to publish distribution of the units of the Big Snowy group and the Amsden formation according to then prevailing subsurface usage and to present a reasonably accurate isopach map of the Big Snowy group (Perry and Sloss, 1943, fig. 1 on p. 1289).

Shortly thereafter Gardner and others (1945), Hadley and others (1945), and Rogers and others (1945), published extensive surface and subsurface correlation charts, maps, and measured sections (Gardner and others, 1946) in central and south-central Montana.

Considerable attention has been given to work by H. W. Scott (1945a, 1945b) in which he announced the discovery of the primitive fusulinid *Millerella* in the Amsden formation and the assignment of the formation to the Pennsylvanian. Scott later (written communication May 20, 1953) informed the writer that the *Millerella* mentioned in the second article (Scott, 1945b) was collected from beds 28 and 29 of his measured section (Scott, 1935b, p. 1024, 1025) on the hillside below the aerial beacon south of Heath. He also kindly donated his specimens to the U.S. Geological Survey, and they are included in the systematic study contained elsewhere in this paper. L. G. Henbest has restudied the specimens donated by Scott and is of the opinion that they are not diagnostic of either a Mississippian or Pennsylvanian age of the containing strata. This is discussed in more detail in the systematic section (p. 28).

Walton's (1946) review of the sedimentary and diastrophic history of the Judith Basin is the most concise account to date of these factors as related to the Big Snowy group. Walton considered the Amsden formation to be Lower Pennsylvanian on the basis of unspecified fusulinid identifications by Scott, and therefore located a pre-Amsden unconformity at the Mississippian-Pennsylvanian boundary.

Paleontologic work by Sloss (1946) showed the close similarity of faunas from the Heath formation and the lower two-thirds of the so-called Amsden formation in central Montana. Sloss (1946, p. 7, 8) somewhat tentatively assigned the lower Amsden fauna to the upper Chester; assigned the "Sacajawea" fauna to the lower Chester, correlating it with the Otter formation; and assigned the Heath formation to the middle Chester. The "upper Amsden" was assigned on provisional identifications to the Morrow (Lower Pennsylvanian).

A critical reevaluation of the collections upon which Sloss based his faunal lists is no longer practicable. This material, unfortunately, was dispersed and part of it apparently has been lost. The part received by the U.S. Geological Survey is available for study at the U.S. National Museum, but so many questions concerning localities, names, and identities of specimens arise when one deals with the collection, that the writer is unwilling to use the incomplete data at hand as bases for citations in the synonymies herein.

J. Steele Williams (1948, p. 331–334) reviewed some stratigraphic problems of central Montana and paid particular attention to the Amsden formation, pointing out that Scott's (1945a, 1945b) finding of *Millerella* in the Cameron Creek formation may not be conclusive evidence of its Pennsylvanian age because the genus is also known in Mississippian rocks. Williams (1948, p. 337, 338) also briefly reviewed the "Sacajawea" versus Amsden usage in Wyoming, and concluded that the "Sacajawea" should at best be no more than a member of the Amsden formation.

Among the most recent articles, Scott (1950) and Sloss (1952) briefly reviewed the stratigraphy of the Big Snowy group, and Hadley (1950) stated the difference of opinions as to whether the Charles formation was ever deposited in the Big Snowy Mountains or has been leached away. Vine and Hail (1950) published a map and stratigraphic sections in which they infer on obscure grounds a pinchout of black Heath formation in a section on East Buffalo Creek. Perry (1951) has shown the pre-Jurassic distribution of formations in central Montana. Honkala (1951) mentioned a possible basal conglomerate of the Amsden formation which may occupy the position of another unconformity whose existence had been previously discussed by Scott (1935b, p. 1021, 1022) and by Perry and Sloss (1943, p. 1293). Sloss (1951) published isopach and lithofacies studies of strata of Chester age in Montana which support Walton's (1946, p. 1300) contention that sands in this part of the section were derived from the south. Barnes (1952, p. 106, 108) has published the most recent isopach studies on the Big Snowy and Amsden units of some authors. Nieschmidt (1953) projected the Heath and Amsden strata from outcrops in the Big Snowy Mountains into the subsurface.

The best and most substantial statement about Upper Mississippian faunas of Western States, embodying ideas of the late G. H. Girty, is published as an accompaniment to Mansfield's discussion of the Brazer limestone of Idaho (Mansfield, 1927, p. 63–71). References to other parts of Girty's text are made elsewhere in this paper, but special note is taken here of the so-called Spergen fauna because much confusion has arisen about it. Girty referred (Mansfield, 1927, p. 68, 70, 71) to an association of species well down in the Brazer limestone as being "comparable to the Spergen and Ste. Genevieve faunas" (p. 68), as the "so-called Spergen fauna from the Brazer" (p. 70), and as "Spergenlike faunas" (p. 71). The tenets of Girty's thesis are that a predominantly molluscan fauna resembling the Spergen fauna is known at diverse levels in the Mississippian and Pennsylvanian of the Eastern United States and that in the Western States the so-called Spergen fauna contains additional species which are either indicative of later faunas or are alien to the Spergen fauna. In effect Girty warns of potential error in dealing with this fauna. In the writer's opinion most, if not all, determinations of Salem and Ste. Genevieve ages in the Northern Rocky Mountains arise from sources of error detailed by Girty in 1927.

The most recent discussions of Carboniferous stratigraphy in the region concern the black shale and sandstone lenses of the Heath and the so-called lower Amsden of some authors. Beekly (1954) has advanced the theory that the "lower Amsden" sandstone and black shales discovered in certain oil fields in the Williston basin were deposited in depressions of an erosional surface developed on the Heath formation. This contention has been amplified by Mundt (1956) who extended Beekly's conception to central Montana.

INCIDENTAL REPORTS

Among shorter systematic papers useful in dating or correlating the Big Snowy group, Gunnell (1932) described some species from the so-called Brazer formation of Utah, but the writer is not certain that all of the specimens came from the Brazer. *Spirifer hammondi* Gunnell, for instance, seems to be *S. centronatus* of authors, which is characteristic of but not confined to the Madison.

J. Steele Williams (1949) briefly reviewed the Amsden problem and suggested that the name Amsden might appropriately be used even if it were of different ages at different places or even if it included rocks of different epochs or periods at any given place, provided that it is a cartographic unit. This corresponds to the official usage of the U.S. Geological Survey which assigns a Mississippian and Pennsylvanian age to the Amsden formation of Wyoming and includes the "Sacajawea" beds at its base.

Parks (1951) described some corals from the Brazer limestone of Utah, of which one of the genera is known from Montana.

Articles by Scott on a malacostracan (1938) and on conodont assemblages (1942b) from the Heath formation contain no information concerning age or correlation but are concerned solely with taxonomic problems.

Two articles on corals from Montana appeared in 1945. Sloss described a *Caninia* from the lower Amsden formation and assigned it to the Chester. Easton (1945a) described four species of corals from the upper part of the Otter formation and concluded that the corals alone indicate a late Chester age on phylogenetic grounds. Present work did not extend as far west as the localities from which the material described by Sloss and by Easton came.

Miller, Downs, and Youngquist (1949) studied some cephalopods from the lower Heath formation and correlated the beds from which the goniatites came approximately with "the White Pine shale of Nevada, the Barnett formation of Texas, the Caney shale of Oklahoma, and probably the upper Viséan at various localities in western Europe and the British Isles" (p. 611), all of which occurrences they considered to be of about Meramec age. They made no firm specific identifications and both of the genera they reported are known in Chester strata as well as in Meramec strata.

J. Stewart Williams (1943) and Williams and Yolton (1945) described sections of the Brazer limestone in northeastern Utah and cited faunal contents of units of the formation. To a certain extent this augments Girty's work (in Mansfield, 1927) and that of Gunnell (1932). Williams and Yolton (1945, fig. 2 on p. 1150) published a general correlation chart in which they showed the Kibbey, Otter, Heath, and Amsden of the Williston basin (Perry and Sloss, 1943) as being of Chester age; the Sacajawea of Branson (1936) as being equivalent to the late Chester Heath; and considered all of the foregoing to lie within the upper half of unit 3 in addition to all of units 4 and 5 of their Brazer formation.

Sloss and Moritz (1951, fig. 9, on p. 2153) correlated the Kibbey through lower Amsden formations of central Montana and the Williston basin with the upper half of the Meramec as well as with the entire Chester.

RÉSUMÉ

The essence of the foregoing review is more tersely stated below.

1. Rocks between the Madison and Ellis groups in central Montana were once referred to the Quadrant formation, but subsequently were referred to the Amsden formation and the underlying Big Snowy group. This change was reasonable because the Quadrant strata could not be traced into central Montana.

2. Earlier age determinations of "Quadrant" or of "Amsden" faunas of Montana were commonly contradictory. Redetermination of every available collection was therefore undertaken with a view to establishing a uniform, objective basis for future discussion of these collections. Some of these are agreed by all observers to be Mississippian. Other collections contain fossils which are regarded either as Pennsylvanian, or as precursor elements in an Upper Mississippian fauna, according to individual predilection.

3. Correlations with the Brazer limestone are difficult because of the extraordinary faunal facies of that formation. Particular confusion surrounds the significance of a molluscan fauna which has been intimated to be as old as the Spergen or Salem limestone, but which may be as young as Chester or Pennsylvanian.

4. Location of the Mississippian-Pennsylvanian boundary in central Montana has been complicated by the discovery of *Millerella* (at first thought to be of Pennsylvanian age) in beds underlying strata which have been regarded on other grounds as Mississippian.

5. A conflict of opinion exists as to the nature of the contact between the Cameron Creek formation and the Heath formation and the degree and significance of an unconformity if present. It seems probable that any marginal unconformity would decrease toward the center of the basin of deposition and may well be absent in much of the basin.

6. The lower age limit of the Big Snowy group is doubtful because fossils have not been obtained from

the Kibbey sandstone. The assignment of a Meramec or Chester age to this unit is based on stratigraphic bracketing and lithic affinities with the overlying beds.

CARBONIFEROUS SYSTEMS

The following account of upper Paleozoic stratigraphy in central Montana is concerned primarily with presenting adequate information on the stratigraphic occurrence of the faunas discussed later on. To this end readily accessible outcropping sections are summarily reviewed. For the most part these are sections already known to be significant by reason of previous fieldwork by others, and a detailed discussion of them is planned for separate publication by Gardner. Descriptions of measured sections can be consulted at the end of this section and a graphic presentation as a correlation chart is included (pl. 14).

MISSISSIPPIAN SYSTEM

MADISON GROUP

MISSION CANYON LIMESTONE

The Mission Canyon limestone consists mainly of massive limestone on which a weathering surface developed in post-Madison time. This surface is not more specifically dated than pre-Kibbey in the areas of outcrops studied. In the area under discussion the Big Snowy group normally rests upon the Mission Canyon limestone with a depositional contact, which is locally irregular (as on Belt Creek).

CHARLES FORMATION

The Charles Formation was named by Seager (1942, p. 863, 864) for limestone, dolomite, anhydrite, salt, and shale lying between massive Mission Canyon limestone and Kibbey sandstone in a well. Since that time the formation has been widely recognized as a subsurface unit, but a difference of opinion exists as to whether the formation crops out. Although evaporites are not known in outcropping sections of strata similar to the Madison in the Big Snowy Mountains, some geologists consider the solution breccias that locally characterize the upper part of the Mission Canyon limestone to be the leached equivalent of the Charles formation (Hadley, 1950, discussed on p. 44; Barnes, 1952, p. 105; Sloss, 1953, p. 152).

Beds 86 to 89 of the section measured on Durfee Creek (pl. 24) may represent the only described outcrop of the Charles formation. The strata are distinctly different from the Mission Canyon limestone by reason of the presence of sandy strata, thin beds, and argillaceous content of both limestone and sandstone. Moreover, the top of the massive Mission Canyon limestone at this locality is overlain by 14 feet of bedded gypsum. The sandy and gypsiferous development are like the Kibbey sandstone, but the presence of limestone is distinctly not like the Kibbey. Unfortunately the absence of massive limestone beds similar to the Madison above the gypsiferous and sandy sequence makes it hard to assign the beds to either the Charles or to the Kibbey. Unidentifiable fragments of brachiopods and possibly of worn ostracodes do not help solve the problem of what name to apply to the beds.

Seager (1942, p. 864) recognized the possibility that the Charles filled the "gap" between Mission Canyon and Big Snowy time, but he assigned the formation to the Big Snowy group because he considered widespread development of porosity at the top of the Mission Canyon limestone to indicate that the "break" came at that place. Subsequently both interpretations have been alluded to; for instance, Walton (1946, p. 1304) recognized a pre-Charles disconformity but Perry (*fide* Hadley, 1950, p. 44) considered the Charles to be evaporites in the last remnants of the Madison seas.

Most recently Sloss (1952), Barnes (1952, p. 105), and Gardner (1959) have given reasons, including faunal evidence, for referring the Charles to the Madison group, and this is consistent with information the writer has from subsurface geologists in the area indicating the Charles to be lithically allied with the Mission Canyon limestone.

LOWER PART OF BIG SNOWY GROUP

The Big Snowy group was named by Scott (1935a, p. 367) and described in detail by him (1935b, p. 1023–1032) as a sequence of variegated shale, sandstone, and limestone lying between the Madison group and the so-called Amsden formation typically exposed on the hillside beneath the aerial beacon at Alaska Bench in the Big Snowy Mountains in sec. 6, T. 12 N., R. 20 E., Fergus County, Mont. Scott divided the Big Snowy group into the Kibbey, Otter, and Heath formations in ascending order. As so defined, the Big Snowy group replaced the name Quadrant formation over most of central Montana.

As discussed above, Seager (1942) added the Charles formation to the base of the Big Snowy group, but the Charles has been generally placed in the Madison group since Sloss referred it there in 1952.

The Big Snowy group has been recognized widely in Montana, North Dakota, and South Dakota, particularly in wells drilled in the Williston basin, as shown by various isopach maps (most recently by Barnes, 1952, pl. 6 on p. 106). Limits of the group as recognized in those isopach studies are as the group was originally defined. Gardner has suggested (1959, p. 338) that the composite section at Stonehouse Ranch

A

B

C

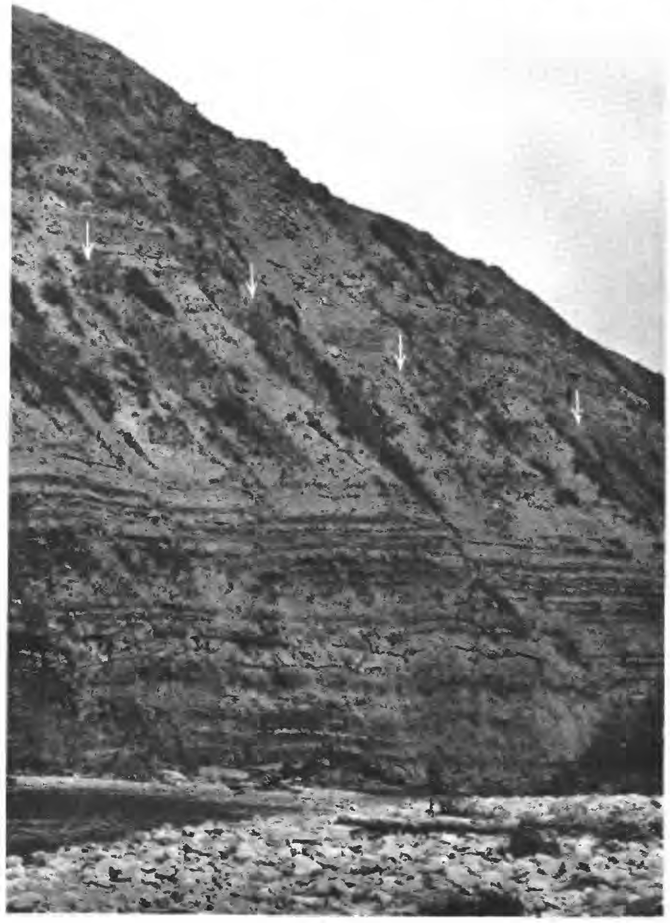
A. Western escarpment of Alaska Bench in sec. 36, T. 13, N., R. 19 E., as viewed north from the aerial beacon south of Health. The cliff-maker is the Alaska Bench limestone. Shale of the Cameron Creek formation makes the steep scree-strewn slope. Grassy slopes below it and beyond it at the second spur are on the Heath formation, but some grassy slopes in the valley are on shale in the Otter formation. Moccasin Mountains are on the horizon beyond Judith Basin. Photograpb by J. E. Smedley.

B. Calcareous algae on an exposed bedding surface in the Otter formation in Stonehouse Canyon. The nodules are mostly less than 1 foot in diameter. Photograph by J. E. Smedley.

C. Heath formation in a road cut south of Heath in sec. 35, T. 14 N., R. 19 E., Fergus County, Mont. Black fissile shale with thin stringers of siltstone and limestone in the upper part of the Heath formation, as shown here, weather to smooth grassy slopes. Locality 13366.

EXPOSURES OF BIG SNOWY ROCKS

A



B

C

D

EXPOSURES OF BIG SNOWY ROCKS

and State Road 25 (measured section 7 of this report) should be considered the standard section of the Big Snowy group as redefined and enlarged to include both the Amsden and the Big Snowy of Scott plus the previously undescribed Devils Canyon strata at the top of the known Carboniferous sequence.

KIBBEY SANDSTONE

The Kibbey sandstone was named by Weed (1899a, p. 2) for reddish and yellowish, agrillaceous, gypsiferous sandstones resting on the Madison group. A type section was not specified, and although gypsum in the Kibbey sandstone crops out near Kibbey School in Little Otter Creek, Cascade County, Mont., Weed made particular mention of the formation only at Riceville, a few miles to the west in the valley of Belt Creek (pl. 2*B*).

In the outcrop area studied by the writer, the Kibbey sandstone rests on the Madison group without noticeable disconformity. Locally, as at Riceville and 3 miles south of Townsend, solution channels in the Mission Canyon limestone are filled with sandstone of the Kibbey (Walton, 1946, p. 1297; Scott, 1935b, p. 1026) but in some subsurface sections (Sloss, 1952, p. 67) the Kibbey and Charles give the appearance of being gradational. Collapse features in the Kibbey, which may be due to solution of sulfate beds beneath the sandstones, are locally impressive, as on Belt Creek (pl. 2*B*) and on Durfee Creek. Inasmuch as the Charles and Kibbey contain some similar rocks, it would be desirable to learn whether any of the seeming gradation is due to reworking or to similar environments of deposition.

In stratigraphic sections studied by the writer the Kibbey sandstone is mostly reddish, argillaceous, fine-grained sandstone grading locally into siltstone. It is not resistant to weathering; hence, its presence is generally indicated by reddish soft soil on slopes of low gradient. Outcrops of it often support stands of scrubby timber or dense brush. The best outcrops known to the writer are along the South Fork of Judith River 13 miles west of Utica, Judith Basin County where 241 feet of Kibbey beds are present. This section (in measured section 3 of this report) is representative of the Kibbey sandstone for the region. At the standard section of the revised Big Snowy group at Stonehouse Ranch the Kibbey is in a poorly exposed interval about 240 feet thick.

In view of the fact that no identifiable fossil has ever been reported unquestionably from the Kibbey sandstone, its precise age is in doubt. Bed 86 of the measured section on Durfee Creek may prove to be referable to the Kibbey. Although it contains the first organic material reported from possible Kibbey strata, the fragments of brachiopods and possible ostracodes are not identifiable in the writer's opinion. Structurally the probably disconformable relation of the Kibbey sandstone with the Madison group when contrasted with its gradational contact with the overlying Otter formation lends support to assigning a Chester age to it. Petrographically, the Kibbey sandstone properly belongs with the diverse sediments of the Big Snowy group rather than with the predominantly carbonate succession of the Madison group.

OTTER FORMATION

Weed (1892, p. 307) named some variegated shales on Belt Creek the "Otter Creek shales" and then (1899a, p. 2) referred to the "Otter shales" as lying above the Kibbey sandstone within the Quadrant formation. Confusion has arisen about the type section for Weed did not designate one, although he said (idem) that the best exposures "are seen in the cliffs along Belt Creek" (pl. 2*B*, *C*) near the Kibbey exposures, which he also mentioned as being near Riceville. Of possible exposures which he mapped elsewhere in the quadrangle the poorest are along Otter Creek, where igneous rocks intrude the sediments. Intermediately good exposures are along Little Otter Creek. Subsequent

PLATE 2

A. Charles(?) or Kibbey(?) strata comprising beds 85 to 89 of the measured section at Durfee Creek in sec. 24, T. 12 N., R. 22 E., Fergus County, Mont. The top of the Madison group (bed 90) is shown in the lower left corner and red beds of the Kibbey sandstone are visible near the upper left corner. Hackly gypsiferous limestone (bed 86) comprises the upper half of the bluff and flaggy sandstone (bed 87), the lower half. Contorted strata, brecciation, and minor features of collapse structure reflect the solution of 14 feet of bedded gypsum from the horizon of the grassy and brushy slope below the bluff. Two hammers in the center of the photograph give the scale; the bluff is 20 feet high.

B. Banded red sandstone strata of the Kibbey sandstone overlain by green shale in the Otter formation. Above the arrows indicating the pre-Jurassic unconformity lies the Ellis group. View along Belt Creek in sec. 11, T. 17, N., R. 6 E., Cascade County, Mont. Undulations in the bedding of the Kibbey sandstone are probably caused by collapse subsequent to removal or heaving due to hydration of one or more gypsum or anhydrite beds in the lower part of the formation. Beds 11 to 16 of the measured section on Belt Creek were measured along these bluffs.

C. Otter formation in bluffs where units 1 to 11 of the measured section on Belt Creek are located. In sec. 11, T. 17 N., R. 6 E., Cascade County, Mont. This is approximately the type section of the Otter formation. The top of the hill consists of Jurassic strata, but a sharp contact of these beds with the Paleozoic strata is not apparent. Locality 14227 is about midway up the hill.

D. Upper part of the measured section on Durfee Creek, sec. 18, T. 12 N., R. 23 E., Fergus County, Mont. Light-colored beds at the top of the slope are the Alaska Bench limestone. The light-colored shoulder in the center of the picture is bed 28, which lies between brick red (dark-colored) sandstone, shale, and conglomerate of the Cameron Creek formation. Closer slopes are of the upper part of the Heath formation with a few stringers of limestone present. The foreground is the Otter formation. Beds 1 to 41 of the measured section are present along the far slope.

geological accounts have dwelt upon the localities near Riceville almost to the exclusion of those on Otter Creek or on Little Otter Creek.

The Otter formation is conspicuous by reason of its almost startlingly green color, but grey, black, purplish, and reddish shales are also present. One or more beds of hemispherical, concentrically laminated, pillow-like heads of "calcareous algae" generally less than a foot in diameter are commonly present, particularly in lower parts of the formation. Beds of ostracode-rich oolitic limestone are generally common in that part of the section containing the calcareous algae. Beds of gypsum occur discontinuosly in the Otter formation, as observed in the hills along the road south of Heath.

Differentiation of the Kibbey sandstone from the Otter formation is not invariably easy on outcrops because the shale in the lower part of the Otter formation is commonly silty or sandy, a condition which reflects what Perry and Sloss (1943, p. 1298) have described as a facies difference between the two formations and which Walton (1946, p. 1300) refers to as a gradational contact. The Otter formation weathers to rounded low slopes which generally are grass covered. Good exposures are on Belt Creek near Riceville, along the South Fork of the Judith River 13 miles west of Utica, and on the northwest flank of the Potter Creek dome 8 miles southeast of Forest Grove. The thickest section known to the writer is 472 feet along the South Fork of the Judith River. This section (in measured section 3 of this report) is representative of the Otter formation for the region, largely because the sections in the area Weed studied are not typical of the lithology of the formation at most other places. At the standard section of the revised Big Snowy group at Stonehouse Ranch the Otter is only 374 feet thick.

Differences of opinion exist as to where to draw the upper limit of the Otter formation, both in surface and in subsurface sections. In its type area along Belt Creek the Otter formation is overlain disconformably by the Ellis group (Jurassic); so, the upper limit of the Otter formation was not established by original definition. On Otter Creek the Otter formation is overlain by the Heath formation, but the contact has to be drawn rather arbitrarily where predominantly green shale in the Otter is succeeded by predominantly black shale in the Heath. Farther to the east, at several localities in the Big Snowy Mountains and in the eastern Little Belt Mountains, Scott (1935b, p. 1016, 1025, 1027) drew the top boundary of the Otter formation at the top of a limestone bed rich in productid brachiopods ("*Dictyoclostus*" *inflatus*). His recognition of the top was followed generally by Walton (1946, p. 1298, 1299) but Walton (p. 1300) also considered the contact to be gradational. Gardner and others (1945) placed the boundary at the contact of the green and black shales; where the green shale grades gradually into the black, the contact was placed where the shale is predominantly black. The writer follows these usages, which are largely based on color differentiation. This procedure assigns Scott's productid limestone to the Heath and includes some black shale in the Otter. Perry and Sloss (1943, p. 1298) report that even the characteristic green of the Otter shale is lost eastward from the Big Snowy Mountains into western North Dakota and subsurface sections are predominantly variegated and red shales. Red shales also occur at the top of the Otter in the type area. The problem is discussed further under the Heath formation.

Peculiar, thin, knobby algal limestone bodies (pl. 1*B*) which crop out at various places in the lower part of the Otter formation, seem to the writer to be lenticular. At least he was unable to trace any of the beds more than a few hundred feet on any outcrop and usually lost the contacts within about 200 feet. These limestones, of course, would make convenient markers if they should prove to hold consistent stratigraphic positions.

Ostracodes are abundant in the Otter formation, even in its lower parts when abnormal environments are commonly indicated, but few good megafossil localities are known and these tend to be in the upper beds. The ostracodes and megafossils indicate a Chester age.

HEATH FORMATION

The Heath formation was named by Scott (1935a, p. 367) and defined (Scott, 1935b, p. 1028, 1029) as black petroliferous shales and sandstones conformably overlying the Otter formation and constituting the top of the newly-erected Big Snowy group. The type locality is on the hillside below the aerial beacon on Alaska Bench in sec. 6, T. 12, N., R. 20 E., south of Heath in Fergus County, Mont. The upper limit of the Heath formation is not distinct because black shales such as those characteristic of the Heath are interbedded with reddish shales assigned to the Cameron Creek formation, and reddish shales such as are normally placed in the Cameron Creek formation occur irregularly below appreciable thicknesses of black shale assigned to the Heath formation. Moreover, introduction of sandstone into this interval further distinguishes the stratigraphy of the eastern Big Snowy Mountains.

Since the writer began his study of the Big Snowy group in 1952, much information derived from drilling has become available about the nature of the sediments and contacts of stratigraphic units within the Heath and Cameron Creek formations. Ideas at variance with those derived from study of the surface sections were first published by Beekly (1954) and are widely held (with variations) by geologists in the petroleum industry. Their thesis is that after deposition of the Heath there was a time of slight uplift and channeling of the Heath. These channels were filled with non-marine black mud derived from the Heath and with sand. Subsequently, the Cameron Creek sediments represented by reddish shale and sandstone were deposited as more widespread blanket deposits on the channel fillings.

The writer did not recognize this sequence of events in the outcrops in the Big Snowy Mountains in 1952; hence, a review of the outcrops was undertaken in 1955 in company of Mr. Beekly by several members of the U.S. Geological Survey and by petroleum geologists representing the Billings Geological Society. Although it is quite possible that lenticular sandstones in the Heath, mentioned below, may be identical in origin with the channel fillings cited by the petroleum geologists, the writer (and presumably the other conferees) could not find incontrovertible evidence to prove this point. Outcrops are not exposed clearly enough to show the lateral termination of the sandstone bodies, and the shales tend to slump down the hillsides. It may be significant, however, that black shale containing an upright stump of the fossil tree *Dadoxylon?* occurs in the upper Heath on Potter Creek Dome in association with lenticular sandstone bodies. Marine fossils, however, definitely occur in black shale above the lenticular sandstones at the cliff beneath the aerial beacon south of Heath.

Since the field conference of 1955, Mundt (1956, p. 1920) has presented several lines of evidence to support Beekly's thesis that these lenticular sandstones are channel deposits, separated from underlying strata by a widespread unconformity. Mundt revived and redefined the name Tyler formation for them.

Evidence is presented later on in this report to show many similarities between the faunas of the Heath and Cameron Creek. Differences are also noted, but they may in part be indicative of ecologic change or of different routes of migration, just as they might well indicate a significant hiatus in the record at this place in the section.

The Heath consists almost entirely of black or dark-brown, carbonaceous, fissile, generally silty shale. Its upper portion commonly contains stringers of dark argillaceous limestone from 1 inch to a few inches thick, separated by equally thin layers of the typical black shale (pl. 1*C*). Here and there throughout the section are lenticular beds of dark limestone a few feet thick or beds of hard shale whose durability is determined by various degrees of calcification. The best exposed section of the Heath formation seen by the writer is at its type locality at Beacon Hill where 364 feet are present. A thickness of 423 feet, however, is estimated in the standard section of the revised Big Snowy group at Stonehouse Ranch (p. 121, sec. 7), and the thickest section is the 840 feet estimated at Potter Creek dome, if it is not repeated structurally. The Heath weathers to low slopes of soft brown soil which are ordinarily grass covered.

From an economic standpoint the most interesting part of the Heath formation is a series of lenticular sandstones in black shale which occur near the top of the Heath and may in part belong to the overlying beds of the Cameron Creek formation (pl. 2*D*). Freeman (1922, p. 827) named the beds the Tyler sand but included most of the Big Snowy group below the Alaskan Bench limestone and above the Otter formation in that term. Freeman implied that the type section is at Tyler, Mont. Actually, the prominent sandstone bluffs near Tyler School are Cretaceous. The probable type section of the Tyler sand should be 0.5 mile west of N-Bar Ranch School in NE¼, sec. 25, T. 13 N., R. 21 E., Fergus County, Mont., where one of the stray sandstones in the upper Heath is conspicuously exposed. Bauer and Robinson (1923, p. 178) recognized the sandstones in the Big Snowy group and suggested their possible economic importance. These sandstone lenses have subsequently proved to be reservoirs for some oil production in the Melstone field where the sandstone has been assigned to the "Heath unit" (Darrow, 1951, p. 72), which is equivalent to the Heath and Cameron Creek formations of this report. Other sandstones in the "lower Amsden" of central Montana have been referred (Billings Geol. Soc., 1951, p. 8) to the "Bell sand" mentioned by Condra, Reed, and Scherer (1940, p. 44). It has not been proved that these sandstones in the Heath and Cameron Creek formations of central Montana are correlative with the "Bell sands" of the Powder River Basin and the Fairbank formation of Condra, Reed, and Scherer (1940) in eastern Wyoming.

The Van Duzen "sand" (Reeves, 1926, p. 68), which produces oil in the Devils Basin field is reported by Mundt (1956, p. 1920) to be actually "a finely crystalline and porous dolomitic limestone of the restricted Heath formation," and by Rader and others (1951, p. 15) to be a "black, dense, fractured limestone 5–10 feet thick near the middle of the Heath formation."

Scott (1935b, p. 1028, 1029) proposed that the Tyler sandstone of Freeman (1922) and the Van Duzen sand be made members of the Heath formation. The writer considers their use as local (drillers') terms to be reasonable but feels that they have no place in formal stratigraphic nomenclature. Fine examples of the lenticular nature of the sandstones in the Heath and Cameron Creek formations are seen at unit 12 of the section at Potter Creek dome; units 7 and 20 of the section at the north end of the hill at the aerial beacon south of Heath; and units 8 and 10 of the section at the south end of the hill at the aerial beacon on Alaska Bench.

Some of the sandstones (as at locality 13388) contain reworked plant remains, and one locality (13397) in the Heath contains a stump of a tree in an upright position. Walton (1946, p. 1301) reported that many of the outcrop sections of the Heath formation which he studied "contain coal beds only a fraction of an inch thick." One such coal bed seen by the writer (in the washout surrounding the casing of the northern or upper of the two abandoned open artesian wells on the hill above the cement plant at Hanover) is more than an inch thick. Perry and Sloss (1943, p. 1303) also report coal from the Heath in wells along the Montana-North Dakota boundary. Some beds of shale in this continental or near-continental portion of the Heath are clay-shales instead of silty shales. Those shales closely associated with the plant remains are not only devoid of marine fossils but commonly are noncalcareous or only slightly calcareous. Indeed, shales associated with the stump at locality 13397 contain crystalline gypsum filling secondary fissures in the sediment, possibly indicating closed-basin conditions subsequent to the deposition of what may be flood-plain or estuarine muds and nearshore sands. If this part of the upper Heath formation was not deposited under continental conditions, then conditions were at least not normally marine. Marine fossils do occur in Heath beds overlying the plant-bearing sediments, as at Potter Creek dome, locality 13396.

Several limestone bodies containing abundant "*Dictyoclostus*" *inflatus* which are present in the lower Heath are lenses which occur at different stratigraphic positions. Some of these lenses are of brownish limestone, others are of greyish limestone, and textures are diverse. Although Scott (1935b) originally placed a productid limestone in the top of the Otter formation, the writer includes the productid limestones in the Heath because of related paleontologic and ecologic evidence. The sudden abundance of "*Dictyoclostus*" *inflatus* in the Big Snowy group accompanied the return of a normal marine environment after the presumably extrasaline conditions which prevailed during the deposition of most of the Otter formation. Invasions of normal sea water earlier in one place than in another resulted in a patchy distribution of the productid beds. Inclusion of all of the productid-rich beds in the Heath stresses the changed environment and renders a homogeneous faunal distribution in which the flourishing of productids is entirely post-Otter in central Montana. Lithically, the limestones near the base of the Heath are mostly dark, fossiliferous, and smell of hydrocarbons. Those of the Otter are mostly light, with sparse megafossils, and commonly have a fetid odor. As thus used, therefore, the Heath formation is extended downward to include the productid limestones. Nieschmidt (1953) extended the Heath in subsurface sections she studied down through dappled shales resting upon a green limestone which she considered to be the top of the Otter formation. The writer could not recognize and extend this relation in the outcropping sections.

Moreover, the upper limit of the Heath formation as originally defined (Scott, 1935b, p. 1024) came below a 4-foot thick limestone bed (bed 24 of Scott's section) which the writer includes with the Heath as its top bed. By so doing, all the dark limestone beds at that part of the section are in the Heath whereas the light-colored limestone and most of the reddish shales are post-Heath. This minute shift is not of much importance insofar as recognition of only one stratum is concerned, but it results in the consistent assignment of dark limestone to the Heath and light limestone to post-Heath units at other localities seen by the writer.

The age of the Heath formation, as determined by abundant fossil collections discussed elsewhere in this paper, is Late Mississippian. The fauna is especially significant because it contains essentially contemporaneous populations of the creatures characteristic of carbonate facies and of those characteristic of shale facies.

MISSISSIPIAN OR PENNSYLVANIAN SYSTEM

MIDDLE PART OF BIG SNOWY GROUP

CAMERON CREEK FORMATION

Cameron Creek formation is the term proposed by Gardner (1959, p. 347) for predominantly shaly beds of variegated colors which had hitherto been referred to as the "lower Amsden" in central Montana. The type section is in sec. 31, T. 11 N., R. 21 E., Stonehouse Canyon, Golden Valley County, Mont., but the name was selected from Cameron Creek, the next canyon eastward on the south side of the Big Snowy Mountains.

The Cameron Creek formation includes what some geologists have referred to as the "lower Amsden," or part of which Freeman (1922, p. 827) called the "Tyler sand," or which Nieschmidt (1953) called "lower member of the Amsden formation."

The Cameron Creek formation consists largely of reddish or purplish silty shale, but it also contains minor amounts of siltstone, limestone, and sandstone. Toward the east end of the Big Snowy Mountains the amount of sandstone increases notably and beds of reddish conglomerate are present (pl. 2*D*).

Interpreting the nature of the contact of the Cameron Creek formation with underlying formations is not easy. From the foregoing discussion it seems that reddish Cameron Creek shales should rest on black Heath shales, but areal studies indicate that shale similar to the Cameron Creek formation locally rests on shale of the Otter formation (Walton, 1946, p. 1304) or even on the Charles formation (Perry and Sloss, 1943, p. 1303). The apparent unconformity mentioned by Walton is due to the deposition of reddish shale similar to shale of the Cameron Creek in the basal Heath formation overlying the Otter formation. Where the Heath is thick and no direct evidence indicates an erosional interval between the shales of the Heath and Cameron Creek formations (as at the aerial beacon south of Heath), black shale similar to the Heath occurs above reddish shale of the Cameron Creek. This relationship could arise from a temporary recurrence in Cameron Creek time of an environment similar to that prevailing during Heath time or from local reworking of Heath sediments. The fact that various species (table 5) occur on both sides of the contact indicates that the two environments were not very dissimilar and that not much time if any elapsed at the supposed break. Lack of evidence of reworking of fossils in Heath-type shale near the contact lends additional support to a belief that conditions such as prevailed during Heath time recurred in early Cameron Creek seas. Presence of sandstone lenses in the upper Heath formation and of sandstone and conglomerate beds in shale of the lower Cameron Creek formation of the eastern Big Snowy Mountains support a hypothesis that these increasingly coarse clastic sediments reflect a wave of diastrophism which began in Heath time and reached at least one culmination in Cameron Creek time. Some geologists interpret the presence of coarse clastics as indicating a regional unconformity at that place in a section, whereas others (including the writer) point out that there is little, if any, physical evidence in the field to support the theory. Gardner (1959, p. 337), for instance, considers that the irregularities along the contact were caused by widely spaced local channeling of the sea floor.

The best outcrops of the Cameron Creek formation are probably those abnormally thin ones beneath the cliff at the aerial beacon south of Heath. More commonly the member is represented by grass-covered reddish-brown soil on steep slopes. The thickest exposure (282 feet) of shale of the Cameron Creek seen by the writer is at the Durfee Creek section. At the type section at Stonehouse Ranch it is 222 feet thick. Gullying and mass wasting tend to expose the upper portions of the formation at localities where the overlying Alaska Bench limestone is a cliff-former (pl. 1*A*).

On many outcrops the Cameron Creek formation is identifiable by the abundance of chonetid brachiopods which strew its surface. The fauna is closely allied to that of the Heath, but it differs in particulars that have resulted in the Geological Survey conception that a Pennsylvanian age cannot be ruled out.

ALASKA BENCH LIMESTONE

The Alaska Bench limestone was proposed by Freeman (1922, p. 827) as a formational subdivision of the Quadrant formation. His original reference reads, in part, as follows:

> * * * Around the Big Snowy Mountains are a series of hogbacks and sloping benches formed by one excessively hard gray fossiliferous limestone that weathers red. This is well exposed on Alaska Bench east of the Snowies. A broad valley [the valley of Spring Creek is the most prominent and readily accessible valley fitting this description] has been carved in the soft shales and sands [Heath formation and Cameron Creek formation of this report] that occur below this hard line. The name of Alaska Bench limestone might well be applied to this bed, which, on Alaska Bench, is 100–150 feet thick.

The type locality may be taken as the well-known cliff delimiting the west edge of Alaska Bench near the site of the aerial beacon in sec. 25, T. 13 N., R. 20 E., and sec. 36, T. 13 N., R. 19 E., Fergus County, Mont. (pl. 1*A*).

Beds referred to herein as the Alaska Bench limestone are what geologists in the region have been calling the "Amsden limestone" or "upper Amsden limestone" (Agatston, 1954, p. 515), or, recently, "middle member of the Amsden formation" (Nieschmidt, 1953). Although these usages stressed the lithic similarity of these carbonates with the typical Amsden of Wyoming, the beds cannot be traced between the two outcrop areas and their faunal identity has not been established. Application of a local term is justified in view of its availability, the existing confusion, and the broad stratigraphic implications inherent in the usage of Amsden in any sense in the Big Snowy Mountains.

Over most of central Montana the Alaska Bench limestone consists of light-gray limestone and some dolomite in beds a foot or two thick. In the eastern Big Snowy Mountains some sandstone strata are incorporated within the basal part of the formation. Good exposures were seen by the writer near the aerial beacon south of Heath and in the sections at Stonehouse Canyon and Durfee Creek. The thickest exposures (143 feet) observed by the writer are at Durfee Creek (pl. 2*D*) and Stonehouse Ranch. The entire sequence is a notable cliff-former in its area of outcrop where it commonly (as at the type section) constitutes a picturesque white brow surmounting hillsides of red, black, and green shale (pl. 1*A*).

Alaska Bench limestone is gradational with the underlying shale of the Cameron Creek formation in areas studied by the writer. The contact is placed at the base of the predominantly carbonate part of the section. Thin beds, crossbedding, fragmentary fossils, and impersistent strata are all indicative of rather strong currents in action during deposition of the lime muds.

The age significance of fossils from the Alaska Bench limestone is not agreed upon. The writer believes they are Mississippian, but his Geological Survey associates consider a Pennsylvanian age probable.

PENNSYLVANIAN SYSTEM

UPPER PART OF BIG SNOWY GROUP

DEVILS POCKET FORMATION

The Devils Pocket formation is a name proposed by Gardner (1959, p. 347) for red siltstone, shales, dolomites, and sandstones overlying the Alaska Bench limestone in the eastern and southern Big Snowy Mountains. The type section (143 feet thick) is in sec. 31, T. 11 N., R. 21 E., Golden Valley County, Mont., in the walls of Road Canyon just south of the narrows in the Alaska Bench limestone. It is also well exposed a few hundred yards north of the stone ranch house in Stonehouse Canyon. This is north of the topographic depression called Devils Pocket and is also north of the Devils Pocket anticline.

The unit is known only in outcrops from Durfee Creek and the type locality and from areas nearby, where it forms grassy slopes or covered intervals. Nieschmidt projected the unit (as the "upper member of the Amsden formation") into the subsurface south of the Big Snowy Mountains (Nieschmidt, 1953, column 11). Its predominant sediment is red argillaceous shale which contains an abundance of tiny doubly terminated quartz crystals. Although the comparison cannot be evaluated in our present state of knowledge, it is worth pointing out that similar euhedral quartz crystals have been found in shale in the Amsden formation of northwestern Wyoming (Love, 1939, p. 28) in strata whose age is inexactly known (either Mississippian or Pennsylvanian).

A massive, well-sorted, nonfossiliferous sandstone stratum at or near the top of the sequence is continuous over most of the area in which the Devils Pocket formation is present. This sandstone has previously (Gardner and others 1946, p. 52, 59; Gardner and others 1945; Nieschmidt, 1953) been called Tensleep(?) or Quadrant (?) by reason of lithic similarity. In a small area in the vicinity of Road Canyon between Stonehouse Canyon and State Road 25, in Golden Valley County, a chert breccia commonly overlies the foregoing sandstone. The top of the Devils Pocket formation (and of the Big Snowy group) is drawn at the top of the breccia, or, if it is not present, then at the top of the massive sandstone.

Gardner and others, (1946, p. 50) recorded 14 feet of breccia in their basal Chugwater(?) formation at Road Canyon, about a mile west of the section studied by the writer in Stonehouse Canyon in 1952. The breccia is included herein as the top unit of the Devils Pocket formation and would be located at the top of unit 4 of measured section 7. In 1953 in Billings, Mont., Mr. G. H. Norton, of Atlantic Refining Company, Dallas, Tex., donated a sample of breccia from in or near Road Canyon to Mrs. C. L. Nieschmidt of the U.S. Geological Survey. The sample (17389) contained primitive fusulinids and was from a unit not otherwise known to contain fossils; so its importance was doubly notable. In view of the author's need for additional information, further fieldwork was generously done by Paul W. Richards, Robert Kunkel, and Howard Smith, some of it being carried on at great personal discomfort in the winter of 1953. Mr. Richards and his party examined the sections called Road Canyon (there turned out to be two canyons of this name) and collected additional samples (17390–17392) from the so-called Chugwater(?) breccia at the locality described by Gardner and others (1946, p. 50).

Henbest (1954, p. 50, 51) reported on the collections made by Norton and by Richards' party. They contain the following composite fauna, according to Henbest:

Textularian	?*Millerella* sp.
Climacammina sp.	*Pseudostaffella* sp.
Endothyra sp.	*Profusulinella* sp.
Bradyina sp.	Sponge spicules
Tetrataxis sp.	Echinoid spine

According to Henbest (1954, p. 51) the assemblage is of Atoka, Pennsylvanian age. Henbest based his opinion largely on the presence of the *Profusulinella* sp. The fauna occurs both in the matrix and in the clasts of the breccia.

Additional collections made by P. E. Cloud, Jr., and M. Gordon, Jr., from the breccia in 1955 were reported by Henbest (written communication, August 6, 1956) to resemble the foregoing collections but also contain serpulopsids, calcitornellids, *Cornuspira* sp., *Spiroplectammina* sp., *Climacammina magna*? Roth and Skinner, 1930, an *Ozawainella*-like fusulinid, and *Millerella* sp. (USGS coll. 16700 and 16701).

Inasmuch as the breccia is above the massive sandstone and is of pre-Tensleep age, the massive sandstone marker bed can no longer be assigned to the Tensleep sandstone.

Cloud also discovered primitive fusulinids 20 feet below the top of Devils Pocket formation at Stonehouse Canyon (USGS coll. 16703). Henbest (written communication, July 23, 1956) reports that the assemblage is similar to those from localities 16700 and 16701.

BEDS OVERLYING BIG SNOWY GROUP

PENNSYLVANIAN(?), PERMIAN(?), OR TRIASSIC(?) UNDIFFERENTIATED

Undifferentiated strata above the Devils Pocket formation and below sandstones of the Ellis group are of concern to this report only insofar as they cap the sequence studied.

Overlying the massive sandstones or the breccia that variously make up the top of the Devils Pocket formation are a few, thin, red beds of shale and siltstone which were doubtfully referred to the Chugwater (Triassic) because of supposed position in the section (Gardner and others, 1945; Gardner and others, 1946, p. 52). These sediments once were supposed to represent the northern featheredge of Chugwater deposits. No fossils have been found in these strata; hence, they are of an indeterminate age that is perhaps between Atoka (Pennsylvanian) and Ellis (Jurassic).

JURASSIC SYSTEM

Except for a few feet of Pennsylvanian(?), Permian(?), or Triassic(?) rocks in the southeastern Big Snowy Mountains, the Big Snowy group is overlain everywhere in the area studied by the Ellis group of Jurassic age. Most commonly the Ellis strata are red beds, evaporites, limestone, and sandstone which have been referred to in the area as the Piper formation of Middle Jurassic age (Imlay and others, 1948). The most extensive unconformity in the area studied in central Montana is that of pre-Ellis age, which is known to truncate all sediments from the Mission Canyon limestone to the Chugwater(?) formation (Imlay and others, 1948).

Fragmentary oysters and belemnites occur in the Ellis group at some localities in the area studied.

UNCONFORMITIES

There are four significant unconformities in the region.

1. Kibbey sandstone in areas of outcrop was deposited on eroded limestone of the Madison group. The Charles formation or its lateral equivalent may or may not be present. Although some geologists believe that these higher portions of the Madison group are of Meramec age, the writer is unaware of conclusive proof that any upper Madison strata in central Montana are other than of Osage age. In any event the Madison-Kibbey unconformity may involve parts of early Chester or Meramec time, or both. Concordant sequences of Mission Canyon, Charles, and Kibbey supposed to be present in the subsurface imply that the unconformity dies out basinward.

2. Some geologists have recognized an unconformity at the base of the clastic portion of the Cameron Creek formation in the subsurface of central Montana, the magnitude of which is sufficient for the Cameron Creek or the Alaska Bench limestone to lie on the Madison group in some places. In the area studied an apparently conformable sequence is observable from the Heath formation into the "lower Amsden" Cameron Creek formation of the same unit. Thus this unconformity recognized elsewhere tends to die out basinward. Deposition of the Big Snowy group in central Montana started in a narrow trough (fig. 1). By the time the Heath formation was laid down, subsidence had almost ceased and the surrounding lowlands were rapidly covered with reddish clastic material during the ensuing marine transgression of Cameron Creek time.

3. The most widely recognized unconformity in the Carboniferous of the north part of the western interior is at the top of the revised Big Snowy group or the base of the carbonate-rich portion of the Amsden (or Minnelusa, or Hartville, or Quadrant). Rather generally in this region strata of middle Des Moines or of early Des Moines age lie upon strata of Mississippian age (or of Early Pennsylvanian(?) age). The position of this unconformity in the Big Snowy Mountains is somewhere above the Alaska Bench limestone (no matter whether this formation is believed to be of Chester or of Springer or Morrow age). In Road Canyon in the Big Snowy Mountains (see section 7, bed 4) a few feet of *Profusulinella*-bearing breccia at the top of the Devils Pocket formation possibly represent the unconformity. Incidentally, if this unconformity in the Big Snowy Mountains is the same as that in Wyoming at the base of the Fairbank formation of Condra, Reed, and Scherer (1940), the correlation of the Darwin sandstone member of the Amsden formation, "Bell sandstone," and "Fairbank formation" should be critically reevaluated, because the Darwin is not above but beneath the unconformity.

4. The major unconformity in this and surrounding areas is generally that which separates Paleozoic from Mesozoic rocks. In central Montana the Ellis group (Jurassic) locally rests upon the Madison group so that the Big Snowy group is entirely cut out. Therefore, the pre-Ellis unconformity may cut down across the pre-Des Moines unconformity, the local pre-Cameron Creek unconformity (pre-Amsden of many geologists), and the pre-Kibbey unconformity.

Inasmuch as oil is being sought in sandstones at unconformities, it follows that potential reservoirs exist in three stratigraphic positions where sandstones occur over unconformities (Kibbey, Cameron Creek, and the Darwin, "Bell," and "Fairbank" level); in one place where sandstones occur under a local unconformity (Heath); and possibly in many places under the pre-Ellis unconformity where it transects all of the previous sandstones.

FAUNAL ANALYSIS

About 4,000 faunal specimens were identified during the course of this investigation. These, which were grouped into 187 minor categories, constitute the elements of the fauna shown on the enclosed stratigraphic distribution chart (table 5). Fifty-six distinct species of megafossils are recognized without qualification, and thirty of these are named as new. A breakdown of the foregoing chart consists of the following categories which are presented as table 5.

Tables 1 and 5 illustrate the overwhelming numerical dominance of brachiopods in the fauna—37 percent of the systematic groups, 50 percent of the groups of megafossils, and 87 percent of the specimens are brachiopods. The 11 most numerous species of brachiopods actually comprise almost 60 percent of the specimens other than microfossils collected. The only other group which is even moderately numerous is pelecypods, which represent 12.8 percent of the specimens in the collections. Everything else combined (some 37 percent of the faunal elements studied) only comprises 6 percent of the specimens in the fauna.

TABLE 1.—*Composition of the fauna and flora of the Big Snowy group*

[— indicates present in undetermined numbers]

Major categories	Known elements		Specimens of larger invertebrates and other fossils	
	Number	Percent	Number	Percent
Plants	3	1.60	[2] [16]	
Foraminifers	[1](17) 4	11.23	[4] [—]	
Sponges	1	.56	3	0.07
Corals	[3](9) 6	8.02	52	1.31
Jellyfish	1	.56	1	.02
Crinoids	2	1.07	2	.05
Echinoids	1	.56	7	.17
Ophiuroids	1	.56	1	.02
Brachiopods	62	33.15	3,449	87.01
Bryozoans	(—) 0			
Worms	3	1.60	56	1.41
Pelecypods	21	11.23	274	6.91
Gastropods	11	5.88	73	1.84
Scaphopods	1	.56	10	.25
Cephalopods	6	3.00	18	.45
Trilobites	2	1.07	11	.27
Malacostracans	1	.56	2	.05
Ostracodes	(30) 0	16.04	[4] [—]	
Shark? teeth	1	.56	[4] [10]	
Fish remains	1	.56	[4] [—]	
Conodonts	(3) 0	1.60	[4] [—]	
Totals	187	99.97	3,964	99.83

[1] Including elements not described herein.
[2] Numbers in [ ] were not used in totals.
[3] Numbers in ( ) are of elements identified by other students.
[4] Not counted.

PRESERVATION

In general the material is well preserved. Even very thin-shelled species are commonly well preserved. Bivalved organisms commonly retain both valves in contact. Most of the fossils are calcite replacements but some localities yielded secondarily silicified specimens. Dolomitization has not occurred at many places. Clay shales in particular break down naturally or artificially to yield good free specimens.

DISTRIBUTION

Fossils are generally not very abundant in the Big Snowy group, but at some places and stratigraphic levels they may be more than ordinarily abundant. These features show up graphically in the stratigraphic columns (pl. 14) and the chart of stratigraphic distribution (table 5). Although a careful search for fossils was made of the outcrops in each stratigraphic section, rather thick barren intervals predominate. Of the fossiliferous localities, several contain only one or a few species and not very many contain a really abundant fauna. These considerations make it difficult to obtain adequate material for conclusive faunal analysis or dating.

Several species are known only at a single locality. These species have no direct value in correlations but are useful in an indirect way, for they may be closely allied to species of known range. Some other species are known from the general area of the Northern Rocky Mountains. A third category of species ranges eastward into the midcontinent region where the standard Mississippian sections are located. The general character is that of a local fauna with close similarities to eastern faunas but having significant differences, only some of which are seemingly due to ecologic factors.

PALEONTOLOGICAL CHARACTERISTICS OF THE FORMATIONS

Elements of the fauna that are widespread in any formation in the Big Snowy group also tend to range through a considerable thickness of stratigraphic section; therefore, from a purely paleontologic standpoint it is often difficult to make faunal distinctions between the stratigraphic units. Because of this general faunal similarity, formations and members in the Big Snowy group must be recognized from a combination of faunal and lithic evidence.

The Big Snowy group is not characterized as a whole by any peculiar association of species. Its most common and characteristic fossils are species of *Spirifer* and *Composita*, brachiopods like *Dictyoclostus inflatus* (McChesney), and ostracodes. Paleontologic evidence bearing on the recognition of units within the Big Snowy group follows.

The Kibbey sandstone cannot be recognized from paleontologic evidence because nothing organic has ever been reported in it, unless unidentifiable fragmentary brachiopods and ostracodes? in bed 86 of the section on Durfee Creek are from the Kibbey.

The Otter formation is not very fossiliferous, the only fairly good fauna being that at locality 13390 where a flood of bryozoans occurs with brachiopods and crinoid ossicles. The formation contains several beds of so-called calcareous algae whose biscuitlike or bouldery appearing surfaces are peculiar to this formation. Of the other common organisms, only *Pugnoides parvulus* Girty has either not been found in higher beds locally or is known from only one locality. Scott (1942a, p. 153) reported that *Lochriella otterensis* Scott is the most abundant and characteristic ostracode in the Otter formation.

The Heath formation is consistently more fossiliferous than is any of the other units of the Big Snowy group. Its most diverse fauna is at locality 13414.

No species is common and widespread, yet restricted to the Heath formation. *Leiorhynchus carboniferus* Girty is known elsewhere in the area from only one locality in the Otter formation. It is the most characteristic species in the Heath fauna. *Girtyella woodworthi* Clark is rare, but restricted to the Heath formation. *Composita ozarkana* Mather is qualified in the same way as *L. carboniferus*, but it is commonly not surely identifiable. The greatest abundances of "*Dictyoclostus*," *Composita*, and *Spirifer* are in the Heath. Indeed, veritable coquinas of *Spirifer* and "*Dictyoclostus*" often are found near the base of the Heath. Several less common species listed on table 5 constitute an assemblage which is characteristic of the Heath.

Locally, as at locality 13420, the reddish shales of the Cameron Creek formation are highly fossiliferous. The member is not characterized by anything approaching the conception of an abundant and ubiquitous "index fossil," but it does contain floods of *Chonetes pseudoliratus* Easton (which is less common in the Alaska Bench limestone) and of the ostracode *Glyptopleura*. "*Marginifera*" *planocosta* Easton is common around Alaska Bench. An association of the peculiar but less common species cited in table 5 identifies the Cameron Creek formation, chief among these being *Antiquatonia*, *Schizophoria*, *Millerella*, and *Neospirifer*.

The Alaska Bench limestone is the predominantly limestone portion of the Big Snowy group. It is moderately fossiliferous throughout, but is only weakly characterized by the scattered species cited in table 50. The Alaska Bench limestone contains many *Composita subquadrata* (Hall) locally.

The overlying Devils Pocket formation is mostly barren of megafossils, but one collection of *Derbyia* has been made. In addition, the presence locally of species of *Profusulinella* and *Pseudostaffella* and a few associated foraminifers is diagnostic of it.

In summary, therefore, the formations below the Devils Pocket formation seem to the writer to be characterized less by their faunal differences than by their faunal similarities, based on the most abundant fossils. Faunal dissimilarities become more notable, however, in strata most distant stratigraphically from the Heath-Cameron Creek contact. Moreover, the Devils Pocket formation contains distinctly Early Pennsylvanian (Atoka or Des Moines) fusulinids.

INTERREGIONAL AND INTERCONTINENTAL CORRELATION PROBLEMS

CHESTER SERIES OF ILLINOIS

Correlation of the Big Snowy group with beds of Chester age in the midcontinent is based largely upon a summation of the faunas by Weller (1931). He reported (p. 263–266) that the upper Chester from the Tar Springs sandstone through the Kinkaid limestone is characterized by the presence of *Sulcatopinna missouriensis* Swallow, *Composita subquadrata* (Hall), and *Spirifer increbescens* Hall. These correspond in the Big Snowy fauna to *Sulcatopinna ludlovi* (Whitfield), *Composita subquadrata* (Hall), and to *Spirifer increbescens* Hall and to its close ally, *Spirifer curvilateralis* Easton. Although this is tenuous evidence for late Chester age of the Big Snowy group, it does agree perfectly with the opinion of Scott (1942a, p. 152) that the ostracodes he studied from lithologically equivalent strata indicate a late Chester age for the Big Snowy group. Several other species are known from upper Chester strata but range down into the middle Chester.

On the negative side (and possibly only pertinent to geographic or ecologic discussions) the faunas studied herein are devoid of some significant early Chester elements in the genera *Platycrinites*, *Agassizocrinus*, *Pterotocrinus*, and *Prismopora* which might establish an age of Golconda or older for parts of the faunas.

SPRINGER FORMATION OF OKLAHOMA

Increasing attention is being given by geologists to the possibility that strata correlative with the Springer formation may exist in the Western United States. It is desirable, therefore, to comment upon the status of the Springer and how it may be related to the Big Snowy group.

Paleontologic correlations with the Springer of the Ardmore Basin in Oklahoma are almost impossible because of the paucity of published data on the faunas from the Springer.[2] Not a single generically or specifically identified fossil animal, other than a few foraminifers and an ostracode (mostly recorded by Harlton in the first volume of the Journal of Paleontology) was recorded in print from the Springer until 1954. At that time M. K. Elias (Bennison, 1954, p. 914) identified 22 faunal elements from the Target limestone of Bennison (1954), which occurs about midway within the named units of the Springer. Of these, 14 are bryozoans or ostracodes not considered herein. The remaining 8 are referred only to genera or to new species, except for 2 common Pennsylvanian spiriferoids. Not a single species is known to be shared with the Big Snowy group, but all 8 of the genera (or presumed subgenera, in some cases) are known to range from Mississippian into Pennsylvanian or younger strata. The writer's personal knowledge of the Springer fauna does not add any basis for correlating the fossiliferous (upper) part of the Springer with any part of the Big Snowy. The presence of *Neospirifer gorei* (Mather) and of *Spirifer rockymontanus* Marcou in the fauna of the Target beds of Bennison (1954) suggests to this writer a decided affinity with the Morrow. Assignment of strata beneath the Target limestone of Bennison (1954) to either the Mississippian or Pennsylvanian has not yet been proved paleontologically; so long-range correlations with those strata are futile at present.

MOSCOW BASIN

Significant similarities with the faunas from the Big Snowy group of Montana are encountered in certain brachiopod faunas from the Moscow Basin in Russia. The stratigraphic position of the Russian brachiopod faunas under discussion is given by Sarycheva and Sokolskaia (1952, p. 15, 244–273) as being in the upper Viséan stage and particularly at the C_1^{tr} (Tarussa) and C_1^{st} (Steshevo) horizons. Sokolov (1939, p. 137) referred both of these units to the D_3 subzone (Hudson and Turner, 1933, chart facing p. 466) of the British lower Carboniferous. In terms of American stratigraphy, the D_3 subzone is thought (Cooper, 1948, p. 354) to embrace the lower Chester series; thus, the Tarussa and Steshevo faunas of Russia indicate a slightly lower position for analogous Montana faunas than do the type Chester faunas. This sort of offset in faunal correlations is the bane of long-range correlations, reflecting as it does the inescapable difficulties of faunal migration and regional ecologic differences such as that of climate.

Besides the host of genera and various species of similar evolutionary attainment that the two regions share, a few particular instances of faunal similarity merit special attention. As identified by Sarycheva and Sokolskaia (1952) in the Russian faunas: *Schizophoria resupinata* (Martin) is close to *S. depressa* Easton from Montana. *Antiquatonia* is particularly abundant in Russia in strata carrying *Antiquatonia nerutshensis* Sarycheva which resembles *Antiquatonia* n. sp. from Montana; moreover, *Antiquatonia insculpta* (Muir-Wood) and *A. hindi* (Muir-Wood) both resemble *A. pernodosa* from Montana. *Marginifera longispinia* (Sowerby) resembles "*M.*" *planocosta* from Montana. *Spirifer parabisulcatus* Semichova is analogous to *S. curvilateralis* Easton from Montana. *S. gröberi* Schwetzov seems to be a primitive stage of *S. botscharovensis* Semichova and the two together are analogous to *S. shoshonenis* Branson and Greger. On the basis of these close relations, the writer tentatively suggests that faunas similar to those from the Tarussa and Steshevo horizons of Russia were ancestral to those from the Heath formation and Cameron Creek formation of Montana. Obviously, additional evidence is needed before direct correlation can be made.

CORDILLERAN GEOSYNCLINE

If there has been faunal migration from Russia into North America, as is indicated in the preceding paragraph, evidence of it should be found in the sediments of the Cordilleran geosyncline as well as in these more platformlike deposits of central Montana, because marine connections probably existed between all these regions. The linear nature of the basin in which the Big Snowy group accumulated (fig. 1) indicates a connection of this basis with the Cordilleran geosyncline to the west in the region of western Montana or eastern Idaho where the Brazer limestone is present. The Brazer, in turn, occurs intermittently south and west into Utah where it and the underlying limestones of the Madison group undergo facies changes to become the White Pine shale (Easton and others, 1953, p. 146,

[2] The outstanding contributions of M. K. Elias (1957) to the fauna of the Springer series had not been published when this analysis was written, but one of Elias's species has now been added to table 4.

147) of western Utah, Nevada, and eastern California.[3] Disregarding irrelevant problems about the age of the lower White Pine shale, it is known that some shales of the upper part, now generally termed the Chainman shale, carry a significant fauna of *Cravenoceras* interpreted as of Chester age and are definitely to be correlated with part of the Big Snowy group (Miller, Downs, and Youngquist, 1949, p. 611). The fauna associated with the cephalopod *Cravenoceras* is meager at most places, but it is known to the writer locally to contain species reminiscent of the Chester of the midcontinent rather than of the Carboniferous of Russia. One of the most interesting localities, however, is in the Confusion Range of western Utah, where a large and varied fauna occurs in limestone and shale intercalations below the massive Ely limestone and in the upper part of the mappable Chainman shale. This fauna (Bacon, 1948, loc. FL 28, p. 1039–1042), in which a Pennsylvanian brachiopod was identified in association with abundant Chester elements, was called Chester by Bacon. Subsequently Ogden (1951, coll. 8, p. 79–81) studied the same fauna (probably at the same locality) and identified several of the fossils with Early Pennsylvanian species from the midcontinent. Thus, a conflict exists as to the interpretation of the fauna, which conflict will be hard to evaluate until a detailed systematic account of the fauna is published. Independent studies by the writer, starting in 1950, indicate to him that the Chainman shale contains a definite Chester fauna (the *Cravenoceras* fauna) and that another higher fauna with mixed typical Chester and Early Pennsylvanian species is also present locally. The exact relationship and age within the Pennsylvanian of this higher fauna have not been established, but the fauna is generally characterized by a flood of *Schizophoria and "Dictyoclostus" inflatus*-like brachiopods. These two faunas span the time during which the Big Snowy group was deposited. Interpretation of the age of the Big Snowy fauna will ultimately be governed in part by interpretation of the two Cordilleran faunas because the Big Snowy shares numerous species with both of these (shown on pl. 14). It may even be that the best evidence as to the exact age of the units in the Big Snowy group will come out of future studies of these Cordilleran strata with which the Big Snowy elements are presumably continuous. Likewise, great assistance in study of the entire Mississippian-Pennsylvanian boundary problem may come from correlating the faunal evidence from Montana with that from the Great Basin.

[3] The term "White Pine shale" (Hague, 1883, p. 253, 266, 267) has been abandoned for use in U.S. Geological Survey publications. In the Eureka district, Nevada, the Upper Mississippian part of the White Pine shale is called the Chainman shale by Nolan, Merriam, and Williams (1956, p. 59, 60). The Chainman shale, as it is now used in other areas, includes some beds that are higher in the section than those of the Eureka district.

ROCKY MOUNTAINS

BRAZER LIMESTONE

The 13 significant species from the Big Snowy group found in the Brazer limestone are distributed as follows: Otter 6, Heath 11, Cameron Creek 6 (including 2 doubtful), Alaska Bench 5 (4 doubtful). It appears that there is considerable faunal similarity between the Brazer limestone and the Heath, some between the Brazer and Otter, and less between the Brazer limestone and the other units of the Big Snowy group. The Brazer limestone is Meramec and Chester in age; so faunal elements found therein are here assigned Mississippian affinities.

SACAJAWEA FORMATION OF BRANSON (1936)

The 13 significant species from the Big Snowy group found in the Sacajawea formation are distributed as follows: Otter 4 (including 1 doubtful), Heath 8, Cameron Creek 10, Alaska Bench 5 (1 doubtful). Most similarity is between the Heath-Cameron Creek and the Sacajawea. The U.S. Geological Survey does not recognize the Sacajawea formation of Branson (1936), the beds concerned being included as a part of a broadly interpreted Amsden formation of Mississippian and Pennsylvanian age. Whenever Sacajawea is used in the report it will be placed between quotation marks to indicate that the Sacajawea of Branson (1936) is meant.

Most workers outside of the U.S. Geological Survey have assigned the "Sacajawea" to the Mississippian. E. B. Branson and D. K. Greger (1918) demonstrated that at least part of the Amsden formation (later named the "Sacajawea" formation by C. C. Branson, 1936) on the east slope of the Wind River Mountains of Wyoming contains Mississippian strata. They concluded (Branson and Greger, 1918, p. 312) that the sediments they studied were paleontologically equivalent to the Ste. Genevieve formation of the Mississippi Valley. Morey (1935, p. 474) concluded from a study of ostracodes that the "Sacajawea" is Ste. Genevieve in age. Croneis and Funkhouser (1938, p. 334) decided that Morey's ostracode assemblage indicated a Chester (about Clore or Kinkaid) age. Shortly thereafter Coryell and Johnson (1939, p. 214) identified "Sacajawea" ostracodes in the Clore, and Cooper (1941, p. 10, 11) identified a like assemblage in the Kinkaid formation. C. C. Branson (1937, p. 653) had, by this time, referred the "Sacajawea" megafossils to the Salem or Ste. Genevieve. He later (1939, p. 1201, fig. 2 on p. 1223) reviewed some of these identifications, and then E. B. Branson and he (1941, p. 131), in a final rather brief comment referred the "Sacajawea" to the late Middle Mississippian (presumably Meramec). Restudy by Biggs, as reported in a paper prepared in 1951 for the University of Wyoming, indicates to him that the "Sacajawea" is correlative with the Brazer limestone. Burk (1954, p. 3) reiterated Biggs' opinion that the fossils studied by Branson and Greger and by Morey were collected from float derived from strata of Madison age. This, of course, could explain the seemingly incongruous mixture of Lower Mississippian fossils with younger fossils. Shaw and Bell (1955) include a Mississippian "Sacajawea fauna" in their Amsden formation.

The writer is of the opinion that the "Sacajawea" fauna is Chester in age, and he therefore refers these species to the assemblage of Mississippian affinity.

FAUNAL RELATIONS

Table 2 is principally useful in showing that the Heath contains the largest fauna (54 percent of the known species) and the Cameron Creek contains the next largest (42 percent), followed by the Alaska Bench (24 percent) and the Otter (20 percent). Other less common combinations, such as the number of species in one unit which are shared jointly by two other adjacent (or two other nonadjacent) units, are not shown. Moreover, the table includes all categories of identification in the count of similiar elements from different strata, whether they are positively identified or are of questionable identity. Although table 1 shows gross relations of the faunas of the several units, it is not particularly definitive because it includes elements which are only incidental to critical analysis of the faunas.

TABLE 2.—*Stratal distribution of all faunal elements*

Faunal elements—	Formations and number of elements				
	Otter	Heath	Cameron Creek	Alaska Bench	Devils Pocket
In	33	89	69	40	18
Restricted to	9	33	18	5	1
Shared by Devils Pocket	0	0	0	1	--------
Shared by Alaska Bench	13	22	27	--------	1
Shared by Cameron Creek	15	44	--------	27	0
Shared by Heath	20	--------	44	22	0
Shared by Otter	--------	20	15	13	0

Table 3 is a compilation of range data presented on table 5. The 64 faunal elements considered by the writer to be of use at this time in establishing the ages of the biotas have been indicated by crosses (X) or by queries (?) in the last two columns on the right side of table 5 as being of Mississippian or of Pennsylvanian affinity. These 64 elements are referred to in the text as "significant species." Species of probable utility have been indicated on table 5 by queries (?). Any elements identified on the locality grid on table 5 by "cf.", or "aff.", or "?", or which are species of doubtful utility (last two columns of table 5), appear on table 3 as doubtful factors.

TABLE 3.—*Age distinction of significant species*

Stratigraphic units	Number of species of Mississippian affinity		Number of species of Pennsylvanian affinity	
	Certain	Doubtful	Certain	Doubtful
Devils Pocket	0	0	5	0
Alaska Bench	8	7	5	0
Cameron Creek	17	9	6	2
Heath	27	9	3	1
Otter	10	5	1	0
Cameron Creek and Alaska Bench	6	3	4	1
Heath and Cameron Creek	12	9	4	0
Otter and Heath	19	4	1	0

LONG-RANGING ELEMENTS

In addition to the 64 important elements of recognized affinity, 10 other elements have affinities with species which are known to cross the Mississippian-Pennsylvanian boundary. These are: *Triplophyllites* cf. *T. spinulosus* (Milne-Edwards and Haime), *Schizophoria depressa* Easton, "*Dictyoclostus*" *inflatus* (McChesney) and its two varieties, *Composita ozarkana* Mather, *Composita* cf. *C. lateralis* (Girty), *Punctospirifer transversus* (McChesney), *Reticulariina spinosa* (Norwood and Pratten), and *Paladin* sp.

ELEMENTS OF MISSISSIPPIAN AFFINITY

The 53 elements of Mississippian affinity are indicated on table 5. Four of these, *Echinoconchus angustus* Easton, *Nucleospira superata* Easton, *Cranaena? circularis* Easton, and *Cranaena?* n. sp., have affinities with pre-Chester species. The remainder have affinity with Chester species, or with species in western formations thought to be of Chester age, or are believed by the writer to signify Late Mississippian age.

Scott (1942a) has published the only account up to this writing on ostracodes from the Big Snowy group. He recognized 26 species in the Otter formation, 3 species from the Heath, and 1 of unstated range. Of these, Scott thought that *Bairdiacypris punctata* Scott from the top of the Heath resembled a Pennsylvanian form, but that most of them resembled species from the Golconda, Menard, and Clore of Illinois.

ELEMENTS OF PENNSYLVANIAN AFFINITY

On table 5, 11 elements indicate Pennsylvanian affinity in the opinion of the writer. Of these, those referred to *Bradyphyllum*, *Lingula*, *Linoproductus nodosus* n. subsp., *Derbyia*, *Myalina* (*Orthomyalina*), and *Pseudozygopleura* have not hitherto been reported beneath the Pennsylvanian. *Dicromyocrinus* is, in the opinion of the writer, of equivocal significance, being more advanced than Chester species and more primitive than the Moscovian (Middle Pennsylvanian) genotype.

PROEMIAL PENNSYLVANIAN ELEMENTS

One of the elements of Pennsylvanian affinity, *Limipecten otterensis* Easton, occurs in strata which everyone presumably would assign to the Mississippian.

Millerella n. sp. is more primitive than any known from Lower Pennsylvanian strata, but could well be ancestral to the later forms. Surface ornamentation of *Chonetes pseudoliratus* Easton bears strong resemblance to that of some Pennsylvanian chonetids, but the structure is also known from a chonetid in the Mississippian ("Sacajawea" formation). "*Marginifera*" *planocosta* Easton resembles very closely "*M.*" *muricatina* Dunbar and Condra from the Pennsylvanian, but, in the opinion of the writer, is also related to "*M.*" *adairensis* Drake from the Mississippian. Although *Neospirifer* has not been reported hitherto from Mississippian strata, *Neospirifer praenuntius* Easton is more primitive than the earliest Pennsylvanian *Neospirifer* and is closely allied with forms referred to *Spirifer*, with which it is associated in strata of Mississippian age. Naturally, the figures shown on table 2 might be altered somewhat, depending upon how one interprets the affinities of these proemial elements.

AGE OF INDIVIDUAL UNITS

The foregoing brief faunal reviews make it plain that the Big Snowy group contains anomalous mixtures of elements constituting a transitional fauna between the Mississippian and the Pennsylvanian.

The Otter formation contains distinctive and diagnostic Chester species, but in addition contains two elements suggestive of Meramec age and one of Pennsylvanian affinity. Moreover, the large assemblages of ostracodes described by Scott (1942a) indicate Chester age.

The Heath formation contains a varied and abundant fauna of Chester age. One-ninth of the significant elements are forms of Pennsylvanian affinity, but in the writer's opinion, only *Bradyphyllum* and *Linoproductus* n. var. are important Pennsylvanian elements.

The Cameron Creek formation contains a notable population of Chester forms, but shows a distinct rise in the relative abundance of forms of Pennsylvanian affinity, there being one-third of the fauna in the latter category. Alteration of the ratio by removal of elements of controversial nature tends to increase the Mississippian quality of the fauna. Uncommon species like *Chonetes pseudoliratus* Easton and *Neospirifer praenuntius* Easton are shared with the Heath formation.

The occurrence of some of these and others like "*Marginifera*" *planocosta* Easton in noteworthy abundance only in the reddish shales of the Cameron Creek formation suggests that their presence may be largely controlled by ecologic factors almost restricted to these reddish deposits. This fauna may have migrated into the region through routes made available coincidental with deformation which is also reflected in the increasing clastic nature of the sediment.

Many of the characteristic Chester species carry up into Alaska Bench limestone and some of the previously mentioned Pennsylvanian elements are also present therein. The ratio of Mississippian to Pennsylvanian elements is still 3 to 1 as it was in the Cameron Creek formation, but this ratio is associated with a decrease in number of elements of both sorts. It is significant, however, that *Derbyia* and a crinoid of strong Pennsylvanian affinities are added to the fauna, making it in these regards still more Pennsylvanian in aspect than is the Cameron Creek formation. On the other hand, the presence of *Composita subquadrata* (Hall) and *Orbiculoidea wyomingensis* Branson and Greger increase the Mississippian aspect of the fauna slightly.

Devils Pocket.—The only megafossils so far reported from the Devils Pocket formation are *Derbyia* sp., which is a subgenus of *Orthotetes* not known elsewhere below the Pennsylvanian and *Straparollus* (*Euomphalus*) sp. which is a genus of little significance in age studies. By far the most significant elements in the fauna of the Devils Pocket formation are the foraminifers. Some of these, such as *Profusulinella* sp. and *Pseudostaffella* sp. have not yet been found in strata older than the Atoka. Moreover, species of the former genus range up at least into the Des Moines, and species of the latter genus (*Pseudostaffella*) occur in the Permian. In addition, the association of *Bradyina*, *Climacammina*, *Endothyra*, and *Tetrataxis* in the abundance they have here is most common in rocks of Atoka or Des Moines age (L. G. Henbest, written communication, July 7, 1954). It is quite clear that the fauna of the Devils Pocket formation is not only distinctly Pennsylvanian in age, but that it represents the later part of the early Pennsylvanian, rather than being earliest Pennsylvanian (such as Springer or Morrow).

The Atoka or Des Moines (Early Pennsylvanian) age of some of the sediments overlying the Big Snowy group at Road Canyon and at Stonehouse Canyon is firmly established on the basis of fusulinids.

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

Unpublished and some published data reveal an increasing awareness on the part of paleontologists that a considerable thickness of very young Mississippian and very old Pennsylvanian strata may exist between beds heretofore placed in these respective systems. For instance, the recent Mississippian correlation chart of the National Research Council (Weller and others, 1948, chart) contains a "Post-Elvira" (post-upper Chester) category with the importance of group rank. Stanley-Jackfork strata in the Ouachitas and "Amsden" or "lower Amsden" (Cameron Creek formation) strata in Montana, for instance, are included in post-Elvira time. The Pennsylvanian correlation chart of the National Research Council (Moore and others, 1944, chart) also shows the Stanley-Jackfork, this time as post-Mississippian strata. These two usages are a manifestation of the two schools of thought on the age of the strata. These (Stanley-Jackfork) and certain Springer strata of about the same stratigraphic interval which are assigned to the Lower Pennsylvanian are a singularly vexatious sequence of beds, so far as age determination is concerned. Weller and others (1948, p. 105–107) have aired some of the paleontologic difficulties in the Mississippian-Pennsylvanian boundary problem—these being mainly that the strata are barren of fossils or sparsely fossiliferous, and that those fossils which have been found are not diagnostic. The effect is to interrupt the continuity of megafossil evidence by a gap encompassing the Mississippian-Pennsylvanian boundary. Some micro-fossil work has been published on very early Pennsylvanian strata, but information on megafossils is almost nonexistent. Until the faunal sequences of the standard sections are better known, accurate dating of faunas from elsewhere (Montana, for instance) remains impossible.

As paleontologic evidence now stands, few concrete and persistent criteria are available for recognizing Late Mississippian as contrasted with Early Pennsylvanian. The Mississippian Subcommittee of the National Research Council (Weller and others, 1948, p. 113) reported that Late Mississippian faunas "are particularly characterized by abundant specimens of *Composita* and *Pentremites*," and the subcommittee also mentions *Archimedes* (which ranges into Permian), large colonial corals, and *Kaskia* as being characteristic. Of actual faunal zones recognized by the subcommittee, the Chester series contains *Productus* [*Diaphragmus*], *Talarocrinus*, *Stenoscisma explanata* (McChesney), *Pterotocrinus capitalis* (Lyon), *Prismopora serratula* Ulrich, *Sulcatopinna*, and *Millerella* (Weller and others, 1948, p. 114, 115). The Pennsylvanian subcommittee reported that "Morrowan strata are distinguished from upper Mississippian zones by the appearance of *Hustedia* and *Squamularia* and by the absence of true *Productus* ("*Diaphragmus*")" (Moore, 1944, p. 675). The difficulties in applying these criteria are as follows: (a) *Composita* is commonly known to be locally very abundant in Pennsylvanian and Permian rocks; (b) *Pentremites*, *Archimedes*, *Kaskia*, *Talarocrinus*, *Pterotocrinus*, and *Prismopora* are unknown in the faunas studied and have rarely or never been reported in western faunas, and *Pentremites*, *Archimedes*, and *Prismopora* all range well above the Mississippian; (c) *Millerella* is now known to occur both in Mississippian and in Pennsylvanian rocks; (d) *Productus* s.s. has never been reported in print from Pennsylvanian rocks, but U.S. Geological Survey records include widely separated occurrences of that genus both above and in association with genera (*Chaetetes*, *Meekella*) previously unknown below the Pennsylvanian (Mackenzie Gordon Jr., personal communication); (e) *Sulcatopinna* and *Stenoscisma explanata* (McChesney) are the last available elements listed as distinctively Chester to be considered, and both *Sulcatopinna* and a species of *Stenoscisma* similar to *S. explanata* occur in the Health shale. *Sulcatopinna* is also questionably present at one locality each in Cameron Creek and Alaska Bench strata. By way of negative evidence, *Hustedia* and *Phricodothyris* [*Squamularia*], which first appear in beds of Mississippian and Morrow age, respectively, have not been found anywhere in the Big Snowy group.

In the early phases of his investigation of the Big Snowy group the writer entertained a working hypothesis that strata from the Heath formation through the Alaska Bench limestone might be of Early Pennsylvanian age. This idea was generated by the presence of *Schizophoria*, "*Marginifera*," *Antiquatonia*, *Neospirifer*, and *Cleiothyridina*, to mention the principal genera in mind. The idea was enhanced by recognition of a seemingly distinct fauna in shale of the Cameron Creek formation which was fundamentally composed of the foregoing genera and is not known as a faunal association elsewhere in North America. It was then thought likely that this fauna of non-Chester species represented an invasion of Early Pennsylvanian elements.

This tentative theory was upset by several developments. In the first place some of the species were found well down in the Heath formation along with species of undoubted Chester connotation like *Productus fasciculatus* McChesney. Secondly, elements of the new fauna really became notably typical and abundant only when associated with reddish shales of the Cameron Creek formation, even though black shales similar to the Heath might be interbedded with the reddish shales. In view of this relationship, the fauna is equally well interpreted as being due to changed environment as it is to passing of time. Third, evolutionary positions of some of the species (as in *Neospirifer*, for example) are such as to ally them with Mississippian species or at least not particularly with Pennsylvanian species. Next, the ostracode fauna from the Heath formation seems to be distinctly Chester in age. Lastly, the fauna which became prolific in the Cameron Creek formation is not referable to any known Early Pennsylvanian fauna described as yet from this country. For instance, there is not a single diagnostic species yet reported from the Morrow series or from the Marble Falls limestone in the fauna. These considerations make it probable that the new species described from the Cameron Creek formation may prove to constitute a distinctive fauna separate from that of the typical midcontinent Chester. Table 2 shows that the combined Otter and Heath elements have a Mississippian to Pennsylvanian ratio of 33 to 1, and the overlying combined Cameron Creek and Alaska Bench units have a ratio of 2 to 1. Incidentally, this latter ratio refers to those strata heretofore called Amsden in this region. Close numerical similarity of the Heath and Cameron Creek faunas has been shown on table 1, and this relationship is augmented by age diagnoses, which show the Mississippian to Pennsylvanian ratio to be 5 to 1 for the combined significant elements restricted to these two units.

The writer prefers to think of all of the Big Snowy group except for the Devils Pocket formation as Chester. He interprets the evidence (a) to indicate a preponderance of Chester species and of forms of Chester affinity in the four particularly fossiliferous units; (b) to reveal the absence of a single described Pennsylvanian species, although the number of elements of Pennsylvanian affinity increases in progressively higher strata; (c) to justify belief that some proemial Pennsylvanian elements are merely the expectable evolutionary steps that one should find in pre-Pennsylvanian species; (d) to place in doubt the ranges of some fossils supposedly known from the Pennsylvanian; (e) to warrant differences of opinion about the identity and interpretation of some of the faunal evidence.

Following its review of the evidence, however, the Geologic Names Committee of the U.S. Geological Survey recommended, and the Survey officially ruled, that the Kibbey, Otter, and Heath formations be assigned to the Upper Mississippian, that the Cameron Creek formation and Alaska Bench limestone be considered Mississippian or Pennsylvanian, and that the Devils Pocket formation be referred to Lower Pennsylvanian. Thus, although the writer's interpretation of the evidence leads him to conclude that the sequence below the Devils Pocket formation is Chester, the official Survey view is that enough latitude is possible in its interpretation to permit the reference of the upper part of these strata to the Pennsylvanian. By extending the thought slightly, it will be realized that the fauna of the Big Snowy group may prove to be particularly significant in subsequent attempts to recognize the Mississippian-Pennsylvanian boundary, because the fauna occurs in the critical interval and is replete with species.

ECOLOGY

Abnormal marine conditions are reflected in the distribution of fossiliferous beds within the stratigraphic sections, particularly within the Kibbey and Otter formations. The thin-bedded, argillaceous, red and yellow, commonly gypsiferous Kibbey formation is seemingly devoid of organic remains.

Only local thin beds within the Otter formation contain fossils in such abundance and diversity as to indicate normal marine conditions. More commonly, one encounters thin streaks of ostracode-rich calcareous shale or oolitic limestone intercalated with the characteristic greenish, silty, commonly gypsiferous, barren shales. In the general absence of any other organisms except ostracodes at these horizons, it seems likely that the local conditions were unsuited for normal marine life, as, indeed, their gypsiferous aspect indicates. In this case, it seems probable that the ostracodes drifted in from elsewhere. If, as seems likely, we are dealing with an evaporite-rich basin or with merely extrasaline conditions, then perhaps the ostracodes lived near the open sea in waters of normal salinity and were carried in by basinward-flowing waters, whereas heavier shells were left behind as a lag deposit. A few thin layers of rounded "heads" of "calcareous algae" are also found in the Otter. Locality 13390 is almost unique for its abundant and diverse fauna in a formation which elsewhere yields only meager collections.

The Heath formation typically consists almost entirely of the singular black calcareous shale facies which Girty (Mansfield, 1927, p. 71) has already particularized as a widespread but not necessarily contemporaneous deposit peculiar to the Upper Mississippian. It almost invariably carries abundant *Leiorhynchus carboniferus* Girty. The first extensive development of normal marine conditions after Otter time is reflected in the widespread development of a *Spirifer*-"*Dictyoclostus*" association near the base of the Heath formation. In the upper part of the Heath formation, the black shales are commonly noncalcareous or even gypsiferous and barren of marine fossils, but may, as at locality 13397, contain a tree stump upright in the shale or may contain plant remains in crossbedded sandstone lentils. It is likely that some or many of these noncalcareous deposits are nonmarine or are possibly estuarine, with the crossbedded sandstones being nearshore deposits. Evidence for weak currents and a slow rate of deposition of parts of the upper Heath, as at locality 13415, is found in the encrusting of complete shells by bryozoans and craniate brachiopods, and by the extensive infestation of certain shells by sulfur sponges (*Clionolithes*).

The Cameron Creek formation contains a large amount of reddish very calcareous shale which presumably was derived from lands nearby. In spite of the fact that fossils are abundant in the member, the red color was not removed by reduction of ferric oxide through organic processes. It appears, therefore, that sediments accumulated rapidly at that time. In support of this, one finds evidence for strong current action (which was capable of transporting a large volume of sediment) in the presence of waterworn and broken fossils and in disassociated valves of bivalved organisms at some localities, particularly in the upper part of the unit. The occurrence of the flood of *Glyptopleura* in the Cameron Creek formation may be the result of the ostracodes being washed in from elsewhere. These organisms are associated with large, husky abraded brachiopods which commonly have been rolled about on the ancient sea floor; so, any currents strong enough to transport large shells would have swept away tiny ostracodes. Ostracodes present may therefore have been transported from elsewhere with or immediately before arrival of the entombing sediments.

The Alaska Bench limestone consists of thin-bedded limestone with waterworn and broken shells. It represents clearer seas after the muddy ones in which beds of the Cameron Creek formation were deposited. There was not, however, enough difference in either time or ecology between Cameron Creek and Alaska Bench to enable any striking faunal differences to develop.

The Devils Pocket formation represents warm, emergent conditions, which favored the deposition of interbedded red clastics and sandy calcareous deposits which altered penecontemporaneously or later to cherty dolomite.

DESCRIPTIVE PALEONTOLOGY

An attempt has been made in the following section to present enough information so that geologists with less than comprehensive paleontological instruction may be able to make use of it.

Accordingly, short diagnoses are given of many genera, in addition to species. Each species is not only differentiated from its closest related species, but is also differentiated from those species in the fauna or in rocks of the same age with which it might be confused. Most of the faunal elements described are also illustrated even though the specimens may not be ideally preserved.

Publications through 1954 are taken account of in the report.

Synonymies are complete for some genera and species but are shortened or omitted for others. In general, recently published comprehensive synonymies have not been duplicated, but a reference is given to them.

PLANTS

Calcareous algae

Plate 1, figure *B*

Material.—Thirteen specimens, USNM and USGS collections. Tons of the material are available at certain localities.

Occurrence.—The large specimen recovered is from the Otter formation at locality 13400. Other supposed calcareous algae occur in the Otter formation at localities 13390 and 14227; in the Heath formation at locality 13424; possibly in the Cameron Creek formation at locality 13362?; and possibly in the Alaska Bench limestone at locality 13407.

Remarks.—At several places in the Otter formation one can observe beds about a foot thick which consist almost entirely of remains of supposed calcareous algae. When stripped by erosion, the upper surface of one of these beds (pl. 1, fig. *B*) consists of a number of heads or pillowlike hemispherical masses which vary in diameter from a few inches to almost a foot, with most of them measuring about 6 inches. Their surfaces are covered with nodules about 3 mm in diameter and with anastomosing ridges about 3 mm wide. The cores of the heads consist of a conglomeration of limestone debris containing fragments as long as 3 cm. The supposed calcareous alga forms a sheath of concentrically laminated material from 0.5 to 3 cm thick which rounds off irregularities in the shape of the core. Laminae are not of consistent thickness, but at one place 7 laminae occur in 1 cm. Weathered fragments of heads commonly develop highly characteristic fine chasing which accentuates the laminated condition of the mass. Thin sections mostly reveal only disorganized blotchy or granular laminae with occasional threadlike markings. J. H. Johnson verified headlike masses collected from locality 13400 as being of algal origin. This is the kind of algal accumulation characteristic of the Otter formation.

Calamites sp.

Material.—2 specimens. USGS collections.

Occurrence.—Heath formation at locality 13388. Cameron Creek formation at locality 13418.

Remarks.—These characteristic longitudinally striated pith casts lack nodes and are not worth illustrating.

Dadoxylon? sp.

Material.—A few fragments of wood, USNM and USGS collections.

Occurrence.—Heath formation, locality 13397.

Remarks.—A stump of a tree about 1 foot in diameter has been identified as *Dadoxylon?* sp. by Sergius Mamay of the U.S. Geological Survey. Lack of leaf scars, primary wood, and adequate preservation of pitting on tracheids prevents accurate identification of the wood. *Dadoxylon* is a form-genus for wood from some cordaitean plants. A host of Carboniferous plants have been referred to this genus but their identification is difficult because adequate material is rare.

The stump in question is right side up and bears roots. It seems to be in the position of growth.

PROTOZOA

Class SARCODINA

Order FORAMINIFERA

Family AMMODISCIDAE

Genus AMMODISCUS Reuss, 1861

Ammodiscus sp.

Material.—3 specimens.

Occurrence.—Otter formation, locality 14227.

Remarks.—These planispiral tubes have about 4 volutions and measure from 0.12 to 0.17 mm in diameter. They have no stratigraphic significance and are not suitably preserved for illustration.

Family FUSULINIDAE

Genus MILLERELLA Thompson, 1942

Diagnosis.—Endothyrid foraminifers with the septa differentiated angularly from the spiral wall.

Remarks.—*Millerella* was first described (1942) from and was considered for a time to be diagnostic of the Lower Pennsylvanian Morrow series. Later Scott (1945a, 1945b) announced the discovery of *Millerella* in the Amsden (Cameron Creek formation of this paper) and concluded that its presence likewise signified a Morrow age of the containing strata. Henbest (1946, p. 57; 1947, p. 373) and Cooper (1946, p. 57) simultaneously announced extension of the range of the genus into the Pitkin formation (Chester) of Arkansas and Kinkaid limestone (Chester) of Illinois, respectively. Then Mellen (1947, p. 1811) announced *Millerella* from the Pennington formation (Chester) of Mississippi. The first Mississippian species of *Millerella* were described by Cooper (1947, p. 82–87). At the same time Cooper (1947, p. 84) quoted Zeller as authority for the discovery of *Millerella* in the Amsden formation of Wyoming associated with purportedly Mississippian megafossils. E. J. Zeller (1950, p. 8, 19, 20) reported *Millerella* or Foraminifera resembling *Millerella* from the Glen Dean and Vienna limestones of Illinois, and D. E. N. Zeller (1953, p. 192–195) described species of the genus from the Glen Dean, Clore, and Kinkaid limestones of Illinois. The presence of *Millerella* in Mississippian strata has also been referred to by J. Steele Williams (1948, p. 333) and by Thompson (1948, p. 23, 27, 28).

Millerella aff. M. chesterensis Cooper, 1947

Plate 3, figure 4

Material.—2 specimens. Figured specimen, USNM 119211 from USGS f 9726.

Occurrence.—Otter formation, locality 14227.

Remarks.—Although only two specimens are available for study, these seem to be distinct from the other *Millerella* discussed herein. The larger specimen has an axial length of 0.23 mm and an equatorial diameter of 0.54 mm. It is seemingly completely involute, and has 24 chambers in the last volution. The septa are notably curved in equatorial section. The outline in the axial plane is evenly rounded.

The equatorial diameter of the smaller (sectioned) specimen figured herein (pl. 3, fig. 4) is 0.43 mm. The first 5 whorls have 7, 10, 14, 19 and 17+ (incomplete) chambers. Septa are relatively thick and are not sharply differentiated from the spiral wall in the last two whorls.

This species agrees in size, relative coarseness of septa, and in distribution of chambers with *M. chesterensis*, but more material is needed to identify the species positively.

Millerella n. sp?

Plate 3, figures 1–3

1945. *Millerella marblensis.* Scott, Geol. Soc. America Bull., v. 56, no. 12, pt. 2, p. 1195. (Amsden formation, Montana).

1945. *Millerella advena.* Scott, idem. (Amsden formation Montana).

Material.—100+ specimens. Figured specimens, USNM 119218–119220 from USGS f 9712. Other material in USGS collections.

Occurrence.—Cameron Creek formation, localities 14146, 14224?, 14225?, and 14226?.

Remarks.—In addition to the material originally studied and identified as *M. marblensis* Thompson by

Scott, the writer has at hand a large number of specimens which he collected from Scott's localities and from the same stratigraphic level at another locality. Although the material generally is closely allied to *M. marblensis* as broadly interpreted by Thompson in 1948 (pls. 23, 24), that species is now so broad as to need restriction. Even so, some consistent differences have been detected by the writer between *M. marblensis* and the material at hand. In the first place, *M. marblensis* consistently has more than 5 volutions, whereas the Montana material rarely has as many as 5 volutions. The axial length of the specimens averages about 0.25 mm, which is significantly greater than that of *M. marblensis* (averaging about 0.20 mm or less). Equatorial diameters of the two species are about the same, as are numbers of chambers per volution, there being some variation in both quantities.

The Montana material has about twice the equatorial diameter of *M. advena* Thompson and lacks the thick septa of *M. chesterensis* Cooper.

L. G. Henbest of the U.S. Geological Survey studied Scott's original material. He (written communication June 29, 1953) thought that the general size and shape of some specimens and their involute structure and low order of septal differentiation from the spiral wall allied them with *M. chesterensis* from the Mississippian rather than with Pennsylvanian forms. On the other hand he (written communication, May 12, 1954) reported that

> The single specimen in equatorial section [pl. 3, fig. 1] identified [by Henbest] as *Millerella* cf. *M. marblensis* Thompson has thin, closely spaced, long septa. In this respect it resembles a stratigraphically higher form than *M. chesterensis*, but the differentiation of the septa from the spiral wall is of a low order, which suggests an earlier age. The variations in some of the Early Pennsylvanian and Late Mississippian millerellids are so extensive that an exact age determination is hardly possible at this time.

Millerella is particularly abundant at locality 14226 where it is associated with a few *Endothyra* and some ostracodes, in addition to the species listed on table 5. Some *Millerella* were noted at locality 14225, but only a few occur at locality 14224 where *Endothyra* becomes particularly abundant. At all three of these localities the ostracode *Ectodemites tumidus* Cooper, which is elsewhere known only in Chester strata, is associated with nondiagnostic species of *Bairdia*. The typical fauna of the Cameron Creek formation which has been found below the fusulinid-bearing beds at several localities, also occurs above the fusulinid zone at locality 14220.

Scott's original specimens are figured herein for the convenience of students who may be interested in the *Millerella* problem.

Family ENDOTHYRIDAE

Genus ENDOTHYRA Phillips, 1845

Diagnosis.—Endothyrid foraminifers with the septa and spiral wall combined into a continuous curve.

Endothyra aff. E. excentralis Cooper, 1947

Plate 3, figures 5, 6

Material.—20? specimens. Figured specimens, USNM 11922 from USGS f 9712(8); USNM 118223 from USGS f 9712(9). Other material USGS f 9712.

Occurrence.—Cameron Creek formation, localities 14146, 14221?, 14223?, 14224?, and 14226?.

Remarks.—L. G. Henbest reported on these specimens (memorandum of June 29, 1953) as follows:

> Several of the endothyrids approximate *E. excentralis* Cooper, 1947. * * * I regard the resemblance of these forms to *E. excentralis* as having little value at this time in a question of Chester *versus* Morrow age for this part of the Amsden.

The specimens studied by Henbest were collected by H. W. Scott and donated by him to the U.S. Geological Survey.

PORIFERA

Order MONACTINELLIDA

Family CLIONIDAE

Genus CLIONOLITHES Clark, 1908

Clionolithes sp.

Plate 3, figure 7

Material.—Numerous examples of this boring were noted but only a few specimens were set aside; these, under USNM 118720.

Occurrence.—Heath formation localities 13415 (common) and 13395 Cameron Creek formation, locality 13421.

Remarks.—Networks of branching and occasionally radiating borings measuring 0.15 to 0.2 mm in diameter were noted parallel with the surface of numerous specimens of *Composita*. These are customarily referred to the form genus *Clionolithes*, which presumably led an existence like that of modern sulfur sponges boring into shell.

COELENTERATA

Class ANTHOZOA

Order TETRACORALLA

Remarks.—Sloss (1945) and Easton (1945a) have both described corals from strata in Montana equivalent to beds herein discussed, but none of their species were found during the present investigation.

Of those previously reported, *Caninia juddi* (Thomson) was reported by Sloss (1945, p. 311) from the lower Amsden formation of Jefferson, Wheatland, and

Beaverhead Counties, Montana. The writer has not seen the specimens.

Caninia bilateralis Easton, *C. enormis* Easton, *Triplophyllites spinulosus* (Milne-Edwards and Haime), and *Pleurodictyum*? cf. *P. meekanum* (Girty) were cited by Easton (1945a) from the Otter formation of Broadwater and Gallatin Counties, Montana. Of these, *C. bilateralis* is herewith assigned to *Caninophyllum* Lewis, 1929. It is similar to *Aphrophyllum foliaceum* Hill, 1934 from the late Viséan of Australia (which seems to be more nearly *Caninophyllum* than like *Aphrophyllum.*).

Family HAPSIPHYLLIDAE

Genus TRIPLOPHYLLITES Easton, 1944

Triplophyllites cf. T. spinulosus (Milne-Edwards and Haime, 1851)

Plate 3, figure 8

Material.—10 specimens. Figured specimen, USNM 118721.

Occurrence.—Heath formation, localities 13365, 13416, and 13417. Cameron Creek formation, locality 13363. Alaska Bench limestone, locality 13407.

Remarks.—Although specimens referable to this genus are very common in most Mississippian and in many Pennsylvanian collections, they are very rare in collections reported on herein.

Easton (1945a, p. 526) reported *Triplophyllites spinulosus* from the Otter formation of Montana. Ten specimens are tentatively referred here from recent collections. Until detailed revision of the species is undertaken it will not have much stratigraphic significance.

Genus BRADYPHYLLUM Grabau, 1928, emend. Easton, n. emend.

Diagnosis.—Amplexoid Hapsiphyllidae with rhopaloid septa which are slightly fasciculate in early stages. The cardinal fossula is usually not on the concave side. Neither dissepiments nor columella are present.

Genotype.—*Bradyphyllum bellicostatum* Grabau, 1928.

Remarks.—In 1922 Grabau proposed the genus *Heterelasma* with *Hadrophyllum edwardsianum* de Koninck, 1872 as genotype. In 1928 he proposed *Bradyphyllum* but left doubt as to whether he meant it to replace the name *Heterelasma*, which was preoccupied, or whether he meant it as a distinct genus. He cited "cf. *Heterelasma*" under his new generic name, and then in his text (1928, p. 36) he said that "*Hadrophyllum edwardsianum* * * * may be an early representative of the genus *Bradyphyllum*," but then he differentiated the two. Inasmuch as Grabau left his intentions uncertain, *Hadrophyllum edwardsianum* has subsequently (Hudson, 1942, p. 258) been referred to *Rotiphyllum* Hudson, 1942. As things now stand, *Heterelasma* Grabau, 1928 has been replaced by *Rotiphyllum*, a solution which, although it is indirect, seems to be satisfactory.

Bradyphyllum, as originally described, was said to have the axial ends of the septa fused into a "solid mass" (stereocolumn). The only longitudinal section which Grabau referred to (his pl. 2, fig. 13) is so far off center as to show only outer portions of septa. Transverse sections which Grabau considered to have a stereocolumn (his pl. 2, figs. 11c, 12c, 18b, and 20) can be explained as being cut exactly through the flat top of or cut just a short distance above the upper surface of tabulae so that the tabular tissue or inner ends of dilated amplexoid septa fill the central area. Significantly, the supposed stereocolumn is discontinuously distributed in the suite of his figures 11b–11e, for 11c is said to show a stereocolumn but earlier and later sections do not. It is not demonstrated therein that a stereocolumn as wide as the one shown is localized for only a few millimeters of vertical distance. It is the writer's conclusion that Grabau was misled into interpreting septal and tabular details as a stereocolumn. Therefore, *Bradyphyllum* is emended to apply to certain corals without a stereocolumn. Grabau's description of *Bradyphyllum* is erroneous as to the nature of tabulae and of dissepiments, for he not only consistently misapplied dissepiments for tabulae, but his sections (particularly the longitudinal section) are devoid of dissepiments. The genus is further emended, therefore, to include only nondissepimented corals.

Bradyphyllum, on merely morphological grounds, finds its place with *Amplexus*. Indeed, the mature portions might well be referred to *Amplexus*. Sowerby proposed *Amplexus* in 1814 for simple cylindrical corals with flat tabulae, with slightly depressed margins, and short thin septa. Various authors have referred to *Amplexus* so many simple corals of unknown relationship but with short (amplexoid) septa, that the name is now used as a form-genus. Among the amplexoid corals similar to *Bradyphyllum*, Soshkina differentiated *Amplexocarinia* in 1928 for corals with amplexoid septa along almost the entire length of the corallite and with margins of tabulae deflected vertically to form an inner wall. In spite of the suggestive name and in spite of Soshkina's use of "carinae" in the original description, the septa of *Amplexocarinia* are not carinate in the commonly understood meaning of the word but are merely amplexoid. *Bradyphyllum* differs significantly from *Amplexocarinia*, as interpreted from their genotypes, for the latter genus has a distinct inner wall of fused vertical margins of tabulae. Moreover, septa of *Amplexocarinia* are not rhopaloid, nor are they long in early stages comparable to early stages of *Bradyphyllum*. It should be pointed out, however, that subsequent usage has broadened *Amplexocarinia* to include rhopaloid species which are probably better referred to *Bradyphyllum*.

Amplexocarinia could be derived from *Bradyphyllum* by a continuation of the amplexoid trend and by further development of tabulae into an inner wall.

Some species of *Lophamplexus* Moore and Jeffords, 1941 resemble *Bradyphyllum* in having rhopaloid septa, but *Lophamplexus* has an axial rod or palicolumella (Moore and Jeffords, 1941, p. 90; 1945, p. 120). Inasmuch as the columella of *Lophamplexus* may be confined to the apical region, immature regions of specimens should be studied in order to differentiate *Lophamplexus* and *Bradyphyllum*.

Rhopaloid septa of *Bradyphyllum* are best seen in sections through mature regions and just above a tabula. The septa tend to lose their rhopaloid character in a portion of the mature region where septa successively rise toward the base of an overlying tabula, and at the same time they retreat in typical amplexoid fashion. That is to say, those portions of amplexoid septa which override tabulae are thicker on their lower edges than along their upper edges. *Fasciculiamplexus* described herein has rhopaloid septa and is amplexoid, but it has a strongly fasciculate septal pattern, its septa are dilated into maturity, and it has a rather long counter septum.

Grabau said that *Bradyphyllum* was distinctive not only by "thickening of the secondaries" (being rhopaloid) but by the presence of a counter fossula as well as of a cardinal fossula. However, hapsiphyllid corals with cardinal fossulae generally have distinctive counter fossulae containing counter septa of different lengths, but the feature is not always persistent and its systematic value is dubious. Tolmachoff (1931, p. 613) proposed *Disophyllum* for what appear to be hapsiphyllid corals with a counter fossula containing a septum. It has no other significant similarities with *Bradyphyllum*, but may preoccupy some subsequent generic name for so-called zaphrenthids from the Carboniferous. A statement of the position of the cardinal fossula, proof of the presence of dissipiments, and better figures of sections are needed before *Disophyllum* can be evaluated. The genus somewhat resembles *Triplophyllites*, *Zaphrentites*, and *Fasciculophyllum*, all of later date than *Disophyllum*.

Dobrolyubova (1940, p. 61, 62) not only was misled by the original description of *Bradyphyllum* but misinterpreted some of the figures and therefore concluded that the genus was nontabulate. Inasmuch as Dobrolyubova said that only the presence of tabulae differentiated the two genera, it follows that *Pseudobradyphyllum* is a junior synonym of *Bradyphyllum*. *Z. nikitini* Stuckenberg, 1888, is referable to *Bradyphyllum*. *Pseudobradyphyllum* was mentioned in 1941 by Soshkina, Dobrolyubova, and Porfiriev (1941, p. 218).

Of the species which have been referred to *Bradyphyllum*, *B. obscurum* Grabau, 1928, is a doubtful representative, having a thick epitheca, and distinct minor septa, but lacking the distinctly rhopaloid major septa. Chi (1931, p. 6) referred the genotype and also *B. obscurum* to "*Brachyphyllum*," but that genus is a typographical error for *Bradyphyllum*.

Bradyphyllum caninoidea Huang, 1932 is correctly referable to *Bradyphyllum*.

Bradyphyllum angeli Heritsch, 1936 is a nearly decorticated member of the Caniniidae, there being even the appearance of a few dissepiments in Heritsch's specimen 158b.

Bradyphyllum sp. figured by Heritsch in 1936 resembles *Amplexocarinia* much more than it does *Bradyphyllum*, by reason of the nonrhopaloid septa.

Bradyphyllum indicum Heritsch, 1937 is a zaphrenthid which cannot be assigned until the location of its cardinal fossula is determined. The species is certainly not referable to *Bradyphyllum*.

Clisiophyllum geinitzi Toula, 1875, was referred, with seeming correctness (although a longitudinal section has not been published), to *Bradyphyllum* by Heritsch in 1939.

Clisiophyllum nordenskiöldi Toula, 1875 was erroneously referred to *Bradyphyllum* by Heritsch in 1939. The figures of it (particularly Heritsch, 1939, pl. 14, fig. 7) suggest that it should be referred to the Caniniidae.

Zaphrentis incerta Koker, 1924, which Heritsch referred to *Bradyphyllum* in 1936 needs to be clarified with the aid of further sections, but it is probably one of the so-called zaphrenthid genera. Its lack of dilated and rhopaloid septa removes it from *Bradyphyllum*.

Stereolasma minus Soshkina, 1925, was referred to *Bradyphyllum* by Heritsch in 1936, probably because the original figures of the species were made from sections tangent to the tops of tabulae. In 1941 Soshkina and some colleagues revised her original work and concluded that the species is a junior synonym of *Polycoelia karpinskyi* (Stuckenberg, 1898). If the latest figures are typical of *S. minus*, then the revision is justified.

Hapsiphyllum djoulfense Heritsch, 1937, seems to be referable to *Bradyphyllum*, but additional study of the species is needed.

Occurrence.—Bradyphyllum is known from the Permian of southern China; from the Weiningian (Moscovian or Middle Carboniferous) of northern China; it is confined to the Gzhel horizon, C $\frac{1}{III}$ of the Upper Carboniferous of the Moscow basin (Dobrolyubova, 1941); it is probably in the so-called "*Otoceras*-beds" of Djoulfa in the Transcaucasus region of Russia, which Bonnet and Bonnet (1947, p. 57) say is Artinskian (Lower Permian) and not Upper Permian as first reported; and finally from the Heath formation and Cameron Creek formation of Montana. In terms of the American section these ranges cover a span from Lower Pennsylvanian (Morrow) to Lower Permian.

Bradyphyllum clavigerum Easton, n. sp.

Plate 3 figures 9–12

Exterior.—Small, simple, conical to cylindrical corals with an apical angle of about 30°. Epitheca with faint septal grooves and growth lines. Occasional constrictions signify points of rejuvenescence. The trace of the cardinal septum, on the few curved corallites on which it is detectable, is on the convex side. The calyx is very deep, occupying half the length of a typical conical specimen 23 mm long and 11 mm in diameter at the calyx. The apex is flattened on the cardinal side of some specimens where they are attached to the substratum.

Ontogeny.—The earliest observed stage of the holotype (pl. 3, fig. 9b, diameter 2.3 mm, early neanic stage) has 13 septa, so dilated that they meet along their sides most of their lengths. The cardinal alar, and counter septa all four meet axially. The cardinal quadrants each have two septa. The left alar pseudofossula is the only one discernable.

In a stage of late youth a paratype (pl. 3, fig. 10), diameter 4.0 mm, has 18 evenly dilated septa which are subradially arranged with 3 in each cardinal quadrant and 11 on the counter side of the section. The cardinal septum crosses the wide cardinal fossula. Septa have retreated from the middle third of the section. Alar pseudofossulae are well developed.

By early maturity, the holotype (pl. 3, fig. 9b), diameter 4.7 mm has 20 septa, which are still dilated almost their entire lengths. The cardinal quadrants contain 3 and 4 septa. The cardinal septum extends across the parallel-walled cardinal fossula. Alar pseudofossulae are distinct. A counter fossula is indicated by extra-wide loculi and the counter septum is slightly rhopaloid.

By middle maturity, the holotype (pl. 3, fig. 9c) has added one septum to the counter side, amplexoid retreat of septa is under way, and the septa are distinctly rhopaloid. The cardinal fossula is slightly swollen axially, but the others are hard to distinguish.

Somewhat later on, the holotype (pl. 3, fig. 9a), diameter 7.9 mm, has 22 radially arranged, mostly markedly rhopaloid septa, which have retreated from the central third of the section. The cardinal septum is short. Minute swellings on the epitheca indicate rudimentary minor septa.

Longitudinal section.—Tabulae (pl. 3, fig. 11) are commonly complete and their nearly flat tops occupy the central three-fourths of their span. Their margins are deflected almost vertically and fairly far. Septal fibers slope inward and downward at about 35°.

Comparison.—Bradyphyllum clavigerum closely resembles *B. bellicostatum* Grabau in general appearance and in number and distribution of septa but differs from Grabau's species in having more dilated septa and in having the amplexoid character introduced later in the growth.

B. clavigerum resembles somewhat *Amplexus adnatus* Easton, 1945 in position of fossula and in somewhat dilated septa in late stages. The latter species is not only spinose, but the septa are not distinctly rhopaloid, they tend to meet axially into late stages, and they are not much dilated in early stages (Easton, 1945b, pl. 87, figs. 1, 2). Tabulae in *B. claviger* are more deflected marginally than they are in *A. adnatus*.

Material.—13 specimens. Holotype, USNM 118722. Paratypes, USNM 118723 A, B, and C. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13414. Cameron Creek formation locality 13420 (type locality).

Genus FASCICULIAMPLEXUS Easton, n. gen.

Diagnosis.—Simple Hapsiphyllidae with the cardinal fossula tending toward being on the convex side, with fasciculate septa in early stages, and with pronounced amplexoid retreat of septa in the late stages.

Genotype.—Fasciculiamplexus contortus Easton, n. sp.

Occurrence.—Cameron Creek formation, Big Snowy Mountains, Montana.

Remarks.—Corals referred to this genus would be assigned to *Amplexus* on the basis of mature features, but *Amplexus* has become such a catch-all for unrelated corals that it is highly desirable to distinguish corals whose phylogeny is presumably recognizable. In the case at hand the early stages are readily distinguishable from those of other amplexoid corals; hence, a new genus is erected to receive these organisms.

Fasciculiamplexus contortus Easton, n. sp.

Plate 3, figures 13–17

Exterior.—Medium-sized simple conico-cylindrical corals with an apical angle of about 30°, but with the cylindrical portion representing as much as two-thirds of the skeleton. Theca thin and has faint septal grooves and growth lines. The exterior trace of the cardinal septum is on the convex side of the corallite or at some place other than on the concave side, except for some straight or highly contorted specimens on which its position is not determinable. Apex fused with the substratum to cause a flattened cardinal side and often equipped with a talon or with rootlets. Growth was in diverse directions, resulting in variously contorted corallites. Constrictions indicate rejuvenescence. Calyces moderately deep, measuring about 1.5 cm at a diameter of 1.5 cm. The longest specimen (incomplete) was 4.6 cm long and 1.5 cm in diameter at the large end. Specimens are commonly about 3 cm long.

Ontogeny.—In the earliest stage observed (pl. 3, fig. 13c, early youthful or neanic stage, diameter 2.5mm) there are 17 septa, of which the right cardinal quadrant contains 4 and the other quadrants in counter-clockwise rotation contain 3, 5, and 3 septa respectively. The first counter-laterals abut against the long counter septum. The cardinal septum joins the counter septum at the axis. Most other septa are grouped in conspicuous fascicles. Alar pseudofossulae are most prominent because the septa are all so dilated that other loculi are almost closed.

The holotype at early maturity (pl. 3, fig. 13d, diameters 8.5 by 9.0 mm) has 27 septa, of which the four primary septa are long and discrete, the alars lying close to the counter sides of the narrow alar pseudofossulae. The cardinal septum extends the length of the **V**-shaped cardinal fossula and meets the long counter septum axially. The left cardinal quadrant contains 7 septa, 6 of which are in fascicles distinct from the left alar septum. Similarly, the left counter quadrant contains 6 septa in fascicles. The 6 septa of the right counter quadrant are pinnate. The right cardinal quadrant contains 5 pinnately arranged septa in addition to the isolated alar septum. Septa of the cardinal quadrants are slightly concave toward the cardinal fossula. Most septa are slightly rhopaloid, as well as considerably dilated.

At a slightly later stage (pl. 3, fig. 13b) with 28 septa (diameter 11 mm) the fasciculate arrangement of septa is hard to discriminate, the septa of the cardinal quadrants tend to be convex to the nearly parallel-sided cardinal fossula, and the septa of the counter quadrants have just started to withdraw from the axis.

In late maturity (pl. 3, fig. 13a, diameter 13.5 by 14.0 mm) the 28 septa have all withdrawn somewhat from the axis and have separated from each other laterally so that their rhopaloid nature is obvious. The cardinal septum is short, apparently because of an accident.

In a section just below the floor of the calyx (pl. 3, fig. 13e, diameters 14.0 by 15.0 mm) the 28 septa have retreated farther from the axis than they have in the previous stage. Minor septa are inserted in the loculi on each side of the counter septum. In this, as in the other sections, fibers constituting the tissue are arranged at right angles to the planes of growth and are distributed by layers.

A paratype (pl. 3, fig. 14, diameter 9 mm) at a stage of middle maturity has 27 septa arranged in fascicles of 6 to each quadrant (except for 5 in the left cardinal quadrant). Alar septa are short and tend to lean against the counter sides of the alar pseudofossulae, thereby simulating the latest counter-laterals. The cardinal septum is short and occupies a cardinal fossula which is slightly swollen axially. Amplexoid retreat of septa from the axis has just begun.

In old age (diameter 16 mm) this paratype has 31 major septa about 1.5 mm long and has rudimentary minor septa or septal ridges in almost all loculi. The cardinal fossula is barely discernable by means of slight deflection of traces of tabulae and by the cardinal septum being slightly longer than are the other septa.

Longitudinal section.—Tabulae (pl. 3, fig. 17) are widely spaced, both complete and incomplete, and thin; 5 or 6 occur in 5 mm. They are extremely deflected at their margins, leaving the central third almost flat-topped. Fibers of the septa change their inclination to the epitheca from 15° to 40° as they are followed downward and axially.

Comparison.—*F. contortus* resembles *Amplexus dilatatus* Easton, 1945b, in size, in shape, in number of septa, and in having the cardinal fossula on the convex side of the corallite, but *A. dilatatus* has only the septa of the counter quadrants dilated and none is rhopaloid, nor are they grouped in fascicles. The writer knows of no other corals which closely resemble this species.

Material.—9 specimens. Holotype, USNM 118724. Paratypes, USNM 118725 A, B, C, D. Topotypes in USGS collections.

Occurrence.—Cameron Creek formation, locality 13420.

Remarks.—*F. contortus* is similar to *Fasciculophyllum* Thomson, 1883. The development of *F. contortus* is that of *Fasciculophyllum* up into the conical part of the corallite, but then the amplexoid trend becomes increasingly strong until it masks the earlier morphology. If one sees only the late stages of *F. contortus*, he would be justified in referring it to *Amplexus*. It seems highly likely that the species developed from a continuation of an amplexoid trend in *Fasciculophyllum* along the lines which Carruthers demonstrated for the *Zaphrentites delanouei* species-group (Carruthers, 1910). The stratigraphic distribution of *Fasciculophyllum* and of *Fasciculiamplexus* is such that the supposed ancestor occurs in the older strata, in this instance being in the Z (early part of Early Mississippian) zone of the British Isles, whereas *Fasciculiamplexus* occurs in the late part of the Late Mississippian of Montana.

Family CANINIIDAE

Genus CANINIA Michelin in Gervais, 1840

Caninia montanensis Easton, n. sp.

Plate 3, figures 18–20.

1945. *Caninia cornucopiae* Sloss, Jour. Paleontology, v. 19, no. 3, p. 310, pl. 48, figs. 5–9. (Yakinikak limestone, Montana). (Not *C. cornucopiae* Michelin *in* Gervais, 1840).

Description.—The epitheca of the figured fragment has from 5 to 7 sharply defined growth lines in 1 mm, but shows septal grooves very faintly. In late maturity (pl. 3, fig. 19, diameter 17 mm) the 31 equally thick major septa extend about half the radius. Dissepiments are in 4 or 5 rows and are of the concentric, the herringbone, and the lonsdaleoid kinds. Minor septa are mostly in the outer rows of dissepiments, but occasional septal spines show in lonsdaleoid dissepiments. The cardinal fossula is broad and shallow. A natural longitudinal section has mostly incomplete tabulae; about 10 tabulae occur in 1 cm and their margins are lightly bent down.

Comparison.—*Caninia montanensis* differs notably from *C. cornucopiae* Michelin in having abundant lonsdaleoid dissepiments, and it tends to have more rows (generally 4 or 5 instead of 1 to 3 rows) of dissepiments introduced at an earlier stage than does *C. cornucopiae*. In this last regard it approaches *C. vesicularis* from the C_2 zone of Belgium. From an evolutionary standpoint, *C. montanensis* is more advanced than are any other members of the *C. cornucopiae* series. It is seemingly an outgrowth of the variety *brockleyensis* (Hill, 1939, p. 107, pl. 5, figs. 10–15) in which the lonsdaleoid kind of dissepiments became dominant.

Material.—4 specimens. Syntypes, Montana School of Mines collections. Figured ideotypes, USNM 118726 and 118727.

Occurrence.—Heath formation, localities 13414 and 13424. Alaska Bench limestone, locality 13407. Yakinikak limestone of Willis (1902), Flathead County, Mont.

Remarks.—Specimens described by Sloss (1945, p. 310) were associated with other organisms which Sloss (idem) tentatively concluded were of lower Viséan (probably Osage) age, but which the writer considers to be in part of Chester age.

Family CLISIOPHYLLIDAE

Genus KONINCKOPHYLLUM Thomson and Nicholson, 1876

Koninckophyllum? sp.

Plate 3, figure 24

Description.—A few poorly preserved simple corals with an acrocolumella and with the cardinal fossula on the convex side of the corallite are referred here. The most advanced stage has 8 or 9 much dilated major septa in each cardinal quadrant and about 20 thin major septa on the counter side of the specimen. The cardinal septum is short and lies in a narrow fossula bounded by two radially arranged septa. Dissepimentarium almost removed except for a few concentric dissepiments separating thin minor septa.

In the figured specimen (pl. 3, fig. 24) there are 28 major septa. The minors are rudimentary, not even crossing the dissepimentarium. The axial structure consists of tentlike tabulae (an acrocolumella). This acrocolumella may be lacking in some sections, in which case the specimen might be referred to *Caninia*. Longitudinal sections not seen.

Material.—4 specimens. Figured specimen, USNM 118728.

Occurrence.—Heath formation, locality 13424. Alaska Bench limestone, locality 13407.

Remarks.—Additional material might be a warrant for one to name this species. It may develop that it should be referred to *Turbophyllum* Parks, 1951.

Family PLEROPHYLLIDAE

Genus LONGICLAVA Easton, n. gen.

Diagnosis.—Plerophyllidae with a long counter septum which is rhopaloid (axially swollen). Several major septa near the counter septum are slightly rhopaloid in mature stages. The cardinal fossula is on the concave side of the corallite. Dissepiments absent.

Comparison.—This genus resembles *Fasciculophyllum* Thomson, 1883 in having a long counter septum, but it lacks the prominent fasciculation of major septa characteristic of Thomson's genus. It resembles *Claviphyllum* Hudson, 1942 and *Rotiphyllum* Hudson, 1942 in having a long rhopaloid counter septum and having other rhopaloid septa which meet axially, but *Claviphyllum* always has certain definite pairs of septa dilated and *Rotiphyllum* has a columella in the calyx.

Moreover, all the genera mentioned herein differ from the *Longiclava* in having their cardinal fossulae on the convex side of the corallite.

Genotype.—*Longiclava tumida* Easton, n. sp.

Occurrence.—Otter formation in Montana.

Longiclava tumida Easton, n. sp.

Plate 3, figures 21–23

1951. *Triplophyllites* sp. A. Parks, Jour. Paleontology, v. 25, no. 2, p. 181, pl. 30, fig. 5. (Brazer limestone, Utah).

Exterior.—Corals small, curved, conical, with circular cross sections, and with calyces sloping toward the cardinal side at about 45°. Epitheca smooth except where worn, in which case septal grooves of not only major but also of minor septa occur in youthful stages, although actual blades of minor septa do not extend into the calyx except in stages of late maturity. Calyces seemingly shallow, floored with upper edges of septa which extend to the axis. Cardinal fossula very prominent, deep, parallel-sided or axially swollen in different specimens, occupied by a cardinal septum which becomes progressively shorter upwards, and lying on the concave side of the corallite. Alar pseudofossulae narrow, extending almost to the axis. Counter septum is very prominent, by reason of it extending farther axially than any other major septa, being axially thickened (rhopaloid), and being higher in the calyx than are any other septal. In some specimens the loculi on either side of the counter septum are slightly wider than are other loculi nearby, thus forming an indistinct counter fossula. Mature calyces contain from 28 to 32 major septa, of which 4 to 6 are in each cardinal quadrant and 8 to 11 are in each counter quadrant. Alar septa extend in to meet the tip of the counter septum at the axis. The apical angle is about 35°. Adult specimens are from 19 mm to 23 mm long and have calical diameters of 10 mm to 12 mm.

One specimen is attached to a fenestellid bryozoan along the cardinal margin and radicles have grown into the fenestrules of the bryozoan. The apex is marked only with extremely fine growth lines for 3 mm (to a diameter of 1.5 mm) and then septal grooves both of major and of minor septa are developed at the same time.

Ontogeny.—In early neanic stage (diameter 1.8 mm) there are 13 septa, of which the counter septum is slightly thicker than are the other septa. The right cardinal quadrant contains 2 septa, the right counter quadrant contains 4 septa, the left counter quadrant contains 4, and the left cardinal quadrant contains only the alar septum. All septa are slender and only slightly thickened. Alar pseudofossulae are prominent but the cardinal fossula is determinable only by the bending of a tabula down into it. In the figured section (pl. 3, fig. 22b) some peripheral tissue of an earlier calyx is partly preserved around the new corallite. The most significant feature of this section is the shortness of the second lateral septum on both sides of the counter septum. In typical zaphrentoid corals the order of insertion of new septa in the counter quadrants is such that the oldest lateral septum is next to the counter septum and by orderly progression the youngest is next to the alar septum. In the section being discussed the short second counter-lateral septa (KL2) abut against the first counter-lateral septa, the third counter-lateral septa also abut against the first counter-lateral septa, yet the fourth counter-lateral septa abut against the third counter-lateral septa. It seems that the order of insertion was KL1, KL3, and then either KL4 or KL2, or KL4 and KL2 simultaneously. From the width of loculi (interseptal spaces), it is probable that the order was KL1, KL3, KL2, KL4. This peculiar hesitation in actual insertion of KL2 until some time after septa of commonly later insertion are emplaced, was apparently demonstrated for the first time by Gerth (1919, p. 211, or see Hudson, 1935, p. 93). Gerth rendered the order of insertion (here using Hudson's septal terminology) of counter-lateral septa in one Permian plerophyllid KL1, KL3, KL4, KL2, KL5–KL10; so, this agrees in so far as stages permit comparison, with the probable order for *Longiclava tumida*. Corals in which some septa are long and persistently rhopaloid from early youth onwards and other septa are notably shortened are called tachylasmoid (Hudson, 1935, p. 92, 93). Tachylasmoid septal plans are characteristic of the Plerophyllidae.

At a very slightly later stage (pl. 3, fig. 22a, early neanic, diameter 2.7 mm) the same specimen has all septa so dilated that they are in contact along about half their lengths. The probable counter septum is the longest, but the alars and the cardinal septum all reach the center. Two new septa have been added to the left cardinal quadrant, but apparently none has been added to the left counter quadrant. The other quadrants are incompletely preserved.

In the holotype the earliest stage preserved (early ephebic—mature—stage, at a diameter of 6 mm) has 24 septa so dilated as to be in contact along almost their entire lengths. The cardinal quadrants have 4 septa each and the right and left counter quadrants 6 and 8 septa, respectively. The counter septum is the longest and most dilated of all. The cardinal septum is least dilated and occupies a narrow parallel-sided fossula.

By middle maturity (diameter 8 mm) the holotype (pl. 3, fig. 21a) has 28 septa, of which each cardinal quadrant has 5 and the right and left counter quadrants have 7 and 9 septa, respectively. The cardinal septum is thin and fused with the left wall of the V-shaped fossula.

At a slightly later stage the holotype has 30 septa, of which the cardinal septum is thin and not quite as long as the parallel-walled fossula it occupies.

By late maturity the holotype (diameter 9 mm) has 31 septa, of which the outer ends of most of them are removed somewhat from neighboring septa so that their axial ends are slightly wider than the peripheral parts. The thin cardinal septum extends less far than the length of the axially enlarged cardinal fossula.

At a slightly later stage at the floor of the calyx (diameter 10 mm), the holotype (pl. 3, fig. 21*b*), has 31 septa, most of which have withdrawn slightly from the axis and separated from their neighbors so that their rhopaloid character is prominent. The counter septum is thickest and longest of all, but the alars extend almost to the axis. The cardinal septum has retreated to the periphery and the keyhole-shaped fossula is occupied only by tabulae.

The most advanced calyx at hand (pl. 3, fig. 23b) (diameters 12 by 13 mm) has 32 major septa, of which the cardinal septum only crosses the large keyhole-shaped cardinal fossula near its bottom; the quadrants contain in counterclockwise rotation 6, 9, 11, and 4 major septa. The counter septum, which is slightly longer and higher but not more dilated than the other major septa, has extra-wide loculi on each side. Alar pseudofossula are long and narrow. All majors have retreated slightly from the axis near the swollen inner end of the cardinal fossula. Minor septa are present in about half a dozen loculi in the counter quadrants.

Longitudinal section.—A natural section through the cardinal fossula of the most advanced paratype has 6 or 7 tabulae in 5 mm. Tabulae are both complete and incomplete. They are highest 2 or 3 mm in from the theca and bend down slightly (about 1 mm) to the theca on the counter side. On the cardinal side they plunge down at angles of 50° to 75° to make the floor of the cardinal fossula. Fiber bundles of the septa are inclined apically and axially at angles of 10° to 15° to the theca.

Comparison.—*Longiclava tumida* differs from *Fasciculophyllum thomsoni* Hudson and Fox, 1943, in lacking the notably fasciculate septal grouping (Hudson and Fox, 1943, p. 105) and in having more rhopaloid septa. Among American Carboniferous corals, this species resembles *Triplophyllites* (*T.*) *clinatus* var. *capuliformis* (Rowley, 1900), in the nature of the counter septum, but Rowley's variety is cuneate (laterally compressed), flaring, and has minor septa in the calyx at early stages. Other members of the *Triplophyllites ellipticus* species-group discussed by Easton (1951) bear similarities to *L. tumida*, but they are all cuneate and lack the thickening of septa in late stages. Although their mature calyces are often quite similar to this species, they either lack the rhopaloid end of the counter septum, have the counter septum only occasionally lengthened, have a depressed counter septum, or have a short counter septum in early or late stages. As with the *T. ellipticus* species-group (cuneate corals), *L. tumida* (a circular coral) may have been derived from something close to *Neozaphrentis acuta*, (White and Whitfield) thus presenting two parallel evolutionary series. It is very doubtful that *L. tumida* has any relationship with the members of the *T. ellipticus* series, but this point cannot be settled now because enough material preserving early stages capable of being sectioned has not been discovered in the *T. ellipticus* series.

Longiclava tumida can be distinguished from *Bradyphyllum clavigerum* Easton by its being twice as long as the latter species, being more contorted, and in having the high and long counter septum.

Material.—12 specimens. Holotype, USNM 118729. Paratypes, USNM 118730 A, B. Other specimens, USNM 11662 and USGS collections.

Occurrence.—Otter formation, locality 13390. Six specimens (USNM 11662) are from "Carboniferous, Virginia City, Montana," which probably means the Brazer limestone on Old Baldy Mountain a few miles south of Virginia City. Brazer limestone in Leatham Hollow, Utah.

Class SCYPHOZOA

Order CONULARIDA

Family CONULARIIDAE

Genus CONULARIA Miller in Sowerby, 1818

Remarks.—Conulariids have been referred to various phyla and classes (Slater, 1907, p. 9–12). Kiderlen (1937, p. 113–169) and Knight (1937, p. 188) assigned the conulariids to the Scyphozoa, a proposal which is followed here because more evidence supports this than supports any alternate proposal. Kiderlen's and Knight's arguments have been reviewed in English by Moore, Lalicker, and Fischer (1952, p. 458–462).

"Conularia" n. sp.

Plate 4, figure 1

Cross section distorted. Corner of the pyramid with a narrow and deep groove into which the ridges extend without being recurved. Ridges of adjacent faces alternate at the groove. Ridges on each face mostly alternate at the median line, which in some places seems to have a rodlike thickening.

Although the largest fragment at hand is only 4.1 cm long, the proportions of the specimen suggest that its original length may have been twice as long, or more. One face is about 2.1 cm wide. Ridges are arranged in rather evenly arcuate series with constant radius of curvature. Nine ridges occur in 10 mm; each ridge is rodlike and smooth; and the furrows between ridges are covered with wrinkles whose axes lie at a 40° angle to the margins and are directed from both sides toward the midline and toward the aperture.

Material.—1 specimen. USNM 118731.

Occurrence.—Cameron Creek formation, locality 13362.

Remarks.—Although conulariids with transverse wrinkles in the furrows have been described at least from Ordovician (*Conularia trentonensis* Hall) to Pennsylvanian (*C. roeperi* Miller and Gurley), the writer is not aware of another instance in which the wrinkles are steeply inclined distally toward the midline. *C. chesterensis* Worthen (USNM 99504) has wrinkles inclined in various directions; so, it may be that obliquity of wrinkles in conulariids is due to shearing stresses in the thin tissue of the furrows when stretched between the heavy rodlike ridges. Sinclair (1952, p. 135) suggested that surficial ornamentation is of very minor use; he depended more on pyramidal corners and on midlines of faces for diagnostic features.

This specimen is not referable to any genus included by Sinclair (1952, p. 138) in the subfamily Paraconulariinae to which this form belongs, but it is also not well enough preserved to warrant either a generic or a specific name.

ECHINODERMATA

Subphylum PELMATOZOA

Class CRINOIDEA

Order CLADOIDEA

Family POTERIOCRINITIDAE

Genus DICROMYOCRINUS Jaekel, 1918

1918. *Dicromyocrinus* Jaekel, Palaeont. Zeitschr., Bd. 3, p. 66.
1940. *Dicromyocrinus.* Moore and Plummer, Texas Univ. Pub., no. 3945, pt. 1, p. 34, 47, 143, 351, 353, 355, 358, 360, 361, 363, 365–367, 378.
1943. *Cromyocrinus* [in part]. Bassler and Moodey, Geol. Soc. America Spec. Paper 45, p. 377.

Diagnosis.—Poteriocrinitidae with large infrabasal plates which are generally flat and not visible from the side; with 3 anal plates, and with 10 uniserial pinnulate arms consisting of wedge-shaped plates.

Remarks.—*Dicromyocrinus* resembles *Phanocrinus* Kirk, 1937 in arm construction and in characteristics of the anal series of plates, but it lacks the inflexed base and has much wider infrabasals in proportion to the diameter of the stem than does *Phanocrinus.* Graphic assistance in differentiating these and other similar genera has been presented by Moore and Plummer (1940, p. 351, 366).

Reference of the material at hand to *Dicromyocrinus* is supported by its having a ratio of stem diameter to width of the infrabasal circlet of .29, and having a ratio of width of infrabasal circlet to width of dorsal cup of .46. No other genus shown by Moore and Plummer (1940, fig. 71 on p. 366) has these parameters except *Parulocrinus*, and that genus has only two plates in the anal series instead of having three.

The genotype of *Dicromyocrinus*, *Cromyocrinus ornatus* Trautschold, 1879, is from the Moscovian (Upper Carboniferous) of Russia.

Dicromyocrinus granularis Easton, n. sp.

Plate 4, figures 4, 5

Description.—Dorsal cups of two specimens 12 and 14 mm high and 22 or 23 mm in diameter. Base flattened and only very slightly depressed. Infrabasal pentagon has a diameter of 9.5 to 10.5 mm. Stem diameter is 3.0 mm. Basals curved and slightly wider than high, except for the posterior basal and the right posterior basal which are modified by the radianal which rests on them. The posterior basal also supports the anal X. The three subequal radials are about 11 mm wide and 7 to 8 mm high. Arm facets cover the upper surfaces of the radials.

The hexagonal radianal measures 6 by 8 mm and is 2 or 3 times as large as the other plates in the anal series. It supports the pentagonal anal X and together with it and the right posterior radial, supports the right tube plate. The anal X, right tube plate, and the left posterior radial support another tube plate.

The ten arms originate from five single large primibrachs from each of which arise two rows of uniserial arm plates, the longest row of which extends 4.2 cm. Arm plates are mixed quadrangular and cuneate. Pinnules are at least 8 mm long.

Surface of the dorsal cup is prominently pustulose, with irregular sizes of nodes which may merge. Two indefinite rows of about 7 nodes each line the edges of the basals and radials.

Column unknown.

Comparison.—This species is characterized by the coarsely granular plates, only slightly concave base, and absence of radial plates on the base of the cup.

Dicromyocrinus granularis differs from various species of *Phanocrinus* with which it might be confused, such as *P. stellaris* (Wright, 1939, p. 25) and *P. gordoni* (Wright, 1951, p. 100) from the E_1 zone, of England, in having a slight instead of a deep basal concavity, in having much larger infrabasal plates, and in having radials not visible in basal view.

Various species now assigned to *Dicromyocrinus* were not concisely differentiated by Trautschold originally. In 1867 he described *Cromyocrinus geminatus* (Trautschold, 1867, p. 25) but appears to have included three species in his notion of the species at that time. Each of these was represented by one specimen which he figured (Trautschold, 1867, pl. 4, figs. 6, 7a–b, 8a–b). Of these, figures 7a–b seem to refer to the species *C. ornatus* (Trautschold, 1879, p. 23, pl. 3, figs. 9, 10), which species subsequently became the genotype of *Dicromyocrinus*. *D. granularis* differs from the genotype in lacking the transverse striations or grooves at sutures on the dorsal cup and in lacking the knotty arm plates and the spikes on the primibrachs.

Figure 6 of Trautschold's 1867 work resembles *Dicromyocrinus granularis* in having smooth arm plates and no spines on PBr_1, but Trautschold's figure shows prominent transverse grooves at the sutures on the dorsal cup and the plates of the cup are quite smooth.

Trautschold's figures 8a–b of 1867 resemble *D. granularis* in having pustulose calical plates, but the Russian specimen, again, has grooved sutures unlike the Montana material. The writer is not aware that *Cromyocrinus geminatus* has ever been restricted to species either like Trautschold's figure 6 or like his figures 8a and b, instead of containing both.

Moore and Plummer (1940, p. 353) assigned the two Chester species, *Agassizocrinus hemisphericus* Worthen, 1882 and *A. papillatus* Worthen, 1882 to *Dicromyocrinus*. Diameters of infrabasal circlets of both of these species are as in *Phanocrinus*, but the infrabasals are flat as in *Dicromyocrinus*. According to the evolutionary patterns described by Moore, Lalicker, and Fischer (1952, pp. 623–625), Worthen's two species are more advanced in size of (have smaller) infrabasal circlets than is *D. granularis*, but are similar in other respects (cup shape, basal concavity, anal features, arm features).

If we apply the same criteria to comparing the evolutionary relationships of *Dicromyocrinus granularis* with the Russian species described by Trautschold, *D. granularis* has a slightly larger uppermost anal plate and relatively larger infrabasals. These differences indicate that *D. granularis* is less advanced than are the Russian species and presumably occupies a lower stratigraphic position than they do. If, as may be possible, *D. granularis* has a slightly more concave base than the Russian material has, then this feature, contrariwise, would indicate that the American specimens are slightly more advanced than is the Russian material in this one respect and might occupy higher stratigraphic position.

Material.—2 specimens. Holotype, USNM 118732. Paratype, USNM 118733.

Occurrence.—Alaska Bench limestone, locality 14100.

Remarks.—In the opinion of the writer, the crinoids are from the "middle Amsden" as used by Nieschmidt (1953) and are not from what is herein called the Devils Pocket formation.

These specimens are the basis for Kirk's preliminary opinion cited by Nieschmidt (1953) that part of the Alaska Bench limestone ("upper Amsden" at Becket Falls) is Pennsylvanian. Kirk's latest opinion (letter to P. E. Cloud, Jr., May 14, 1954) is that the crinoids are referable to *Phanocrinus* Kirk and that

> There is a close resemblance on the generic level between the high Chester and the lower Pennsylvanian and a positive age determination on the basis of a single crinoid is hazardous, to say the least. The Montana crinoid in question is so unlike the Chester species that a separate generic assignment would almost be warranted. It is obviously much later in the genetic line than the Chester forms and I would be inclined to place it as of at least Morrow age.

Considerable difference of opinion arose during the preparation of this manuscript as to the age significance of these two crinoids. The writer, far from feeling as Kirk does that the Montana crinoids are "obviously much later in the genetic line," has presented two lines of morphologic evidence above that they may well be earlier and one line of possible evidence that they may be later in the genetic line. Moreover, this species seems to the writer to have as much affinity with *Dicromyocrinus hemisphericus* (Worthen) and *D. papillatus* (Worthen) from the Chester, as it does with *D. ornatus* (Trautschold) from the Upper Carboniferous of Russia. It is apparent, then, that more information is needed about the ranges of species before this genus can be used with confidence for narrow age determinations within or including both Mississippian and Pennsylvanian strata.

Incertae sedis

Crinoid plates

Plate 4, figures 6–11

Columnal plates of crinoids are conspicuous in many outcrops of the Big Snowy group and of the Amsden formation, but most of these ossicles are nondescript. A few, however, may be useful to stratigraphers, as may be some of the calical plates (Moore, 1938).

A circular crinoid columnal (USNM 118734a), from locality 13414 in the Heath formation (pl. 4, fig. 10), has a petalate canal, crenellae (ridges) confined to the outer 0.7 mm of the articular face, and an average-sized plate diameter of 8 mm. Associated with this kind of columnal are nodose tegmen plates such as is shown on plate 4, figures 9a, 9b.

Another kind of circular plate large enough to be readily seen in the field is shown in plate 4, figure 11. Its crenellae extend over about 1.7 mm of the 8 mm wide plate and increase the number toward the periphery by bifurcation and by implantation. The circular canal is bordered by a narrow flange which extends inward from the indented inner face of a somewhat thicker flange so that the cross section of the plate has two steps between the articular face and the midplane. The plates are USNM 118735, from locality 13390 in the Otter formation.

Although uniformly small (about 1.0 mm or less in diameter), the pentagonal columnal plates are a noteworthy element in the fauna. A typical representative (USNM 118736, from locality 13361 in the Cameron Creek formation, pl. 4, fig. 7) has a pentagonal canal and one pair of crenellae meet like chevrons to enclose a third at the angles of the pentagons. Associated with this are circular columnal plates (pl. 4, fig. 6) about 1.0 mm in diameter, having some crenellae implanted and others bifurcated.

The final notable kind of columnal plate has a stellate outline. In this kind (USNM 118737, from locality 13372 in the Alaska Bench limestone, pl. 4, fig. 8) the crenellae meet like chevrons along the rays of the stars. The diameter is 1.3 mm. This and the other pentagonal plates are decidedly like the so-called *Pentacrinus* or *Isocrinus* plates which are so commonly used in the Western States as a rule-of-thumb method of recognizing Mesozoic (usually Triassic) strata. Pentagonal plates are not unknown in Paleozoic rocks, but it it rare to find any with the chevronlike crenellae. Pentagonal plates were frequently observed in the field in strata of the Otter, Heath, and Cameron Creek formations.

Small, largely pentagonal crinoid plates were also noted at localities 13382, 13421?, 14221, 14224, and 14226 in the Cameron Creek formation.

Subphylum ELEUTHEROZOA

Class ASTEROZOA

Ophiuroid plate

Material.—1 specimen. USNM 118903.

Occurrence.—Cameron Creek formation, locality 14226.

Remarks.—A single wedge-shaped vertebral ossicle of an ophiuroid was collected. The specimen is about 1 mm in diameter.

Class ECHINOIDEA

Order PERISCHOECHINOIDEA

Family ARCHAEOCIDARIDAE

Genus ECHINOCRINUS Agassiz, 1841

Echinocrinus sp.

Plate 4, figures 2, 3

Several isolated plates and spines can be referred to the form-genus *Echinocrinus*. The nearly complete interambulacral plate and associated spine (USNM 118738, locality 13372 in the Alaska Bench limestone, pl. 4, fig. 2a,b) are 1.4 mm and 1.7 mm in greatest dimensions, respectively.

A large spine (USNM 118739, from locality 13385 in the Alaska Bench limestone, pl. 4, fig. 3) has small secondary spines. It is 26 mm long, but is still incomplete. A similar fragment is known from locality 13420 in the Cameron Creek formation.

Material.—7 specimens. Figured specimens, USNM 118738, 118739.

Occurrence.—Cameron Creek formation, localities 13420, 14221, and 14226. Alaska Bench limestone, localities 13372 and 13385.

BRACHIOPODA

Class INARTICULATA

Order ATREMATA

Suborder LINGULACEA

Family LINGULIDAE

Genus LINGULA Brugière, 1792

Lingula cf. L. carbonaria Shumard, 1858

Plate 4, figure 12

Material.—13 specimens, mostly fragmentary. Figured specimen, USNM 118740.

Occurrence.—Heath formation, locality 13402. Cameron Creek formation, locality 13380. Alaska Bench limestone, locality 13398. Widespread in Pennsylvanian of the United States.

Remarks.—Several specimens at hand agree in size, shape, and ornament with *Lingula carbonaria*. Internal molds show a pair of faint depressions running along the midline of valves. This feature may be a reflection of a median groove on the surface mentioned in the original description by Shumard.

Order NEOTREMATA

Suborder DISCINACEA

Family DISCINIDAE

Genus ORBICULOIDEA d'Orbigny, 1847

Remarks.—This genus formerly appeared as *Lingulidiscina* in many faunal lists.

Orbiculoidea wyomingensis Branson and Greger, 1918

Plate 4, figure 13

1918. *Orbiculoidea wyomingensis* E. B. Branson and Greger, Geol. Soc. America Bull., v. 29, no. 2, p. 314, pl. 19, figs 7, 8. (Amsden formation, Wyoming).

1937. *Orbiculoidea wyomingensis.* C. C. Branson, Jour. Paleontology, v. 11, no. 8, p. 655, pl. 89, fig. 34. (Sacajawea formation, Wyoming).

Ventral valve.—Outline unknown. Apex seemingly subcentral and eccentric toward the posterior end. External ornamentation consists of lirae, of which 4 are preserved in 1 mm in the only observable place. Internal ornamentation consists of shallow grooves corresponding to the lirae and generally spaced about 8 in 2 mm, with 2 to 4 of these more distinct than the others. Furrows radiate from the apex and diverge until 4 occur in 3 mm at the margin; these are almost as strong as the lirae, hence, must have been visible on the surface of the valve. Pedicle furrow 4.0 mm long, 1.0 mm wide, lanceolate in shape, and extending three-fourths of the distance to the apparent margin.

Dorsal valve.—An incomplete dorsal valve was at least 20 mm long and probably almost as wide when complete. The apex was perhaps midway between the center and margin. External ornamentation consists of 3 or 4 concentric lirae in 2 mm, separated by depressed interspaces whose surfaces have 4 or 5 striae. Very faint radiating wrinkles occur, 3 or 4 in 1 mm. Internal ornamentation consists of concentric furrows corresponding with external lirae and of very faint radiating furrows, 3 or 4 to 1 mm, with erratically disposed stronger ones. No median septum present.

Material.—1 specimen. Figured specimen, USNM 118741. The cotypes are University of Missouri 2641, and a hypotype is University of Missouri 7168.

Occurrence.—Alaska Bench limestone, locality 13399. The other specimens are from the Sacajawea of Branson (1936), or lower Amsden formation in Wyoming.

Remarks.—C. C. Branson's hypotype (UM 7168) (probably a ventral valve) has 5 lirae in 2 mm separated by interspaces containing as many as 5 very faint striae. The conclusion that radiating wrinkles showed on the external surface is supported by their faint development on this specimen.

The specimen from Montana agrees with the others in shape, in nature and spacing of lirae, in having radiating wrinkles, and in size. It is in effect complete, measuring 16 mm wide, 18 mm long, and about 3 mm high. The ventral valve is crushed into concavity. The apex is subcentral.

This species is distinctive because of its large size, relatively coarse ornamentation, and particularly because of the distinct radiating wrinkles.

The writer herewith designates as holotype of *Orbiculoidea wyomingensis* the ventral valve figured by Branson and Greger (1918, pl. 19, fig. 7). Branson and Greger did not originally designate either of the cotypes as the holotype.

Orbiculoidea interlineata Easton, n. sp.

Plate 4, figures 14–16

Ventral valve.—Valves almost circular, mostly measuring about 9 mm in diameter. Apex centrally located, presumably raised in normal shells, but all specimens at hand are compressed. External ornamentation consists of prominent, raised concentric lirae separated by minutely striate depressed interspaces. Adult valves have 18 to 21 lirae, of which 7 or 8 occur in 2 mm near the periphery; lirae are more closely crowded near the center of the valve than near the periphery. Striae generally vary from 1 to 5 on each interspace, with some interspaces locally smooth. Pedicle groove from 2.5 mm to 3.0 mm long, 1.0 mm wide, and depressed. Internal ornamentation consists of shallow depressions corresponding to lirae and of smooth tissue corresponding to interspaces. Pedicle tube extended to the inner posterior margin of the shell, but barely in contact with the posterior margin of the shell.

Dorsal valve.—Apex is located about one-quarter to one-third of the distance toward the margin. The least deformed shell is about 1 mm high, but most shells are seemingly flattened into low cones. External ornamentation consists of about 16 to 20 lirae per millimeter, most of which are very tenuous; however, about 6 of them in a distance of 2 mm are very slightly to distinctly stronger than the others so that there is a distant similarity between external ornamentation of both valves. Internal ornamentation consists of shallow furrows corresponding with the stronger external lirae. Barely discernable radiating wrinkles seen rarely on flattened specimens are probably accidental because well-preserved material fails to show them. No septum present.

Comparison.—*Orbiculoidea interlineata* is characterized by presence of striae between the external ridges; the feature is best seen on ventral valves but is common on dorsal valves. The striae readily differentiate it from *O. missouriensis* (Shumard), which it resembles in size, shape, and presence of coarse lirae. In the latter species the interspaces are not only smooth but the lirae are stronger, are closely spaced, and are very regularly arranged on both valves.

Only two other species known to the writer have striate interspaces. *Orbiculoidea wyomingensis* Branson and Greger, 1918, from the Sacajawea formation of C. C. Branson (1936) is not only twice as large as *O. interlineata* and the lirae are twice as far apart, but the former species has distinct radiating ridges both externally and internally.

Orbiculoidea keokuk Gurley, 1884, from the Keokuk limestone of Indiana is about 3 times as large as *O. interlineata* and only 2 or 3 strong lirae occur in 2 mm.

Material.—43 specimens. Holotype and paratypes on one slab, USNM 118742. Topotypes and other specimens, USGS collections.

Occurrence.—Heath formation, localities 13366 and 13367.

Orbiculoidea sp. A

Material.—1 specimen, USNM 118743.

Occurrence.—Otter formation, locality 13375.

Remarks.—The pedicle valve measures 15 mm by 15.5 mm and is 2 mm deep. The apex is subcentral. External ornament is of fine lirae. Internal ornament is of faint, broad, concentric swellings crossed by about 7 very faint radial lirae in 1 mm. A groove crossing the apical third of the anterior slope may indicate former presence of a septum on the internal mold. The larger size and possible septum differentiate this species from the smaller and aseptate *O. interlineata* described above.

Orbiculoidea sp. B

Occurrence.—Heath formation, locality 13425.

Remarks.—A single specimen 15 mm wide and 23 mm long, although not identifiable, is too large and too elongate to be included logically in any of the foregoing species.

Suborder CRANIACEA

Family CRANIIDAE

Genus CRANIA Retzius, 1781

Crania cf. C. modesta White and St. John, 1868

Plate 4, figure 18

Description.—These valves were attached to brachiopods and to a coral. They measure from 5 mm to 6 mm in diameter, are almost flat, have a subcentral nubbin at the apex, and have slightly thickened margins. Ornamentation is of vague concentric lirae.

Material.—10 specimens. Figured specimen, USNM 118744.

Occurrence.—Otter formation, locality 13390. Heath formation, localities 13391, 13396, 13402, 13416, and 13425.

Remarks.—*Crania chesterensis* Miller and Gurley, 1897, has the same external shape as this species. As the author could not differentiate the two species, he has used the older name for his specimens.

Class ARTICULATA

Valuable assistance in the study of the articulate brachiopods was obtained in Schuchert (1897) and in Shimer and Shrock (1944) which is not otherwise acknowledged.

Orientation of the articulate brachiopods used herein refers to pedicle and brachial valves. Percival (1944, p. 16–18; Cloud, 1948, p. 247) believed that the pedicle valve of the articulate, *Terebratella inconspicua*, was embryologically dorsal and not ventral but decided after later study of *Tegulorhynchia nigricans* (Percival, 1953, p. 436) that the pedicle valves in both species are oriented ventrally. The writer here uses brachial and pedicle in reference to the two valves on the recommendation of P. E. Cloud, Jr. (written communication, September 16, 1953) that less ambiguity is possible this way. This usage, incidentally, antedated that of dorsal and ventral.

Order PROTREMATA

Superfamily PENTAMERACEA

Genus STENOSCISMA Conrad, 1839

1839. *Stenoscisma* Conrad, New York Geol. Survey Ann. Rept. 3, p. 59.
1844. *Camerophoria* King, Annals and Mag. Nat. History, v. 14, p. 313, [nomen nudum].
1845. *Camerophoria* King, Neues Jahrb., 1845, p. 254, [nomen nudum].
1846. *Camerophoria* King, Annals and Mag. Nat. History, v. 18, p. 89.
1846. *Camarophoria* Herrmannsen, Indices generum Malacozoorum Primordia, p. 161 [emended spelling].
1847. not *Stenocisma* Hall, Pal. New York, v. 1, p. 142 [=*Zygospira*.]
1850. *Camarophoria*. King, Permian fossils of England, Palaeont. Soc. Mon., p. 113.
1867. not *Stenocisma* Hall, Pal. New York, v. 4, p. 334 [= *Rhynchospirina*].
1877. *Stenocisma* Dall, U.S. Nat. Mus. Bull. 8, p. 65. [emended spelling].
1893. *Camarophoria*. Hall and Clarke, Pal. New York, v. 8, pt. 2, p. 212. [This contains a long synonymy].
1902. *Camarophoria*. Tschernyschew, Russia, Geol. Kom. Trudy, v. 16, no. 2, text, p. 76, 488.
1910. *Camarophoria*. Weller, Geol. Soc. America Bull., v. 21, p. 498.

1913. *Camarophoria.* Licharew, Russia, Geol. Kom. Trudy, novaia ser., v. 85, p. 30.
1914. *Camarophoria.* Weller, Illinois Geol. Survey Mon. 1, p. 169.
1927. *Camarophoria.* George, Geol. Mag., v. 64, p. 193.
1929. *Stenochisma* Kozlowski, Palaeontologia Polonica, v. 1, p. 146. [emended spelling].
1930. *Camarophoria.* King, Texas Univ. Bull. 3042, p. 110.
1936. *Camarophoria.* Licharew, Am. Jour. Sci., 5th ser., v. 32, no. 187, p. 55.
1942. *Stenocisma.* Cooper, Washington Acad. Sci. Jour., v. 32, no. 8, p. 229.
1944. *Stenoscisma.* Cooper *in* Shimer and Shrock, Index fossils of North America, p. 315.
1944. *Camarophoria.* Reed, India Geol. Survey Mem., Palaeontologia Indica, new ser., v. 23, mem. 2, p. 133.
1952. *Camarophoria.* Sarycheva and Sokolskaia, Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 38, p. 170.
1954. *Stenoscisma.* Stehli, Am. Mus. Natl. History Bull., v. 105, art. 3, p. 338.

Diagnosis.—Small rhynchonelliform brachiopods with a prominent pedicle sulcus and brachial fold. Plications usually are distinct on both valves. Pedicle interior has a well-developed spondylium which is either sessile or supported by a median septum. Brachial interior has an undivided cardinal plate and sometimes a minute cardinal process. A spoon-shaped camarophorium clasps a prominent median septum beneath the cardinal plate, and the median septum continues to the floor of the valve. That portion of the median septum between the camarophorium and the hinge plate is called the intercamarophorial plate. Crura project from the margin of the hinge plate and often are associated with the edges of the camarophorium.

Occurrence.—*Stenoscisma* is widely recognized in upper Paleozoic rocks over the world.

Remarks.—The synonymy above, although very short, gives a fairly complete history of the generic usage and also a few recent references in American publications. Dozens of additional citations can be found in the references cited in the synonymy—particularly in Hall and Clarke (1893) and in George (1927b). The most recent account in English of internal structure (Licharew, 1936) has been used in writing the above diagnosis. Although *Stenoscisma* clearly has priority over *Camerophoria*, the latter genus has proved hard to repress. First Dall (1877), then Kozlowski (1929), and more recently Cooper (1942) have indicated (in references cited in the synonymy) that Conrad's name is the available one. Because a complete and conclusive summary of the reasons it must be used was given by Dall as early as 1877, there seems to be no good reason a different name should be adopted now.

Stenoscisma obesa (Clark, 1917)

Plate 4, figures 24–27

1917. *Camarophoria obesa* Clark. Harvard Coll. Mus. Comp. Zoology Bull., 61, no. 9, p. 373, pl. 2, figs. 13–24; text figure 3 on p. 374. (Madison limestone [=Brazer limestone], Montana).

Pedicle valve.—Small broadly convex valves with a sharply rounded umbo whose flanks diverge at 100° and are sharply turned dorsally along the posterior margins. The beak is pointed and enrolled. A broad sulcus occupies the anterior half of the valve and slopes dorsally about 50° to the plane of commissure. An average specimen is 9.3 mm long, 9.5 mm wide, and 6.7 mm high.

Internally the dental lamellae join to make a deep spondylium which rests upon the floor of the valve for about half its length and then is supported by a short median septum which only extends about 1 mm beyond the anterior margin of the spondylium. Teeth are minute and seemingly circular.

Brachial valve.—This valve is almost hemispherical and is about twice as high as the pedicle valve. The fold is inconspicuous.

Internally the cardinal plate is broadly triangular, slightly raised above the posterior shell margins, and deeply excavated laterally for the sockets. It is concave with the axis of concavity transverse. A slight triangular depression of the central portion is bounded by the inner extensions of the crural processes, the free anterior ends of which are short spines on the cardinal plate. The median septum is very high, and its anterior edge slopes ventrally and slightly anteriorly. Its ventral edge is fused with the convex side of the camarophorium and reaches the anterior edge of this latter structure. The camarophorium is elongate and deeply concave, with a sharply rounded anterior edge. The intercamarophorial plate does not extend to the anterior edge of the camarophorium but it does fuse ventrally with the cardinal plate. Its presence may even show as a ridge (cardinal process?) in the central depression on the ventral surface of the cardinal plate. The camarophorium lies very close to the cardinal plate, being more than three-fourths of the distance along the median septum.

Ornamentation.—Plications are exceedingly faint, broadly rounded, and only discernible near the anterior margins. The fold has 2 faint plications which interlock with 1 faint plication in the sulcus. Lateral margins have 1 or 2 very faint plications. Minute concentric growth lines are present.

Comparison.—The new species *Stenoscisma obesa* is characterized by the faint plications and very high dorsal median septum.

It differs from *S. explanata* (McChesney) in being about twice as large and in having much less distinct and quite broadly rounded plications. A plastoholotype of McChesney's species (USNM 62495) has slightly deeper plications than Weller's hypotype of the same species (Weller, 1914, pl. 23, figs. 48–51), but the two specimens are otherwise identical.

S. cestriensis (Snider) rarely has even one plication on the lateral slopes and its sulcus is deep and troughlike longitudinally, and the anterior shell margin of the sulcus is semicircular instead of being nearly straight across as viewed from the anterior.

S. thera (Walcott) differs from *S. obesa* in its lack of lateral plications.

Material.—90 specimens. Hypotypes, USNM 118749 A, B, C, D. Other specimens, USGS collections.

Occurrence.—Heath formation, locality 13414. The types, although described as being from the Madison limestone, are actually from the Brazer limestone.

Superfamily STROPHOMENACEA

Family STROPHOMENIDAE

Genus ORTHOTETES Fischer de Waldheim, 1829

Diagnosis.—Strophomenidae with a median septum and with strong to weak dental lamellae.

Subgenus ORTHOTETES Fischer de Waldheim, 1829

Diagnosis.—Nonplicated *Orthotetes* with a spondylium supported by the median septum.

Remarks.—*Orthotetes* (*Orthotetes*) can be differentiated from *Orthotetes* (*Derbyia*) Waagen, 1884, *Schuchertella* Girty, 1904, *Streptorhynchus* King, and *Werriea* Campbell, 1957, only by the internal structures of the pedicle valve. *Streptorhynchus* and *Schuchertella* lack dental lamellae and median septum. *Schuchertella* differs from *Streptorhynchus* only in having a low pedicle interarea instead of a high one. The typical form of the subgenus *Derbyia* has a median septum which just touches the ridgelike dental lamellae. The subgenus *Orthotetes* has a spondylium or chamber enclosed by the two bladelike dental lamellae which fuse with the median septum. Although other genera have similar external characters, the three above are most apt to be confused in the faunas under study. For an excellent discussion of the genera, see Dunbar and Condra (1932, p. 66–78, 121). A new review of these genera and subgenera is needed in order to establish the limits of variation between systematic groups. For the present the writer considers *Werriea* to be a junior subjective synonym of *Orthotetes*.

Unidentifiable orthotetinids were observed in the Cameron Creek formation at locality 13364 and in the Alaska Bench limestone at localities 13399 and 13423. In addition, specimens which could not be assigned clearly either to *Orthotetes* or to *Derbyia* were found in the Alaska Bench limestone at localities 13404 and 13406.

All together 55 specimens were referable to *Orthotetes*.

The writer is especially indebted to P. E. Cloud, Jr., and Mackenzie Gordon, Jr., of the U.S. Geological Survey and to G. A. Cooper of the U.S. National Museum for assistance in identifying the orthotetinids.

Orthotetes (Orthotetes) sp.

Plate 5, figures 1–5

Diagnosis.—*Orthotetes* of medium size (maximum about 5 cm), with a low brachial valve, and with a low pedicle interarea.

Material.—76 specimens. Hypotypes, USNM 118750 and 118751A–D.

Occurrence.—Otter formation, locality 13375. Heath formation, localities 13416 and 13424. Alaska Bench limestone, 13422?.

Remarks.—Girty differentiated *Orthotetes subglobosus* in 1910 for specimens with highly inflated brachial valves and with 13 or 14 subequal to alternating lirae in 5 mm. At the same time he recognized the variety *protensa* for specimens with very high pedicle interareas. In 1915 he recognized the variety *batesvillensis* for specimens with moderately inflated brachial valves and with 13 to 16 nearly equal lirae in 5 mm. On all the above forms from the Batesville sandstone the lirae tend to be finer than they are on the specimens from Montana.

The specimens at hand have about 14 to 16 alternating strong and fine lirae in 5 mm. Over some parts of the shells only the coarse ones are visible. Brachial valves are low to moderately convex. Crural ridges diverge at about 120°. The cardinal process is short, thin, deeply bilobed, and the posterior faces of the lobes are deeply spoon-shaped. The median septum is fused with the dental lamellae for only about 1 or 2 mm, beyond which they diverge broadly. The spondylium thus formed is very small, occupying only the tip of the beak of the pedicle valve. Indeed, internal molds preserve the small conical filling of the spondylium imperfectly. This species differs from *Orthotetes mutabilis* Girty, 1927, from the Wells formation of Utah in lacking the extraordinary high ventral interarea and fine (18 to 20, and sometimes 24 lirae in 5 mm) lirae of Girty's species. As in other instances, these specimens are intermediate between *Orthotetes* and *Derbyia*, although closer to the former genus. Weller (1914, p. 74–77) and Girty (1915, p. 43, 44) both commented upon the difficulty of differentiating *Orthotetes* and *Derbyia*.

Subgenus DERBYIA Waagen, 1884

1884. *Derbyia* Waagen, India Geol. Survey. Palaeont. Indica, Mem., ser. 13, v. 1, pt. 4, fasc. 3, p. 591.

1932. *Derbya*. Dunbar and Condra, Nebraska Geol. Survey, ser. 2, Bull. 5, p. 75.

Diagnosis.—*Orthotetes* in which the nearly obsolete dental lamellae do not form a spondylium supported on the median septum.

Orthotetes (Derbyia) sp.

Plate 4, figures 17, 30

Pedicle valve.—One valve 3 cm wide and 2.5 cm long has 15 or 16 rounded lirae in 1 cm at the anterior margin. Lirae tend to alternate in strength where slender ones are intercalated between older and stronger ones. Interspaces are as broad as the lirae. Broad concentric swellings are also present. In a specimen about 3 cm long the median septum extends 1 cm from the beak and is at least 1 mm high at the posterior end. Of three internal molds of pedicle valves studied by the writer, one had no trace of dental lamellae but only a slightly swollen posterior end of the median septum. A second had a notably swollen median septum. The third had low rounded dental lamellae with semicircular cross sections near the teeth, but these died out short of reaching the median septum. An incipient apical chamber was created thereby.

Brachial valve.—A valve 3.5 cm wide and 3 cm long is 1 cm high and is evenly convex. The bifid cardinal process is connected with thick crural plates which diverge at 80° and extend about 3 mm before becoming low ridges which continue another 7 mm and become nearly parallel alongside the dorsal muscle field.

Material.—23 specimens. Figured specimens, USNM 119717.

Occurrence.—Cameron Creek formation, locality 13362?. Alaska Bench limestone, localities 13403 and 16185. Devils Pocket formation, locality 16180.

Remarks.—This species is transitional between *Orthotetes* and *Derbyia* because it has an incipient apical chamber. It is closer to *Derbyia*, however.

Genus SCHUCHERTELLA Girty, 1904

Diagnosis.—Strophomenidae whose pedicle valves are without median septum or dental lamellae but have a low interarea.

Schuchertella sp.

Plate 5, figures 6, 7

Material.—3 specimens. Figured specimens, USNM 118752 and 118753.

Occurrence.—Heath formation, localities 13365 and 13414.

Remarks.—Imperfect specimens referable to this genus have 9 and 11 lirae in 5 mm.

Superfamily PRODUCTACEA

Family CHONETIDAE

Remarks.—The chonetids constitute an important but vexatious element of most late Paleozoic faunas. Dunbar and Condra (1932, p. 133–138) have published a very helpful generic key which is largely based on external characteristics. Evidence helping to distinguish the genera on internal features is slowly accumulating and ultimately will have to be coordinated with external features. Until then the status of the Chonetidae is apt to be in the present state of flux.

Genus CHONETES Fischer de Waldheim, 1837

Diagnosis. — Convexo-concave or convexo-plane Chonetidae with cardinal spines, low fold and sulcus if any, nondenticulate hinge, radial ornamentation stronger than concentric ornamentation, short muscle scars, and 3 dorsal septa.

Remarks.—The specimens here assigned to *Chonetes* seem to lie about midway between this genus and what is generally interpreted as *Lissochonetes* Dunbar and Condra, 1932. Indeed, the specimens are difficult to assign on external features alone. *Lissochonetes* has no external radial lirae, but has internal radial rows of very oblique internal papillae which sometimes can be easily confused with external ornamentation in shells which have lost their outer layers. The specimens at hand are quite smooth externally, and not only have radially arranged internal papillae, but also have distinct intervening radial walls which are invested by the thin sheet of smooth tissue. Internal characters do not help greatly in assigning the specimens under study. They have 3 distinct dorsal septa, but the nature of the brachial interior of the genotype of *Lissochonetes* is not positively known.

Use of septa to describe the brachial interiors of chonetids may be misleading, for these structures rarely are bladelike, but are almost always mere ridges. Pedicle interiors, however, do have true septa.

Geinitz figured specimens of two different sizes when he originally described the genotype of *Lissochonetes*. His description, which says that the brachial valve contains two lateral septa and a median septum, may correspond to a figure (Geinitz, 1866, pl. 4, fig. 17) which seems to represent the internal impression of a once-attached brachial valve and the actual interarea of the pedicle valve. The writer has examined numerous specimens from the type locality, including seven interiors or interior molds of brachial valves. It happens that the assemblage at that locality contains, among other things, two different species of chonetids. One, which is about 16 mm wide at maturity, is faintly striate radially, and definitely has three septa in the brachial valve, although the median septum is low enough to qualify as "almost obsolete" in the words of Dunbar and Condra (1932, p. 170), for it is really a ridge which is nowhere a platelike septum (pl. 5, figs. 23, 24). The other species is 12 mm wide at maturity and is quite smooth. This latter is surely *Lissochonetes geinitzianus* (Waagen), the genotype of *Lissochonetes*. In one specimen of the latter species the position of the median septum is represented by about four papillae fused together at the midlength of the valve (pl. 5, fig. 21). Another specimen, unfortunately broken, definitely lacked any trace of anything which might be termed a median septum or ridge. Dunbar and Condra (1932) do not refer to the brachial interior, beyond saying that the brachial median septum is almost obsolete and to imply that the brachial interior otherwise resembled *Chonetes* (which would mean that it had three septa). Ramsbottom (1952, p. 15) mentioned a specimen in the British Museum which had "only a short median septum," but this specimen seems either not to belong to the genotype species or to be highly aberrant. It is demonstrated above that *Lissochonetes* does not invariably have a median septum or ridge in the brachial valve. In fact, it still remains to be proved that the genus has one at all. Evidence from additional topotypes is needed, evidence which clearly excludes possible inclusion of immature specimens of the faintly striate species. If, as seems distinctly possible, Geinitz included two species in the cotypes of *L. geinitzianus*, then the interpretation of *Lissochonetes* will have to wait for designation of a holotype of the type species.

If *Lissochonetes* has no brachial median septum, then *Tornquistia* Paeckelmann, 1930, may replace *Lissochonetes*. *Tornquistia* rests upon a genotype described from three localities simultaneously, but of which no one specimen has been designated as holotype. Ramsbottom (1952, p. 15) studied the original specimens and said that the pedicle interior of one has "a single median septum." Inasmuch as the brachial interior was not observable from the original material, Ramsbottom cited a specimen from a fourth locality as evidence that the brachial interior has two long, narrowly diverging lateral septa but no median septum. This last specimen may represent the genotype species, but it is highly doubtful that Paeckelmann's interpretation of the genotype is acceptable. For instance, although Ramsbottom interpreted two of Paeckelmann's figures (1930, p. 15, figs. 11a, 12) as brachial valves, they are actually pedicle valves as Paeckelmann originally said they were. Under the circumstances, the species Paeckelmann figures has three septa in the pedicle valve and thereby differs from all other chonetids known to the writer (they have one septum). *Tornquistia* needs to be stabilized by designation of a holotype and a type locality so that additional specimens of significance may be studied.

Unless additional evidence is produced, it seems that *Tornquistia* and *Lissochonetes* both lack the median brachial septum, in which case they seem to be distinguished internally by the fact that the brachial lateral septa of *Lissochonetes* are short and broadly diverging, whereas they are long and narrowly diverging in *Tornquistia;* externally *Tornquistia* has an indistinct sulcus and fold, and *Lissochonetes* has a broad sulcus and fold.

Lissochonetes geinitzianus could have been derived from something like the specimens at hand by loss of the median septum, progressive loss of the pseudolirate radial markings, and consistent development of a sulcus and fold. This possibility is quite as feasable as the proposition that *Lissochonetes* was derived from *Mesolobus* (Dunbar and Condra, 1932, p. 170).

Although these externally smooth chonetids with three brachial interior septa seem to be generically distinct, a new genus is not established for them because the status of closely allied and possibly identical genera is not yet clarified.

Chonetes pseudoliratus Easton, n. sp.

Plate 5, figures 8–13

?1876. *Chonetes platynotas* [in part]. White *in* Powell, U.S. Geol. Geog. Survey Terr., Report on the geology of the eastern portion of the Uinta Mountains, etc., p. 90. (Lower Aubrey group, Utah).

Pedicle valve.—Shells are either evenly convex or have the anterior portion more steeply curved than the posterior portion. Anterior slope is ordinarily flattened and is less commonly depressed into a very faint broad sulcus. Margin of the shell is generally continuously rounded to the hinge line so that the greatest width is near midlength. In some valves the cardinal extremities may be very slightly extended but still not enough to make the hinge line the widest part of the shell. Interareas are inclined about 140° to the plane of commissure. Six or seven spines of unknown length line the cardinal margin. Their broken bases seem to be inclined toward the interarea at 60°. The holotype is 13.7 mm wide, 8.8 mm long, and 3.5 mm high. The average width-to-length proportion for 20 shells is 67.6.

Internally the median septum is platelike only under the beak, anterior to which it is reduced to a low or faint ridge which seems to terminate short of midlength, although its continuation may be confused by a row of papillae. Adductor scars in maturity occupy narrow ridges extending beyond midlength. Diductor scars are difficult to detect in young shells, but in maturity they are fan-shaped depressions with indefinite anterior terminations. Papillae occur about 3 or 4 in 1 mm radially and line up in as few as 8 or 9 moderately well-defined radial rows in 2 mm.

Brachial valve.—Profile concave with the anterior slope commonly very slightly flattened and steeper than the almost plane posterior half.

Internally the median septum is fused with the two lateral septa in a callus carrying a depression and lying just anterior to the cardinal process. The median septum is a low ridge which extends two-thirds to three-fourths of the length of the valve. The two lateral septa diverge at about 50° and extend about one-third of the length of the valve. Papillae are arranged in as few as 5 or 6 indefinite rows medially and as many as 11 or 12 well-defined rows laterally. Crural ridges diverge from the cardinal process at about 135° and shortly lose their distinctiveness as they begin to turn parallel with the hinge line. The cardinal process has four ridges on its posterior face.

Ornamentation.—The surface of both valves is almost always quite smooth, except for minute concentric growth lines. If the shells are slightly corroded or abraded, or even wetted, then a system of radial ornamentation is revealed in which about 18 lines or slightly raised ridges occur in 2 mm. Minute pits denoting papillae numbering about 4 in 1 mm occupy the depressions between lirae. The exact nature of the radial ridges is hard to distinguish for rare unabraded specimens show extremely faint radial ridges and the abraded specimens definitely have solid tissue which tends to stand in relief betewen the rows of papillae.

Comparison.—*Chonetes pseudoliratus* is characterized by the smooth exterior surface which gives way to radial lirae when abraded.

This species is very closely related to *Chonetes platynota* White, 1874, and probably intergrades with it. *C. platynota* has a nearly plane to distinctly convex brachial valve, instead of a slightly concave brachial valve. Crushed specimens of both species are often not separable.

This species differs externally from known members of the new genus *Nix* described below (and containing so-called *C. loganensis* Hall and Whitfield) in having 18 faint radial lines instead of 9 or 10 distinct lirae in 2 mm.

C. chesterensis Weller and *C. oklahomensis* Snider have only 11 or 12 and 9 or 10 lirae in 2 mm, respectively, and both of these species lack smooth exteriors.

C. suttoni Branson, 1937, closely resembles *C. pseudoliratus* but is not well enough known yet to warrant conclusive differentiation. The holotype and only known specimen of *C. suttoni* has a moderately well developed sulcus and is very large (20 mm by 13 mm) instead of having almost no sulcus and being decidedly smaller like *C. pseudoliratus*. The internal features of Branson's species are unknown. The exterior is badly abraded but seems to have the same kind ornamentation as *C. pseudoliratus*.

Material.—100+ specimens. Holotype, USNM 118754. Paratypes, USNM 118755A–E. Topotypes and other specimens in USGS collections.

Occurrence.—Heath formation, locality 13396. Cameron Creek formation, localities 13364, 13373?, 13382, 13419, 13420 (type locality), 13421, 14220, 14221, and 14226 (cf.). Alaska Bench limestone, localities 13372, 13384, 13398, 13403? and 13423.

Genus NIX Easton, n. gen.

Diagnosis.—Convexo-concave Chonetidae with distinct radial ornamentation, cardinal spines, nondenticulate hinge line, a shallow pedicle sulcus and brachial fold, short, tapering adductor muscle scars in the pedicle valve, complete absence of interior septa or ridges in the brachial valve, and only a pit at the anterior base of the cardinal process.

Genotype.—*Nix angulata* Easton, n. sp.

Comparison.—This genus is principally characterized by the absence of all brachial septa, and the interior of the brachial valve bears only a pit at the base of the cardinal process.

Nix cannot be distinguished from typical *Chonetes* on external features. Many *Chonetes* lack any trace of sulcus or fold; hence, these can be distinguished from *Nix* offhand. Unfortunately, some species of *Chonetes* (see, for instance, various figures by Paeckelmann, 1930) have a sulcus and fold, so one seemingly needs to see the brachial interior of a specimen to be most readily assured of its generic assignment. It differs internally from *Chonetes* not only by lacking the brachial septa but in having tapering adductor muscle scars in the pedicle valve.

Aside from *Nix*, other chonetid genera which lack a brachial median septum are *Tornquistia* Paeckelmann,

577887 O—61——3

1930 (or *Paeckelmannia* Licharew, 1934?), *Chonetina* Krotow, 1888, and seemingly *Lissochonetes* Dunbar and Condra, 1932. All three of these genera differ notably from *Nix* by being smooth externally.

Chonetinella Ramsbottom, 1952, differs externally from *Nix* in having a deep and narrow pedicle sulcus and brachial fold. *Nix* seems to stand about midway between *Chonetes* and *Chonetinella* in strength of development of the sulcus and fold. All three genera are radially striate. Internally, *Chonetinella* is equipped with 3 brachial septa and generally resembles *Chonetes*.

Occurrence.—*Nix* is known from the Heath formation of Montana, the Brazer limestone, and possibly from the Madison group.

Nix angulata Easton, n. sp.

Plate 5, figures 14–20

Pedicle valve.—Moderately convex valves, a large specimen measuring 15 mm wide, 10 mm long, and 3 mm high. Greatest height at about midlength or slightly posterior to midlength. The sulcus, when well developed, starts at the umbo as a flattening and quickly becomes broad and shallow but distinct. It is almost obsolete in some specimens. Interareas of both valves together are 1 to 1.3 mm high, with the ventral interarea the larger of the two, and with the interareas inclined 35° to the plane of commissure. From 6 to 8 spines occupy each side of the posterior edge of the ventral interarea and are inclined 45° to the hinge line. In a shell 13 mm wide the last spine is 4 mm long. The hinge line meets the postero-lateral margin of the shell at a right angle, or the cardinal extremities are somewhat sharp pointed. Lirae radiate from the beak and are parallel with the posterior margin. About 9 or 10 lirae occur in 2 mm and are slightly wider than are the intervening spaces. Extremely faint concentric growth lines may be mostly on lirae or mostly in striae, but when magnified give a cancellated fine pattern with the coarser radial elements of the ornamentation.

Internally the median septum is high at its extreme posterior end, but is a very low ridge as it extends forward from one-half to two-thirds the length of the valve. Papillae are low, sparse, and arranged in rows coinciding with external striae, except in late growth they may only number 8 rows in 2 mm near the anterior margin. Adductor muscle scars are narrow, tapering forward, and extend about half the length of the valve. Diductor muscle scars are broad and almost as long as the median septum.

Brachial valve.—Moderately to slightly concave, being about one-third as deep as the pedicle valve is high. The fold is generally very shallow and broad and is only noticeable near the anterior margin.

Internally the surface of the valve is marked by rows of papillae which correspond to external striae except commonly near the margin where newly inserted striae may lack papillae. Crural ridges diverge first at 150° and then swing parallel with the hinge line (180°). The cardinal process is like that of *Chonetes*. No median or lateral septa (or ridges) are present. The base of the cardinal process is marked by a rather deep round pit which is the singular feature of the genus. Muscle scars are too faint to be detected.

Comparison.—This species is characterized by the right-angled or even slightly mucronate lateral margins. *Nix angulata* resembles *N. loganensis* (Hall and Whitfield, 1877) very closely. The principal point of difference between the two species is that *N. loganensis* is widest at about midlength with the lateral margin curving in to the hinge line, whereas *N. angulata* is widest at the hinge line with the lateral margins either at a right angle to the hinge line or even curving out to make the slightly mucronate ends. In suites of specimens *N. angulata* is proportionately wider than is *N. loganensis*, the average ratio of length to width for a dozen specimens of each being 65 and 73, respectively. Because these organisms tend to lengthen disproportionately in old age, ratios of length to breadth is actually more apparent than the randomly selected specimens measured above would imply. The ratio of length to breadth of mature specimens of *N. angulata* is commonly about 60, and of *N. loganensis* about 75. In addition to these differences, *N. loganensis* has a slightly less well developed sulcus and fold than has the other species.

Material.—About 100 specimens. Holotype, USNM 118756. Paratypes, USNM 118757A, B, C, D. Ideotypes, USNM 118896, 118897. Topotypes and other specimens in USGS collections.

Occurrence.—Heath formation localities 13414 (type locality) and 13425.

Remarks.—*N. loganensis* has not been adequately described. The types are mediocre specimens on a slab and do not lend themselves well to description or to illustration. The only figure Hall and Whitfield gave of the species (1877, pl. 4, fig. 9) is so unlike any of the specimens on the type slab as to suggest that the original figure is of some other chonetid. Their description also implies that the lateral margins either meet the hinge line at a right angle or that the ends are even mucronate, when actually all the specimens observable have rounded lateral margins and greatest widths at about midlength. Cardinal spines are not preserved on any of the type specimens, but perforations at their bases on the cardinal margin can be seen in certain lights. Instead of there having been 4 spines, there were from 6 to 8 spines (pl. 5, fig. 22).

About 12 or 13 lirae occur in 2 mm and about 8 or 9 rows of papillae (although sometimes as many rows as there are external striae) occur in 2 mm. The brachial interiors lack septa and muscle scars.

Williams (1943, p. 596, 598, 612) cited *Chonetes loganensis* as being common in most outcrops of the Brazer limestone and he particularly mentioned it as occurring in the upper part of the Brazer. He (1943, p. 602) also cited it as *Chonetes* cf. *C. loganensis* from the uppermost Madison limestone. This generally disagrees with the occurrence of the type specimens, which presumably came from a locality "about 1,500 feet above the lowest beds exposed" in Logan Canyon (Hague, 1877, p. 406, 407) and were associated with a typical Madison fauna. However, Williams (1943, p. 595) only recognized 845 feet of Madison limestone in Logan Canyon, so, according to that, the types had to be from the Brazer. The conflicts need solution in the field.

Family PRODUCTIDAE

Remarks.—The most recent exhaustive key in English to the multitude of productid genera is in Dunbar and Condra (1932, p. 190, 191). Sutton (1938, p. 557) has published a key to Mississippian productids and has assigned various species to genera. Chao (1928, p. 51), Muir-Wood (1930, p. 105–107), and King (1930, p. 65) have also published keys to the productids. As with the chonetids, the systematics of the productids is in flux.

Genus ECHINOCONCHUS Weller, 1914

Diagnosis.—Productidae with bands of large and small spines throughout life.

Remarks.—*Echinoconchus* is most similar to *Pustula* Thomas, 1914, and to *Juresania* Fredericks, 1928. *Pustula* only has one size of spine to each band, whereas *Juresania* lacks bands completely in early stages and has only indefinite bands in later stages. Immature specimens identifiable only as *Echinoconchus* sp. were collected from the Heath formation at localities 13413, 13414, and 13416, and from the Cameron Creek formation at locality 13362.

Echinoconchus angustus Easton, n. sp.

Plate 5, figures 25, 26

1927. *Pustula* aff. *P. genevievensis*. Girty *in* Mansfield, U.S. Geol. Survey Prof. Paper 152, p. 68, 69 (Brazer limestone, Idaho).

Pedicle valve.—Shell small for the genus and not very inflated. Holotype measures 28 mm in width, 26 mm in greatest length, 21 mm in length of brachial valve, and 13 mm in height. Beak overhangs hinge line less than 1 mm. Umbo projects posteriorly rather far and is rather sharply raised above the lateral slopes with its sides diverging at about 75°. A distinct sulcus starts within 5 mm of the beak and extends with increasing distinctiveness to the anterior margin where it causes a slight emargination of the otherwise evenly curved outline.

Internally the adductor muscle scars are on slightly raised ridges about 11 mm long and 3.5 mm broad across their combined anterior ends. The scars diverge at about 5° and terminate at midlength in the valve. Diductor scars seem to be fan-shaped grooved areas lying adjacent to the adductors but whose anterior terminations are indefinite. A very faint median ridge separates the adductor scars and coincides with their length.

Brachial valve.—Posterior portion nearly flat but the margins slope with increasing steepness from the lateral to the anterior portions. A broad fold originates about one-third of the way to the fore. Hinge line of the holotype is about 15 mm long (partly estimated). The concavity of the holotype is about 2 mm.

Internally the median septum extended 13 mm in a brachial valve about 19 mm long (partly estimated). The septum was perhaps 0.5 mm high at its best development between muscle scars. Adductor muscle scars are on slightly elevated ridges 7.5 mm long in the 19 mm long (estimated) specimen above. These ridges are, together, 3 mm broad at their widest span some 4 mm toward their pointed anterior ends. The adductor scars are separated slightly from the median septum by a groove on each side of it. These grooves are mostly flaked off the figured specimen (pl. 5, figs. 26a,b). The cardinal process is about 1.5 mm long and has two ridges on its ventral surface.

Ornamentation.—Spines are of two sizes and occur in as many as 3 or 4 rows on raised concentric bands which, in turn, occur some 6 or 7 in 1 cm.

Comparison.—*Echinoconchus angustus* is characterized by the narrow hinge line, rather small size, and prominent sinus.

E. genevievensis Weller, 1914, is very similar to *E. angustus* but has a much less prominent sulcus and the hinge line of the former species is proportionately much the longer. The hinge line of *E. genevievensis* is 78 percent as long as the greatest width of the shell, whereas the same relationship in *E. angustus* is only 54 percent.

E. angustus is only about half as large as *E. alternatus* (Norwood and Pratten) and *E. semipunctatus* (Shepard), both of which species are commonly recorded in the Carboniferous of America.

Material.—9 specimens. Holotype, USNM 118758.

Paratype, USNM 118759. Topotypes in USGS collections.

Occurrence.—Heath formation, locality 13416. Cameron Creek formation, locality 13362 (type locality).

Remarks.—*Echinoconchus genevievensis* Branson and Greger, 1918, is not an *Echinoconchus*, but may be a *Dictyoclostus* or a *Productus*.

Echinoconchus aff. E. alternatus (Norwood and Pratten, 1855)

Plate 4, figure 28

Material.—12 specimens. Figured specimen, USNM 118760. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13368, 13416, and 13424. Cameron Creek formation, locality 13382. Alaska Bench limestone, localities 13385, 13399, and 13406?

Remarks.—Several fragments of large *Echinoconchus* measuring 5 cm in greatest diameter resemble this species. The median sulcus is broad and shallow. The umbo projects posteriorly beyond the hinge line and its sides converge at about 85°. The beak is enrolled over the brachial valve. Six or 7 bands carrying 2 to 4 rows of spines in two sizes occur in 1 cm.

This species has the size, wide hinge line, and coarse spines reminiscent of *E. alternatus*, but the beak is produced posteriorly like *E. semipunctatus* (Shepard).

Genus PRODUCTUS Sowerby, 1814, emend. Muir-Wood, 1930

1814. *Productus* Sowerby, The mineral conchology of Great Britain, v. 1, p. 153.
1910. *Diaphragmus* Girty, New York Acad. Sci., Annals, v. 20, no. 3, pt. II, p. 217. (As a subgenus of *Productus*).
1928. *Productus*. Muir-Wood, Great Britain Geol. Survey Mem., Paleontology, v. 3, pt. 1, p. 35.
1930. *Productus*. Muir-Wood, Annals and Mag. Nat. Hist., Ser. 10, v. 5, p. 102. (Emended diagnosis).
——. *Diaphragmus* of authors.

Emended diagnosis.—Shell elongate, both valves geniculate; hinge narrow; pedicle valve with long spreading trail. Flanks steep and posteriorly flattened. Shell costate in all growth stages, costae numerous, flexuous. Ribs few, seldom prominent. Spines set in rows on ears and cardinal slopes and scattered on trail. Teeth, dental sockets, and delthyrium absent. Marginal ridges narrow, short. A thin shelly plate or diaphragm developed round anterior margin of visceral disc of brachial valve, extending across space between trails of the two valves. (Muir-Wood, 1930, p. 102).

Occurrence.—True *Productus* is known from as low as the C zone of the British Lower Carboniferous, into the Upper Carboniferous. Thus far, the genus has been reported in North America only in the Mississippian and Pennsylvanian.

Remarks.—The abbreviated synonymy of the genus used here merely cites the four principal references of interest to Americans. Since *Productus* was originally proposed in 1814 it became a dumping ground for all sorts of species of "productids." Girty tried to differentiate those productids having a diaphragm by erecting *Diaphragmus*, but Muir-Wood discovered that the genotype of *Productus* also had a diaphragm, and so now paleontologists are trying to use *Productus* in the narrow sense hitherto reserved for *Diaphragmus;* but a long ancestry of loose usage subverts the elegance of the attempt. Many species with a reticulate umbo which formerly were placed in *Productus* are now referred to *Dictyoclostus*, but the generic substitution is not perfect for rule of thumb purposes.

Productus fasciculatus McChesney, 1860

Plate 6, figures 1–5

1860. *Productus fasciculatus*, McChesney, Descriptions of new species of fossils from the Paleozoic rocks of the western states, p. 38. (Kaskaskia limestone, Illinois and Indiana).
1877. *Productus fasciculatus*. Miller, American Paleozoic fossils, p. 123.
1889. *Productus fasciculatus*. Miller, North American geology and palaeontology, p. 364.
1909. *Productus fasciculatus*. Bassler, Virginia Geol. Survey Bull. 2A, pl. 29, figs. 12, 13. (Greenbrier limestone, Virginia).
1911. *Diaphragmus elegans*. Girty, U.S. Geol. Survey Bull. 439, p. 51, pl. 4, figs. 4, 5. (Fayettville shale, Arkansas, erroneously referred to Moorefield shale; fide Gordon, 1944, p. 1630).
1911. *Diaphragmus elegans*. Reagan, Science, new ser. v. 34, p. 127. (Lower Redwall limestone, Arizona).
1914. *Diaphragmus elegans* [in part]. Weller, Illinois Geol. Survey Mon. I, p. 136–138. (Chester group, Mississippi Valley Basin).
1915. *Diaphragmus fasciculatus*. Girty, U.S. Geol. Survey Bull. 593, p. 56, pl. 3, figs. 1–4. (Batesville sandstone, Arkansas).
1930. *Diaphragmus fasciculatus*. Croneis, Arkansas Geol. Survey Bull. 3, p. 62, pl. 15, figs. 6, 7, 14. (Batesville sandstone, Arkansas).
1935. *Productus fasciculatus?*, Hernon, Jour. Paleontology, v. 9, no. 8, p. 681. (Paradise formation, Arizona).
1938. *Productus fasiculatus* [sic]. Sutton, Jour. Paleontology, v. 12, no. 6, p. 559.

Pedicle valve.—Rather small and low with the posterior part sharply rounded but with the anterior slope nearly straight. Umbonal flanks diverge at 70° and merge gradually with sloping ears. The beak protrudes slightly beyond the hinge line and is slightly enrolled. The margin is rather evenly rounded so that the greatest width lies forward of midlength. A broad shallow sulcus starts within 1 cm of the beak and continues to the anterior margin where it causes a reentrant in the outline. A typical specimen is 22 mm long, 18 mm wide at the hinge line, 28 mm wide at the widest point about three-fourths of the length, 14 mm high, and the opening for the brachial valve is 17.5 mm long.

Internally the adductor muscle scars are on low subparallel ridges 1 cm long which expand slightly anteriorly and reach a combined width of 3 mm before they terminate 15 mm from the beak. A narrow groove separates them. Diductor muscle scars are broad fluted areas lying on each side of the adductor scars but rather hard to distinguish from internal reflection of external costae.

Brachial valve.—Valve nearly flat but abruptly bent into a long trail about three-fourths of the length. Umbonal region slightly depressed along faint flexures which diverge from the beak at 70°. A very low indefinite fold is present. Ears are quite flat. The trail is parallel with that of the pedicle valve.

Internally the cardinal process is short, bearing two lobes on the pedicle side and three lobes on the brachial side. A small pit lies at the intersection of the low posterior marginal ridge and the cardinal process. The marginal ridge continues very faintly around onto the lateral flanks of the visceral disc. The median septum extends the full length of the visceral disc and reaches a height of 2.1 mm before descending abruptly to the floor. Adductor muscle scars lie on prominent triangular platforms on the posterior half of the visceral disc. Posterior adductor scars are nodular and not as elevated as the smaller smooth anterior scars. A deep furrow separates the scars from the septum.

The diaphragm which characterizes the genus projects outward from 4 to 5 mm in the plane of the visceral disc at its maximum width anteriorly. Its surface is sculptured with minute concentric crenulations and with distinct but fine radial striae. Its general appearance is that of a smoother apron bordering upon the coarsely costate visceral disc.

Ornamentation.—The pedicle valve is covered with low broadly rounded costae which number 13 or 14 in 10 mm at midlength and 12 or 13 in 10 mm at the anterior margin. The costae increase prominently by bifurcation, but they maintain nearly the same strength over the anterior half of their extent. Rather stout spine bases are scattered on 4 to 6 mm centers over the surface. An indefinite row of spines borders the hinge margin. Concentric wrinkles are distinct on the flanks but almost die out over the ventral part of the visceral cavity. Minute growth lines are present.

The brachial valve is like the pedicle valve, except that the ornamentation is less well developed and no spine bases are discernable. A few dimples lie on the surface, however, being particularly common near the ears. The diaphragm in an unweathered specimen is distinctly smoother than is the visceral disc.

Comparison.—*Productus fasciculatus* is characterized by the presence of a sulcus in the pedicle valve, distinct spine bases, and by relatively coarse costae.

It can be readily differentiated from *P. phillipsi* Norwood and Pratten, 1855, the only other western species of *Productus* so far described, in having 12 to 14 instead of only about 9 costae in 10 mm.

Productus fasciculatus externally resembles most closely the group of "*Diaphragmus*" *inflatus* from the faunas of Montana. When the characteristic diaphragm is not revealed, *P. fasciculatus* can be differentiated from the latter group by its lower pedicle valves, sloping instead of inflated ears, and less distinct concentric wrinkles over the umbo.

Productus cestriensis Worthen, 1860 (which has been commonly cited as *Diaphragmus elegans* (Norwood and Pratten) in American literature) is much smaller than *P. fasciculatus* and has no ventral sinus.

Productus montesanae Ulrich, 1917 is also a much smaller species than this and has very coarse costae.

Material.—33 specimens. Hypotypes, USNM 118761, 118762, and 118763 A, B, C. Other specimens, USNM 118764 and USGS collections.

Occurrence.—Heath formation, localities 13395, 13414, 13416, 13425.

Remarks.—A copy of McChesney's original description was made readily accessible by Girty (1915, p. 58).

A few specimens from the Heath shale (locality 13409) have a very faint pedicle sinus and finer costae than do typical *Productus fasciculatus*, therein approaching closely to *P. cestriensis*.

Genus LINOPRODUCTUS Chao, 1927

Diagnosis.—Productids with fine radiating lirae, spines on the cardinal margin as well as on the surface, and with a large visceral cavity and trail.

Remarks.—The foregoing diagnosis concerns external features only. When bearing the fine radial lirae, *Linoproductus* is readily separable from most other genera with which it occurs. *Striatifera* Chao, 1927, has a thin visceral chamber, and *Gigantoproductus* (formerly *Gigantella* Sarycheva, 1928) is much larger and more ornate than is *Linoproductus*, but the ornamentation of all these genera is similar. *Linoproductus* with coarse radial ridges grades into *Dictyoclostus* but lacks concentric wrinkles on the umbo.

Accounts of *Linoproductus* are by Dunbar and Condra (1932, p. 239) and Sutton (1938, p. 557).

Differentiation of species in this genus is difficult, owing to the great variability in members of a population. Various paleontologists have concluded that the common Mississippian species is *Linoproductus ovatus*, and that differences are of varietal significance at best. This philosophy has led to the use of *L. ovatus* in an extremely broad sense.

Linoproductus nodosus (Newberry), n subsp.

Plate 6, figures 6–8

Pedicle valve.—Surface evenly curved from the pointed beak overhanging the hinge line to the evenly curved anterior margin. Sides of beak diverge at 90°. Sulcus absent. Profile from the anterior is nearly semicircular but is slightly depressed at the midline. Posterolateral slopes sharply wrinkled. Where wrinkles meet the hinge line there is usually a stout cardinal spine which projects pedically or posteriorly.

Interior without a median septum. Two indefinite adductor scars may leave elongate ridges. Diductor scars are indefinite grooved areas bordering the adductor scars.

A moderately large valve is about 3 cm long and 3 cm wide.

Brachial valve.—Slightly concave but with a rather sharply produced anterior margin. Hinge line as wide as or nearly as wide as the greatest width. Wrinkles may extend from the hinge line around the valve concentrically, being weakest medially.

Internally a very faint trace of a median septum is sometimes visible. Other internal features not observed.

Ornamentation.—Lirae number 6 or 7 in 5 mm and are low and broadly rounded. A single row of about 5 strong spines lines the cardinal margin and these may either be erect or deflected posteriorly. A few (1 to perhaps 5) extremely stout spine bases occur on the front half of the shell. Some specimens have 1 to 3 large spine bases lying along or near the midline, but others have an isolated excentrically located spine base or have as many as 5 spine bases scattered around the surface asymmetrically. The brachial valve occasionally has a large spine base on it.

Comparison.—*Linoproductus nodosus* is characterized by having a row of extraordinarily large spine bases lying along the midline of the pedicle valve. The Big Snowy subspecies differs from typical *L. nodosus* only in having a somewhat erratic distribution of spine bases.

Some specimens cannot be distinguished from *L. nodosus*, but other specimens seem to lack all signs of having the large anterior spine bases.

Intermediate specimens resemble *L. magnispinus* Dunbar and Condra but have fewer spine bases and a narrower beak than the latter species has.

L. ovatus Hall is similar to *L. nodosus*, but *L. ovatus* is very convex and has inconspicuous spine bases.

L. prattenianus (Norwood and Pratten) is also similar to *L. nodosus*, but *L. prattenianus* is broadly arched ventrally and has a regular pattern of rather prominent spine bases.

Material.—53 specimens. Figured specimens USNM 118765 and 118766. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13412, 13413?, 13414, and 13424. Cameron Creek formation, localities 13361–13364, 13383, and 13421. Alaska Bench limestone, localities 13372?, 13385, 13398, 13399?, 13403, and 13404.

Linoproductus croneisi Branson, 1937

Plate 6, figure 9

1927. *Productus ovatus.* Girty, U.S. Geol. Survey Prof. Paper 152, p. 68. (Brazer limestone, Idaho).

1927. *Productus* aff. *P. parvus.* Girty, U. S. Geol. Survey Prof. Paper 152, p. 68. (Brazer limestone, Idaho).

1937. *Linoproductus croneisi.* Branson, Jour. Paleontology, v. 11, no. 8, p. 656, pl. 89, figs. 13–15 (Sacajawea formation, Wyoming).

1938. *Linoproductus croneisi.* Sutton, Jour. Paleontology, v. 12, no. 6, p. 558.

Diagnosis.—Small, convexo-concave productids with a double row of 8 spines, each parallel with the hinge line; with about 18 costae in 5 mm at midlength and 13 costae in 5 mm on the anterior slope; with strong wrinkles on the flanks; and with occasional large spines.

Comparison.—*Linoproductus croneisi* resembles very much the next species described herein, but differs from that species in having 18 instead of 12 costae in 5 mm.

Linoproductus ovatus subsp. *minor* (Snider, 1915), is also very similar to *L. croneisi* in size, but it has a very convex pedicle valve and about 21 costae in 5 mm. It is not known whether there is a double row of spines on the hinge margin of Snider's variety.

L. croneisi, *L. ovatus* subsp. *minor*, and the next species described below are all only about one-third as large as most other species of *Linoproductus.*

Material.—8 specimens. Hypotype, USNM 118767. The types of *Linoproductus croneisi* are University of Missouri 6831.

Occurrence.—Heath formation, localities 13368 and 13395. Cameron Creek formation, locality 13382. The species was described from the Sacajawea formation of C. C. Branson (1936) of Wyoming and is known from the Brazer limestone of Idaho.

Remarks.—The holotype has 6 spines in the posterior rows and three in the anterior rows, but the figured specimen from Montana has 8 in each row. The Montana specimen also has a very convex pedicle valve; the holotype is low but is possibly deformed. The Montana specimen has from 12 to 16 costae in 5 mm. Bifurcation of costae is dominant on the pedicle valve, but implantation of new costae is dominant on the brachial valve. The best Montana specimen is 18 mm wide (reconstructed) at about two-thirds of the length, 12 mm wide at the hinge line, 10 mm long, and 9 mm high.

Linoproductus? duodenarius Easton, n. sp.

Plate 6, figures 10–12

Pedicle valve.—Small and very convex productids. The curvature in lateral profile decreases steadily from the beak. Umbonal flanks diverge at 80° to 90° and stand high above the ears. The ears are horizontal to slightly recurved ventrally.

Internally the muscle scars are so weak that they are indistinguishable among the impressions of costae. No septum is present.

The holotype is 14 mm long, 16 mm wide at midlength, 8 mm high, the hinge line is 13 mm long, and the length of the aperture for the brachial valve is 13 mm long.

Brachial valve.—The posterior portion is slightly concave, but the anterior portion is so very geniculate that the entire valve is deeply concave. The visceral cavity is only about 2 to 5 mm deep.

Internally the axis of the cardinal process extends posteriorly from the hinge line as a very short, bilobed swelling. Other details of the interior of the brachial valve are lost because of exfoliation of the shells.

Ornamentation.—The surface is covered with broadly rounded rather flexuous costae about 12 of which occur in 5 mm. The costae on the pedicle valve increase largely by implantation, and those of the brachial valve increase largely by splitting or bifurcation. Prominent spine bases occur at about 3 mm intervals over the pedicle valve. The brachial valve is similarly marked but with depressions which may have been spine bases. Costae are a little stronger near spine bases than elsewhere, and the costae may either coalesce or diverge where they coincide with spines. The ears of the pedicle valve are marked with two rows each of about 5 to 7 spines parallel with the hinge line. The brachial valve has two rows of depressions bordering the hinge line, which roughly correspond to the distribution of spines on the pedicle valve. The ears and lower lateral flanks of the umbones are marked by about 4 coarse wrinkles. Microscopic concentric growth lines are present. Internal molds give a faithful representation of external ornamentation.

Comparison.—This species is characterized by its small size, double row of marginal spines, and the occurrence of 12 costae in 5 mm.

Linoproductus? duodenarius differs from *L. croneisi* Branson in having only 12 instead of 18 to 21 costae in 5 mm. Otherwise the species are very similar, although *L. croneisis* may be less convex and have fewer marginal spines.

Linoproductus ovatus minor (Snider, 1915) from the midcontinent has about 21 costae in 5 mm, but is otherwise very similar to this species.

Material.—28 specimens. Holotype, USNM 118768. Paratypes, USNM 118769A, B. Ideotype, USNM 118770. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 1390. Heath formation, localities 13387, 13414, and 13416 (type locality). Cameron Creek formation, locality 13420. Alaska Bench limestone, locality 13403.

Remarks.—Assignment of this species to *Linoproductus* is queried for two reasons. Evidence of dimples on the brachial valve signifies the probable development of spines, but *Linoproductus* typically not only lacks brachial spines, but also lacks dimples simulating distribution of spine bases. Moreover, the cardinal process of this species is a short, blunt, barely bilobed structure instead of being strongly bilobed and protuberant. Sutton (1938, p. 557, 558) has stated the difficulty of separating certain species of productids on the basis of strength of costae, strength of wrinkles (rugae), and relative width of hinge lines. In a few instances specimens of *L.? duodenarius* are faintly wrinkled on the umbo like *Dictyoclostus.* All specimens, however, have the narrow hinge line of *Linoproductus. L.? duodenarius* is small, has umbonal wrinkles, and has spine bases over most of the pedicle valve, all of which characteristics are diagnostic of *Cancrinella*, but are also found in *Linoproductus;* so, the two genera seem inseparable on these features.

Linoproductus sp.

Material.—32 specimens. USNM 118771. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13393, 13415, 13395, and 13424. Cameron Creek formation, locality 13361. Alaska Bench limestone, locality 13422.

Remarks.—The material at hand resembles *Linoproductus croneisi* Branson in the remarkable fineness of the radial lirae, upswept ears, and seeming presence of two rows of spines on the ears, but the specimens are twice as large or larger than is *L. croneisi.* A nearly complete specimen would have been about 3 cm wide and 4 cm long. Spine bases are sparsely distributed, only a few being as close as 5 mm apart.

About 15 costae occur in 5 mm, and 12 costae occur in 5 mm on *Linoproductus nodosus* and on *L. ovatus*, and only 9 or 10 costae occur in 5 mm on *L. prattenianus.*

Genus DICTYOCLOSTUS Muir-Wood, 1930

1930. *Dictyoclostus* Muir-Wood, Annals and Mag. Nat. History: ser. 10, v. 5, p. 103.

Diagnosis.—Shell elongate or quadrate in outline. Hinge moderately wide; pedicle valve evenly convex or produced into a short curved trail, brachial valve concave or geniculate. Costate in all growth stages, costae often prominent, bearing numerous spine bases. Spines also in rows on ears and cardinal slopes. Ribs on visceral disc numerous and forming netlike ornament by enlargement at point of intersection with costae. Diaphragm absent. Marginal ridges prominent, extending along hinge. Hinge-teeth, sockets, and cardinal area not developed. (Muir-Wood, 1930, p. 103).

Comparison.—*Dictyoclostus* resembles *Buxtonia* in shape and somewhat in ornamentation, the two genera tending to grade into each other in this latter regard. Spine bases of *Buxtonia*, however, typically terminate in elongate oblique ridges, instead of being circular and erect. *Buxtonia* is described on p. 61.

Some species of *Marginifera* also have a semireticulate umbo, but they all have a characteristic internal ridge around the visceral disc of the brachial valve. In *Eomarginifera* the ridge dies out along the lateral parts of the visceral disc. As the genotype of *Dictyoclostus* has a similarly disposed ridge, *Eomarginifera* and *Dictyoclostus* are alike in this character.

Occurrence.—Common in post-Devonian Paleozoic rocks of many parts of the world.

Remarks.—Because *Productus* is restricted to those shells with a diaphragm, most semireticulate species formerly referred to *Productus* are now referred to *Dictyoclostus*.

Only the original citation is given in the synonymy because of uncertainty as to what should be included in the genus. Most paleontologists refer here semireticulate species without anterior limbs of the marginal ridge. Unfortunately, the internal anatomy of these shells is generally inadequately known, so that when similarity of external features renders reference to internal characteristics desirable, one commonly finds necessary information lacking.

American shells referred to *Dictyoclostus* may not be correctly assigned. Internal features of many of them are almost unknown. Some uncertainty exists in the writer's mind regarding the nature of *Dictyoclostus semireticulatus*, the genotype. Muir-Wood said (1928, p. 95) that its median septum extends "nearly to the anterior margin of the brachial valve" and that the marginal ridges extend a little forward of the hinge line. Although the cardinal process of the genotype is not discussed so far as the writer knows, Miss Muir-Wood (p. 18) said in respect to the whole semireticulate group that

The cardinal process in the *semireticulatus* and *longispinus* groups projects above the margin of the brachial valve, and is divided by a median furrow into two parts which are smooth and rounded; these are continued dorsally as two curved laminae separated from the median process by deep sulci. The dorsal view of the process shows it to be trilobate and transversely striated.

Definite statements seem to be lacking in the published record concerning the shape of that part of the median septum lying between the cardinal process and the adductor muscle scars, but a specimen of the genotype donated to the U.S. National Museum (accession 189969) shows a very slight ventral sag to laminae along the crest of the ridge.

In American species known to the writer the median septum ordinarily extends three-fourths or less of the length; the posterior half of the median septum may have either a distinct median furrow or no furrow at all; and marginal ridges tend to die out at the cardinal extremities. The cardinal processes are ventrally bilobed, but are dorsally trilobed owing to a deep excavation on the dorsal surface of each lateral lobe. These excavations leave the median halves of the lateral lobes in close approximation so that they simulate a median lobe with a ventral groove on it.

Although the cardinal processes of American species (at least some) seem like that of the genotype, the short median septa, less extensive marginal ridges, and occasional absence of posterior furrows on the median septum seem to cast doubt on the correctness of referring some species to *Dictyoclostus*. The writer therefore uses the name as a temporary receptacle for semireticulate productids not otherwise assigned and indicates his qualification of the usage by placing the name "*Dictyoclostus*" in quotation marks.

"Dictyoclostus" inflatus (McChesney, 1859)

1860. *Productus inflatus.* McChesney, Descriptions of new species of Paleozoic fossils, p. 40 (1859). (Carboniferous, Indiana).

1865. *Productus inflatus.* McChesney, Illustrations of new species of fossils, pl. 6, figs. 1 a–c.

1868. *Productus inflatus.* McChesney, Chicago Acad. Sci. Trans., v. 1, p. 27, pl. 6, figs. 1 a–c.

1877. *Productus semireticulatus.* American Paleozoic fossils, p. 123.

1889. *Productus semireticulatus.* Miller, North American geology and paleontology, p. 364.

1898. *Productus cherokeensis* [in part] Drake, Am. Philos. Soc. Proc., v. 36, no. 156, p. 404, pl. 9, figs. 4, 5. *Reissued as* Leland Stanford Jr. Univ. Pubs., Contr. Biol. from Hopkins Seaside Lab., v. 14. (Boston group, Oklahoma).

1902. [not] *Productus inflatus.* Tschernyschew, U.S.S.R., Geol. Kom. Trudy, v. 16, no. 2, p. 261, pl. 28, figs. 1–6.

1903. [not] *Productus inflatus.* Girty, U.S. Geol. Survey Prof. Paper 16, p. 359, pl. 3, figs. 1–3.

1904. [not] *Products inflatus.* Girty, U.S. Geol. Survey, Prof. Paper 21, p. 52, pl. 11, figs. 5, 6.

1906. [not] *Productus inflatus.* Keidel, Neues Jahrb., Beilage-Band 22, p. 361.

1909. *?Productus inflatus.* Gröber, Akad. Wiss. München, Abh., math.-phys. Kl., v. 24, pt. 2, p. 378, pl. 2, figs. 7 a–c; pl. 3, figs. 5 a–c.

1912. [not] *Productus inflatus.* Jakowlev, U.S.S.R., Geol. Kom. Trudy, novaia ser., v. 79, p. 5, pl. 2, figs. 4, 5; pl. 3, fig. 8.

1914. *Productus inflatus.* Weller, Illinois Geol. Survey Mon. 1, p. 111, pl. 10, figs. 1–6. (Okaw formation, Mississippi valley basin).
1915. *Productus inflatus.* Snider, Oklahoma Geol. Survey Bull. 24, pt. 2, p. 78. (Mayes formation?), and Fayetteville formation, Oklahoma).
?1915. *Productus cherokeensis.* Snider, Oklahoma Geol. Survey, Bull. 24, pt. 2, p. 80, pl. 3, figs. 22–24. (Fayetteville shale, Oklahoma).
1916. [not] *Productus inflatus.* Tschernyschew and Stepanow, Rept. 2d Norwegian Arctic Expedition in the *Fram*, no. 34, Kristiana Soc. Arts Sci., p. 30, pl. 5.
1917. *Productus inflatus.* Butts, Kentucky Geol. Survey, Mississippian Series in Western Kentucky, p. 78, pl. 21, figs. 7–9. (Fredonia oolite to Gasper oolite, Kentucky).
1917. *Productus inflatus.* Ulrich, Kentucky Geol. Survey, Missisippian Series in Western Kentucky, p. 249, pl. 3, figs. 4–13. (Fredonia oolite, Ohara limestone, and Gasper formation, Kentucky).
1917. [not] *Productus inflatus.* Grönwall, Copenhague Univ., Mus. mineralogie et géologie, Comm. Paléont., no. 13, p. 578, pl. 29, figs. 17–19; *and* Meddelelser om Grønland, v. 43, p. 578, pl. 29, figs. 17–19.
1920. *Productus inflatus.* Weller, Illinois Geol. Survey, Bull. 41, p. 138?, 148, 157, 183, 195?, 196?. (Shetlerville formation, Renault formation, Golconda formation, and Glen Dean limestone(?), Illinois).
1926. *Productus inflatus.* Butts, Alabama Geol. Survey, Spec. Rept. 14, p. 188, pl. 61, figs. 13–17. (Gasper formation and Ste. Genevieve limestone, Alabama).
1927. [not] *Productus inflatus.* Chao, Palaeontologia Sinica, ser. B., v. 5, fasc. 2, p. 36, pl. 2, fig. 13; pl. 3, figs. 1–5.
1930. *Productus inflatus.* Croneis, Arkansas Geol. Survey Bull. 3, p. 69, pl. 18, figs. 5, 6. (lower Fayetteville shale, Arkansas).
1930. *Productus inflatus.* Morse, Mississippi Geol. Survey, Bull. 23, p. 134, pl. 10, figs. 1–6. (Alsobrook formation, Alabama).
1931. *Productus inflatus.* Weller, Kentucky Geol. Survey, ser. 6, 36, pl. 43, figs. 6a, b. (Chester series, Kentucky).
1931. [not] *Productus inflatus.* Frebold, Meddelelser om Grønland v. 84, no. 2, p. 13.
1935. "*Productus*" *inflatus.* Hernon, Jour. Paleontology, v. 9, no. 8, p. 681. (Fifth and Seventh members of the Paradise formation, Arizona).
1936. *Productus inflatus.* Morse, Mississippi Geol. Survey, Bull. 32, p. 22, 23, pl. 2. (Alsobrook formation, Alabama).
1938. *Dictyoclostus inflatus.* Sutton, Jour. Paleontology, v. 12, no. 6, p. 563.
1941. *Productus* (*Dictyoclostus*) *inflatus.* Butts, Virginia Geol. Survey Bull. 52, p. 358?, 360?, 361, 365, 373, 375, 376, 380, 387?, 392, pl. 128, figs. 1–8. (Warsaw formation, St. Louis limestone, Ste. Genevieve formation, Gasper limestone, and Glen Dean formation, Virginia).
1943. "*Productus*" *inflatus.* McFarlan, Geology of Kentucky, Lexington, Ky., p. 87, pl. 17. (Beech Creek limestone, Kentucky).
1944. *Dictyoclostus inflatus.* Cooper *in* Shimer and Shrock, Index fossils of North America, p. 350, pl. 136, figs. 9–14. (Chester of midcontinent).
1950. *Dictyoclostus inflatus.* Plummer, Texas Univ. Pub., no. 4329, p. 41, 43, 44, 126, pl. 8, fig. 13. (Barnett formation and Helms formation, Texas).

Diagnosis.—Productids of moderate size with a narrow and rather deep sulcus in the pedicle valve, generally inflated ears, concentric wrinkles on the umbo, costae over the entire valve which occur about 12 in 10 mm at midlength, a row of spines near the hinge line, and with a rather geniculate and concave brachial valve.

Internally the pedicle valve has a high platform to which the adductor muscles were attached. The brachial valve has a fundamentally bilobed cardinal process with secondary excavations of the lobes which give it three-lobed appearance, a low median septum, and ridges at the brachial impressions.

Material.—58 specimens. Specimens in USGS collections.

Occurrence.—Otter formation, locality 14227 (cf.). Heath formation, localities 13391, 13402, and 13416. Cameron Creek formation, localities 13382 and 13421?. Alaska Bench limestone, localities 13389, 13398, 13403, 13404, 13406, and 13423.

Remarks.—This species is one of the better known productids in the American Chester group. It is closely allied in external features with a host of other Mississippian and Pennsylvanian species which are commonly referred to *Dictyoclostus*, but *D. inflatus* and its varieties differ from them internally. The prominent internal pedicle platform is a distinctive feature. Internal molds and even fragmentary pieces of pedicle valves commonly show this platform (pl. 6, figs. 20–24).

The systematic postion of the *D. inflatus* species-group will be handled by Drs. G. A. Cooper and H. M. Muir-Wood in a forthcoming publication. Their studies antedate those of the writer.

Principal directions of evolution in the species-group involve strength of the sulcus in the pedicle valve, strength of costae, and the number and distribution of rows of spines near the hinge line and on the lateral flanks of the umbo.

Productus cherokeensis was named by Drake in 1898 for shells which were said to differ from *D. inflatus* in having a less prominent and less incurved umbo and somewhat coarser ribs. Snider (1915, p. 81) commented on the presence of two species at the type locality of *P. cherokeensis* and he retained the name for one with less inflated ears, which is also larger, broader, and has a greater reticulate area with sharper concentric wrinkles. The holotype of *P. cherokeensis* was lent for study through the kindness of Dr. Myra Keen of Stanford University. It is 26 mm wide at the hinge line, the pedicle valve is 22.5 mm long and 15 mm high, and the brachial valve is 17 mm long and 4.5 mm deep. Costae number 10 in 10 mm at midlength, and 15 in 10 mm at the anterior margin. A single row of 5 spines crosses each ear at a 7° angle to the hinge line. *P. cherokeensis* is here considered as a variety of *P. inflatus* whose distinguishing feature is the coarseness of the costae. Other features in a suite of shells from near the type locality are extremely variable, but all these shells have finer costae (about 13 in 10 mm) than does the holotype. Inasmuch as the writer is unable to find a specimen with as coarse costae as the holotype, he considers it likely that the type specimen represents an extreme variation. Even so, it is difficult to distinguish it from "*Dictyoclostus*" *inflatus*.

The writer recognizes two subspecies of "*Dictyoclostus*" *inflatus* in the faunas from Montana, subsp. *spinolinearis* and subsp. *obsoletus*. When shells are so poorly preserved as not to permit assignment to either of the following varieties, then they can still be assigned to "*D.*" *inflatus*.

"Dictyoclostus" inflatus subsp. spinolinearis Easton, n. subsp.

Plate 6, figures 13–24

Pedicle valve.—Rather geniculate and broadly quadrate productids with the umbo and anterior slope rather flattened. The beak extends slightly beyond the hinge line posteriorly and is slightly enrolled over the hinge line. The umbo tends to stand high with steep lateral flanks diverging at 70° and descending steeply to the ears. The ears are either at about a right angle to the lateral slopes or are separated therefrom by a narrow depression parallel with the lateral slopes, so that the ears are strikingly convex. A broad and shallow sulcus begins within about 1 cm of the beak and continues with somewhat increasing depth onto the anterior slope, where it becomes nearly or entirely obsolete and is represented by merely a flat anterior margin of the valve. A specimen of average size is 28 mm long, 29 mm wide at the hinge line, 20 mm long across the brachial valve, and is 20 mm high.

Internally the adductor muscle scars are on a generally very prominent platform which slopes gently downward posteriorly but has a steep anterior slope. These platforms may be divided along their axes by a groove, by a groove bearing a ridge, or by a ridge. The platforms are about 10 mm long and 5 mm wide. Diductor scars are channeled areas lying on both sides of the platform.

Brachial valve.—Moderately concave in the posterior two-thirds, but rather abruptly geniculate along the anterior margin.

Internally (pl. 6, fig. 18) the adductor scars occupy two slightly raised elongate areas. A median septum arises between the adductor muscle scars at their anterior halves and continues about three-fourths of the length of the valve, where its anterior termination is steeply oblique. The median septum is about 1 mm high at its peak. A semicircular brachidial ridge lies on either side of the median septum with the open portions facing the septum some 5 mm distant. Areas included by the brachidial impressions are smooth, in contrast to the generally papillate surrounding surface. The axis of the cardinal process is directed posteriorly in the plane of the valve. Its pedicle surface is bilobed but its brachidial surface is trilobed by reason of deep excavations in the centers of two main lateral lobes so that three draperylike folds are visible dorsally (pl. 6, fig. 19b).

Ornamentation.—Costae on the pedicle valve become nearly or entirely obsolete along as much as 1 cm of the anterior slope (pl. 6, fig. 17). High on the anterior slope where costae are best developed, about 12 costae occur in 10 mm. The costae bifurcate and also anastamose along their courses. The umbo is crossed by prominent, broad, concentric wrinkles somewhat stronger than the costae. A row of 3 or 4 strong spine bases commonly crosses the ears at about 15° but may be parallel with the hinge line in some cases. A second single row of generally 3 or 4 but sometimes as many as 7 or 8 strong spine bases lies on the lateral flanks of the umbo just above the furrow delineating the ears (pl. 6, figs. 14b, 16). The second row of spines commonly joins with a double row of spines on the anterior slope and roughly differentiates the costate and smooth portions of the valve. The entire surfaee, when well preserved, is covered by very wavy growth lines, of which about 10 occur in 1 mm. Spine bases are scattered about the surface occasionally.

Ornamentation of the brachial valve is similar to that of the pedicle valve. Some specimens have about 3 spine bases in a line obliquely crossing each cardinal margin, similar to the second row of spines in the pedicle valve. When somewhat exfoliated, traces of the median septum and of the brachial ridges may be seen.

Comparison.—This variety is characterized by the single row of spines on both of the lower lateral flanks. It shares with the next described variety the evanescent sinus and oblique row of spines on the ears.

"*Dictyoclostus*" *inflatus* subsp. *spinolinearis* can be distinguished from *D. inflatus* most readily by the presence of the characteristic row of spines on the flanks. If the pedicle valve is much exfoliated, then the diagnostic spine bases may not be preserved, in which case the variety cannot be distinguished from equally exfoliated specimens of the variety next described below. Both varieties have obsolescent anterior portions of the sulcus in the pedicle valve.

Girty (1910, p. 216) named a large, broad, huskily spined productid with a single row of spines on the lateral flanks or in the furrows *Productus inflatus* var. *coloradoensis*. This species is based on material from the Pennsylvanian system of Colorado. At the time that he named the variety, Girty rather tentatively referred some specimens from the Fayetteville shale of Arkansas to it. The specimens at hand from Montana are much smaller than "*Dictyoclostus*" *coloradoensis*, one of the syntypes of which is 39 mm long, 26 mm high, and 41 mm broad. Moreover, "*D.*" *coloradoensis* has coarse ribs or pairs of ribs raised above the general shell surface anterior to the spine bases on the anterior slope.

Productus semireticulatus subsp. *animasensis*, which Girty said was similar to specimens having a diagonal line of spines near the juncture of the ear and the flanks, is apparently a nomen nudum.

"*Dictyoclostus*" *inflatus* var. *clydensis* was originally described by Girty in 1910 as having a cluster of spines on the ears, but the cluster is actually made up of a randomly placed spine near the hinge line and a single row of spines running obliquely across each of the ears at 30° to 40°.

"*Dictyoclostus*" *fayettevillensis* (Mather, 1915), has a double row of spines either in the furrow or very low on the lateral flanks.

"*Dictyoclostus*" *welleri* (Mather, 1915), resembles "*Dictyoclostus*" *inflatus* subsp. *spinolinearis* in having an oblique row of spines on the ears but has about 8 spines instead of about 4 as in *spinolinearis*. "*D.*" *welleri* also generally lacks a sulcus or has a very inconspicuous one and lacks the row of spines on the flanks which *spinolinearis* has.

Other similar American species of "*Dictyoclostus*" lack rows of spines except along the hinge line.

Material.—315 specimens. Holotype, USNM 118772. Paratypes, 118773, A, B, C, D. Ideotypes, USNM 118774–118777. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13359, 13367, 13368, 13370, 13402, 13409, 13410, 13411, 13412, 13414, 13425. Cameron Creek formation, localities 13362 and 13382.

"Dictyoclostus" inflatus subsp. obsoletus Easton, n. subsp.

Plate 6, figures 25–29

1876. *Productus costatus* var. White *in* Powell, Report on the geology of the eastern portion of the Uinta Mountains, chapt. III, p. 89 (lower Aubrey group, Utah).

Pedicle valve.—This valve is entirely similar externally to pedicle valves of "*Dictyoclostus*" *inflatus* subsp. *spinolinearis* Easton, except that the single row of spines on each of the lateral flanks is absent, and the anterior slope is less smooth.

Internally the characters are the same as in the foregoing subspecies.

Brachial valve.—Externally the flat posterior part of the valve is nearly smooth, except for faint concentric radial ornamentation.

Internally the valve seems just like like that of the foregoing subspecies.

Comparison.—This subspecies is characterized by the nearly or entirely obsolete sulcus on the anterior slope of the pedicle valve and by the row of spines running at about 15° across the ears.

"*Dictyoclostus*" *inflatus obsoletus* is most closely related to "*D.*" *inflatus spinolinearis* Easton and probably intergrades with that subspecies. The subspecies *obsoletus* is distinguished from subspecies *spinolinearis* principally by lacking the row of spines on the lateral flanks. In both subspecies the pedicle sulcus becomes obsolete anteriorly on the anterior slope, in this way differing from typical "*D.*" *inflatus*.

"*Dictyoclostus*" *welleri* (Mather, 1915), is very similar to subspecies *obsoletus*, but the sulcus is either absent or at best is inconspicuous, whereas the sulcus in *obsoletus* is quite prominent over half the length of the pedicle valve. "*D.*" *welleri* has a row of about 8 spines lying at about 15° to the hinge line, whereas the same row in *obsoletus* has only about 4 spines. Subspecies *obsoletus* resembles "*D.*" *welleri* as much as it does subspecies *spinolinearis*.

Material.—244 specimens. Holotype, USNM 118778. Paratype, USNM 118779. Ideotypes, USNM 118780, 118781. Other specimens, USNM 33334 and in USGS collections.

Occurrence.—Heath formation, localities 13368, 13393, 13402 (type locality), 13411, 13412, and 13414. Lower Aubrey group, Utah (USNM 33334).

"Dictyoclostus" confluens Easton, n. sp.

Plate 7, figures 1, 2

Pedicle valve.—Small geniculate productids with a quadrate shape. The umbo is low and its flanks, which diverge at 70°, merge gradually with the convexly rounded ears. The hinge line is at the greatest width and the nearly parallel lateral margins swing out to round off the ears. Lateral flanks are steep. A narrow sulcus originates within 5 mm of the beak and continues to the anterior margin. The holotype is 21 mm long, 22.5 mm wide (incomplete) at the hinge line, 20 mm wide at midlength, 15 mm high, and the opening for the dorsal valve is 15 mm long.

Internally the diductor muscle scars extend from within 2 mm of the beak almost to the geniculation, about 10 mm distant. They bear 5 or 6 broad but shallow grooves. The adductor muscle scars occupy a moderately raised platform with a rather steep, rounded, anterior edge, which extends slightly beyond the diductor scars.

Brachial valve.—The valve is very geniculate with its trail almost parallel to the anterior slope of the pedicle valve. A triangular central area is depressed about 2 mm below the ears along flexures which diverge from the beak at about 85°. A broad low fold is present.

Internally the cardinal process is bifid on its pedicle side and trifid on its brachial side, resembling the general type of process seen in this group. A median septum extends 10 mm anteriorly, stopping just posterior to the geniculation. The adductor muscle scars are on triangular ridges about 5 mm long. Just anterior to them, but starting 4 mm to each side of the median septum are two oval brachidial impressions. No diaphragm is present.

Ornamentation.—The pedicle valve is completely covered with costae of which 16 occur in 10 mm at the geniculation. The costae become enlarged anteriorly until only about 12 are present in 10 mm at the margin. Concentric wrinkles are low and are confined to the visceral areas and to the ears. Large spine bases are located on about 5 mm centers, except that they do not occur on the visceral area. A row of 4 spine bases lies on each side of the beak at 15° to the hinge margin. On the anterior and lateral slopes, costae become coarse and high anterior to where they happen to coincide with a spine. Moreover, adjacent finer costae may become incorporated into one of the extraordinarily coarse radial ribs.

Ornamentation of the brachial valve is influenced by that of the pedicle valve. Four dimples, however, take the place of the row of spines oblique to the hinge margin, and no spine bases are visible on the valve.

Comparison.—This species is characterized by its small size, geniculate shape, narrow sulcus, and coarse confluent costae.

"*D.*" *confluens* resembles "*D.*" *inflatus obsoletus* somewhat in size and shape, but is smaller, more geniculate, has a narrower sulcus and has coarser costae than does typical *inflatus*.

The new species of *Antiquatonia* described on page 58 has very similar costae anteriorly, but it is larger, less geniculate, has a shallower sinus, and has the characteristic spinose ridge of *Antiquatonia*.

Material.—22 specimens. Holotype, USNM 118782. Paratypes, USNM 118783 A, B, C, D, E. Other specimens in USGS collections.

Occurrence.—Cameron Creek formation, locality 13362 (type locality).

"Dictyoclostus" richardsi (Girty, 1927)

Plate 7, figures 3–5

1927. *Productus richardsi* Girty, U.S. Geol. Survey, Prof. Paper 152, p. 68, 69, 414, pl. 23, figs. 7–19. (Brazer limestone, Idaho).

1938. *Dictyoclostus richardsi.* Sutton, Jour. Paleontology, v. 12, no. 6, p. 563.

Pedicle valve.—Small rather quadrate productids with a very high umbo. Umbonal flanks diverge at 70° and descend vertically to the ears, from which they are separated by a faint furrow or concavity. The ears slope outward and are concave fore and aft. A broad shallow sulcus arises over the umbo and continues to the anterior margin. Lateral margins meet the hinge line at about 90°. The holotype is 14.5 mm long, 16.5 mm wide at the hinge line, 12 mm high, and the opening for the brachial valve is 12.5 mm long.

Internal features are not definitely known, although the adductor muscle scars occupy a slightly raised platform which is flanked by faintly grooved diductor muscles. No median septum is present.

Brachial valve.—The nearly flat to slightly concave visceral disc is sharply delimited by a geniculation. Ears are nearly flat. A median fold is much the sharpest on the anterior slope.

Internal characteristics are almost unknown. If there is a median septum, it is either very short or no higher than an internal costa. No diaphragm is present.

Ornamentation.—Broad concentric wrinkles are conspicuous over the visceral cavity of both valves and extend onto the ears. Costae are faint over the visceral areas but are very coarse anteriorly. About 6 to 8 costae occur in 5 mm at the anterior edge of the visceral cavity and 5 to 7 costae occur in 5 mm near the anterior margin. A row of 4 spine bases diverges from the beak over each ear at an angle of 30° to 35° to the hinge line. A few large spine bases are scattered over the lateral flanks and the anterior slope of the pedicle valve. A few dimples on the brachial valve simulate the distribution of spine bases on the pedicle valve. Minute growth lines are occasionally discernable.

Comparison.—"*Dictyoclostus*" *richardsi* is characterized by its small size and very coarse costae.

Linoproductus gallatinensis (Girty, 1899), from the Madison limestone, is about the same size but lacks the distinct sulcus and has 8 or 9 costae in 5 mm.

Dictyoclostus parviformis (Girty, 1899), also from the Madison limestone, likewise lacks the sulcus, and moreover has 10 costae in 5 mm and is a smaller, flatter shell than is "*D.*" *richardsi*.

Productus fasciculatus McChesney resembles "*Dictyoclostus*" *richardsi* more than any other in size, presence of sulcus, strength of costae, and general shape, but has an internal diaphragm. Externally, they can be differentiated because *P. fasciculatus* is about twice as large as is this species.

"*D.*" *richardsi* resembles "*D.*" *confluens* from Montana rather closely. It is only about half as large as "*D.*" *confluens*, however, and lacks the extraordinarily coarse and high costae of that species.

Material.—Nine specimens. Hypotypes, USNM 118784. Other specimens in USGS collections.

Occurrence.—Heath formation, locality, 13414.

Remarks.—Girty's syntypes for "*Dictyoclostus*" *richardsi* comprises 6 specimens from 3 localities. The writer hereby designates as holotype the specimen figured by Girty (1927, pl. 23, figs. 11–13).

Genus ANTIQUATONIA Miloradovich, 1945

Dictyoclostus [in part] of authors

1935. *Productus* [in part] Girty, Jour. Paleontology, v. 9, no. 1, p. 7–9.
1945. *Antiquatonia* Miloradovich, Akad. Nauk SSSR, Izvestiîa, Biol. Ser., 1945, no. 4, p. 496 (Russian text), p. 499 (English abstract).
1948. *Antiquatonia*. Branson, Geol. Soc. America Mem. 26, p. 291.
1949. *Antiquatonia* [in part]. Sarycheva, Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 18, p. 167.
1951. *Antiquatonia*. Ivanova, Akad. Nauk SSSR, Doklady, Novaîa ser., v. 77, no. 2, p. 330.
1952. *Antiquatonia*. Sarycheva and Sokolskaia, Akad. Nauk SSSR, Paleont. Inst., Trudy, tom 38, p. 145.
1954. *Antiquatonia*. Stehli, Am. Mus. Nat. History Bull., v. 105, art. 3, p. 316.

Discussion.—Girty (1935, p. 7–9) described in detail but did not name a group of semireticulate brachiopods which were characterized by a spinose ridge bordering the inner edges of both ears; the ridge is represented internally by a nearly vertical plate which partitions off the ears from the visceral cavity. Girty recognized the homology of the plate with the submarginal ridge which is better developed in *Marginifera*.

Miloradovich (1945, p. 496) erected *Antiquatonia* for this group of productids in the following words (as translated from the Russian by the author with the help of Esther Samuel):

Within the genus *Dictyoclostus* s. lato there can be distinguished a group of forms for which I give the name *Antiquatonia*,[1] and although the representatives of it have a cardinal process of the linoproductid type, in spite of it they have a whole series of features which differentiate them from *Dictyoclostus* and *Linoproductus* and to a certain degree making them closer to *Marginifera*.

In the Upper Carboniferous a group of forms can be distinguished from *Antiquatonia*, which group has lost its sculpture but which has retained the flanges near the ears and a row of spines. This is the so-called genus *Horridonia* (for example *P. horridus* Sow., *P. timanicus* Stuck., etc.).

The English summary reads as follows:

It is necessary to distinguish a new genus—*Antiquatonia* (Genotype *Pr. antiquatus* Sow.), which is characterized by a semireticulate sculpture, the presence of pre-aural crests (described by Girty, 1935) and a row of spines on [begin p. 500] the cardinal slopes, the absence of diaphragm and laminated region and in the most highly organized representatives of the *Linoproductus* type—of the process. To this genus may be referred: *P. insculptus* M.W., *P. pinguis* M.W., *P. uralicus* Tschern., *P. inflatus* McChesney, *P. hermosanus* Girty, *P. coloradoensis* Girty, etc. In the Upper Carboniferous a group of forms branched off this genus which had lost the sculpture but retained the pre-aural crests and the rows of spines. They are usually united in the genus Horridonia. (Miloradovich, 1945, p. 499, 500)

Certain differences betwen the original Russian and English texts can presumably be weighted in favor of the definitive Russian version (as, for instance, the different species cited and the confusion as to which "*P. inflatus*" is under consideration. In any case, the writer sees no basis for Branson's belief (Branson, 1948, p. 291; reiterated by Stehli, 1954, p. 316) that *Antiquatonia* was proposed with the prior genus (*Horridonia*) as a subgenus and that *Antiquatonia* is therefore invalid. Miloradovich even says in the diagnosis reproduced above that *Horridonia* can be distinguished from *Antiquatonia*. It is not clear from the Russian text whether *Antiquatonia* was established as a genus or as a subgenus. Referring to it as being "within the genus *Dictyoclostus* s. lato" technically signifies subgeneric rank for *Antiquatonia;* but, on the other hand, *Dictyoclostus* has often been used in such a wide sense as to be a form genus for all semireticulate productids. The English summary however, distinctly says *Antiquatonia* has generic rank.

Sarycheva gave the following emended diagnosis of *Antiquatonia:*

Genus *Antiquatonia* Miloradovich 1945 nov. emend.

Typical species: *Productus antiquatus* Sowerby 1823

Diagnosis. Shell from small to large size with very convex ventral and geniculate dorsal valves. Visceral cavity spacious, differentiated in the usual way. Well developed small ears are separated from the visceral part by diagonal ridges with a row of large spines on them. Besides that, these spines form one to two rows along the hinge margin and they are spread over the entire ventral valve. Costae very distinct and characteristic for different species. Concentric wrinkles are well developed but neither the costae nor the wrinkles extend as far as the ears where only spines are situated. The internal structure is usual for all semireticulate productids; many species have a characteristic appearance of two pairs of adductors on the dorsal valve, of which the anterior ones have a much weaker dendritic or smooth contour. There are no marginal laminations.

[1] Genotype, *Productus antiquatus* Sow. Characteristic features: semireticulate ornament, flanges near the ears (Girty, 1935) and a row of spines on the main flanks, with an absence of a lamellar zone and similar structures. Besides *P. antiquatus* Sow., to it can be referred *P. insculptus, P. pinguis* M.W., *P. uraliqus* Tschern., *P. inflatus* Tschern. (non McChesn.), *P. transversalis* Tschern., *P. hermosanus* Girty, *P. coloradoensis* Girty, etc.

(Translation by Esther Samuel and W. H. Easton. See Sarycheva, 1949, p. 167.)

Sarycheva (1949, p. 169, 170) explained that although the genus was founded on shells having the ridge-like feature originally detailed by Girty, she understood that the genotype lacks this external ridge. It seems, therefore, that she considered the genus emended to include semireticulate productids with either a spinose ridge or merely a row of spines on the lower flanks adjacent to the ears, even though she did not particularize this interpretation in her so-called emended conception. Actually, the genotype seemingly does have the diagnostic ridge bordering the ears. At least a specimen in the U.S. National Museum (64542) identified as *Antiquatonia antiquatus* by Miss Muir-Wood has the ridge. It agrees with figures of a specimen Muir-Wood illustrated from the D_2 subzone of England, which is seemingly also *A. antiquatus* (Muir-Wood, 1928, pl. 7, figs. 4a and b). The figures just cited are not oriented to show the ridge to its best advantage, but it seems to be present just the same. The writer therefore concludes that Sarycheva's emendation is unnecessary and would make the interpretation of *Antiquatonia* too broad. To the knowledge of the writer, various and diverse productids may have a row of spines on the lower flanks; yet they may not have either an external ridge or an internal flange.

Ivanova (1951, p. 330) merely refers to *Antiquatonia* as being closely allied to *Kutorginella* in outer form and sculpture, but differing from it in form of the cardinal process and muscle scars, in weak development of brachial impressions even in old specimens, and in having the sharply expressed marginal ridge.

Comparison.—*Antiquatonia* can be most readily differentiated from *Dictyoclostus* by the spinose ridge at the base of the lateral flanks. Otherwise the genera are externally inseparable. The spinose ridge also serves to differentiate *Antiquatonia* from *Marginifera*, which latter genus approaches *Antiquatonia* in having an internal flange which separates the ears from the visceral cavity.

Range.—The genus is known in the United States from the Upper Mississippian, the Lower Pennsylvanian Morrow series, the Des Moines series, Permian strata of Leonard age, and from equivalent sequences elsewhere in the country. Representative foreign species are known from as low as the D_2 subzones of the Viséan of Ireland (genotype) and elsewhere in the D_2 subzone of the British Isles through the Upper Carboniferous of Europe to as high as the Permian of Russia.

Remarks.—Although the steady proliferation of productid genera is a source of despair to many paleontologists, *Antiquatonia* is a useful generic name because the distinguishing and persistent generic feature can be seen easily both externally and internally, and is possessed by a closely knit group of species with a long stratigraphic range and wide areal distribution.

Antiquatonia has not formally been reported from the Mississippian of North America heretofore, but it is recorded here in the unquestioned Upper Mississippian Heath formation.

Antiquatonia pernodosa Easton, n. sp.

Plate 7, figures 6–8

Pedicle valve.—Productids of medium size with an evenly convex curvature. The median sulcus is shallow and very broad, originating from a flattening in the posterior part of the umbo. The beak only extends slightly beyond the hinge line and is not noticeably enrolled. Umbonal flanks diverge anteriorly at 110°; they diverge brachially at about 35° and are separated from the rather flaring ears by a furrow above which is the generically diagnostic spinose ridge. The holotype is about 35 mm wide at its greatest width (at midlength) and 28 mm long, the visceral cavity is 14 mm deep, and the total height of the valve is at least 30 mm.

Internally the adductor muscle scars are subparallel ridges of low relief, the centers of which are at the anterior edge of the umbo. Diductor scars bear two or three broad, indistinct flutings and lie somewhat forward of and to the sides of the adductor scars. External ornamentation is reflected on the interior surface.

Brachial valve.—The visceral disc is slightly concave and is roughly triangular with the central part depressed between sides which slope up to the ears along flexures which diverge at about 100°. The geniculation is rather abrupt. The hinge line is straight.

Internal features are hard to observe, but a median septum crosses the anterior two-thirds of the visceral disc and is 3 mm high at the geniculation. Brachidial impressions are present.

Ornamentation.—Costae extend from the beak to the anterior margins of both valves, becoming higher and wider as they go. About 14 costae occur in 10 mm over the umbo, but only about 8 are near the anterior margin. Concentric wrinkles have formed over the umbo of the ventral valve and over the visceral disc of the brachial valve. They are rather weak on the pedicle valve but are of equal strength with the costae on the brachial valve so that the latter valve has a quite nodose appearance over its reticulate portion. The ears may bear faint wrinkles but lack costae.

The ridge on the lower flanks bears four husky spine bases of increasing strength as one traces the ridge anteriorly. At least 8 or 10 very heavy spine bases lie scattered toward the margin of the anterior slope. The umbo is devoid of spine bases. No spine bases were noted anywhere on the brachial valve. One large spine base at the outer extremity of each ear and possible one or two smaller medial ones lie on each hinge margin.

The coincidence of costae at a spine base on the anterior slope and on the antero-lateral flanks is marked by fusion of costae and the continuation anteriorly from the spine base of a coarse, wide, and high costae. Moreover, broad bundles of costae may simulate fascicles which stand in slight relief above the general contour of the shell.

Comparison.—This species is characterized by the strikingly nodose visceral disc of the brachial valve, by the broad form, very broad sulcus, rather low height, by the fascicles of costae, and by the presence of four spine bases on the ridge bordering the ears.

Antiquatonia pernodosa is about the same size and breadth as *A. morrowensis* (Mather, 1915), but *A. morrowensis* has 20 costae in 10 mm on the umbo and about 10 at the margin, instead of about 14 and 8, respectively. Moreover, Mather's species has only a slight sulcus on the anterior half of the pedicle valve.

Antiquatonia coloradoensis Girty is proportionately longer than *A. pernodosa*, has only a slightly developed ridge near the ears, and the ridge bears 6 instead of 4 spine bases. *A. coloradoensis* has 12 to 15 costae in a distance of 10 mm at the umbo and about 12 at the margin, the costae not fusing into such coarse costae anteriorly as they do in *A. pernodosa*. Spine bases are generally scattered over the pedicle valve of *A. coloradoensis*.

Antiquatonia hermosana (Girty, 1927), is half again as large as *A. pernodosa*, is widest at the hinge line, has a narrower sulcus, and lacks the proportionately strong development of costae anteriorly. Its number of costae and number of spines on the ridge bordering the ears resembles those of *A. pernodosa*.

Material.—14 specimens. Holotype, USNM 118785. Paratype, USNM 118786. Ideotype, USNM 118787. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13395 and 13414. Cameron Creek formation, localities 13362 (type locality), 13421?, and 14220.

Remarks.—Two specimens from the Cameron Creek formation (locality 13421) lack a ventral sinus but otherwise are fairly similar to this species.

Antiquatonia n. sp.

Plate 7, figures 9, 10

Material.—7 specimens. Figured specimens, USNM 118788A, B.

Occurrence.—Heath formation, localities 13366 and 13367?.

Remarks.—Shells at one locality, although closely resembling *Antiquatonia pernodosa*, differ from that species in having a narrower sulcus and in the nature of the costae. On this form costae number 11 in 10 mm at the anterior part of the umbo and 9 in 10 mm on the anterior slope; so, they become very slightly coarser anteriorly. The costae are also higher, being semicircular in profile, whereas the costae of *A. pernodosa* are broadly convex. Adequate material for description of this species is not available.

Genus RUGOCLOSTUS Easton, n. gen.

Diagnosis.—Productidae resembling the semireticulate group in shape, but having only concentric wrinkles on the umbo. A narrow elongate interarea is present, which is divided by a triangular delthyrium. Both valves are spinose except near the umbones. The pedicle valve has adductor muscle scars on a prominent platform and has large diductor muscles which originate at the umbo where prominent diverging accessory muscle-scars are located. The brachial valve has a very large, prominently three-lobed cardinal process, which is bent through 90° to lie well inside the umbonal cavity of the pedicle valve. It also possesses a median septum and small muscle scars located well toward the posterior end.

Genotype.—*Rugoclostus nivalis* Easton, n. sp.

Comparison.—*Rugoclostus* is characterized externally by the absence of costae on the umbo, a feature which readily distinguishes it from the otherwise externally very similar genus *Dictyoclostus*. The large, ventrally recurved, trifid cardinal process is decidedly unlike those of other productids in its size and curvature.

Buxtonia is similar to *Rugoclostus*, but, again, *Buxtonia* has radial ornamentation on the umbo and has elongate raised spine bases, besides having a bilobed cardinal process.

Sinuatella Muir-Wood, 1928 resembles *Rugoclostus* externally in having only concentric wrinkles in early stages and a small interarea with a delthyrium, but *Sinuatella* is sharply geniculate. Moreover, Miss Muir-Wood's genus has a small cardinal process, an anteriorly enlarged instead of a tapered median septum, and dendritic adductor muscle scars in the brachial valve.

Tschernyschewia Stoyanow, 1910 also has a cardinal area, but it has a median septum in the pedicle valve.

Occurrence.—The only known species occurs in the Cameron Creek formation.

Remarks.—True interareas are rarely recognized in productids. Muir-Wood (1928, p. 10, 11) mentioned their division into interior (articular surface) and exterior portions. Dunbar and Condra (1932, p. 219) recorded their presence in occasional specimens of *Dictyo-*

clostus. The presence of a true interarea in the species at hand is of great diagnostic value, but some preparation is generally necessary to make it visible.

Rugoclostus nivalis Easton, n. sp.

Plate 7, figures 11–15

Pedicle valve.—Productids of medium size and of rather quadrate shape; they become geniculate near midlength. The umbo is rather flattened and has flanks which diverge at 70° and slope almost vertically to the ears. The beak is slightly enrolled and protudes a little beyond the hinge line. Ears are horizontal and merge abruptly with the lateral flanks of the umbo. The lateral margin and the hinge line meet at 90° or the ears may even protrude slightly beyond the general line of the lateral margin. A broad and shallow sulcus starts on the umbo and becomes a little narrower anteriorly. The holotype is 33 mm long, 40 mm wide at the hinge line, 23 mm high, and the opening for the dorsal valve is 25 mm long.

Internally, the adductor muscle scars in old individuals occupy a very prominent triangular boss about 3 mm wide which merges gradually with the inner posterior surface but descends almost vertically to the inner surface at the subangular anterior end. A very faint median ridge divides the scars. Conspicuous radial grooves make large fan-shaped diductor muscle scars which originate well up under the umbo only about 4 mm from the beak, diverge around the adductor platform, and continue as recessed fan-shaped patches about as far forward as do the adductors. A pair of small, lanceolate, deep scars measuring 7 mm between tips diverge at about 70° and lie posterior to the diductor scars. A low convex welt about 2 mm wide makes a semicircular border on the steep anterior base of the adductor platform. The remaining anterior shell surface reflects external costae faintly and is abundantly granular or postulose. One specimen which seems to be younger than the foregoing one lacks the grooving of the diductor scars except where the specimen is broken off just at the posterior edge of the adductor platform. The extra muscle scars under the umbo are distinct and a third scar lies between the first two. No median septum is present.

Brachial valve.—The concavity is deep, being 14 mm in the holotype. A triangular central part of the posterior half of the valve is depressed along sloping inner margins which diverge from the beak at 70°. Geniculation is rounded rather than sharp. A broad low fold corresponds to the sinus of the opposite valve. Ears lie horizontal and merge gradually with the inner slopes.

Internally the cardinal process is unusually strong and prominent. It extends 3.7 mm beyond the hinge line in one specimen and curves dorsally nearly or quite through a 90° arc to lie well up into the beak of the pedicle valve. The pedicle surface (pl. 7, fig. 15b) has a broad and faint groove along its midline and is prominently three-lobed, with the groove bisecting the median lobe. The brachial surface (pl. 7, fig. 15a) of the process is also deeply trifid. It has a low median ridge in line with the median lobe and recessed into a deep median cleft formed by fusion of two lateral clefts. A minute node marks the anterior end of the median cleft. The hinge margin is bordered by a strong ridge on each side of the cardinal process. A low and broad median ridge extends 5 mm anterior to the cardinal process to a point where it is almost engulfed by the adductor muscle scars, but it continues beyond that point with increasing height until it is 2 mm high, at a point 14 mm from its origin. It slopes from that point steeply to the floor of the valve, being a total of 15 mm long. Adductor muscle scars are low, smooth, club-shaped ridges about 4 or 5 mm long which diverge at about 25° and whose narrow posterior ends start about 4 mm from the cardinal process. A fragment of the inner anterior slope of the valve 15 mm long is covered with very oblique fine spines 1 mm or less apart.

Hinge features.—The ridge on the hinge margin of the brachial valve is convex posteriorly. This convex surface articulates with a corresponding concave surface about 1 mm wide near the beak on the hinge margin of the pedicle valve. A concave interarea 0.2 mm high may extend as far as 9 mm on each side of the beak. Both the cardinal area and the articular surface are interrupted by a delthyrium whose sides diverge at 135°. No deltidial plates were observed.

Ornamentation.—The umbo of the pedicle valve is nearly smooth, except for concentric wrinkles on the first 10 mm from the beak. The rest of the posterior half of the valve is covered both by radial costae and by concentric wrinkles, but the spacing of the wrinkles farther apart (6 wrinkles in 10 mm) than the costae (10 costae in 10 mm) makes the reticulate pattern consist of elongate nodes instead of roughly circular nodes. The anterior slope quickly loses first the wrinkles and then most of the costae, but it develops some very coarse, broad, costaelike radial ribs. Spine bases about 0.3 to 0.5 mm in diameter are scattered over almost the entire surface (except for the umbo) on about 3 mm centers. No particular lineation of spines was noticed except for a moderate tendency for a row of spines to develop along the hinge margin.

The brachial valve is ornamented like the pedicle valve, with an almost smooth umbo. Spines are bent anteriorly and measure from 3 to 5 mm in length.

Spine bases are about twice as frequent on the outer 1 cm of the ears as elsewhere.

Comparison.—*Rugoclostus nivalis* is characterized externally by the presence of a small interarea, by concentric wrinkles without costae on the umbo, by the tendency toward coarseness and then obsolescence of costae anteriorly, and by the presence of spine bases generally over both valves. Internally the species is characterized by having adductor muscle scars far forward, by the remarkably heavy, long, and trifid cardinal process, and by the smooth posterior surface of the pedicle valve.

This species can be readily differentiated externally from "*Buxtonia*" *arizonensis*, which it resembles some what in size, shape, and ornamentation, by having only concentric ornamentation on the umbo and in having circular spine bases.

R. nivalis resembles *Antiquatonia pernodosa* described above in the tendency of the costae to become obsolete anteriorly and to be replaced by extra-heavy, broad, radial ridges, but *R. nivalis* lacks the spinose lateral ridges which so easily distinguish *Antiquatonia*.

Material.—8 specimens. Holotype, USNM 118789. Paratypes, USNM 118790 A–E.

Occurrence.—Cameron Creek formation, localities 13373? and 13420 (type locality).

Genus BUXTONIA Thomas, 1914, emend. Muir-Wood, 1928

1914. *Buxtonia* Thomas, Great Britain Geol. Survey Mem., Paleontology, v. 1, pt. 4, p. 259.

1928. *Buxtonia* emend. Muir-Wood, Great Britain Geol. Survey Mem., Paleontology, v. 3, pt. 1, p. 36.

Emended diagnosis.—Costate and spinose in neanic and ephebic stages, developing concentric bands on which are numerous small spine-bases in the gerontic stage. In phylogerontic individuals, bands are developed in the ephebic stage. Spine-bases developed in pedicle and brachial valves. Pedicle valve evenly convex, rarely geniculated. Brachial valve flattened or concave. Marginal ridges short. Median septum usually bifurcating about 5 mm. below the cardinal process, the two branches uniting with the two lobes of the cardinal process. (Muir-Wood, 1928, p. 36).

Comparison.—*Buxtonia* is commonly characterized externally by the presence of oblique spine bases terminating elongate ridges, and, internally by the presence of a bifurcated median septum.

This genus seems to intergrade in ornamentation with *Dictoyoclostus*, but typical representatives of the latter genus have circular erect spine bases and a distinctly reticulate umbo.

Occurrence.—*Buxtonia* has been rather generally reported throughout the Lower Carboniferous and into the Upper Carboniferous. The genotype, *B. scabricula*, is from the D_2 subzone of the British Viséan series.

Remarks.—The external ornamentation consisting of raised oblique spine bases is supposed to be characteristic of *Buxtonia*, but several other morphologic features are inadequately known. In the first place, the cardinal process of the genotype has not been distinctly described, although the emended diagnosis of the genus quoted above mentions it as having two lobes. Fortunately, this feature can be cleared up by examination of specimens of the genotype identified and donated to the U.S. National Museum (accession 189969) by Miss Muir-Wood. The figured specimen (pl. 8, fig. 4a) has a cardinal process with two prominent lobes that are fused at the base (pl. 8, figs. 4a,b).

This two-lobed process is strikingly different from the three-lobed processes of otherwise similar productids (such as, pl. 8, fig. 6), which are brought about by the medial fusion of the separate seats of diductor muscle attachment. The writer finds in collections available to him various specimens which have the external ornamentation of *Buxtonia*, but have three-lobed cardinal processes like *Dictyoclostus*. As a matter of fact, this is true in all instances of so-called *Buxtonia* in America in which the cardinal process is known to the writer.

Further difficulty concerns the value of the bifurcated median septum of *Buxtonia* as a diagnostic character. The specimen of the genotype figured herein (pl. 8, fig. 4a) is slightly exfoliated so that the two strands of the median septum show on either side of the matrix which forms the internal mold of the median furrow. The writer scraped away part of the matrix to make a depression there so that the feature could be photographed, for otherwise it was only certainly discernable by microscopic study when moistened. but, unfortunately, several other groups of productids also have median furrows on the septa. Muir-Wood (1928, p. 19) reports this in the genotypes of *Productus*, and of *Eomarginifera*, and in exfoliated specimens of the genotype of *Pugilis*. The writer has discussed earlier, under *Dictyoclostus*, the presence of the same feature in the genotype of *Dictyoclostus* and among some American species which generally are referred to *Dictyoclostus*. It appears, therefore, that the feature is variable and is different in degree only.

So-called *Buxtonia* includes productids which have a deep or shallow septal furrow, a dorsally bilobed or dorsally trilobed cardinal process, and slightly reticulate visceral areas. The writer, therefore, uses the name "*Buxtonia*" to include those productids with the elongate oblique ridges terminating in spine bases, and puts the name in quotation marks to signify the loose usage being followed. Obviously, additional work is needed, particularly to demonstrate the degree of variation in the genotype.

"Buxtonia" arizonensis Hernon, 1935

Plate 8, figures 5, 6

1927. *Productus* aff. *P. Keokuk* Girty, U.S. Geol. Survey Prof. Paper 152, p. 64, 78, 69, pl. 21, figs. 3–6 (Brazer limestone, Idaho. (Not *Productus setiger?* var. *keokuk* Hall, 1858).

1935. *Buxtonia arizonensis* Hernon, Jour. Paleontology, v. 9, no. 8, p. 663?, 664?, 665, 668, 681, pl. 81, figs. 1a–1c (Paradise formation, Arizona).

1938. *Buxtonia arizonensis*. Sutton, Jour. Paleontology, v. 12, no. 6, p. 564.

Pedicle valve.—Length and breadth almost equal, the holotype measuring 40 mm long, 42 mm wide, and 20 mm high. Sulcus broad and shallow anteriorly, represented posteriorly only by a flattened umbo.

Brachial valve.—Posterior part flat but anterior part is sharply geniculate. Fold broad and wide anteriorly, absent posteriorly where even a slight concavity exists.

Ornamentation.—Surface of both valves covered with costae which occur 4 or 5 in 5 mm. Each costa bears oblique spines about every 10 mm. Spines weakest on the brachial valve and on the ears. Concentric wrinkles are weak on the median portion of the pedicle valve and on the entire brachial valve.

Internal features.—Besides the characteristics abstracted above from the original description, a specimen from Montana enables internal details to be described. The cardinal process (pl. 8, fig. 6) is bifid but is divided into three lobes of draperylike folds. The process is continuous with the median septum, which latter is less than 1 mm high and extended (when entire) at least half the length of the valve. The posterior part of the median septum is faintly groved for about 2 mm. The dorsal adductor muscle scars are on two semicircular bosses 12 mm long. The hinge line is strengthened by a thick, ventrally directed, shelflike rim.

Material.—29 specimens. USNM 118791A, 118791B, and probably USNM 33339.

Occurrence.—Otter formation, localities 13374 (cf.). Heath formation localities 13369, 13370, and 13393. Cameron Creek formation locality 13421? Alaska Bench limestone locality 13403. Also known from the top of the Brazer limestone of Idaho, the upper Paradise formation (Stoyanow, 1926) of Arizona, and probably from the so-called lower Aubrey of Utah (USNM 33339 in part).

Remarks.—"*B.*" *arizonensis* is characterized by the coarse costae, oblique spine bases, and by the presence (though nearly obsolete) of concentric wrinkles on the posterior portions of both valves.

The writer refers certain specimens to this species on external characteristics alone because the interior of type material has not been described. Dimensions of one specimen from Idaho are within 1 mm of matching dimensions given for the holotype.

This species is very difficult to assign generically for it shares features of *Dictyoclostus* and of *Buxtonia*. The costae and spines are like *Buxtonia*. The trilobed cardinal process and reticulate ornamentation (though faint) are like *Dictyoclostus*.

Miss Muir-Wood said (1928, p. 36) that the dorsal median septum of *Buxtonia* was "usually bifurcating about 5 mm below the cardinal process." The material at hand lacks the profound fissure present in the genotype but does have a very faint groove in the same location. Depending upon how much latitude is allowed in interpreting "bifurcation," the species may or may not be referred to *Buxtonia* on this character.

"*Buxtonia*" *arizonensis* is most apt to be confused in the west with *Dictyoclostus americanus*, Dunbar and Condra, 1932 which it resembles in shape, size, and somewhat in coarseness of ornamentation. *D. americanus*, however, has distinct umbonal reticulations in addition to the less readily determined trilobed cardinal process.

Productus arkansanus Girty, 1910, which has sometimes been referred to *Buxtonia*, is a much smaller organism than is "*B.*" *arizonensis*, has a trilobed cardinal process, and has a tendency to have sharply delimited bands of spines on the umbo. It is possibly a *Dictyoclostus*.

Productus peruviana d'Orbigny, 1848, from the Permian has also been referred to *Buxtonia*. Although it lacks the split septum and bilobed cardinal process of *Buxtonia*, it has similar external ornamentation. It is much larger and has much coarser ornamentation than does "*B.*" *arizonensis*.

"Buxtonia" sp.

Plate 8, figures 1–3

Material.—5 specimens. Figured specimens, USNM 118792 and 118793 A and B. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13366 and 13412.

Remarks.—Some imperfect specimens have the characteristic surface ornamentation of *Buxtonia*. One group of these has a deep depression just anterior to the seemingly dorsally bilobed cardinal process. It may represent true *Buxtonia*.

The other group is represented by a thin brachial valve with a shallow furrow in the median septum, but with a trilobed cardinal process. The brachial surface of this specimen is covered with slender spines at least 3 mm long.

Genus MARGINIFERA Waagen, 1884

Diagnosis.—Small productids with an internal ridge which tends to enclose the visceral disc of the brachial valve. Externally the pedicle valve is evenly convex, spinose, and costate, with a reticulate umbo. The brachial valve is geniculate and may have reticulate ornamentation but lacks spines.

Remarks.—*Marginifera* is characterized by a ridge bordering the visceral disc of the brachial valve. When it is best developed, the ridge diverges symmetrically from the cardinal process and the two strands follow near the margins of the valve until they reach the region of sharp geniculation, where they curve abruptly toward each other and fuse at the midline. Less advanced stages have weakly developed anterior portions of the ridge or even have the ridge confined to posterior and lateral portions of its course, being highest posteriorly. Muir-Wood erected *Eomarginifera* for certain of the seemingly ancestral species which lack the anterior part of the ridge, have a smooth instead of a crenulate ridge, and have six prominent spines on the ventral valve. The writer agrees with Sutton (1938, p. 561) that inasmuch as *Eomarginifera* differs from *Marginifera* primarily in the strength of the marginal ridge, *Eomarginifera* should not be considered generically distinct from *Marginifera.*

In the faunas under study from Montana, *Marginifera* is very similar to *Dictyoclostus*, both having similar shapes, sinus in the pedicle valve, and reticulate umbo. Brachial interiors are very difficult to see; so the genera are most readily distinguished by the smaller size and weaker costae of *Marginifera.*

Marginifera, as used herein, is more loosely construed than is the current tendency. The growing trend of brachiopod students is to assign considerable value to spine patterns in differentiating productid genera. Accordingly, Stehli (1954, p. 321, 322) has pointed out that *Kozlowskia* Fredericks, 1933, should receive certain Carboniferous species with a row of cardinal spines but without a row of spines above the ears—species which have hitherto been assigned to *Marginifera* by American students. Unfortunately, the species described below has a row of spines above the ears, as well as a row of cardinal spines, and therefore is assignable neither to *Marginifera* nor to *Kozlowskia* within the narrowly construed limits noted above. Moreover, the genus *Eomarginifera* is not applicable here because it has just six large spines on the pedicle valve, lacking the row above the ears and the cardinal row. In the face of uncertainties about the proper assignment of the following species, it is referred to "*Marginifera*" herein as a means of indicating other than strict usage of the generic concept.

"Marginifera" planocosta Easton, n. sp.

Plate 8, figures 7–18

Pedicle valve.—Small rather evenly convex shells with a very shallow broad sulcus or no sulcus at all. Umbo low with its flanks diverging at about 120° and sloping steeply to the ears. Ears are horizontal or even slightly recurved brachially. The beak projects slightly beyond the hinge line but is not enrolled. Lateral margins make a right angle with the hinge line or meet it at an angle of as little as 70°. The holotype is 23 mm wide, 16.5 mm long, 10 mm high, and the aperture for the brachial valve is 13.5 mm long.

Internally the surface is covered with elongate pustules on the anterior slope and with concentric wrinkles under the umbo. Adductor muscle scars are generally indefinite but may occupy a pair of slightly raised triangular platforms about 2 mm long and 5 mm from the beak. Diductor scars are faintly discernible radially grooved areas on each side of the adductor scars. The outermost 2 mm of the valve is beveled anterior to the ears so that internal molds have a convex band at the margin. The concave cavity which underlies the ears is separated in adulthood from the visceral cavity by a low flange or ridge which meets the hinge line at about 65°. Grooves on the inner side of this flange slope dorsally and anteriorly at about 60°.

Brachial valve.—Very concave and somewhat geniculate with a slightly concave visceral disc and a long trail. In a specimen with a ventral valve 10.5 mm high, the brachial valve is 7.0 mm deep. The posterolateral angles flare out horizontally or are even slightly concave beyond the flange bordering the inner edge of the ears of the pedicle valve. The lateral flare diminishes toward the beak along the hinge line and an angle is thereby formed with the flaring edge and the steep ventral slope of the medial part of the valve. The extreme marginal edge of the valve is truncated externally and thickened internally so as to fit into the bevel on the inside of the pedicle valve.

Internally the cardinal process is fundamentally bifid, but the two lateral lobes are excavated on their dorsal surfaces so that a three-lobed process is formed. Anterior to the cardinal process a pair of very low ridges diverge at about 20° and extend with increasing width to about midlength before dying out. The anterior half of each ridge is either flat-topped or bears an elongate furrow which presumably delineates the adductor muscle scar. A thin median septum originates between the muscle scars and rises to a height of about 1 mm before descending to the floor at a point about two-thirds of the length of the valve. In a specimen 15 mm long (pl. 8, fig. 15) the paired ridges extend 5 mm and the median septum extends 10 mm. The posterior edge of the valve is beveled off to the hinge line. A low rounded ridge arises on either side of the cardinal process and lies where the bevel meets the visceral disc. These ridges diverge at 170° and tend to encircle the visceral disc, becoming increasing faint anteriorly until they generally die out on the sides of the visceral disc.

Ornamentation.—The pedicle valve has 20 costae in 10 mm at the posterior edge of the umbo and has 13 costae in 10 mm high on the anterior slope. Costae are low and broadly rounded and are not particularly distinct. Concentric wrinkles mark the umbo and are stronger there where the costae are weakest, but a reticulate pattern prevails, even so. Spine bases are scattered over the surface, but an irregular row of 5 or 6 borders the hinge line, 3 or 4 spines make a row low on the lateral flanks of the umbo, and 10 or 12 irregularly scattered spines make a row about 5 mm wide near the margin on the anterior slope. The ears are smooth, except for the spine bases.

Ornamentation of the brachial valve is like that of the pedicle valve, except that spines are not developed. The lateral flares on the posterior margin and over the ears are entirely smooth.

Comparison.—"*Marginifera*" *planocosta* is characterized by the small size, wide but low costae, prominent row of spines anteriorly, and weak development of a sulcus in the pedicle valve.

It differs from "*Marginifera*" *adairensis* (Drake, 1898), which is the only other similar species known on this continent, in having a less prominent sulcus, 12 instead of 20 to 25 costae in a distance of 10 mm and located high on the anterior slope, nearly 90° instead of 60° postero-lateral margins, more flaring instead of sloping ears, and the ears are smooth instead of costate and wrinkled (pl. 8, figs. 19, 20). Internally the circum-visceral ridge is very strong in "*M.*" *adairensis*, the adductor muscle scars are short and are united with prominent brachial platforms, and the median septum is higher, thicker, and shorter than in "*M.*" *planocosta.*

"*M.*" *planocosta* is as closely allied to Pennsylvanian species as it is to "*M.*" *adairensis*. It differs from *Marginifera muricatina* Dunbar and Condra, 1932 in being larger, less spinose, and without costae and wrinkles on the ears.

Kozlowskia haydenensis (Girty, 1903) is smaller than "*M.*" *planocosta*, has a more distinct sulcus in the pedicle valve, about twice as fine costae, and fewer spine bases on the anterior slope.

"*M.*" *planocosta* is most readily confused in the faunas under study with "*Dictyoclostus*" *inflatus* (McChesney) and its varieties because they are similarly shaped, have reticulate umbones, and may have weakly developed sulcuses in the pedicle valves. "*M.*" *planocosta* is only two-thirds as large as those forms and is proportionately much lower and broader than they are.

Material.—113 specimens. Holotype, USNM 118794. Paratypes, USNM 118795A–I. Other specimens in USGS collections.

Occurrence.—Cameron Creek formation, localities 13420 (type locality) and 14221.

Order TELOTREMATA

Superfamily RHYNCHONELLACEA

Family CAMAROTOECHIIDAE

Genus LEIORHYNCHUS Hall, 1860

1860. *Leiorhynchus* Hall, New York State Cabinet Nat. Hist., Ann. Rep. 13, p. 75.

1951. *Nudirostra* Cooper and Muir-Wood, Jour. Washington Acad. Sci., v. 41, no. 6, p. 195.

Diagnosis.—Rhynchonellid brachiopods with a troughed cardinal plate, with a relatively thin median septum and poorly defined adductor muscle scars in the brachial valve, and with nondenticulate dental sockets.

Occurrence.—*Leiorhynchus* is known from Devonian, Mississippian, and Pennsylvanian rocks in North America.

Comparison.—*Leiorhynchus* is separable from *Leiorhynchoidea* Cloud (1944, p. 57) only by internal features. In *Leiorhynchoidea* the median septum is relatively thick and posteriorly expanding, the cardinal plate is untroughed (undivided hinge plate), the adductor muscle scars in the brachial valve are low and elongate, and the dental sockets are denticulate or are transversely striate.

Crickmay (1952) erected *Basilicorhynchus* and *Caryorhynchus* for two Upper Devonian species which he had formerly described as *Leiorhynchus*. Both of these genera can be differentiated externally from *Leiorhynchus* by their greatly inflated shapes.

Remarks.—The genotype of *Leiorhynchus*, *L. quadracostatus* (Vanuxem), 1843, is not adequately known, largely due to the poor preservation of specimens of it (which usually occur crushed in black shales). A specimen (USNM 11823) from the basal New Albany shale at Lexington, Ind., however, shows the internal features of the brachial valve quite distinctly (pl. 9, fig. 9).

Nudirostra was proposed by Cooper and Muir-Wood (1951, p. 195) to replace *Leiorhynchus* Hall, 1860, on the assumption that, with emended spelling, Hall's generic name is a junior homonym of *Liorhynchus* Rudolphi, 1801. Action taken by the International Commission for Zoological Nomenclature in 1953 reversed the basis on which emendations of generic names were, for a time, required; hence *Leiorhynchus* Hall, 1860 is still available.

Leiorhynchus carboniferus (Girty, 1911)

Plate 9, figures 1–8

1877. *Leiorhynchus quadricostatus?* Meek, U.S. Geol. Explor. 40th Par. Rept., v. 4, p. 79, pl. 3, figs. 9–9b. (Carboniferous (White Pine shale), Nevada).
1909. *Liorhynchus* aff. *L. mesicostale*. Girty, U.S. Geol. Survey Bull. 377, p. 26, pl. 2, figs. 11, 12. (Caney shale, Oklahoma).
1909. *Liorhynchus* aff. *L. laura*. Girty, U.S. Geol. Survey Bull. 377, p. 27, pl. 2, figs. 13–15. (Caney shale, Oklahoma).
1911. *Liorhynchus carboniferum*. Girty, U.S. Geol. Survey Bull. 439, p. 54, pl. 6, figs. 1–10; pl. 7, figs. 13–16. (Moorefield shale, Arkansas; White Pine shale, Nevada).
1911. *Liorhynchus carboniferum* var. *polypleurum*. Girty, U.S. Geol. Survey Bull. 439, p. 59, pl. 7, figs. 7–12. (Moorefield shale, Arkansas).
1915. *Liorhynchus carboniferum*. Girty, U.S. Geol. Survey Bull. 595, p. 29, pl. 2, fig. 11. ("Boone" chert, Arkansas).
1915. *Liorhynchus carboniferum* var. *polypleurum*. Girty, U.S. Geol. Survey Bull. 595, p. 29, pl. 1, fig. 5. ("Boone" chert, Arkansas).
1915. *Leiorhynchus carboniferum*. Snider, Oklahoma Geol. Survey Bull. 24, p. 86. (Mayes formation, Oklahoma).
1915. *Leiorhynchus carboniferum* var. *polypleurum*. Snider, Oklahoma Geol. Survey Bull. 24, p. 87. (Mayes formation, Oklahoma).
1921. *Leiorhynchus carboniferum*. Plummer and Moore, Texas Univ. Bull. 2132. pl. 6, figs. 2, 3. (Marble Falls limestone, Texas).
1924. *Leiorhynchus carboniferum*. Morgan, Oklahoma Bur. Geol. Bull. 2, pl. 43, fig. 8 (Woodford formation, Oklahoma).
1924. *Liorhynchus carboniferum polypleurum*. Morgan, Oklahoma Bur. Geol. Bull. 2, pl. 43, fig. 9. (Woodford formation, Oklahoma).
1926. *Leiorhynchus carboniferum*. Butts, Alabama Geol. Survey Special Rept. 14, p. 198, 204, pl. 65, fig. 13. (Floyd shale, Alabama; Fayetteville shale, Arkansas; Caney shale and Moorefield shale of Arkansas and Oklahoma.)
1927. *Leiorhynchus carboniferum*. Girty, U.S. Geol. Survey Prof. Paper 152, p. 71. (Brazer limestone, Idaho).
1930. *Leiorhynchus carboniferum*. Mertie, U.S. Geol. Survey Bull. 816, p. 103. (Calico Bluff formation, Alaska).
1935. *Leiorhynchus carboniferum*. Scott, Jour. Geology, v. 43, no. 8, pt. 2, p. 1025, 1029–1031. (Heath shale, Montana).
1938. *Leiorhynchus carboniferus polypleurus* [sic] [in part]. Demanet, Mus. royale histoire nat. Belgique Mém. 84, p. 83–87. (Namurian stage, Belgium).
1941. *Leiorhynchus carboniferus polypleurus* [sic] [in part]. Demanet, Mus. royale histoire nat. Belgique Mém. 97, p. 65. (Namurian stage, Belgium).
1944. *Leiorhynchus carboniferum*. Cooper *in* Shimer and Shrock, Index fossils of North America, p. 313, pl. 119, figs. 14–16. (Mississippian of Arkansas, Oklahoma, Montana, and Nevada).
1948. *Leiorhynchus carboniferum*. Cloud and Barnes, Texas Univ. Publ. no. 4621, p. 53, 56, 57, 161, 257, 460, pl. 44, figs. 28–32. (Barnett formation, Texas).
1950. *Leiorhynchus carboniferum*. Plummer, Texas Univ. Publ. no. 4329, p. 37, 62, 126, pl. 8, figs. 7 and 8. (Barnett shale, Texas).
1952. ? *Leiorhynchus* cf. *L. carboniferum*. Crickmay, Jour. Paleontology, v. 26, no. 4, p. 590. (Kinderhook group, Alberta, Canada).

Pedicle valve.—Outline ovate with a prominent umbo whose flanks diverge at 85° to 100° and merge insensibly with the lateral and anterior slopes. A very shallow and broad sulcus occupies the anterior half of the valve. The beak projects as much as 4 mm posterior to the hinge line. The delthyrium is high and broad and its posteriorly curved margins diverge at 120°. Shell surface is evenly rounded from the dethyrial margins onto the postero-lateral slopes. Shell substance is very thin away from the thickened umbonal region. The posterior margins diverge at 130° to 140° and terminate laterally a little more than half the greatest width of the valve. Large specimens measure 4 cm wide at midlength, 3.5 cm long, and the hinge line is 2.8 cm long. The greatest height measured was 7 mm, taken about 1 cm from the beak.

Internally, the large and bluntly rounded hinge teeth are supported by short dental lamellae which are inclined toward each other at an obtuse angle and thereby enclose a deep to moderately deep delthyrial cavity. Very narrow spaces lie between the dental lamellae and the inner surface of the shell. A low ridge connects ends of the dental lamellae and thereby outlines the anterior edge of the delthyrial cavity. Adductor muscle scars are elongate, narrow, nearly parallel, slightly raised ridges which extend from within the anterior part of the delthyrial cavity to a point about midway along the shell. Diductor muscle scars are usually too faint to be seen, but are large, fan-shaped, slightly grooved areas which enclose the adductor scars and may be outlined in old age by a ridge which delineates their shieldlike shape.

Brachial valve.—Nearly oval valves with posterior margins diverging at 130° to 140° from a very low beak. Convexity a little less than that of the pedicle valve. A very shallow and broad fold is present but is hard to define.

Internally, the hinge plate is furrowed increasingly deep into the denticulate or striate sockets. No cardinal process was observed. The two short but very thick crura diverge at 10°. A median septum starts at the crurae where it is 1.0 mm wide and 1.5 mm high, then continues forward with decreasing width and height until it dies out about two-thirds of the length of the valve.

Ornamentation.—Both the sulcus and the fold are costate, there being an average of about 5 or 6 costae, but the variability in their number is considerable;

from 3 to 8 costae occur most commonly in the sulcus. Lateral slopes are almost smooth, but extremely faint costae are visible on many of the better preserved specimens. Costae are rarely absent, for there are nearly always a few very faint ones at the anterior end of the sulcus.

Comparison.—This species is characterized by the depressed oval shape, shallow sulcus and fold, and noncostate or faintly costate lateral slopes but costate sulcus and fold.

When typically preserved, no other species in the fauna can be confused with this one. If it is poorly preserved, or if it is one of the variants with sparse costae, then a specimen may be hard to distinguish from *Martinia* or *Composita*.

Leiorhynchus haguei (Girty, 1899), from the Madison limestone, is quite tumid and has 6 distinct mesial costae but has quite smooth slopes.

Leiorhynchus rockymontanus (Marcou, 1858), from the Pennsylvanian, is also a tumid species, but its deep sulcus and 2 or 3 sharp costae on the fold and sulcus distinguish it.

Material.—About 160 specimens. Hypotypes, USNM 118796, 118797, 118798, 118799 A, B, 118800. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13374. Heath formation, localities 13359, 13365, 13366, 13367, 13394, 13408, 13414, and 13417.

Remarks.—This species is known from black or brown shales at many localities, but it has rarely been reported in other kinds of sediment. Except for some specimens in limestone which Girty collected in Arkansas, the species is represented by crushed specimens only. As a result, poorly preserved material is the rule in the species.

Unfortunately, this species is one of the most variable brachiopods known to the writer. Extremes of size, convexity, and of number and distribution of costae, are common in most collections. Girty originally suggested that specimens with costae on the slopes be called *Leiorhynchus carboniferus* var. *polypleurus;* so this varietal name is available for certain specimens at hand which certainly fit that description. In addition, however, some of the specimens from Montana are almost twice as large as the average large specimens Girty had. Some of these large specimens have costae on the lateral slopes and some do not; thus the chances for rapid increase in varietal names are manifold. The writer considers the species to be one highly variable entity because the nature of preservation makes discrimination of minor differences nearly impossible. Almost any collection contains individuals which do not clearly fit within any one of a half dozen possible ranges of variations in size, shape, and features of costae.

Demanet (1938, p. 83–87) reported *Leiorhynchus carboniferus* [sic] from a number of localities in the Namurian of Belgium. He used the varietal name in his citation because "nearly all" of his specimens had costae on the lateral slopes. It is assumed from his statement that some specimens might just as well be called *L. carboniferus;* hence the reference is included in the synonymy herein. His subsequent citation is listed in this synonymy because he was referring to the 1938 reference. His synonymy (1938, p. 83) contains numerous citations for *L. carboniferus polypleurus* in Europe.

The writer designates as holotype of this species the specimen figured by Girty (1911, pl. 6, figs. 1–1c). This bears the U.S. National Museum type number 188890.

The best interiors yet seen by the writer are those figured by Girty (1911, pl. 7, figs. 15, 16). The foregoing figure 15 shows the ridge at the anterior edge of the diductor field more prominently than in any other specimen yet seen by the writer. An impression of the brachial interior of the genotype of *Leiorhynchus* is illustrated (pl. 9, fig. 9) for comparison with figure (pl. 9, fig. 8) of an excellent specimen in Girty's type lot of *L. carboniferus* (Girty, 1911, pl. 7, fig. 16).

Except for the two citations by Morgan and the questioned identification by Crickmay—all of species from lowest Mississippian strata—the species is restricted to strata of Chester age.

Genus **PUGNOIDES** Weller, 1910

1910. *Pugnoides* Weller, Geol. Soc. America Bull., v. 21, no. 3, p. 512.

1914. *Pugnoides.* Weller, Illinois Geol. Survey Mon. 1, p. 192.

Diagnosis.—Shells rhynchonelliform, below medium size, subovate in outline, with the fold and sinus well developed. Both valves marked by rounded or subangular plications which become obsolete in the posterior portion of the shell. Internal characters of both valves essentially as in *Camarotoechia.* (Weller, 1914, p. 192.)

The pedicle interior has small hinge teeth supported by vertical dental lamellae. The brachial interior has a median septum which divides posteriorly to support the inner margin of each half of the divided (or troughed) cardinal plate and thereby leaves a small crural cavity.

Comparison.—*Pugnoides* is very similar to *Camarotoechia*, *Pugnax*, and *Wellerella*. *Camarotoechia* has plications which extend the length of the valves. *Pugnax* has no median septum. *Wellerella* has neither a split in the median septum nor a division of the hinge plate into two halves.

Remarks.—Only a partial synonymy for the genus is given.

Pugnoides quinqueplecis Easton, n. sp.

Plate 9, figures 10, 11

1918. *Pugnoides ottumwa.* Branson and Greger, Jour. Geology, v. 29, no. 2, p. 312, 319, pl. 18, figs. 12–14. (Amsden formation, Wyoming).

1937. *Pugnoides ottumwa.* C. C. Branson, Jour. Paleontology, v. 11, no. 8, p. 652 (Sacajawea formation, Wyoming).

Pedicle valve.—Rather flat with a prominent beak terminating a slightly raised umbo. Umbonal flanks diverge at 100° and become indented along the margin to form a false cardinal area. Laterally and anteriorly the margin is abruptly curved dorsally, and the anterior margin is much extended dorsally to form a tongue which terminates the broad and deep sulcus. The sulcus forms a slight depression on the rather inflated umbo.

The holotype is 12 mm long, 14.5 mm wide, and 10 mm high.

Internal features not seen.

Brachial valve.—Convexity very great. Beak rounded and enveloped by beak of pedicle valve. The fold is conspicuous only anteriorly.

Internally the cardinal plate is divided and a median septum is present, but minute details are not preserved. Sockets are small and buttressed by a swelling on their inner sides. Crura are as much as 2.2 mm long, slender, and diverge at 25°.

Ornamentation.—Plications mostly originate at about one-third of the length and become stronger anteriorly. They may be subangular, but always have rounded crests and are mostly low and broadly rounded without any angularity. Mature specimens generally have 4 plications in the sulcus and 5 plications on the fold, but nearly half of the specimens have 3 and 4 plications, respectively. Lateral margins generally have 7 plications, of which the lateral ones are exceedingly faint ridges but show up as distinct crenulations on the margin. Growth laminae give a chevron-like aspect to the anterior margins of old shells.

Comparison.—This species is characterized by its large size, oblate shape, rounded plications, and presence commonly of 5 plications on the fold.

Pugnoides quinqueplecis differs from *P. ottumwa* (White), which it most closely resembles, in being larger, in having less angular plications, and in having 5 or 4 plications on the fold instead of 4 or 3.

Pugnoides uta (Marcou) is as large as *P. quinqueplecis* but is lower, has sharper plications, and usually has 3 plications on the fold.

Pugnoides loganensis Gunnell is quite low, has a concave pedicle valve, and has no more than 4 plications on the fold.

Material.—24 specimens. Holotype, USNM 118801. Paratype, USNM 118802. Other specimens, University of Missouri 2648 (Branson's figured specimen), and in USGS collections.

Occurrence.—Cameron Creek formation, locality 13420 (type locality). Alaska Bench limestone, locality 13399. Sacajawea formation of C. C. Branson (1936) of Wyoming.

Pugnoides parvulus Girty, 1927

Plate 9, figures 12, 13

1927. *Pugnoides parvulus* Girty, U.S. Geol. Survey Prof. Paper 152, p. 414, pl. 23, figs. 34–44. (Brazer limestone Idaho).

1932. *Pugnoides parvulus.* Gunnell, Am. Midland Naturalist, v. 13, no. 5, p. 292. (Brazer limestone, Utah).

Pedicle valve.—Valve small and flat with a prominent pointed beak from which the umbonal flanks diverge at 90° and are bent sharply dorsally to make small false interareas. Lateral slopes are slightly or not at all dorsally bent. A wide and conspicuous almost quadrate sulcus occupies the anterior half of the valve. The figured specimen is 6.7 mm long, 6.9 mm wide, and 3.0 mm high.

Internal features not seen.

Brachial valve.—Valve slightly convex to very convex with a low rounded umbo and rounded lateral margins. The fold is low.

Internal features not seen.

Ornamentation.—Two-thirds of the specimens have 4 angular plications on each lateral slope and either 3 or 4 plications on the fold and 2 or 3 plications in the sulcus. Other specimens have as few as 2 and as many as 5 plications on the lateral slopes, and as few as 2 and as many as 5 plications on the fold.

Comparison.—This variable species is characterized by its small size, generally flat shape, and presence generally of 3 or 4 angular plications on the fold.

It resembles no other species in the fauna very much. It is much smaller than *P. quinqueplecis* Easton and has more costae than species of *Stenoscisma.*

Material.—32 specimens. Hypotypes, USNM 118803.

Occurrence.—Otter formation, localities 13390 and 14227.

Remarks.—The writer hereby designates as holotype of *P. parvulus* the specimen figured by Girty (1927) on his plate 23, figures 34–36. This specimen is USNM 118640.

Superfamily SPIRIFERACEA

Family SPIRIFERIDAE

Genus SPIRIFER Sowerby, 1815

1914. *Spirifer.* Weller, Illinois Geol. Survey Mon. 1, p. 307, 308.

1932. *Spirifer*. Dunbar and Condra, Nebraska Geol. Survey, ser. 2, Bull. 5, p. 317.

1941. *Spirifer*. Sokolskaia, Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 12, no. 2, p. 8–12.

1949. *Spirifer*. Gatinaud, Mus. nat. histoire Bull., ser. 2, v. 21, no. 1, p. 408–413.

Diagnosis.—Biconvex Spiriferidae whose width ordinarily exceeds the length and is greatest along the hinge line. Pedicle sulcus and brachial fold distinct and bearing plications. Ribs of lateral slopes usually simple but may bifurcate. Pedicle interarea prominent with prominent delthyrium over which extends the enrolled beak. Pedicle interior with short dental lamellae; brachial interior with notothyrium, dental plates, and obscure cardinal process. Surface generally has minute radial lirae and concentric growth lines.

Remarks.—The synonymy refers only to a few principal references in which detailed accounts or extensive references are available.

Discrimination of species of *Spirifer* is a problem for anyone who deals with rocks of Late Mississippian or of Early Pennsylvanian age. The accompanying table (table 4) contains data useful in identifying the 28 species cited therein. Almost all of the species have the typical form of *Spirifer*, sensu stricto, only *S. parvus* Sutton and Wagner and *S. annectans* Walcott being readily separable from the others by reason of their sparse plications. The first two columns of numerals represent the numbers of plications in the sinus and on each lateral slope. When there is a considerable range in number, as in *S. curvilateralis* Easton, those numerals in italics represent the characteristic number of ribs. The nature of ribs, whether rounded, subangular, or angular, is shown in the next column. Also in this column is an indication of whether the ribs are simple or split ("split" being a short word for "bifurcated"). The column of remarks specifies significant features useful in identifications. With this table it is possible to narrow down the choice of species, and to select quickly similar species which need to be differentiated. A few of these names are considered by the writer to be unnecessary, but all are listed for the sake of completeness. Citation of the author and date of each name facilitates reference to more extended information on individual species.

Spirifer curvilateralis Easton, n. sp.

Plate 9, figures 14–19

Pedicle valve.—Width greatest about 3 mm anterior to hinge line and greater than length. Umbo high and beak is sharply enrolled over the cardinal area. Lateral slopes convex from umbo to rounded cardinal extremities. Sulcus broad and shallow, extending

TABLE 4.—*External characteristics of Late Mississippian and Early Pennsylvanian species of* Spirifer

Name of species	Number of ribs		Cardinal extremities	Plications	Remarks	Stratigraphic occurrence
	Sinus	Lateral slopes				
Spirifer annectans Walcott, 1884	1	5	Rounded	Simple, rounded	Plication in sinus almost obsolete.	White Pine shale (Hague, 1883).
S. arizonensis Hernon, 1935	3	10–*11*–14	Right angled to acute	Simple, rounded	Concave lateral slopes	Paradise formation (Stoyanow, 1926).
S. arkansanus Girty, 1911	8	25?	Commonly rounded	Flat, split	Large	Moorefield shale.
S. boonensis Swallow, 1860	3–5	12–13	Acute	Simple, rounded		Lower Pennsylvanian.
S. brazerianus Girty, 1927	15+	25	Rounded	Low, split	Very large	Brazer limestone.
S. breckenridgensis Weller, 1914	3	9–10	Rounded	Simple, rounded	Ovate, elongate	Chester series.
S. casteri Elias, 1957	4	7–8	Rounded	Simple	Reticulate sculpture	Redoak Hollow formation (Elias, 1957).
S. curvilateralis Easton, n. sp	3–*5*–7	–*12*–16+	Rounded	Rarely split, rounded	Rounded extremities	Big Snowy group.
S. fayettevillensis Snider, 1915	10–12	15	Right angled	Rounded	Broad round sulcus	Fayetteville shale.
S. girtyi Dunbar and Condra, 1932					Nomen nudum	
S. hammondi Gunnell, 1932					= *S. centronatus*	Madison(?) group.
S. haydenianus Girty, 1927	20?	40?	Acute	Split, rounded	Very transverse	Brazer limestone.
S. increbescens Hall, 1858	3–5	14–18	Acute	Some split, rounded	Transverse	Chester series.
S. increbescens americanus Swallow, 1866.					Small *S. increbescens*?	
S. increbescens transversalis Hall, 1858.	3	12–14?	Acute	Simple, rounded	Twice as wide as long	Chester series.
S. leidyi Norwood and Pratten, 1855.	3	7–*8*–10	Commonly right angled	Split, angular	Split median fold	Chester series.
S. matheri Dunbar and Condra, 1932.	7–9	9–12	Rounded to acute	Some split, subangular	High ventral beak	Lower Pennsylvanian.
S. moorefieldanus Girty, 1911	3	8–9	Acute	Split, rounded	Faint plications in sulcus, reticulate surface.	Moorefield shale.
S. multistriatus Gunnell, 1932					= *Gigantoproductus brazerianus*	Brazer limestone.
S. occiduus Sadlick, 1960	3–5	11–16	Acute or right angled	Split, rounded	Plications internally subangular	Lower Pennsylvanian.
S. opimus Hall, 1858	3–6	8–10	Rounded	Simple, rounded	Ovate, weak plications in sulcus	Lower Pennsylvanian.
S. parvus Sutton and Wagner, 1931	1	6–7	Obtusely angular	Simple, rounded		Chester series.
S. pellaensis Weller, 1914	3–5	–*10*–*11*+	Commonly acuminate	Simple, rounded	Angular sulcus	Chester series.
S. pellaensis cavecreekensis Hernon, 1935.	5?	9–12	Right angled or acute	Simple, rounded	Plications in sulcus equally strong.	Paradise formation (Stoyanow, 1926).
S. rockymontanus Marcou, 1858	*5*–7	8–12	Rounded	Simple, subangular	Plications equally strong on slopes and sulcus.	Lower Pennsylvanian.
S. shoshonensis Branson and Greger, 1918.	3–8	15–17	Right angled or acute	Split, rounded	Numerous splits of plications	Sacajawea formation (Branson, 1936).
S. subventricosus McChesney	7–9	16–20	Rounded	Split, subangular		Pennsylvanian.
S. welleri Branson and Greger, 1918.	3	9–12	Rounded	Simple, rounded	Ovate	Sacajawea formation (Branson, 1936).

from beak to tonguelike anterior extension. Interarea high and nearly plane near hinge line but sharply curved under the beak. Delthyrium higher than wide, with grooved margins. The average dimensions of 7 mature specimens are 23.3 mm long, 29.2 mm wide, and 18.2 mm high.

Internally the hinge teeth are supported by short dental lamellae which are at first inclined toward each other and then descend vertically to the floor of the valve. Muscle scars taper off to a point at midlength. In old shells the scars are sunken in the shell substance and sclerenchyme encompasses the bases of the dental lamellae and fills up the posterior part of the umbonal cavity.

Slender rods or tubes buried within the tissue of the cardinal area normal to the hinge line terminate in denticles which occur 6 or 7 in 2 mm.

Brachial valve.—Convexity like that of pedicle valve. Umbo is low and the beak is inconspicuous. Lateral flanks slope almost straight to the cardinal extremities. Fold originates at the beak and rises anteriorly to become very high and steepsided. The very narrow interarea is divided by a broadly triangular notothyrium whose margins diverge at 115°.

Internally the seat of attachment of the diductor muscles (cardinal process?) is a vertically fibrous spongy protuberance. Sockets are large openings at the ends of roofed-over socket grooves which are bounded medially by prominent socket plates whose terminal ends are recurved laterally over the sockets. The inner edges of the socket plates are each produced into thin low plates which almost converge under the cardinal process, and in old shells they merge into two very short lamellae under the beak of the valve. A faint groove runs along the margin of the cardinal area and bears pits which receive hinge denticles of the opposite valve. Adductor muscle scars are indefinitely delimited. Spiralia have at least 15 whorls in the laterally pointed coils.

Ornamentation.—The pedicle valve usually has 5 ribs in the sulcus and from 12 to 16 ribs on each lateral slope, although the ranges are from 3 to 7 in the sulcus and from 10 to 18 on each lateral slope. The median rib is simple and extends the length of the sulcus. Each of the two major ribs bounding the sulcus gives off first one and then a second riblet from its inner side. Lateral ribs are almost always simple but an occasional split takes place, in which case it generally involves the third lateral plication. Evenly rounded and almost equally strong ribs and interspaces give a sinusoidal trace in cross section.

Ribs of the brachial valve alternate with those of the pedicle valve.

Micro-ornament of both valves consists of equally strong radiating lirae and concentric growth lines which make a minutely reticulate pattern. Cardinal areas are both horizontally and vertically striate.

Comparison.—*Spirifer curvilateralis* is characterized by generally having the greatest width anterior to the hinge line, and by generally having 5 ribs in the sulcus, and from 12 to 16 rounded generally simple ribs on each lateral slope.

S. curvilateralis resembles *S. increbescens* Hall, 1858 very closely but has rounded ears instead of pointed ears. They have similar shape and number of ribs in the sulcus and on the lateral slopes. *S. increbescens* tends to have more lateral ribs than does *S. curvilateralis*.

S. shoshonensis Branson and Greger also resembles *S. curvilateralis* closely, but has right-angled ears, a tendency toward more ribs in the sulcus and on the lateral slopes, and, most importantly, has a series of split lateral ribs instead of having them simple. *S. curvilateralis* and *S. shoshonensis* occur together and seem to intergrade. More abundantly plicate specimens of *S. curvilateralis* tend to develop right-angled or even pointed cardinal extremities like *S. shoshonensis*.

S. occiduus Sadlick also resembles *S. curvilateralis* in number and distribution of ribs but has pointed instead of rounded ears and, like *S. shoshonensis*, tends to have split lateral ribs. Moreover, the ribs of *S. occiduus* are subangular, particularly on internal molds.

S. pellaensis Weller generally has pointed ears, but less commonly may have rounded ears. Even so, it tends to have fewer plications than does *S. curvilateralis*. These two species tend to intergrade slightly in that part of the range wherein *S. curvilateralis* has fewest plications and a transverse shape.

S. subventricosus Swallow, 1866 is very similar to *S. curvilateralis* in most respects but has about 7 instead of 5 plications in the sulcus and generally has 16 or more plications on the lateral slopes instead of fewer than 16. Incidently, *S. subventricosus* should not be considered as a junior synonym of *S. rockymontanus* (Marcou).

Material.—220 specimens. Holotype, USNM 118804. Paratypes, USNM 118805 A, B. Ideotypes, USNM 118806 A–C. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13365, 13370, 13393 (cf.), 13395 (type locality), 13412, 13413, 13415, and 13424 (cf.). Cameron Creek formation, localities 13363 and 13420. Alaska Bench limestone, localities 13403 and 13423.

Remarks.—Numerous specimens from the type locality permit some study of variation in this species. For instance, comparison of the number of ribs in the sulcus and on the fold results in the following numerical frequencies:

Number of specimens	*Ribs in sulcus*	*Plications on lateral slope*
4	3	10
1	3	15
1	5	10
31	5	12
3	5	14
6	5	16
4	5	18
6	7	15

Expressed as percentages, 56 percent of the specimens have 5 and 12 ribs, respectively, in the sulcus and on the lateral slopes, and 71 percent have 5 plications in the sulcus and from 12 to 16 on each lateral slope. In the listing above, specimens at the top of the table verge on *S. pellaensis* Weller, and specimens at the foot of the table verge on *S. shoshonensis* Branson and Greger.

Spirifer increbescens Hall, 1858

Plate 9, figure 20

1914. *Spirifer increbescens.* Weller, Illinois Geol Survey Mon. 1, p. 343, pl. 46, figs. 1–12. (Contains some prior synonymy.)

Diagnosis.—*Spirifer* with acute cardinal extremities, 3 to 5 ribs in the sulcus, and from 16 to 18 ribs on each lateral slope.

Comparison.—This species differs from *S. curvilateralis* only in being widest at the hinge line with accompanying acute cardinal extremities.

Material.—1 specimen. Hypotype, USNM 118807.

Occurrence.—Cameron Creek formation, locality 13420. The species has been extensively reported from the Chester series (especially the upper Chester series) of Illinois, Kentucky, Iowa, Missouri, Indiana, Ohio, Arkansas, Virginia, and Alabama.

Remarks.—The only reference in the synonymy is to the latest complete account of the species. Publications on Upper Mississippian strata abound in references to this ubiquitous species.

Spirifer shoshonensis Branson and Greger, 1918

Plate 9, figures 21, 22

1918. *Spirifer shoshonesis* Branson and Greger, Geol. Soc. America Bull., v. 29, no. 2 p. 318, pl. 18, figs. 26, 27. (Amsden formation, Wyoming).

1937. *Spirifer shoshonensis.* Branson, Jour. Paleontology, v. 11, no. 8, p. 652. (Sacajawea formation, Wyoming).

Diagnosis.—Alate *Spirifer* with about 7 ribs in the sulcus and 15 ribs on each lateral slope. The first few ribs bordering the sulcus or fold are pairs which are formed by splitting of older ribs.

Comparison.—This species differ from all other *Spirifer* of similar age in having split ribs. It grades into *S. increbescens* Hall in number of plications, and one occasionally finds a specimen of the latter species with a random split of a rib.

Material.—13 specimens. Hypotypes, USNM 118808 and 118809. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13370 and 13395. Cameron Creek formation, locality 13382.

Remarks.—The largest specimen among the four syntypes (Branson and Greger, 1918, pl. 18, fig. 27) has 18 lateral plications, but the others have 14 or 15 each.

Spirifer welleri Branson and Greger, 1918

Plate 9, figure 23

1918. *Spirifer welleri.* Branson and Greger, Geol. Soc. America Bull., v. 29, no. 2, p. 312, 317, pl. 18, figs. 10, 11, 16. (Amsden formation, Wyoming)

1937. *Spirifer welleri.* Branson, Jour. Paleontology, v. 11, no. 8, p. 652, (Sacajawea formation, Wyoming).

Diagnosis.—Small *Spirifer* with the hinge line much shorter than the greatest width, slightly wider than long, with a high narrow pedicle interarea, and the brachial valve less convex than the pedicle valve. The shallow sulcus in the pedicle valve contains 3 ribs, and each lateral slope has from 9 to 11 simple rounded ribs with equally strong interspaces. The fold on the brachial valve is low and bears 4 ribs. Ribs on lateral slopes alternate with those of the opposite valve.

Dimensions in millimeters, of the three syntypes are: length 16.2, 15.2, 17.1; width 17.9, 16.6, 16.1; height 11.0, 11.6, 14.0.

Comparison.—This species is primarily characterized by the extremely short hinge line and resulting ovate shape; also by having 3 ribs in the sulcus and from 9 to 11 on each lateral slope.

Spirifer opimus Hall resembles this species very closely in shape and in number, form, and distribution of plications. The only apparent difference between the species are the higher interarea and shorter hinge line of *S. welleri.* The cardinal extremities of *S. opimus* tend to be right-angled instead of quite rounded, and the ventral interarea tends to extend out to the tips of the cardinal extremities; thus, it is proportionately lower than in *S. welleri.* Expressed as angles, the sides of the interarea in *S. opimus* diverge at 140°, and they diverge at 125° in *S. welleri.*

Material.—3 specimens. Hypotype, USNM 118810. Other specimens in USGS collections.

Occurrence.—Health formation, locality 13414?. Alaska Bench limestone, localities 13403? and 13404.

Spirifer sp.

Numerous specimens which were only identifiable as *Spirifer* sp. were noted from the following localities. Otter formation (1 specimen), locality 14227. Heath formation (45 specimens), localities 13359, 13365, 13368, 13387, 13393, 13402, 13409, and 13413. Cameron Creek formation (38 specimens), localities 13362, 13364, and 14220. Alaska Bench limestone (43 specimens), localities 13384, 13389, 13398, 13399, and 13403. These specimens were not considered to be an integral part of the fauna for purposes of correlation or age determination.

Genus NEOSPIRIFER Fredericks, 1924

1924. *Neospirifer* Fredericks, USSR, Geol. Kom. Izv., 1919, v 38, no. 3, p. 311.
1930. *Neospirifer*. King, Texas Univ. Bull. 3042, p. 115.
1932. *Neospirifer*. Dunbar and Condra, Nebraska Geol. Survey, ser. 2, Bull. 5, p. 326.
1941. *Neospirifer*. Muir-Wood *in* Muir-Wood and Oakley, India Geol. Survey Mem., Palaeontologia Indica, new ser., v. 31, no. 1, p. 29.
1952. *Neospirifer*. Sarycheva and Sokolskaia, Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 38, p. 190.
1954. *Neospirifer*. Stehli, Am. Mus. Nat. History Bull., v. 105, art. 3, p. 340.

Diagnosis.—Large Spiriferidae with very acute cardinal extremities; otherwise resembling *Spirifer* except that the ribs are grouped into raised fascicles of three ribs to a fascicle.

Remarks.—The synonymy above contains a few principal references. The first adequate diagnosis was that of King (1930). More recent accounts by Muir-Wood (1941) and by Sarycheva and Sokolskaia (1952) referred to in the foregoing synonymy contain additional citations.

This is the first time that *Neospirifer* has been cited in North America from rocks of Mississippian age, and it seems to be the oldest occurrence of the genus yet cited anywhere. Dunbar and Condra (1932, p. 327) mention the tendency for ribs to split in species of *Spirifer* known from Lower Mississippian strata, but the species they cite and at least five others also figured by Weller (1914) are characterized by simple two-fold splits. On the other hand, as Dunbar and Condra (1932, p. 327) point out, *Neospirifer* is characterized by having three-fold divisions of ribs which together form bundles raised above the general contour of the shell. The only instances of three-fold rib-division in Early Mississippian *Spirifer* known to the writer occur rarely on the first rib bounding a side of the sulcus of the pedicle valve, in which one branch lies in the sulcus and another lies on the lateral slope, but the strong main rib continues along the crest bordering the sulcus (see Weller, 1914, pl. 53, fig. 2; pl. 55, fig. 9). Sokolskaia (1941, pl. 1, fig. 3b) figures a Lower Carboniferous *Spirifer* from the C_1 beds of the Moscow basin in which the tendency toward two-fold splitting is strong, but at least one raised fascicle of three ribs is apparent on the right lateral slope, with two ribs intervening between the fascicle and the margin of the fold in the brachial valve. Grouping of ribs in Lower Carboniferous spiriferids has also been mentioned by Muir-Wood (1948).

Although the presence of *Neospirifer* may still be a useful rough method of identifying Pennsylvanian or Permian strata, such identification should be made cautiously in view of the material figured by Sokolskaia, Muir-Wood, and herein.

Neospirifer praenuntius Easton, n. sp.

Plate 9, figures 24, 25

Pedicle valve.—Very transverse and width twice length. Profile has a nearly straight anterior slope but with a tightly enrolled beak projecting posteriorly. Lateral slopes evenly and slightly convex. Cardinal extremities at a 65° angle. Median sulcus shallow and broadly concave, bounded by strong ribs which diverge at 25°. Cardinal area 4 mm high, meeting the plane of commissure at 90° but sharply curved under the beak; about 6 scallops occur in 2 mm on its inner margin, and exfoliated shells bear faint furrows in line with the scallops. The delthyrium is higher than wide with its grooved margins diverging at 45° from the beak. Reconstructed dimensions of an average pedicle valve are 20 mm long, 38 mm wide, and 11 mm high.

Internally the short stout teeth lie at the ends of the grooves along the delthyrial margins and are supported by short dental lamellae whose middle planes lie directly underneath the delthyrial grooves. A low ridge extends into the delthyrium from alongside each delthyrial groove.

Brachial valve.—Less convex than pedicle valve. Lateral slopes are evenly convex. Beak inconspicuous. Fold low and rather round in profile. Interarea about 1.5 mm high with a broad notothyrium. Convexity is about 6 mm.

Internal features not seen, except that adductor muscle scars are not impressed on the shell.

Ornamentation.—From 5 to 7 ribs lie in the sulcus, of which the middle one extends from the beak and the others diverge from the ribs bounding the sulcus. Lateral slopes each have about 13 strong rounded ribs which all diverge from the beak. Ribs tend to be grouped into fascicles near the sulcus and fold, there usually being 2 and sometimes 3 distinct fascicles, of which one involves the crest of the border of the sulcus. The center rib of each fascicle is higher and stronger than the subsidiary ribs it gives off on each side. Rounded concave interspaces between fascicles are better developed than are the adjacent subsidiary ribs; this development adds to the fasciculate appearance of the ornamentation. Other ribs tend to bifurcate except for those nearest the lateral margins.

Micro-ornament consists of rather distinct chevron-like growth lines which occur 9 or 10 in 2 mm. Radial striae are either vaguely represented or are absent. Inner shell substance is radially fibrous and outer shell substance is concentrically fibrous.

Comparison.—This species is characterized by the combination of three-fold fascicles and bifurcated ribs, with only about 13 ribs in all on each lateral slope.

Neospirifer praenuntius resembles *Spirifer shoshonensis* Branson and Greger, 1918, in its general shape, size, proportions, and presence of bifurcated ribs, but has some three-fold fascicles and generally has fewer ribs.

N. cameratus (Morton, 1836) and *N. triplicatus* (Hall, 1852), like all other American *Neospirifer*, have more ribs in the sulcus and on the lateral slopes than does this species.

Material.—7 specimens. Holotype, USNM 118811. Paratypes, USNM, 118812A, B. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13369, 13370, and 13409 (type locality). Cameron Creek formation, locality 13364 (cf.).

Remarks.—This is the oldest species of *Neospirifer* known to the writer to have been named and is the first species to be reported from Mississippian strata.

The close similarity of *Neospirifer praenuntius* to *Spirifer shoshonensis* and their association together in the same strata (locality 13370) lends credence to a theory that they are related. It seems quite reasonable that *N. praenuntius* could have arisen from *N. shoshonensis* by further development of the tendency toward numerous bifurcate ribs to become in part trifurcate and fasciculate. It is not uncommon for the rib bounding a sulcus in spiriferoids to be trifurcate; so, extension of the trait onto the next one or two main lateral ribs is not too much to expect. If, as the writer suggests, this took place, then we see in the population of *Spirifer* from the Big Snowy group the transition from *Spirifer* into *Neospirifer*. Moreover, the tendency of ribs of *Spirifer increbescens* to bifurcate suggests a possibility that *Spirifer shoshonensis* is closely related to and possibly derived from that species by perfection and extension of the process of bifurcation of ribs. The two species resemble each other closely otherwise.

Neospirifer gorei Mather, 1915 from the Morrow series has been hitherto the oldest *Neospirifer* known in America. It is not similar to *N. praenuntius* because it has far more numerous, finer, and less prominently fasciculate ribs. It might eventually be demonstrated that *Neospirifer* contains two strains, of which one, like *N. gorei*, has fine and low fascicles and the other, like *N. triplicatus*, has coarsely fasciculate ribs.

Genus **BRACHYTHYRIS** McCoy, 1844

Brachythyris sp.

Plate 7, figure 16

Material.—1 specimen. USNM 118813.

Occurrence.—Cameron Creek formation, locality 13362.

Remarks.—The one fragmentary specimen has an ovate outline, pointed beak, broad low ribs, and a broad, rather deep sulcus in the pedicle valve. The sulcus has 5 ribs and each lateral slope has at least 7 ribs, but the last ones are almost obsolete.

This species has a deeper sulcus with more ribs in it than have either *Brachythyris chesterensis* or *B. laticosta*, which otherwise are rather similar shells.

Genus **MARTINIA** McCoy, 1844

Diagnosis.—Smooth or faintly-ribbed, biconvex, subcircular spiriferoid brachiopods. Interarea in pedicle valve only, commonly poorly defined. Delthyrium large. No dental lamellae or median septum present. Sulcus of pedicle valve ordinarily distinct, but brachial fold may be indefinite.

Remarks.—*Martinia* cannot be diagnosed externally because it superficially resembles *Brachythyris*, *Reticularia*, *Crurithyris*, *Phricodothyris*, *Composita*, *Ambocoelia*, and *Ambothyris*, most of which genera are apt to occur with *Martinia*. As loosely used, *Martinia* comprises smooth rounded spiriferoids without dental plates and without a median septum in either valve. This concept is inadequate for careful discrimination of the genus, but a wholesale revision of allied forms is needed before ready differences can be indicated. A start on this has been made by George (1927a, 1927b, 1931, 1932, 1933).

"Martinia" sp. A

Plate 10, figures 1–3

Description.—Shell substance is as much as 2 mm thick and consists of prisms of calcite whose long axes are at right angles to the surface of the valve. Hinge teeth are short and heavy. No distinct interarea is present, but the surfaces on either side of the large open delthyrium are rounded. The beak overhangs the delthyrium slightly. A very faint sulcus is on the anterior half of the valve. The greatest width is near midlength, which is about 3 mm anterior to the hinge line. No dental lamellae or median septum is present. A distinct trough runs along the midline of the pedicle valve and sharply incised radial vascular markings are prominent. Brachial valves were not positively seen. A typical pedicle valve is 19 mm long, 20 mm wide, 7 mm high, and the hinge line is about 13 mm long.

Material.—10 specimens. Figured specimens, USNM 118815 A, B, C. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13393, 13409, and 13413?.

Remarks.—These specimens are assigned somewhat arbitrarily to *Martinia* on the basis of shape and on the similarity of vascular markings and median groove to specimens of true *Martinia* figured by George (1927a, p. 112). The specimens from Montana lack a well-defined cardinal area, however.

The specimens at hand do not particularly resemble any of the described species known to the writer. *Martinia lata* Girty, 1927, from beds of about the same age, has distinct cardinal areas in both valves and is most assuredly not a *Martinia* at all. It may be a *Crurithyris*, but its internal features are unknown.

Specimens of *M. glabra* (Martin), the genotype of *Martinia*, in the U.S. National Museum (63235) have the singular prismatic structure of the shell noted in the specimens from Montana. The value of this character has not been investigated systematically.

"Martinia" sp. B

Plate 10, figure 4

Description.—A pedicle valve has a distinct cardinal area but otherwise resembles "*Martinia*" sp. A.

Material.—1 specimen. Figured specimen, USNM 118816.

Occurrence.—Heath formation, locality 13409.

Superfamily ROSTROSPIRACEA

Family MERISTELLIDAE

Genus NUCLEOSPIRA Hall, 1859

Diagnosis.—Small, subcircular, biconvex brachiopods. Pedicle sulcus and brachial fold almost obsolete. Interarea and triangular delthyrium small. Pedicle interior with long median septum but without dental lamellae. Brachial interior with intricate cardinalia and spiralium, but with a long median septum. Surface of minute spinules usually exfoliated.

Comparison.—*Nucleospira* resembles *Cleiothyridina* in being spinose, but the former genus has smaller spines, a distinct interarea, and no pedicle foramen at the end of a tightly enrolled beak.

Occurrence.—Although reported from Silurian, Devonian, and very early Mississippian strata, the genus has not heretofore been reported as high as the Chester series, so far as the writer knows.

Remarks.—The diagnosis presented above is abstracted from Weller (1914, p. 453).

Nucleospira superata Easton, n. sp.

Plate 10, figure 17

Pedicle valve.—Outline subcircular with a pointed beak enrolled beyond a low umbo. Interarea very low, faintly striated horizontally, with sides diverging at 130° from the overhanging beak. Delthyrium large, with sides diverging at 90°. Pseudodeltidial plates not seen. A faint sulcus extends from almost the beak to the anterior margin. The holotype is 7.7 mm long, the greatest width is 8.2 mm at midlength, the hinge line is 2.7 mm long, and the two valves together are 4.9 mm high.

Internally the teeth are large and short. Dental lamellae are absent. A low median septum extends over three-fourths of the length of the valve.

Brachial valve.—Rather evenly convex and slightly higher than the pedicle valve. The umbo is evenly convex and overhung by the beak of the pedicle valve. The fold is not delimited by change in slope, but it may be flattened or even have a slight sulcus along its midline.

Internally the low median septum extends over three-fourths of the length of the valve. Adductor muscle scars are two quadrate depressions at midlength. Other details not seen.

Ornamentation.—Minute single-rayed spines about 0.5 mm long lie oblique to the surface and occur 12 in 1 mm transversely. When they are abraded, the surface has a frosty appearance with vague concentric lineation of pits.

Comparison.—This species is characterized by the comparatively large size and subcircular outline.

Nucleospira barrisi (White, 1860), is about the same size as this species, but is distinctly wider than long and has a much more distinct sulcus and fold.

Other species cited from the Mississippian system of this country are all much smaller than *N. superata.*

Material.—12 specimens. Holotype, USNM 118823. Paratypes, USNM 118824.

Occurrence.—Otter formation, locality 14227 (aff.). Cameron Creek formation, locality 13420 (type locality).

Remarks.—The next youngest species of *Nucleospira* known to the writer is from the Burlington limestone of Osage age, so *N. superata* is named from its circumstance as the apparent survivor of the genus.

Family ATHYRIDAE

Genus CLEIOTHYRIDINA Buckman, 1906

1906. *Cleiothyridina.* Buckman, Annals and Mag. Nat. History, ser. 7, v. 18, p. 321.
1914. *Cliothyridina.* Weller, Illinois Geol. Survey Mon. 1, p. 472.
1932. *Cleiothyridina.* Dunbar and Condra, Nebraska Geol. Survey, ser. 2, Bull. 5, p. 359.

Diagnosis.—Ovate biconvex Athyridae which may have a fold and sulcus. The beak is tightly enrolled against the brachial valve and has a foramen. Ornamentation is characterized by lamellae which project from the surface at a low angle and are divided into slender flat spines. Internal features similar to *Athyris.*

Comparison.—*Cleiothyridina* is characterized by the external lamellae which merge into flat spines, and by the tightly enrolled beak of the pedicle valve. When the delicate lamellae and spines are lost, which is commonly the case, then concentric ridges mark the traces of their attachment.

Squamularia resembles *Cleiothyridina* somewhat, but the beak of the pedicle valve is elevated freely above the brachial umbo, the spines are single shafted, and they arise from the upper surface of lamellae instead of from the edges.

Remarks.—The partial synonymy given above does not begin to reflect the widespread recognition of the genus, but it refers the reader to some principal references.

Cleiothyridina hirsuta (Hall, 1857)

Plate 10, figures 19–22

1857. *Spirigera (Athyris) hirsuta* Hall, Albany Inst. Trans., v. 4, p. 8 (advance issue, see Walcott, 1884, p. 222). (Warsaw limestone, Indiana and Illinois).
1860. *Spirigera hirsuta.* Shumard, St. Louis Acad. Sci. Trans., v. 1, p. 406. (Ste. Genevieve limestone, Illinois).
1864. *Spirigera (Athyris) hirsuta.* Hall, Albany Inst. Trans., v. 4, p. 8. (Warsaw limestone, Indiana and Illinois).
1873. *Spirigera hirsuta.* Shumard, Missouri Geol. Survey Rept. (1855–1871), p. 293. (Ste. Genevieve limestone, Illinois).
1882. *Athyris hirsuta.* White, Am. Mus. Nat. History Bull, v. 1, p. 49, pl. 6, figs. 18–21. (Warsaw formation, Indiana and Illinois).
1883. *Athyris hirsuta.* Hall, Indiana Geol. Survey, Ann. Rept. 12, p. 328, pl. 29, figs. 18–21. (unnamed strata ["Warsaw formation"], Indiana and Illinois).
1884. *Athyris hirsuta.* Walcott, U.S. Geol. Survey Mon. 8, p. 222, pl. 18, fig. 5. (Lower portion of Carboniferous group, Nevada).
1894. *Cliothyris Roysii* [in part]. Hall and Clarke, New York State Geologist, Ann. Rept. 13, v. 2, pl. 35, fig. 10 (not fig. 9?).
1894. *Cliothyris Roysii* [in part]. Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, pl. 46, fig. 24 (not fig. 23). (Chester limestone, Kentucky).
1894. *Cliothyris hirsuta.* Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, pl. 46, figs. 25–28. (St. Louis limestone, Indiana).
1906. *Cleiothyris hirsuta.* Beede, Indiana Dept. Conserv. Pub., Ann. Rept. 30, p. 1320, pl. 22, figs. 18–21; pl. 19, figs. 1, 1a. (Salem limestone, Indiana and Illinois).
1909. *Cliothyris hirsuta.* Grabau and Shimer, North American index fossils, v. 1, p. 354, fig. 464. (St. Louis and Kaskaskia of Kentucky, Indiana, Illinois, and Montana).
1911. *Cleiothyris hirsuta.* Morse, Ohio Acad. Sci., Proc., v. 5, pt. 7, Spec. Paper 17, p. 388, fig. 15 (Maxville limestone, Ohio).
1914. *Cliothyridina hirsuta.* Weller, Illinois Geol. Survey, Mon. 1, p. 479, pl. 80, figs. 13–34. (Warsaw formation, Salem limestone, and Ste. Genevieve limestone, Mississippi valley basin).
1915. *Cliothyridina hirsuta?.* Girty, U.S. Geol. Survey Bull. 598, p. 19. (Boone limestone, Arkansas).
1918. *Cleiothyridina hirsuta.* Branson and Greger, Geol. Soc. America, Bull., v. 29, p. 320, pl. 19, fig. 14. (Amsden formation, Wyoming).
1926. *Cleiothyridina hirsuta.* Shimer, Canada Geol. Survey Bull. 42, p. 72. (Lower Mississippian, Alberta).
1927. *Cliothyridina hirsuta.* Girty, U.S. Geol. Survey Prof. Paper 152, p. 69. (Brazer limestone, Idaho).
1932. *Cliothyridina hirsuta.* Gunnell, Am. Midland Naturalist, v. 13, no. 5, p. 298, pl. 27, figs. 41–43. (Brazer formation, Utah).
1938. *Cliothyridina hirsuta.* Branson, Missouri Univ. Studies, v. 13, no. 4, pt. 2, p. 29, pl. 21, figs. 19–21; pl. 22, figs. 9–11. (Northview shale, Missouri).
1944. *Cleiothyridina hirsuta.* Cooper *in* Shimer and Shrock, Index fossils of North America, p. 333, pl. 128, figs. 1, 2. (Warsaw formation through Ste. Genevieve formation, Indiana, Kentucky, and the Ohio valley).
1917. *Cliothyridina hirsuta.* Ulrich, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 96, 141, 149 (cf.). Ste. Genevieve limestone, Kentucky).

Pedicle valve.—Nearly circular and low with a sharply rounded umbo whose flanks diverge at 70°. Beak enrolled over umbo of brachial valve to hide the foramen. The greatest width is near midlength. A specimen of average size is 11.2 mm long, 12.7 mm wide, and 5.5 mm high (both valves).

Internal features not seen.

Brachial valve.—Very similar to pedicle valve in shape and outline and of about the same convexity.

Internal features not seen.

Ornamentation.—Lamellae occur 8 or 9 in 2 mm over the umbo. Spines are flat, about 2 mm long near the margin of the shell, and tend to line up in rows which occur 5 or 6 in 2 mm near the margin.

Comparison.—*Cleiothyridina hirsuta* is characterized by being about 1 cm long, nearly circular, and having both valves of about equal convexity.

C. sublamellosa (Hall) is very similar to this species, but tends to be about twice as large and to have the brachial valve decidedly more convex than the pedicle valve.

C. orbicularis from the Pennsylvanian is much more convex than is this species, but the two are the same size and have similar outlines.

Material.—72 specimens. Hypotypes, USNM 118825 and 118826 A, B. Branson and Greger's specimen is University of Missouri 2654. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13390. Heath formation, locality 13414?. Cameron Creek formation, locality 13420. Alaska Bench limestone, locality 134077?.

Cleiothyridina aff. C. sublamellosa (Hall, 1858)

Plate 10, figure 18

1914. *Cliothyridina sublamellosa.* Weller, Illinois Geol. Survey Mon. 1, p. 482, pl. 80, figs. 31–60. (Ste. Genevieve limestone and Chester group, Mississippi valley basin).

Remarks.—The specimens at hand have the outline and size of this species, but, although somewhat crushed, seem not to have the brachial valve more convex than the pedicle valve.

Material.—4 specimens. Figured specimen, USNM 118827. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13359.

Cleiothyridina atrypoides (Girty, 1910)

Plate 10, figures 23, 24

1910. *Cliothyridina sublamellosa* var. *atrypoides* Girty, New York Acad. Sci. Annals, v. 20, no. 3, pt. 2, p. 223. (Fayetteville shale, Arkansas).

Pedicle valve.—Moderately convex with a rather low umbo whose flanks diverge at 100° from the prominent and enrolled beak. A mesial flattening develops into a very shallow and broad sulcus in the anterior half of the valve. The greatest width is a little posterior of midlength. The holotype, which is of average size, is 13.8 mm long, 13.7 mm wide, and 8.4 mm thick (both valves).

Internally a pair of nearly vertical dental lamellae bound the deep umbonal cavity which is about 5 mm long. Adductor muscle scars are elliptical depressions 4 mm long and 4.5 mm wide (combined) which are separated from the umbonal cavity by a low node. A broad low ridge runs lengthwise across the umbonal cavity and separates the adductor scars. Faint radiating vascular markings are present.

Brachial valve.—Almost hemispherical but rather low with an inconspicuous beak. It is slightly less convex than is the pedicle valve. The fold is not distinct but is caused by the less convex anterior extension of the valve.

Internally the adductor muscle scars are distinct depressions 5 mm long with a combined width of 2 mm. They are separated by a faint to distinct median septum of the same length as the scars and as high as they are deep. Cardinal plate not seen. Radiating vascular markings faint.

Ornamentation.—Shell substance is thick and fibrous, exfoliating very easily. About 8 very slightly projecting concentric lamellae occur in 2 mm and give rise to nearly circular rather erect spines which tend to line up in radiating rows occurring about 6 in 2 mm. Occasional coarse wrinkles are present. A very indefinite radial ribbing to the shell may make a tenuous reticulate pattern with the bases of exfoliated lamellae.

Comparison.—This species is characterized by the thickness of the shell, by notable height of the valves, and by coarse spines.

Cleiothyridina hirsuta has much lower convexity, finer spines, and more nearly circular outline than does *C. atrypoides.*

C. sublamellosa has a more convex brachial valve than pedicle valve.

Material.—8 specimens. Hypotypes, USNM 118828. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13393. The primary types are from a limestone lens in the lower part of the Fayetteville shale in the SW corner, sec. 9, T. 16 N., R. 29 W., about 6 miles (airline) east of Fayetteville, Ark.

Remarks.—The writer raises to specific rank the forms originally described as a variety of *C. sublamellosa* (Hall) and hereby selects as holotype one of the three original syntypes which is figured herein for the first time (pl. 10, figs. 23a–c).

Genus CRURITHYRIS George, 1931

Crurithyris n. sp.

Plate 7, figures 17, 18

Pedicle valve.—Slightly ovate with the greatest width slightly anterior to midlength. Umbo increasingly enrolled, perforated by a circular pedicle foramen which touches the triangular delthyrium. Interarea is minute.

Internally no septum is present. The positions of dental lamellae are occupied by very short ridges which terminate under the teeth.

Brachial valve.—Slightly less convex than the pedicle valve with a rather prominent umbo which overhangs the hinge line slightly.

Internally no median septum is present. Muscle scars lie well posterior of midlength. The short cardinal plate is supported by diverging crural lamellae.

Sockets are long and bounded medially by very low ridges.

Ornamentation.—Surface covered with concentric rows of minute flattened spines which are ordinarily lost so that at best a faint pattern of concentric ridges remains on the nearly smooth surface.

Comparison.—This species differs from any similar shells in the fauna by its nonsinuate valves with prominent umbones.

Ambocoelia planoconvexa (Shumard) has a nearly flat brachial valve.

Phricodothyris perplexa (McChesney) resembles this species somewhat but has a terraced surface, double-barrelled spines, greatest width posterior to midlength, and the edges of the almost horizontal crural plates are nearly parallel instead of diverging and being steep.

Remarks.—The writer inadvertently removed the minute spines with acid while trying to prepare the specimens.

Material.—6 specimens. Figured specimens, USNM 118814A, 118814B. Other material in USGS collections.

Occurrence.—Heath formation, localities 13395 and 13414.

Genus COMPOSITA Brown, 1845

1845. *Composita* Brown, Illustration of the fossil conchology of Great Britain and Ireland, with descriptions and localities of all the species; London, Smith, Elder, and Co., (1838–1849), p. 131.

1906. *Composita*. Buckman, Annals and Mag. Nat. History, ser. 7, pp. 18, p. 324, 326.

1914. *Composita*. Weller, Illinois Geol. Survey Mon. 1, p. 484.

Remarks.—The composite quality for which the genus was erected arises from the fact that the shape is that of a terebratuloid brachiopod but the shell contains a spiriferoid brachidium. The genotype, *Spirifer ambiguus* Sowerby, has more distinct grooves on the fold than do some other species usually referred to this genus. For a time American and other paleontologists referred shells to *Seminula* McCoy, 1844, which are now placed in *Composita*. Only a few key references are given in the synonymy above.

Diagnosis.—Small to medium size, biconvex Spiriferidae with rather ovate outlines and smooth shells. A pedicle sulcus and brachial fold are generally present and each may bear a faint median sulcus. The ventral beak with a circular foramen overhangs the brachial valve prominently and has rounded flanks on both sides of the large delthyrium. Internally the pedicle valve has prominent nearly parallel dental lamellae and long parallel muscle scars but no septum. The brachial valve has a cardinal plate which is perforate unless closed by stereoplasm. Adductor muscle scars are long parallel grooves which may be separated by a faint median ridge. Apices of spiralia point laterally.

Comparison.—This genus is very hard to differentiate from various other genera with similar shapes, unless one can see internal features or the hinge area. *Cleiothyridina*, *Squamularia*, and *Reticularia* normally bear traces of their minute spine bases, whereas *Composita* is quite smooth. *Martinia* has a small interarea on the pedicle valve, but otherwise is very similar to *Composita*. The similarity is enhanced because the minutely striate surface of *Martinia* is duplicated by surficial patterns of shell fibers under certain conditions of preservation of *Composita*, *Ambocoelia*, *Crurithyris*, and *Phricodothyris*.

Remarks.—In the following descriptions the general features of *Composita* are minimized because all species resemble each other rather closely and only differences need be accentuated.

Weller (1914, p. 484–486) has established the intergradational nature of different species of *Composita* and has pointed out the necessity for having suites of specimens in order to make specific assignments.

Composita laevis Weller, 1914

Plate 11, figures 1, 2

1914. *Composita laevis* Weller, Illinois Geol. Survey Mon. 1, p. 491, pl. 82, figs. 14–20. (Chester group, Kentucky).

1932. *Composita farrelli* Gunnell, Amer. Midland Naturalist, v. 13, no. 5, p. 299, pl. 27, figs. 45, 47, 38 (not fig. 46). Brazer limestone, Utah.

1935. *Composita laevis* Hernon, Jour. Paleontology, v. 9, no. 8, p. 689. (Fourth, Fifth, Sixth?, and Seventh members of the Paradise formation, Arizona).

Diagnosis.—Small, rather elongate *Composita* with the greatest width definitely anterior to the midlength. A prominent sulcus runs almost the length of the pedicle valve. The brachial valve has a prominent umbo for the genus. The fold is obsolete, being represented by an anterior flattening along which runs a faint groove. An average of 10 mature specimens shows the angle of divergence of the posterior margins to be 85° and the specimens average 14.2 mm long, 13.5 mm wide, and 9.6 mm high.

Comparison.—This species is characterized by the acute angle formed by the posterior margins, by the greatest width being anterior to midlength, and by the emargination of the anterior margin where the pedicle and sometimes the brachial sulcus terminate.

Composita laevis is only about half as large as *C. ozarkana* Mather and *C. sulcata* Weller, with which it is associated. Moreover, it has no distinct brachial fold, a higher brachial umbo, no sags in the anterior margin of the brachial valve, and it is 1.4 times as wide as high, instead of being 1.8 or 1.7 times as wide as high.

C. lewisensis Weller, 1914, is quite similar to *C. laevis*, but lacks the anterior emargination of that species.

Material.—96 specimens. Hypotypes, USNM 118820A, 118829B. Other specimens in USGS collection.

Occurrence.—Otter formation, locality 13390. Heath formation, localities 13391, 13395, 13409 (cf.), and 13415.

Composita cf. C. lateralis (Girty, 1910)

Plate 11, figures 3, 4

1910. *Composita subquadrata* var. *lateralis* Girty, New York Acad. Sci. Annals, v. 20, no. 3, pt. 2, p. 222. (Basal Fayetteville shale, Arkansas).

1911. *Composita subquadrata* var. *lateralis*. Girty, U.S. Geol. Survey Bull. 439, p. 75, pl. 4, fig. 10. (Moorefield shale, Arkansas).

Diagnosis.—Very wide *Composita* of low convexity. The pedicle sulcus is narrow and deep, but the brachial fold is low or almost obsolete. The anterior margin is slightly emarginate where the sulcus of the pedicle valve terminates and the reentrant may be accentuated by a faint groove on the brachial fold. The average dimensions of 4 specimens are 16.9 mm long, 21.2 mm wide, 11.5 mm high, and the posterior margins diverge at 108°.

Comparison.—*Composita lateralis* is characterized by notably wide shells. Girty's type figured here is 2.2 times as wide as high. Its dimensions are 19.1 mm long, 23.7 mm wide, 11.0 mm high, and the posterior margins diverge at 104°.

Composita transversa Mather is not so wide proportionately as is this species, and has no brachial fold at all.

C. lateralis is distinctly wider proportionately than any other shells from the collections from Montana with which it might be confused.

Material.—6 specimens. Figured specimen, USNM 118830. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13414 and 13425. Cameron Creek formation, locality 13363.

Remarks.—The writer raises the variety to specific rank.

Neither of the type specimens has been figured heretofore. The writer hereby designates the syntype figured herein (pl. 11, figs. 4a–d) as holotype. The other syntype may not belong to this species, for it is proportionately less wide but is higher and has very deep sags alongside the brachial fold. It is very close to *C. ozarkana* Mather, if not referable to that species. Adequate material for analysis of this species is not available.

Composita ozarkana Mather, 1915

Plate 11, figures 5–7

?1914. *Composita trinuclea* [in part] Weller, Illinois Geol. Survey Mon. 1, pl. 81, figs. 31–34. (Salem limestone, Illinois).

1915. *Composita ozarkana* Mather, Denison Univ., Sci. Lab. Bull. 18, p. 198, pl. 13, figs. 11–15c. (Morrow group, Arkansas and Oklahoma.)

?1924. *Composita ozarkana*. Morgan, Oklahoma Geol. Survey Bull. 2, pl. 42, fig. 12, (Wapanucka formation, Oklahoma).

?1926. *Composita ozarkana*. Shimer, Canada Geol. Survey Bull. 42, p. 73. (Pennsylvanian, Alberta.)

?1950. *Composita ozarkana*. Plummer, Texas Univ. Pub. 4329, p. 53, 54, 132, pl. 11, figs. 12a, b. (Sloan formation Texas).

Diagnosis.—*Composita* with a subquadrate shape, the greatest width at midlength, and subequally convex but low valves. The pedicle sulcus is rather broad and shallow and bears a distinct narrow groove which extends from the beak to the anterior margin. The brachial fold is low and broadly rounded with rather steep lateral flanks near the anterior margin; it bears either a faint groove along its anterior two-thirds, or the growth lines make posterior reentrants along the midline. The anterior margin has a slight sulcus on either side of the fold. An exceptional specimen (pl. 11, fig. 6) reveals both spiralia with 18 volutions to each limb. Average dimensions of specimens are 21.8 mm long, 23.1 mm wide, and 13.0 mm high. The posterior margins diverge at 102°.

Comparison.—*Composita ozarkana* is characterized by having a groove in both the sulcus and on the fold, and the anterior margin sags slightly on both sides of the fold. This species is similar to the genotype, *C. ambigua* (Sowerby), in having a groove along the fold.

Composita ozarkana is very similar to *C. sulcata* Weller and intergrades with it by losing the sulcus on the fold and developing a narrower and deeper sulcus in the pedicle valve.

Material.—286 specimens. Hypotypes, U S N M 118831 A–C. Other specimens in USGS collection.

Occurrence.—Otter formation, locality 13390. Heath formation, localities 13370, 13395, 13414, and 13415. The species has formerly been known only in Pennsylvanian strata.

Composita sulcata Weller, 1914

Plate 11, figures 8, 9

1914. *Composita sulcata* Weller, Illinois Geol. Survey Mon. 1, p. 490, pl. 82, figs. 1–10. (Chester group, Kentucky).

?1926. *Composita ozarkana*. Stoyanow, Am. Jour. Sci., ser. 5, v. 12, p. 317. (Paradise formation, Arizona).

1927. *Composita sulcata.* Girty, U.S. Geol. Survey Prof. Paper 152, p. 64, pl. 23, figs. 28–33. (Brazer limestone, Idaho).

?1931. *Composita subquadrata* [in part?]. Weller, Kentucky Geol. Survey, ser. 6, v. 36, p. 265, pl. 44, fig. 4a?. (Vienna to Kinkaid formations, Kentucky) [not figs. 4b, 4c-*C. subquadrata*].

?1935. *Composita* cf. *C. ozarkana.* Hernon, Jour. Paleontology, v. 9, no. 8, p. 689. (Fourth to Seventh members of the Paradise formation, Arizona).

Diagnosis.—*Composita* closely resembling *C. ozarkana* Mather, 1915, except that there is neither a groove nor indented growth lines along the brachial fold. The average dimensions of 10 mature specimens are 24.0 mm long, 25.3 mm wide, and 15 mm high. The posterior margins diverge at 79°.

Material.—379 specimens. Hypotypes, U S N M 118832 A and B. Other specimens in USGS collection.

Occurrence.—Heath formation, localities 13395, 13415, 13416, and 13424. Cameron Creek formation, localities 13363, 13364 (cf.), and 13380. Alaska Bench limestone, locality 13385 (cf.).

Remarks.—*Composita sulcata* is characterized by having a groove in the pedicle sulcus but not on the fold and the brachial anterior margin sags slightly on both sides of the fold.

It seems to be intermediate between *Composita trinuclea* (Hall) and *C. ozarkana* Mather. *C. trinuclea*, as interpreted by the writer, is smaller than *C. sulcata*, has the greatest width anterior to the midline, and is distinctly trilobate. As thus defined, characteristic specimens of *C. trinuclea* are those figured by Weller (1914) on plate 81, figures 16–30, but Weller's figures 31–34 on the same plate are referred to *Composita ozarkana* in the present report.

C. subquadrata (Hall) resembles *C. sulcata* rather closely but can be recognized most readily by the lack of sags along the anterior margin of the brachial valve alongside the fold.

Composita subquadrata (Hall, 1858)

Plate 11, figures 10–18

1858. *Athyris subquadrata* Hall, Geol. Survey Iowa Rept., v. 1, pt. 2, Palaeontology, p. 703, pl. 27, figs. 2a–d; p. 708, fig. 118. (Kaskaskia limestone, Illinois and Kentucky).

?1877. *Athyris subquadrata?.* Hall and Whitfield, U.S. Geol. Explor. 40th Par. Rept., v. 4, p. 271, pl. 5, figs. 19, 20. (Lower Carboniferous, Utah).

1891. [not] *Athyris subquadrata.* Whitfield, New York Acad. Sci. Annals, v. 5, p. 585, pl. 14, figs. 1–3. . [*C. trinuclea.*].

?1893. *Seminula subquadrata.* Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 95. (Kaskaskia limestone, Kentucky). (Advance distribution).

1894. [not] *Seminula subquadrata.* Hall and Clarke, Introduction to the study the Brachiopoda, pt. 2, pl. 35, figs. 13, 15 [=*C. trinuclea*].

1894. [not] *Seminula subquadrata.* Hall and Clarke, New York State Geologist Ann. Rept. 13, v. 2, pl. 35, figs. 13, 15 [=*C. trinuclea*].

?1895. [not] *Athyris subquadrata* Keyes, Missouri Geol. Survey, v. 5, pt. 2, p. 92 [=*C. trinuclea?*].

1895. *Seminula subquadrata* [in part]. Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 95, pl. 84, figs. 30, 31. (Kaskaskia limestone, Illinois). Not pl. 47, figs. 7–9, 15, 16 [=*C. trinuclea*].

1895. [not] *Athyris subquadrata.* Whitfield, Ohio Geol. Survey Rept., v. 7, p. 472, pl. 10, figs. 1–3, (1893). (Maxville limestone, Ohio).

1897. [not] *Athyris subquadrata.* Weller, New York Acad. Sci. Trans., v. 16, p. 258, pl. 19, fig. 16 [=*C. trinuclea*].

?1903. *Seminula subquadrata?* Girty, U.S. Geol. Survey Prof. Paper 16, p. 296, pl. 1, fig. 5. (Leadville limestone and Millsap limestone, Colorado).

1909. *Seminula subquadrata.* Grabau and Shimer, North American index fossils, p. 354. (Kaskaskia of Ohio, Kentucky, Illinois, and Utah).

1909. [not] *Seminula subquadrata.* Bassler, Virginia Geol. Survey Bull. 11A, pl. 29, figs. 6–8 [=*C. trinuclea*].

1911. [not] *Seminula subquadrata.* Morse, Ohio State Acad. Sci. Proc., v. 5, pt. 7, spec. paper 17, p. 383, text figs. 13a–c on p. 384 [=*C. trinuclea*].

1914. *Composita subquadrata.* Weller, Illinois Geol. Survey Mon. 1, p. 489, pl. 81, figs. 1–15. (Chester Group, Mississippi valley basin).

1915. [not] *Composita subquadrata.* Girty, U.S. Geol. Survey Bull. 593, p. 72, pl. 4, figs. 15–16a [=*C. trinuclea*].

1917. *Composita subquadrata.* Butts, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 78, 87, 108, 115, 116, pl. 28, figs. 1, 2. (Glen Dean limestone, Menard formation, Clore formation, and Buffalo Wallow formation, Kentucky).

1917. *Composita subquadrata.* Ulrich, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 56, 80, 82, 85, 87, 117, 125, 221, 229, 233, and 236. (Glen Dean, Golconda, Clore and Menard formations of Kentucky; Chester group of Tennessee; Birdsville group of Alabama).

?1920. *Composita subquadrata?* Girty, U.S. Geol. Survey Prof. Paper 111, p. 651, pl. 53, figs. 9, 9a. (Upper Mississippian, Utah).

1920. *Composita subquadrata* [in part?] Weller, Illinois Geol. Survey Bull. 41, p. 208, 209, 214, 215, 375, pl. 11, figs. 12, 13, 14? (Menard limestone and Clore limestone, Illinois). [fig. 14 = *C. sulcata?*].

1922. *Composita subquadrata.* Butts, Kentucky Geol. Survey, ser. 6, v. 7, p. 177, 180. (Glen Dean limestone and Buffalo Wallow formation, Kentucky).

1926. *Composita subquadrata.* Butts, Alabama Geol. Survey Spec. Rept. 14, p. 198, 204, pl. 65, figs. 10–12. (Bangor limestone and Floyd shale of Alabama; Glen Dean formation of Illinois).

1930. *Composita subquadrata.* Morse, Mississippi Geol. Survey Bull. 23, p. 126, 139, 170. (Southward Pond formation, Alsobrook formation, and Forest Grove formation, Mississippi).

1931. *Composita subquadrata.* [in part?] Weller, Kentucky Geol. Survey, ser. 6, v. 36, p. 265, pl. 44, figs. 4a? 4b, 4c. (Vienna to Kinkaid formation, Kentucky). [fig. 4a=*C. sulcata?*].

1941. *Composita subquadrata.* Butts, Virginia Geol. Survey Bull. 52, pt. 2, p. 241, pl. 130, figs. 16–18. (Glen Dean limestone, Virginia).

1944. *Composita subquadrata.* Cooper *in* Shimer and Shrock, Index fossils of North America, p. 335, pl. 128, figs. 13–15. (Upper Mississippian of southern Appalachians, Mississippi valley, Arkansas, and Oklahoma).

Diagnosis.—*Composita* with a subquadrate shape, the greatest width at midlength, and with subequally and rather strongly convex valves. The pedicle sulcus extends along the anterior three-fourths of the valve and is narrow and deep posteriorly, but is broad and rounded anteriorly. The brachial fold is low and broad with rather steep anterior flanks but without a median groove. The anterior margin of the brachial valve rises at the fold above the plane of commissure. The average dimensions of 10 mature specimens are 23.2 mm long, 22.2 mm wide, 14.2 mm high, and the posterior margins of the pedicle valve diverge at 100°.

Internally the pedicle valve has strong teeth supported by vertical dental lamellae which diverge slightly and enclose laterally a prominent pedicle cavity. The large circular foramen encroaches on the triangular delthyrium. The muscle field makes an elongate oval indentation in the shell anterior to the pedicle cavity that gives the cavity and field together an hourglass shape.

Internally the brachial valve has two short but large dental sockets above which a prominent concave cardinal plate stands 1 mm or so. The posterior lateral margins of the cardinal plate each has a prominent ridge which extends posteriorly into the umbo of the pedicle valve. A medial perforation, which in old shells may be filled with stereoplasm, occurs at the back of the cardinal plate. Adductor muscle scars are elongate ribbonlike grooves. Two very stocky ridges support the hinge plate and are separated by a small space which led into the perforation of the cardinal plate. Spiralia have from 12 to 15 volutions in each laterally pointed coil.

Comparison.—*Composita subquadrata* is characterized by the subquadrate shape, broad sulcus and fold ordinarily without a longitudinal groove, and especially by the lack of sags below the plane of commissure along the anterior margin on both sides of the brachial fold.

C. subquadrata (Hall), as generally interpreted, intergrades with *C. trinuclea*, but it also is very similar to *C. sulcata* Easton and *C. ozarkana* Mather. It can be differentiated from all these species because it alone lacks the sags of the anterior margin of the brachial valve.

C. subtilita (Hall) has the same anterior course of the brachial valve margin as does *C. subquadrata*, but it is much narrower than the latter.

Material.—293 specimens. Hypotypes, USNM 118883 A–I. Other specimens in the USGS collections.

Occurrence.—Cameron Creek formation, localities 13362 (cf.) and 13419. Alaska Bench limestone, localities 13404 and 13423.

Remarks.—The synonymy contains only major references, but because this species is widely recognized in America, equally important references have no doubt been overlooked.

Composita sp.

Specimens identifiable only as *Composita* sp. were collected from the following localities. Heath shale (45 specimens), localities 13359, 13365, 13368, 13387, 13393, 13402, 13409, and 13413. Cameron Creek formation (37 specimens), localities 13361 and 13373. Alaska Bench limestone (53 specimens), localities 13384, 13389, 13398, 13399, and 13403. These specimens were not considered to be useful in determining the age or correlation of strata.

Superfamily PUNCTOSPIRACEA

Family SPIRIFERINIDAE

Genus PUNCTOSPIRIFER North, 1920

1920. *Punctospirifer* North, Geol. Soc. London Quart. Jour., v. 76, pt. 2, p. 212.

1927. *Punctospirifer.* Muir-Wood, Annals and Mag. Nat. History, ser. 9, v. 19, no. 110, p. 289.

1930. *Punctospirifer.* King, Texas Univ. Bull. 3042, p. 124.

1931. *Punctospirifer.* Paeckelmann, Neues Jahrb., Beilage-Band 67, Abt. B, p. 51.

1932. *Punctospirifer.* Dunbar and Condra, Nebraska Geol. Survey, ser. 2, Bull. 5, p. 350.

1935. *Punctospirifer.* Thomas, Am. Midland Naturalist, v. 16, no. 2, p. 204.

1941. *Punctospirifer.* Sokolskaia, Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 12, no. 2, p. 50.

1948. *Punctospirifer.* Muir-Wood, Malayan lower Carboniferous fossils: British Mus. (Natl. History), p. 62.

1952. *Punctospirifer.* Sarycheva and Sokolskaia, Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 38, p. 226.

1954. *Punctospirifer.* Stehli, Am. Mus. Natl. History Bull., v. 105, art. 3, p. 345.

Spiriferina [in part], of some authors [see Girty, 1908, p. 371–374].

Spiriferellina [in part], of some authors.

Reticulariina [in part], of authors.

Diagnosis.—The principal distinguishing characters of *Punctospirifer* are (1) V-shaped jugum; (2) hinge line approximately equal to the greatest width of the shell, and width of shell usually equal to twice the length; (3) broad, rounded, median fold and wide shallow sinus, and six to twelve narrow rounded plications on each lateral slope; (4) fine evenly developed lamellose ornament; (5) moderately high flattened or concave cardinal area with angular margins sharply defining it from the lateral slopes (Muir-Wood, 1948, p. 63).

Occurrence.—The genus has been reported commonly from Mississippian, Pennsylvanian, and Permian strata in North America and from various localities in Malaya, Russia, Europe, and the British Isles.

Remarks.—*Punctospirifer* is generally applied to punctate spiriferoids with coarse plications and a median septum in the pedicle valve, but, unfortunately, these features do not absolutely differentiate the genus.

Spiriferina d'Orbigny, 1847, is founded on a Mesozoic species with a globose shape and nearly smooth shell. Some other species are plicate but have indefinite fold and sulcus and short hinge lines; so, they are readily differentiated from *Punctospirifer.*

Spiriferellina Fredericks, 1924, does not have the pedicle interarea sharply set off from the lateral slopes, but otherwise differs from *Punctospirifer* only in degree. "It resembles *Spiriferellina* in having a punctate shell, but differs from it in having more numerous and less angular plications on the lateral slopes, and in having a more flattened, broader median fold, and shallower sinus. The concentric lamellose ornament is more prominent in *Punctospirifer.*" (Muir-Wood, 1948, p. 63, 64.)

Reticulariina Fredericks, 1916 differs from *Punctospirifer* in having coarse spines on the surface.

Callispirina Cooper and Muir-Wood, 1951, was proposed to replace *Mansuyella* Reed, 1944, which, in turn, was thought to supplant *Maia* Fredericks, 1919. *Callispirina* differs from *Punctospirifer* only by having less prominent external lamellae and shorter dental lamellae.

Punctospirifer transversus (McChesney, 1859)

Plate 10, figures 6–11

1859. *Spirifer transversa* McChesney, Descriptions of new species of fossils from the Paleozoic rocks of the Western States, p. 42 (also issued in 1860). (Kaskaskia division, Alabama).

1864. *Spirifer transversa.* McChesney, Illustrations of new species of fossils, etc., pl. 6, figs. 3a–c.

1868. *Spirifer transversa.* McChesney, Chicago Acad. Sci. Trans., v. 1, p. 34, pl. 6, figs. 3a–c. (Chester division, Alabama).

1874. *Spiriferina transversa.* Derby, Cornell Univ. Bull. (Sci.), v. 1, no. 2, p. 21, pl. 2, figs. 4–6, 13; pl. 3, figs. 12–14, 17; pl. 5, fig. 4. (Coal Measures, Brazil).

1876. *Spiriferina Kentuckensis* [in part]. White *in* Powell, U.S. Geol. and Geog. Survey Terr., Report on the geology of the eastern portion of the Uinta Mountains, p. 90 (Lower Aubrey Group, Utah).

1883. *Spirifera transversa.* Hall, New York State Geologist Ann. Rept. (1882), pl. 60, figs. 19–25. (Keokuk limestone, Indiana; Chester limestone, Alabama; Carboniferous, Brazil).

1893. *Spiriferina transversa.* Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 46, 54 (advance distribution).

1894. *Spiriferina transversa.* Hall and Clarke, New York State Geologist Ann. Rept. (1893), pl. 31, figs. 1, 3. (Chester limestone, Alabama; Carboniferous limestone, Brazil).

1894. *Spiriferina transversa.* Hall and Clarke, Introduction to the study of the Brachiopoda, pt. 2, pl. 31, figs. 1, 3. (Chester limestone, Alabama; Carboniferous limestone, Brazil).

1895. *Spiriferina transversa.* Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 46, 54, pl. 35, figs. 19, 20, 23–25 (Chester limestone, Alabama; Carboniferous limestone, Brazil).

1903. *Spiriferina transversa.* Katzer, Grundzüge de Geologie des unteren Amazonas Gebietes (des Staates Pará in Brazilien), p. 158, pl. 4, figs. 2a–c; (=Geologia do Estado do Pará, 1933, p. 154, pl. 4, fig. 2; pl. 5, fig. 3 [fide Dresser, 1954 p. 63].

1908. *Spiriferina transversa.* Girty, U.S. Geol. Survey Prof. Paper 58, p. 371, 372, 374.

1914. *Spiriferina transversa.* Weller, Illinois Geol. Survey Mon. 1, p. 297, pl. 35, figs. 41–49 (Chester Group, Mississippi valley basin).

?1915. *Spiriferina transversa.* Girty, U.S. Geol. Survey Bull. 593, p. 68, pl. 4, fig. 10 (Batesville sandstone, Arkansas).

1915. *Spiriferina transversa.* Mather, Denison Univ., Sci. Lab., Bull. 18, table opp. p. 192, pl. 13, figs. 7, 8. (Hale formation, Brentwood limestone, Kessler limestone, and Morrow formation, Arkansas and Oklahoma).

1915. *Spiriferina transversa.* Snider, Oklahoma Geol. Survey Bull. 24, p. 92 (Mayes formation and Fayetteville formation, Oklahoma).

1917. *Spiriferina transversa.* Butts, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 77, 82, 93. (Gasper oolite and Golconda formation, Kentucky).

1917. *Spiriferina transversa.* Ulrich, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 104, 134 (var.), 141 (var.), 150, 176, 221, 229, 236 (Ste. Genevieve and Chester, Kentucky and Illinois).

1920. *Spiriferina transversa.* Weller, Illinois Geol. Survey Bull. 41, p. 138, 139, 141, 148, 158, 172, 174, 182, 183, 195, 196, 207, 214, 215, 353, pl. 8, figs. 17, 18 (Chester series, Illinois).

1922. *Spiriferina transvera.* Butts, Kentucky Geol. Survey, ser. 6, v. 7, p. 177. (Glen Dean formation, Illinois, Kentucky, and Virginia).

1924. *Spiriferina transversa.* Morgan, Oklahoma Bur. Geol. Bull. 2, pl. 45, fig. 9. (Wapanucka formation, Oklahoma).

1926. *Spiriferina spinosa.* Stoyanow, Am. Jour. Sci., ser. 5, v. 12, p. 317. (Paradise formation, Arizona).

1926. *Spiriferina transversa.* Butts, Alabama Geol. Survey Spec. Rept. 14, p. 198, pl. 65, figs 20–23 (Gasper formation, Alabama).

1927. *Spiriferina transversa.* Girty, U.S. Geol. Survey Prof. Paper 152, p. 69 (Brazer limestone, Idaho).

1930. *Punctospirifer transversa.* King, Texas Univ. Bull. 3042, p. 124.

1930. *Spiriferina transversa.* Morse, Mississippi Geol. Survey Bull. 23, p. 119, 126, 127, 139, 162, 170, pl. 20, figs. 1, 2. (Southward Pond formation, Alsobrook formation, and Forest Grove formation, Mississippi and Alabama).

1931. *Spiriferina transversa.* Weller, Kentucky Geol. Survey, ser. 6, v. 36, p. 261, pl. 39, figs. 2a–c (Ste. Genevieve limestone and Chester series, Kentucky).

1935. *Spiriferina transversa.* Hernon, Jour. Paleontology, v. 9, no. 8, p. 686 (Fifth and Seventh members of the Paradise formation, Arizona).

1935. *Spiriferina spinosa* var. *cochisensis* Hernon, Jour. Paleontology, v. 9, no. 8, p. 685, pl. 82, fig. 1 (Fifth and Seventh members of the Paradise formation, Arizona).

1941. *Spiriferina transversa.* Butts, Virginia Geol. Survey Bull. 52, pt. II, p. 241, pl. 130, figs. 14, 15 (Glen Dean limestone, Virginia).

1950. *Punctospirifer transversa.* Plummer, Texas Univ. Pub. 4329, p. 43, 53, 71, 74, 142, pl. 14, figs. 4a–c (Marble Falls formation, Big Saline formation, and Helms formation, Texas).

1954. *Punctospirifer transversa.* Dresser, Bull. Am. Paleontology, v. 35, no. 149, p. 63, pl. 7, figs. 1–6.

Pedicle valve.—Moderately convex and has greatest width along the hinge line. Umbo moderately high with the beak overhanging the interarea. Interarea prominent, nearly normal to the plane of commissure of the valves near the hinge line, but progressively sharply curved approaching the beak. The interarea is sharply delimited from the lateral flanks along margins which diverge from the beak at 140°. Sides of the delthyrium diverge at 35° from the beak and bear a groove along each interarea parallel with the delthyrial margins. A prominent and deep sulcus extends from the beak to a tonguelike extension at the anterior margin. A small specimen with very sharp ears is 22.3 mm wide, 8.7 mm long, and 6.7 mm high. Corresponding measurements of the largest specimen at hand are about 34 mm, 17 mm, and 12 mm.

Internally the hinge teeth are short and rounded but prominently developed. They are supported by husky dental lamellae which extend about 4 mm out on the floor of the valve. A high median septum extends up into the beak 6 mm from a solid mass of stereoplasm which fills the space between the dental lamellae and under the delthyrial opening.

Brachial valve.—Valve evenly convex with a low umbo. The beak overhangs the interarea slightly. The interarea is only about 1 mm wide and is in the plane of commissure. It is divided by a broad notothyrium whose margins diverge at 130° and whose apex at the beak is truncated. The fold is prominent and flat topped, extending from the beak to the margin.

Internally the cardinal process is a large multilobate structure with two smooth lower shafts which each separate into four small club-shaped strands. The two groups are divided by a separate, slightly larger, median strand. Sockets are long troughlike depressions running into the beak and bounded medially by heavy socket plates. The slightly excavated medial surfaces of the socket plates leave a ridge on the inner dorsal edges of the plates. The complete cardinalia form a heavy mass supported by strong ridges resembling crural lamellae. These ridges are short under the cardinalia but have long, lower, massive extensions on the floor of the valve, which tend to loop around the brachial adductor muscle scars. A median septum originates about 2 mm anterior to the hinge plate and extends almost to the anterior edge of the valve but is always very short.

Ornamentation.—Generally has about 12 prominent rounded plications with narrow interspaces occupying each side of the pedicle valve. The plications bounding the sulcus diverge at 25° and are considerably stronger and higher than are the other plications. The first four radiate from the beak, but the others originate along the cardinal margins. The flat floor of the sulcus is interrupted along its anterior half by a low broad plication. Plications of the brachial valve alternate with those of the pedicle valve so that interspaces bounding the fold are deeper and broader than are other interspaces. The flat top of the fold is incised along its anterior half by a slight longitudinal groove.

When exceptionally well preserved, the plications of both valves are covered with characteristic sculpture. Concentric laminae loop up and posteriorly over each plication to give a distinctive chevronlike design in which 7 to 9 laminae occur in 2 mm over the anterior parts of the valves, but laminae are more closely spaced posteriorly. Each lamina becomes separated into tubular frills along its outer edge. Although the tubules at first are fused together, they ultimately separate into minute spinules of unknown length. Accessory spinules also arise obliquely from the upper surfaces of laminae so that they make a mat of spinules near the ears where laminae diverge, or they protrude between laminae along the main body of the valve. From 10 to 15 spinules occur in 1 mm.

The interareas are minutely striated laterally and vertically, and one may see a reticulated pattern in exceptionally well preserved specimens. Very prominent and large punctae are arranged in rows along the bases of laminae. About 6 punctae occur in 1 mm.

Comparison.—This species is characterized by the acute angle at the ears, approximately 12 plications on each flank, and the presence of a plication in the sulcus and a groove on the fold.

Punctospirifer transversus differs from *Reticulariina spinosa* (Norwood and Pratten) in having more plications, sharp ears, and a much greater size. Well-preserved examples of both species have spinose surface, but the spines of *R. spinosa* are large and relatively sparse.

Material.—15 specimens. Hypotypes, USNM 118817 A–D, 118818, and 118819. Other specimens in USGS collections.

Occurrence. — Heath formation, localities 13359, 13414, and 13425. Cameron Creek formation, localities 13382, and 13420. Alaska Bench limestone, locality 13372.

Remarks.—In nature of minute surface ornamentation, *Punctospirifer transversus* is closely allied with *P. kentuckiensis.* Moreover, both of these species have a distinct groove on the fold and a plication in the sulcus, or at least have notched lamellar patterns indicating the presence of a groove or plication. The genotype of *Punctospirifer* differs from these two species in having an evenly rounded fold and sulcus without a groove or plication. Moreover, there is no record of minute spines on the genotype but it is still possible that they might be present in superior material. As Paeckelmann (1931, p. 51) has already observed, spiriferellinid brachiopods seem always to have minute spines or papillae. *P. transversus* also differs from the genotype in having stereoplasm in the pedicle cavity, but this development is generally considered to be a feature connected with individual old age, although Muir-Wood (1927, p. 291) considered it to be of racial old age.

Even though differences seem to separate these American species from *Punctospirifer*, a more exhaustive study of material is needed before a revision of names is warranted.

Genus **RETICULARIINA** Fredericks, 1916

1914. *Spiriferina* [in part]. Weller, Illinois Geol. Survey Mon. 1, p. 291. (followed by most American authors until 1944).
1916. *Reticulariina* Fredericks, Russia, Geol. Kom. Trudy, novaia ser., v. 156, p. 15, 16.
1924. *Reticulariina*. Fredericks, U.S.S.R., Geol. Kom. Izv. 1919, v. 38, no. 3, p. 298.
1926. *Reticulariina*. Fredericks, Akad. Nauk SSSR, Izv., ser. 6, v. 20, nos. 5, 6, p. 409.
1931. *Punctospirifer* [in part]. Paeckelmann, Neues Jahrb., Beilage-Band 67, Abt. B, p. 51 (as a subgenus, at the most).
1944. *Reticulariina*. Cooper *in* Shimer and Shrock, Index fossils of North America, p. 361.
1944. *Reticulariina*. Reed, India Geol. Survey Mem., Palaeontologia Indica, n. ser., v. 23, mem. 2, p. 251.
1954. *Reticulariina*. Stehli, Am. Mus. Nat. History Bull., v. 105, art 3, p. 345.

Diagnosis.—Punctate spiriferinids with coarse plications on the flanks, a long hinge line, prominent and rounded interarea, sulcus on pedicle valve and a fold on the brachial valve. Coarse spines are rather irregularly distributed over the nearly smooth surface but papillae may also be present. A few distinct chevron-like concentric lamellae occur. Internally dental lamellae are prominent, the median septum of the pedicle valve is high but short, brachial socket plates are ridgelike, the cardinal process is distinct, and at most only a very low median ridge is present in the brachial valve.

Remarks.—Fredericks (1916, p. 14, 21) divided the Spiriferidae into three groups on the basis of sculpture of the surface. Of these, group C was called the Fimbriatae and was in turn divided into two subsidiary groups called Unicispinae and Duplicispinae, according to whether the spines were single- or double-barrelled. It is to these groups that Fredericks referred in the abbreviations preceding his diagnosis of *Recticulariina.*

Original diagnosis.— C. *us.* [group C, subgroup *unicispinae*] *Reticulariina* nov. nom. Representatives described under the name *Spiriferina* possess decorations of concentric rows of single-shafted tubes. (Trigonotreta-like, but spinose.) (Type specimen) *Reticulariina* (*Spiriferina*) *spinosa* Norvood [sic] and Pratten [4]). (Translation by the writer of diagnosis in Russian by Fredericks, 1916, p. 16. His footnote 4 is to references.)

Fredericks did not make it clear that he was erecting *Reticulariina* as a new genus. In fact, from the form of his citation of the genotype it looks as if *Spiriferina* is meant to be a subgenus of the new name *Reticulariina*, in which case he would have made the generic name *Reticulariina* unavailable from that date. However, study of other instances in which he cites some name as if it were a subgenus demonstrates that he merely put a name in parentheses as a form of parallel construction. For instance, he cites "*Oldhamina* (*Lyttonia*)" on pages 74 and 76, but clearly indicates on page 61 that he thinks the names are equivalent; he cites "*Keyserlingina* (*Parakeyserlingina*)" on page 67, yet shows both as genera on page 61. Admittedly, his intent can be argued, so nomenclatural difficulty may arise over his indefinite handling of names. If, as the writer believes, Fredericks did not intend to imply by use of parentheses that *Reticulariina* is a subgenus, then neither is *Parakeyserlingina* (in which case *Parakeyserlingina* is a synonym of *Keyserlingina*). Not having translated his entire publication of 1916, the writer has no general gauge to Fredericks' nomenclatural technique, but from context is satisfied that *Reticulariina* was not improperly erected.

Reticulariina and *Punctospirifer* are not sharply differentiated. It is likely that no matter what identifying difference is suggested intermediate stages can be found that will make discrimination of this character arbitrary. The common presence of spines on punctate spiriferoids is becoming more widely recognized than it formerly was. *Reticulariina spinosa* has coarse spines, of which 4 or 5 ordinarily occur in an irregular row directly down the limbs of the dorsal fold, whereas *Punctospirifer transversus* has perhaps three times as many spines in discrete rows.

Paeckelmann's opinion (1931, p. 51) that *Reticulariina* is at best only a subgenus of *Punctospirifer* has a certain appeal, particularly when one wishes to refer generally to punctate spiriferinids, but even if this idea were formally adopted, it would have to be that *Punctospirifer* would be a subgenus of *Reticulariina* in order to give generic status to the prior name.

Reticulariina spinosa (Norwood and Pratten, 1855)

Plate 10, figures 12–16

1855. *Spirifer spinosus* Norwood and Pratten, Acad. Nat. Sci. (Philadelphia) Jour., ser. 2, v. 3, p. 71, pl. 9, figs. 1a–d. (Near top of Mountain limestone, Illinois and Missouri).

?1856. [not] *Spiriferina spinosa*. Hall, Albany Inst. Trans., v. 4, p. 8, [=*S. norwoodana*?]. (Warsaw limestone, Indiana and Illinois).

1858. *Spirifer spinosus* Hall, Geol. Survey of Iowa Rept., v. 1, pt. 2, Palaeontology, p. 706, pl. 27, figs. 5a–c. (Kaskaskia limestone, Illinois and Kentucky).

1883. *Spiriferina spinosa*. Hall, New York State Geologist Rept. (1882), pl. 60, figs. 26–29. (Chester limestone, Illinois).

1884. *Spiriferina cristata* [in part]. Walcott, U.S. Geol. Survey Mon. 8, p. 218, pl. 18, fig. 12 (not fig. 13). (Chester limestone, Illinois).

1891. not *Spiriferina spinosa*. Herrick, Geol. Soc. America Bull., v. 2, p. 46, pl. 1, fig. 19 (Keokuk group, Ohio). [=*S. depressa*?].

1893. *Spiriferina spinosa*. Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 52–54 (advance distribution).

1894. *Spiriferina spinosa*. Hall and Clarke, New York State Geologist Ann. Rept. 13 (1893), pl. 31, figs. 4–7. (Chester limestone, Illinois).

1894. *Spiriferina spinosa*. Hall and Clarke, Introduction to the study of the Brachiopoda, pt. 2, pl. 31, figs. 4–7. (Chester limestone, Illinois).

1895. *Spiriferina spinosa*. Keyes, Missouri Geol. Survey, v. 5, p. 85. (Kaskaskia limestone, Missouri).

1895. *Spiriferina spinosa*. Hall and Clarke, New York Geol. Survey, Paleontology, v. 8, pt. 2, p. 52–54, pl. 35, figs. 26–29. (Chester limestone, Illinois).

1900. *Spiriferina spinosa*. Lane and Cooper, Michigan Geol. Survey, v. 7, pt. 2, p. 301. (Maxville limestone, Michigan).

1903. *Spiriferina spinosa*. Girty, U.S. Geol. Survey Prof. Paper 16, p. 397–400.

1909. *Spiriferina spinosa*. Grabau and Shimer, North American index fossils, p. 314, fig. 395 (left fig.). (Kaskaskia of Kentucky, Indiana, and Illinois; Carboniferous of Nevada).

1914. *Spiriferina spinosa*. Weller, Illinois Geol. Survey Mon. 1, p. 299, pl. 35, figs. 50–58. (Chester series, Mississippi Valley).

1915. *Spiriferina spinosa*. Girty, U.S. Geol. Survey Bull. 593, p. 66, pl. 4, fig. 9. (Batesville sandstone, Arkansas).

1915. *Spiriferina spinosa*. Snider, Oklahoma Geol. Survey Bull. 24, p. 93. (Mayes, Fayetteville, and Pitkin formations, Oklahoma).

1916. *Reticulariina spinosa*. Fredericks, Geol. Kom. Trudy, novaia ser., vyp. 156, p. 16. [designated genotype of *Reticulariina*].

1917. *Spiriferina spinosa*. Butts, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 77, 93, 99, 108, 111, 115, pl. 23, figs. 12–14. (Chester group, Kentucky).

1917. *Spiriferina spinosa*. Ulrich, Kentucky Geol. Survey, Mississippian series in western Kentucky, p. 96, 121, 134, (aff.), 141 (var.), 150, 153, 175, 221, 229, 236. (Ste. Genevieve limestone and Chester series, Kentucky and Illinois.)

1918. *Spiriferina spinosa*. E. B. Branson, Missouri Univ. Bull., v. 19, no. 15, p. 104, pl. 5, figs. 14, 15. (Chester limestone, Missouri).

1918. *Spiriferina browni*. E. B. Branson and Greger, Geol. Soc. America Bull. v. 29, p. 312, 316, pl. 18, figs. 15, 17. (Amsden formation, Wyoming).

1920. *Spiriferina spinosa*. North, Geol. Soc. London Quart. Jour., v. 76, pt. 2, p. 211.

1920. *Spiriferina spinosa*. Weller, Illinois Geol. Survey Bull. 41, p. 148, 158, 171–174, 182, 183, 185, 195, 196, 207, 215, 353, 354, pl. 8, figs. 15, 16. (Chester series, Illinois).

1926. [not] *Spiriferina spinosa*. Stoyanow, Am. Jour. Sci., ser. 5, v. 12, p. 317 [=*P. transversus*.]

1926. *Spiriferina spinosa*. Butts, Alabama Geol. Survey, Spec. Rept. 14, p. 197, 198, 203, 204, pl. 65, figs. 18, 19. (Gasper formation and Floyd shale, Alabama).

1930. *Spiriferina spinosa*. Morse, Mississippi Geol. Survey Bull. 23, p. 119, 126, 127, 154, 170, pl. 16, figs. 5–8. (Southward Pond formation and Forest Grove formation of Mississippi and Alabama).

1931. *Spiriferina spinosa*. Weller, Kentucky Geol. Survey, ser. 6, v. 36, p. 280, pl. 39, figs. 3a–c. (Ste. Genevieve limestone and Chester series, Kentucky).

1931. *Spirifer spinosus*. Paeckelmann, Neues Jahrb., Beilage-Band 67, Abt. B., p. 51. [Placed in *Punctospirifer* and mentioned as genotype of *Reticulariina*].

1935. *Spiriferina spinosa*. Hernon, Jour. Paleontology, v. 9, no. 8, p. 658. (Sixth and Seventh members of the Paradise formation, Arizona).

1937. *Punctospirifer browni*. C. C. Branson, Jour. Paleontology, v. 11, no. 8, p. 652. (Sacajawea formation, Wyoming).

1944. *Reticulariina spinosa*. Cooper *in* Shimer and Shrock, Index fossils of North America, p. 361, pl. 141, figs. 9–13. (Chester series of Kentucky, Tennessee, Alabama, and Illinois).

Pedicle valve.—Valve nearly pyramidal with a prominent beak overhanging the interarea. Interarea high, curved, and fairly well delimited laterally from the flanks by angular margins which diverge at 120° from the beak. Delthyrium higher than wide, with margins which diverge from the apex at 40°. A groove lies just at the edge of each delthyrial margin. The shell is generally widest at the rounded cardinal extremities just anterior to the hinge line, but specimens with pointed ears exist. A deep round-floored sulcus starts at the beak and terminates anteriorly in a round-margined tonguelike extension. A large specimen is 15.2 mm long, 14.5 mm wide at the hinge line, 17.1 mm wide at the greatest width, 8.0 mm high, and the two valves together are 15 mm high.

Internally the long stout teeth are supported by slender dental lamellae with concave anterior edges which do not extend beyond the hinge line. A very high slender median septum extends two-thirds of the way toward the delthyrial opening and reaches a height of 2 mm at a distance of 3.5 mm from the beak, at which distance its anterior edge descends vertically to the floor of the valve. Only a very slight apical callous is visible, even in very old specimens.

Brachial valve.—Convexity is about the same as that of the pedicle valve, but the beak is short and inconspicuous, extending only a short distance over the interarea. A very high, narrow, round-topped fold extends the length of the valve. The interarea is very low, being less than 1 mm high. It is interrupted medially by a broadly triangular notothyrium.

Internally the cardinal process is small and gobletlike, with a few minute tubercles on its distal surface. Socket grooves which diverge from the beak widen anteriorly and are bounded on the medial sides by prominent socket plates. Horizontal shell-like flanges extend medially from the inner brachial edges of the socket plates and widen posteriorly to where they fuse beneath the cardinal process. These flanges are most distinct in oldest specimens. A pair of strong rounded ridges diverge from beneath the cardinalia and extend forward along the margins of the fold, dying out about 4 mm anterior to their origins. A very faint median ridge extends from the cardinalia most of the way to the margin in some specimens.

Ornamentation.—Five or 6 round-topped plications lie on the flanks of each valve, alternating with grooves of the opposite valve. The pair of plications which bound the sulcus of the pedicle valve diverge at 25° and are disproportionately stronger than the other plications. Accordingly, the grooves on the margins of the brachial fold are exceptionally deep and wide as compared with the remaining grooves.

Plications of both valves are crossed by irregularly disposed lamellose growth lines which loop posteriorly over the plications to make a chevronlike pattern. About 3 or 4 lamellae occur in 2 mm over most of the shell. On an old individual the lamellae were superimposed along the anterior margins as the shell added layers of new material but did not increase in length. Prominent punctae occur 6 or 7 in 1 mm in rows parallel with the margins of the lamellae. No spines were observed.

Comparison.—This species is characterized by being generally less than 20 mm wide, by often having rounded cardinal extremities, by having only about 6 plications on each flank, by moderate convexity, by the rounded, nonplicate, moderately high fold, and by the nonplicate sulcus.

Reticulariina spinosa differs from *Punctospirifer transversus* (McChesney), with which it is associated in the faunas from Montana, in having fewer plications, shorter hinge line, fewer lamellae, and rounded fold and sulcus.

Differentiation of some western shells resembling *R. spinosa* is often very difficult, as others have commented (White, 1877, p. 140; Girty, 1903, p. 396–400). *Spiriferina spinosa* var. *campestris* White, 1874, was described to accommodate some Pennsylvanian brachiopods like *R. spinosa*, but which lack the minute spines. Later on Meek (1877, p. 85) described *Spiriferina gonionota* for shells characterized by being "larger and more robust and more gibbous" than *Spiriferina* [*Punctospirifer*] *kentuckiensis* Shumard, and "in having its mesial fold *much* more elevated" than either *S. kentuckiensis* or *S. octoplicata* Sowerby. From study of hypotypes of *S. campestris* White (one of which he figured as *S. octoplicata* (White, 1877, pl. 10, figs. 8b, c)) and the type of *S. gonionota* Meek, the writer is convinced that they are the same species and that they are properly referable to *Reticulariina*. *Reticulariina campestris* is characterized by being ordinarily more than 20 mm wide, having the greatest width at the hinge line, commonly being quite tumid, having the brachial fold quite high and round-topped, having 6 plications on each flank, and having the surfaces of both valves covered with coarse spines and occasional lamellae when very well preserved. The best illustration to date of the species is of the holotype of *R. gonionota* (USNM 14459) which has lost the pointed ears and surface sculpture but has the shape, size, and high brachial fold of the species.

Material.—35 specimens. Hypotypes, USNM 118820 and 118821 A, B, C, D. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13414, 13416, and 13424. Cameron Creek formation, locality 13363. Alaska Bench limestone, locality 13389.

Remarks.—The types of *R. browni* (one of the junior synonyms of *R. spinosa*) are not very well preserved, but the writer has seen additional specimens of the species in the collections of the U.S. National Museum (Keyte collection) which prove conclusively that this is a *Reticulariina.*

Family RHYNCHOSPIRIDAE

Genus EUMETRIA Hall, 1864

Diagnosis.—Small, triangular, punctate, biconvex brachiopods with radial costae. Foramen touches apex of delthyrium. Cardinal area small. Dental lamellae lacking. Complex hinge structure of brachial valve is supported by two lamellae, spiralia and yoke are present, median septum lacking.

Comparison.—*Eumetria* is generally larger and has finer costae than has *Hustedia*, but otherwise the genera are externally alike. *Hustedia* has a median septum in the brachial valve and a tube lying along the inner surface of the pseudodeltidium, but both of these structures are lacking in *Eumetria.*

Eumetria cf. E. vera (Hall), 1858

Plate 10, figure 5

1914. *Eumetria vera.* Weller, Illinois Geol. Survey Mon. 1, p. 444, pl. 76, figs. 13–17. (Chester series of Mississippi valley basin.)

Pedicle valve.—Small and quite convex, with a prominent enrolled beak bearing a large circular foramen which touches the apex of the deltidial plates. Umbonal flanks diverge at about 60°. The figured specimen is 9 mm long and 7.5 mm wide at its greatest length about three-fourths of the length of the valve.

Internal structure not seen.

Brachial valve.—Moderately convex with a low umbo. Hinge line straight, 2 mm long.

Internal features not seen, but, by elimination, the specimens studied can belong to no described genus other than *Eumetria* and presumably have the internal features described above.

Ornamentation.—Both valves are covered with almost semicircular costae separated by narrow sharply indented interspaces. About 44 costae occur on each valve, but the exact number is hard to determine because the costae become exceedingly fine on the flanks. The shell substance is punctate.

Comparison.—This species is characterized by the fine costae, the greatest width being anterior to midlength, and the low convexity.

Eumetria verneuiliana (Hall) is exceedingly similar to *E. vera*, but is more convex and has the greatest width at midlength. Both species may have the same number of costae, although *E. verneuiliana* may have as many as 55 costae.

Material.—8 specimens. Figured specimen, USNM 118822. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13390.

Remarks.—The specimens at hand are somewhat crushed and are all smaller than typical *E. vera. E. vera* has been reported from Illinois, Kentucky, Arkansas, and Arizona.

Superfamily DALMANELLACEA

Family SCHIZOPHORIIDAE

Genus SCHIZOPHORIA King, 1850

Remarks.—*Schizophoria* can be confused with *Rhipidomella* and with *Orthotichia.* It differs from the latter genus only by having a median ridge in the pedicle valve instead of having a median septum; the two genera are seemingly gradational, if actually distinct. *Schizophoria* can be distinguished externally from *Rhipidomella* in being generally wider than long and in having a long hinge line with distinct interareas and a shallow sulcus in the pedicle valve, whereas *Rhipidomella* is commonly triangular or subcircular, with the short hinge line bordered by very narrow interareas and without a sulcus in the pedicle valve. Details on the differentiation of these genera are available in Schuchert and Cooper (1932, p. 133–135, 143, 144), Dunbar and Condra (1932, p. 52–55), and Weller (1914, p. 147, 148, 161, 162).

Bond (1942, p. 286–287) restudied some European Tournaisian and Viséan Schizophoriidae and concluded that differentiation should be made on coarseness (as opposed to fineness) of ornament, angle of divergence of dental lamellae, shape of the fold in the anterior margin, and the nature of the interareas. Bond (1942, p. 248) considered size, presence of brachial sulcus, and attainment of obesity as generally of negligible value. The writer, however, uses all features for differentiation which appear to be useful at the present time. Differences among species of *Schizophoria* are so subtle that even distinctions based on consistent differences of size and of shape are valid.

Schizophoria depressa Easton, n. sp.

Plate 4, figures 19–23

1918. *Schizophoria swallovi?.* E. B. Branson and Greger, Geol. Soc. America Bull., v. 29, no. 2, p. 312, 313, 321, pl. 19, figs. 12, 13 (Amsden formation [=Sacajawea formation], Wyoming).

1937. *Schizophoria swallowi?.* C. C. Branson, Jour. Paleontology, v. 11, no. 8, p. 652.

Pedicle valve.—Slightly resupinate to flat shells with a broad and shallow sinus or no sinus, and with very slight anterior emargination, if any. Beak sharp, overhanging shell beyond hinge. Horizontally striate interarea at right angle to plane of commissure, except for portion near the beak which is sharply curved posteriorly. Lateral borders of interareas converge at 125° angle at the beak. Margins of delthyrium converge at about 40°.

Hinge line extends a trifle more than half of the width. Teeth thick and have triangular posterior faces and small accessory sockets on the anterior faces. Dental plates short, oblique to the floor of the valve, and diverging at 35° at the floor.

Brachial valve.—Shell not inflated; when viewed lengthwise its outline has straight lateral slopes which generally converge at angles of from 100° to 130° toward the slightly flattened midregion. No fold, sulcus, or emargination of the valve, but only a slight flattening on the anterior half. Interarea inclined to the plane of commissure at an angle of 70° but curves sharply toward the beak which overhangs the posterior edge. Lateral margins of the interarea converge to the beak at 140° to 160°. The outer margins of the notothyrium converge at 80°, but the sides of the notothyrial cavity formed by the posterior extensions of the brachiophores converge at 60°, thus leaving a posteriorly tapered shelf just inside the notothyrial cavity. The brachiophores are very stout but taper anteriorly into thin blades. Sockets are prominent, and fulcral plates are rudimentary, merely being deeply recessed ridges. The cardinal process varies from a mere oval nubbin to a multilobate myophore. The anterior margin may be evenly and broadly curved up into a fold or is straight across the midregion.

Ornamentation.—Minute surficial ornamentation is preserved on some specimens at hand (from locality 13387). Eight lirae occur in 2 mm and often every fourth or fifth one is enlarged and terminates in a spine. Extremely minute incremental lines cross the lirae transversely. Concentric ridges mark stages of growth. New lirae increase by splitting off from both sides of a strong lira but remain very fine for a long distance so that in some places the ornamentation consists of alternating coarse and fine lirae; or two fine ones may occur between strong lirae. Three or four punctae occur in the width of an average lira.

Comparison.—*S. depressa* is principally characterized by its low brachial valve, in which respect it differs from American Pennsylvanian species with which it might be confused.

Two rather distinct types of *Schizophoria* are known from Pennsylvanian strata in this country. One type is represented by *S. resupinoides* (Cox), 1857 and *S. oklahomae* Dunbar and Condra, 1932, both of which are large shells, measuring 5 cm or more in width. They can be differentiated from other species and between themselves by the nearly hemispherical brachial valve of *S. resupinoides* and by the flat pedicle valve of *S. oklahomae*. The other type is represented by *S. altirostris* (Mather), 1915 (including *S. texana* Girty, 1927)[4] which is only about 2 cm to 2.5 cm wide. The brachial valves of this species are very obese, the lateral slopes usually converging in profile at angles of 70° or 80° and rarely exceeding 90°. In contrast, the lateral slopes of the new species *S. depressa* converge at angles of 100° to 130°, and in all examples observed exceed 90°. Brachial valves of *S. depressa* have the interarea inclined 70° to the plane of commissure, whereas *S. altirostris* has the interarea in the plane of commissure. *S. depressa* has a very low broad fold at the anterior margin, whereas *S. altirostris* has a nearly semicircular fold.

Material.—61 specimens from Montana. Holotype, USNM 118746. Paratype, USNM 118745. Ideotypes, USNM 118747, 118748. Other specimens in USGS collections and University of Missouri 2647 (Branson and Greger, 1918).

Occurrence.—Otter formation, locality 13378. Heath formation, localities 13387 and 13412. Cameron Creek formation, localities 13362–13364, 13373, 13380, 13382, 13421, and 14220. Alaska Bench limestone, localities 13384 and 13398. Sacajawea formation of C. C. Branson (1936) of Wyoming.

Family RHIPIDOMELLIDAE

Genus RHIPIDOMELLA Oehlert, 1890

Diagnosis.—Nearly equivalved, generally elongate, biconvex orthids with the diductor muscle scars of the pedicle valve surrounding the adductor muscle scars.

Rhipidomella n. sp.

Plate 4, figures 29a–c

Description.—Shell small, about equally convex, and quadrate to elongate, with rather straight sides. The figured specimen is 11 mm long and 11 mm wide, but the other specimen is 11.5 mm long and 10.5 mm wide.

[4] Some new information is available about *Schizophoria altirostris* (Mather), which was originally described from a single pedicle valve. Girty assembled hundreds of specimens from strata likewise of Morrow age in Arkansas which are referable to this species. Specimens at hand from Girty's locality 1998 (mostly topotypes) show features of the brachial valve very well. Length and breadth are both from 15 to 17 mm and height is 5 or 6 mm. Lateral slopes converge at an angle of about 75°. A faint, narrow sulcus is commonly present and may extend near the beak. The anterior edge of the valve is slightly emarginated. Eight lirae occur in 2 mm at 1 cm from the beak; from 1 to 3 weak lirae occur between strong lirae. Concentric wrinkles are common. Brachiophore plates diverge at 60° in specimens from another Morrow locality. Brachial valves have their interareas in plane of commissure. Dental plates in specimens from this latter locality (2849) diverge at 65° to 70° and the median ridge separating muscle scars is low and broad. The anterior margin is folded up noticeably into a near semicircle.

The types of *Schizophoria texana* Girty are not available for restudy, but the figures and description, augmented by much comparative material of *S. altirostris,* convince the writer of the identity of the two species. *S. altirostris* is the prior name.

The pedicle valve has a deep and broad sulcus on the anterior half. Its beak is slightly protuberant over the prominent triangular interareas. The hinge line is about 4 mm long in both specimens. Interiors not seen.

The brachial valve is evenly convex without either a sulcus or a fold. Its beak is not prominent. Interiors not seen.

The surface is covered with punctae and about 70 radial lirae.

Comparison.—This species differs from *Perditocardinia dubia* (Hall) in being straight sided and quadrate instead of being triangular. *Rhipidomella carbonaria* from the Pennsylvanian system is wider than long and has prominent beaks in both valves.

Material.—2 specimens. Figured specimen, USNM 118900. Other specimen USNM 118901.

Occurrence.—Heath formation, localities 14102, 14103.

Remarks.—These specimens were referred to *Perditocardinia dubia* by Sloss (1946, p. 11). So far as the writer knows, this is the first report of *Rhipidomella* of Chester age in this country.

Superfamily TEREBRATULACEA

Family TEREBRATULIDAE

Genus GIRTYELLA Weller, 1911

1911. *Girtyella.* Weller, Jour. Geology, v. 19, no. 5, p. 442.
1914. *Girtyella.* Weller, Illinois Geol. Survey Mon. 1, p. 271.

Diagnosis.—Terebratuliform shells with a sulcus in both valves and commonly a median plication in the brachial sulcus. Pedicle valve with dental lamellae. Brachial valve with a concave cardinal plate supported by a median septum and by extra lamellae laterally at the sockets. Brachidium is short.

Comparison.—*Girtyella* has the external shape of *Dielasma* and *Dielasmoides*, from both of which genera it can only be differentiated surely because they lack a median septum in the brachial valve.

Girtyella woodworthi Clark, 1917

Plate 12, figures 1–7

1917. *Girtyella woodworthi.* Clark, Harvard Coll. Mus. Comp. Zoology Bull., v. 61, no. 9, p. 377, pl. 2, figs. 1–12; text figure 5 on p. 377. (Madison limestone [=Brazer limestone], Montana).
1932. *Girtyella wellsvillensis.* Gunnell, Am. Midland Naturalist, v. 13, no. 5, p. 292, pl. 27, figs. 18–21. (Brazer limestone, Utah).

Pedicle valve.—Valve longer than wide and rather convex with a sharply enrolled beak. Prominent slightly concave false interareas meet the umbonal slopes along rather sharp angles which diverge from the beak at 100°. A flattening of the middle of the valve becomes a broad shallow sulcus anteriorly and causes a definite reentrant of the rather squared off anterior margin. A shell of average size is 19 mm long, 16 mm wide, and 10.5 mm high.

Internally the dental lamellae are nearly parallel and extend anteriorly 4 mm to the edge of the hinge. Muscle scars consist of a very faint, flat-floored, median groove bounded by an exactly similar groove on each side. These latter scars diverge at 5°, extend about two-thirds of the length of the valve, and have a total width of 4 mm at their anterior ends.

Brachial valve.—The valve is oval and rather evenly convex, but not so high as is the pedicle valve. A broad, shallow, median sulcus occupies the anterior half of the valve.

Internally there is a short concave cardinal plate. It is supported by a prominent median septum which extends about half the length of the valve, and by two, short lateral lamellae which are almost horizontal. The laterally divergent margins of the cardinal plate join the inner ends of the lateral lamellae along a ridge which is continued anteriorly as the crura. The crura are almost circular near their origins, but as they curve toward the pedicle valve they become bladelike and terminate 2.0 mm anterior to the cardinal plate. A pair of narrow, elongate adductor muscle scars extend two-thirds of the length of the valve and bend away from each other midway along their extent to leave a lanceolate space, the posterior part of which is split by the descending end of the median septum.

Ornamentation.—The surface of both valves is almost smooth, except for minute concentric growth lines and for very conspicuous puncta which occur in slightly oblique rows numbering 18 puncta in 1 mm transversely and 14 puncta in 1 mm longitudinally. Considerable variation is seen in the nature of the sulcuses. Some valves have only faint sulcuses but in others they are quite prominent. Many specimens have a median plication of greater or less distinctiveness in the dorsal sulcus and have a corresponding pair of ridges divided by a prominent trough in the pedicle valve to interlock with the dorsal margin.

Comparison.—*Girtyella woodworthi* is characterized by its elongate shape, large size, and commonly developed plication in the sulcus of the brachial valve.

G. woodworthi is almost or more than twice as large as *G. turgida* (Hall), *G. intermedia* Weller, or *G. brevilobata* (Swallow) all of which it resembles in having a median plication in the sulcus of the brachial valve.

G. woodworthi is similar to *Cranaena occidentalis* Girty in external shape, but it has more pronounced sulcuses and a median internal brachial septum.

Material.—49 specimens. Hypotypes, USNM 118834 A–F. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 11367, 13370, 13393, 13409, 13413, 13414 and 13425.

Remarks.—Strata from which this species came are referable to the Brazer limestone and not to the Madison limestone, although Madison strata do occur at the head of Alder Gulch where Clark (1917, p. 377) made his collections.

Family CENTRONELLIDAE

Genus HAMBURGIA Weller, 1911

Diagnosis.—*Cranaena*-like brachiopods with a partially sessile, imperforate, cardinal plate.

Hamburgia? cf. H.? walteri (Branson, 1937)

Plate 12, figure 8

1937? *Selenella? walteri* Branson, Jour. Paleontology, v. 11, no. 8, p. 657, pl. 89, figs. 21, 22. (Sacajawea formation, Wyoming).

Description.—Shells subtriangular and biconvex but rather flattened. Surface smooth. No sulcus or fold present. Pedicle beak sharp, posteriorly directed, and with a flat false interarea on either side of a triangular delthyrium. No pedicle foramen. Dental lamellae short, thin, and slightly divergent anteriorly and pedically.

Brachial valve subequally convex with pedicle valve but with almost no beak. A cardinal plate without a perforation is clearly visible in one specimen. No median septum present. Traces of a centronelliform loop were seen.

The figured specimen, which is relatively large, is 4.0 mm long and 1.5 mm high.

Material.—18 specimens. Figured specimens USNM 118838 and 118839.

Occurrence.—Heath formation, locality 13414. Cameron Creek formation, locality 14226.

Remarks.—The specimens from Montana are closely similar to, if not conspecific with, the species *Selenella? walteri* from Wyoming. Definitive evidence as to the nature of the loop is lacking for the writer's specimens and even less is known about the species from Wyoming. The two do resemble each other in size, shape, and peculiar flat areas adjacent to the delthyria.

As Cloud (1942, p. 71) has already remarked, Mississippian species assigned to "*Selenella*" have characters of the pedicle beaks resembling immature shells. This remark applies equally well to the types of *S.? walteri* and to the specimens in the Heath formation. Presence of abundant small specimens and lack of anything that could be the adults of these specimens if they merely were immature individuals indicate to the writer that these are in actuality mature individuals.

Cloud (1942, p. 71) has observed that *Selenella* is inadequately known and is probably a junior synonym of some other generic name. Better evidence exists for reference of the specimens to *Hamburgia* than to *Selenella.* At least, nothing refutes this reference and the imperforate cardinal plate is strongly suggestive of it. If these are properly assigned to *Hamburgia*, then they constitute the latest known occurrence of that genus, which has hitherto been known from Devonian and Kinderhook (Mississippian) strata.

Family DIELASMATIDAE

Genus CRANAENA Hall and Clarke, 1893

1942. *Cranaena.* Cloud, Geol. Soc. America Spec. Paper 38, p. 132 (contains prior synonymy).

Diagnosis.—Shell small to moderately large, smooth, terebratuliform. Pedicle foramen typically permesothyrid [touches lip of delthyrium]. Cardinal plate free and perforate. Loop short, consisting of simple lateral bands joined by a short, posteroventrally recurved transverse band. Median septa absent. Dental plates present. (Cloud, 1942, p. 132).

Comparison.—*Cranaena* resembles *Dielasma*, *Dielasmoides*, and *Girtyella* externally. It differs from *Girtyella* internally, however, in lacking a median septum in the brachial valve, although it may have a low median ridge between areas of muscle attachment which simulates a median septum, and, in the specimens here discussed, even seems to develop into one true if short septum which does not, however, support the cardinal plate. *Dielasma* has extra lateral dorsal lamellae and a troughlike, median plate for muscle support in the brachial valve, and *Dielasmoides* has lamellae supporting the sockets; hence, both of these genera have divergent plates in the beak of the brachial valves which are lacking in *Cranaena.*

Occurrence.—*Cranaena* has been widely reported from rocks of Devonian and Mississippian age in various parts of the world.

Cranaena? circularis Easton, n. sp.

Plate 11, figures 19–21

Pedicle valve.—Valve broadly convex and low, becoming more convex at the umbo, the lateral flanks of which diverge at 80° from the sharply enrolled beak. The posterior margins diverge at 95° from the beak and along a sharp angle where the posterior surface is deflected over the flanks of the beak. The foramen is circular and encroaches slightly on the beak. The holotype is 14.3 mm long, 13.5 mm wide, and 6.2 mm thick.

Internally the dental lamellae are about vertical and diverge anteriorly, extending about 3 mm from the beak. A low ridge may connect their ends and thereby outline the anterior margin of the crural cavity. A very faint median ridge is sometimes visible on the floor of the crural cavity. Muscle scars are faint, elongate, narrow bands having a combined width of 3.5 mm at the anterior ends.

Brachial valve.—Very low broadly convex valves with a circular outline, except for the posterior margins which diverge at 130° from the low beak. Less convex than the pedicle valve. The holotype is 12.4 mm long.

Internally there is commonly a slight median ridge which may be obsolete or may rise into a thin but definite median septum, although it does not support the cardinal plate. An extremely faint pair of lateral ridges diverge from the beak and lie near the change of slope on the flanks. Adductor muscle scars are extremely faint narrow bands which curve slightly and extend about two-thirds of the length of the valve. The cardinal plate lies almost horizontal and seems to be short, but details are not observable.

Ornamentation.—There is no suggestion of either a fold or a sinus in either valve. Minute growth lines are visible, and occasionally a faint concentric wrinkle is present. Conspicuous puncta occur in oblique rows, with 15 to 18 punctae in 1 mm.

Comparison.—This species is readily identifiable because of its flatness, circular outline, and especially by absence of any sinus or other distinctive ornamentation.

Cranaena? circularis differs from *C. brazerianus* in being nearly circular and having very low convexity of both valves.

C.? circularis is easily distinguishable from *Girtyella woodworthi*, with which it is sometimes associated, because the latter is quite convex, elongate, and has a sulcus in both valves.

Material.—29 specimens. Holotype, USNM 118835. Paratype, USNM 118836. Ideotype, USNM 118837. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13375. Heath formation, localities 13359, 13370, 13414, and 13425 (type locality). Cameron Creek formation, locality 13361.

Remarks.—*C.? circularis* has a tendency to develop a median septum in the brachial valve, whereas *Cranaena* typically has only a very faint low ridge, at best. For this reason, the species is referred to *Cranaena* with a query.

If this species is retained in *Cranaena*, it is the youngest species assigned to that genus, so far as the writer knows.

Cranaena? n. sp.

Plate 11, figures 22, 23

Material.—24 specimens. Figured specimen USNM 118904. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 14227.

Remarks.—This species seems to have the internal structure of *Cranaena*, although the cardinal plate was not seen. Some specimens resemble *C.? circularis* Easton in being flattened, but all the specimens at hand are much smaller and generally more elongate than is that species. The figured specimen is 8.5 mm long, 5.4 mm wide, and 4.4 mm high. Some small shells only about 1 mm long are referred here doubtfully from this locality. The species is not described because no uncrushed specimens were collected and the nuances of shell shape are therefore unknown.

A pair of short dental lamellae and a faint median ridge in the brachial valve were observed in a specimen ground down at the beak.

ANNELIDA

Class CHAETOPODA

Genus SPIRORBIS Daudin, 1800

Spirorbis aff. S. moreyi C. Branson, 1937

Plate 12, figures 9–10

1937. *Spirorbis moreyi* C. Branson, Jour. Paleontology, v. 11, no. 8, p. 654, pl. 89, figs. 1, 2. (Sacajawea formation, Wyoming).

Shell of about 3½ volutions, attached at the apical portion through perhaps 3 volutions, leaving a surface modified to fit the host. Open end often twisted up at right angles to plane of coiling. Surface crossed by prominent growth lines which swing posteriorly at the midline and again into the umbilicus. Growth lines surmounted by or divided into conspicuous low nodes distributed so as to suggest their arrangement into longitudinal rows; about 25 or 30 nodes lie between the umbilicus and the plane of coiling. Diameter of shell about 1.5 mm.

Material.—39 specimens. Figured specimens, USNM 118840. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13390. Cameron Creek formation, locality 14226 (aff.).

Remarks.—These specimens resemble the original description of *S. moreyi* very closely, but the cotypes of that species before me do not show the longitudinal ribs mentioned for the species. Until additional material of *S. moreyi* comes to hand, it is not possible to evaluate the species.

Spirorbis sp.

Plate 12, figure 11

Shell with about two volutions, not perceptibly attached, and 2.5 mm in greatest diameter. Aperture elliptical. Surface covered with alternating flat-topped ridges and flat-troughed interspaces arranged transversely and directed backward, lying parallel with the apertural margin.

Material.—12 specimens. Figured specimen USNM 118841. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13387, 13395, and 13402.

Remarks.—Unidentifiable fragments attached to their hosts occur in the Heath formation at localities 13395 and 13402.

Genus CORNULITES Schlotheim, 1820

Cornulites sp.

Plate 12, figure 12

The best preserved of the attached, acute, conical shells referred here is 3.0 mm long. It is nontabulate but has several coarse swellings encircling it. The specimens are lodged between the ribs of a *Spirifer.*

Material.—5 specimens. Figured specimen USNM 118842. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13395.

MOLLUSCA

Class PELECYPODA

Order TAXODONTA

Superfamily NUCULACEA

Family NUCULIDAE

Genus NUCULOPSIS Girty, 1911

1911. *Nuculopsis* Girty, New York Acad. Sci. Annals, v. 21, p. 133.

1934. *Nuculopsis.* Schenck, Mus. royale histoire nat. Belgique Bull., v. 10, no 20, p. 29.

Remarks.—Schenck (1934) greatly emended Girty's original description, as a result of which work *Nuculopsis* is used for Paleozoic nuculids with a smooth ventral interior margin.

Subgenus PALAEONUCULA Quenstedt, 1930

1930. *Palaeonucula* Quenstedt, Geol. u. palaeont. Abh., n. ser., v. 18, pt. 1, p. 112

1934. *Palaeonucula.* Schenck, Mus. royale histoire nat. Belgique Bull., v. 10, no. 20, p. 35.

Diagnosis.—*Nuculopsis* with beaks slightly or not all opisthogyrate (turned posteriorly).

Nuculopsis (Palaeonucula) montanensis Easton, n. sp.

Plate 12, figures 13–16

Description.—Small *Nuculopsis* with subtriangular shells whose anterior margin is sharply rounded, ventral margin is broadly rounded, and whose posterior margin continues the ventral outline with increasing sharpness. The orthogyrate beaks are appressed over the convex cardinal margin. Escutcheon and lunule faintly outlined by ridges. The posterior margin protrudes slightly beyond the ridges delimiting the lunule. The chondrophore is slightly oblique and is bordered by about 10 to 13 anterior teeth and about 9 posterior teeth. Ornamentation consists of low concentric ribs with narrow interspaces. Ribs, which are continued onto the escutcheon but not onto the lunule except as faint growth lines, occur 16 or 17 in 2 mm. The average dimensions of 7 specimens are length 10.1 mm, height 8.5 mm, width of single valves 3.0 mm, and the shell margins diverge at about 77° from the beaks.

Comparison.—This species resembles *N. welleri* Schenck, 1939, in the posterior protrusion of the valve and in nature of ornamentation, but *N.* (*P.*) *montanensis* has less well-defined lunule and escutcheon, the ornamentation continues onto the escutcheon, and the ventral margin is more convex. *N. welleri* tends to be relatively elongate, being from 1.3 to 1.5 times as long as high.

The proportions of *N. montanensis* are rather like those of *N. okawensis* Schenck, 1939 (the former species is 1.19 times as long as wide, whereas the latter is 1.22 times as wide as high) but *N. okawensis* has coarser ornamentation, a straight instead of curved cardinal margin, and lacks the posterior extension of the shell.

Nuculopsis platynotus (Weller, 1920), is much more triangular than is this species.

Nuculopsis randolphensis (Weller, 1920), is very similar to *N. montanensis* in shape, size, and convexity, but lacks the anterior protrusion of the dorsal anterior margin beyond the main surface of the lunule.

Material.—9 specimens. Holotype, USNM 118843. Paratypes, USNM 118844 A–C. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13391 (type locality) and 13414.

Family NUCULANIDAE

Genus NUCULANA Link, 1807

1930. *Nuculana.* Stewart, Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 48.

Diagnosis.—Crescent-shaped equivalved shells with a rounded anterior margin, much produced posterior margin, opisthogyrate beaks which lie anterior of midlength, taxodont dentition with a posteriorly inclined chondrophore, a slight pallial sinus, usually with smooth interior margins, and usually with ornamentation of concentric ridges.

Remarks.—These shells were for many years known as *Leda.* Nomenclatural details are discussed in the single reference cited in the synonymy.

Nuculana biangulata Easton, n. sp.

Plate 12, figures 17, 18

Description.—Moderately large *Nuculana* whose average length is 1.84 times the height. Beaks notably enrolled and situated one-third of distance from the anterior margin. Lunulate and escutcheonal areas deeply indented and each set off by a sharp ridge which originates at the beak. A narrow and shallow sinus originates near the beak and is directed ventrally and slightly posteriorly. Surface covered with concentric ridges which occur 10 or 11 in 2 mm and do not extend onto the anterior or posterior indented areas.

The average dimensions of 11 single valves are 18.8 mm long, 10.2 mm high, and 3.5 mm wide. The corresponding measurements of the largest valve are 22.8 mm and 13.7 mm.

Internal features, aside from some faint taxodont teeth on one specimen, were not observed.

Comparison.—This species is characterized by its rather large size and two sharp ridges extending from the beak.

N. biangulata is similar to *Nuculana chesterensis* (Weller, 1920) in size and in ornamentation but Weller's species is proportionately shorter (the average length-to-height ratio of the 4 figured specimens being 1.38) and is not so sharply carinate near the beaks.

Other described species of *Nuculana* with which *N. biangulata* might be confused are all much smaller than it.

Material.—16 specimens. Holotype, USNM 118845, Paratype, USNM 118846. Other specimens in USGS collections.

Occurrence.—Cameron Creek formation, locality 13361.

Remarks.—The longest specimen of *Nuculana chesterensis* reported has a length-to-height ratio of 1.64, which is still less than the average of *N. biangulata*. It is very probable that the two species are closely related.

One specimen has a length-height ratio of 1.43, which is approximately that of *N. chesterensis*, but has the bicarinate beaks of *N. biangulata*.

Nuculana rugodorsata Easton, n. sp.

Plate 12, figures 20, 21

Description.—Small *Nuculana* with the beaks nearly orthogyrate and situated anterior to the midlength. Length-to-height ratio is 1.66. Escutcheonal area is deeply indented near the beaks, but is wide and rather flat posteriorly, except for the raised cardinal margins which extend along its midline; sides of the area are bordered by very strong carinae which extend dorsally and laterally, interrupting the even posterior convexity of the shell and to making the posterior flanks almost flat. Ornamentation is of low, convex, concentric ribs with distinct flat-bottomed interspaces, of which 12 occur in 2 mm near the ventral margin. Ribs extend anteriorly to the cardinal margin under the beaks but do not cross the escutcheonal area.

Internally the chondrophore is small and inclined vertically beneath the beaks. There are 21 taxodont teeth, of which 10 are anterior to the chondrophore. Posterior trace of the pallial line not seen.

The average dimensions of 11 specimens are 7.8 mm long, 4.7 mm high, and 3.6 mm wide (both valves). Corresponding measurements of the largest individual are 9.7 mm, 5.9 mm, and 4.5 mm.

Comparison.—This species is characterized by the remarkably strong ridge bounding the flat escutcheonal area.

Nuculana rugodorsata is much smaller than *N. biangulata* Easton and has a prominent ridge instead of just a sharp angle bounding the escutcheonal area.

Nuculana nasuta (Hall, 1856), and *N. curta* (Meek and Worthen, 1861), are similar in size and in ornamentation but have the beaks centrally or posteriorly located from midlength instead of being anterior.

Nuculana vaseyana (McChesney, 1860), is of the same size and beak arrangement as *N. rugodorsata* but lacks the prominent ridges of the latter species and has a median, internal, almost vertical ridge extending ventrally from the beaks.

Nuculana stevensiana (Girty, 1910), from the Fayetteville shale, is proportionately longer than this species and lacks the prominent carinae. It has a faint inner ridge under the umbo like *N. vaseyana.*

Material.—44 specimens. Holotype, USNM 118847, paratype, USNM 118848. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13391 (type locality) and 13414.

Nuculana sp. A

Plate 12, figure 19

Description.—This species has stronger concentric ornamentation than *Nuculana rugodorsata* and lacks the sharp umbonal ridges of that species. The specimen at hand is 12 mm long, 7.5 mm high, and has 6 or 7 concentric ridges in 2 mm near the ventral margin.

Material.—1 specimen, USNM 119964.

Occurrence.—Alaska Bench limestone, locality 13399.

Nuculana sp. B

Material.—1 specimen, in USGS collections.

Occurrence.—Otter formation, locality 14227.

Remarks.—This single specimen is about the same size as *Nuculana biangulata* but lacks the prominent ridge on each valve and is seemingly quite smooth. The specimen is not suitable for illustrating, being poorly preserved and incomplete.

Order ANISOMYARIA

Superfamily MYTILACEA

Family MYALINIDAE

Genus MYALINA de Koninck, 1842

Diagnosis.—Triangular to subovate shells which may develop a posterior auricle but always are distinctly oblique toward the nearly terminal beaks. Ligament principally opisthodetic. Generally anisomyarian muscle scars. Hinge commonly without teeth.

Subgenus MYALINA de Koninck, 1842

Diagnosis.—Thick-shelled *Myalina* with a distinct anterior lobe which may extend beyond the beaks.

Myalina (Myalina) parallela Easton, n. sp.

Plate 12, figure 22

Description.—Elongate *Myalina* with the posterior margin rounded until the dorsal and ventral margins are nearly parallel. The anterior lobe is wide and distinctly delimited by a sinus which merges with the broad median sulcus to make a reentrant on the ventral margin. Hinge line extends to about half the greatest length. Beaks almost hemispherical. Surface covered with edges of lamellae which only become free posteriorly.

The holotype is 23.5 mm in greatest length, 21.2 mm long parallel with the hinge, 13.2 mm high, 6.5 mm wide (single valve), and the hinge line is 12.3 mm long. Its posterior margin meets the dorsal margin at 148°, and the angle between the dorsal margin and the umbonal ridge in maturity is 40°. Ratios of greatest length to height and of length to thickness of a series of 5 left valves are 1.63 and 3.58, respectively.

During growth, the species increases the umbonal angle and proportionately increases the length and shortens the hinge line.

Internal features are not visible.

Comparison.—*Myalina* (*Myalina*) *parallela* is characterized by the subparallel posterior margins.

Myalina illinoisensis Worthen, 1884, is similar to *M. parallela* but has a proportionately longer hinge line and a less well-developed median sulcus.

M. parallela differs from *Septimyalina* by having a prominent anterior lobe and by lacking the internal decklike plate of *Septimyalina*.

Material.—20 specimens. Holotype, USNM 118849. Paratypes, USNM 118850. Other specimens in USGS collection.

Occurrence.—Otter formation, locality 13426 (type locality). Heath formation, localities 13392 and 13413 (cf.).

Remarks.—The anterior lobe extends beyond the beaks, which is a condition not known in *Promytilus* Newell, 1942, but otherwise this species cannot be differentiated from *Promytilus* on external features alone.

Subgenus ORTHOMYALINA Newell, 1942

1942. *Orthomyalina.* Newell, Kansas Geol. Survey, v. 10, pt. 2, p. 56.

Diagnosis.—Subquadrate *Myalina* with the axis of the shell normal to the hinge line. Shell substance is generally thick. Muscle scars near posteroventral margin.

Myalina (Orthomyalina) sp.

Plate 12, figure 27

Description.—The single specimen resembles *Myalina sancto-ludovici* Worthen, 1873 in general proportions but has the beaks more nearly normal to the hinge line. The surface is covered with broad concentric wrinkles. No anterior lobe present. Muscle scars indefinite.

Material.—1 specimen, USNM 118851.

Occurrence.—Cameron Creek formation, locality 13421.

Remarks.—This is the oldest species of the subgenus *Orthomyalina* so far reported, the others ranging from the Des Moines through the Wolfcamp groups, according to Newell (1942, p. 56).

Genus SEPTIMYALINA Newell, 1942

1942. *Septimyalina.* Newell, Kansas Geol. Survey, v. 10, pt. 2, p. 64.

Myalina in part of authors.

Diagnosis.—*Myalina*-like shells with an internally decked-over umbonal cavity.

Septimyalina n. sp.

Plate 12, figures 23–25

1918. *Myalina sancti-ludovici.* E. B. Branson and Greger, Geol. Soc. America Bull., v. 29, no. 2, p. 322, pl. 19, fig. 26. (Amsden formation, Montana). (Not *M. St. Ludovici* Worthen, 1873).

1937. *Myalina sancti-ludovici.* C. C. Branson, Jour. Paleontology, v. 11, no. 8, p. 652. (Sacajawea formation, Wyoming).

Description.—Small shells with prominently ridged umbones and an almost obsolete anterior lobe. The cardinal margin extends half the length of the shell and is met at an angle of 130° by the posterior margin. The angle between the ventral and anterior cardinal margin is 50° and the angle between the cardinal margin and the umbonal ridge is about 55° to 60°. Ventral surface flat and at right angle to plane of commissure. Length 20 mm, height 15 mm. Surface covered with protuberant lamellae.

Internally the umbonal plate is short, thick, and rounded. Teeth are almost obsolete ridges nearly parallel with shell margins. Other internal details not seen.

Comparison.—This species resembles *Myalina compressa* Snider, 1915, somewhat but has a shorter hinge line.

Material.—9 specimens. Figured specimens USNM 118852 A, B, and University of Missouri 2658. Other material in USGS collections.

Occurrence. — Otter formation, locality 13375?. Heath formation, locality 13392. Cameron Creek formation, locality 13363. Sacajawea formation (C. C. Branson, 1936) Wyoming.

Remarks.—Only one good specimen is available; so naming of a new species among these highly variable creatures is not warranted on this material. *Myalina sancti-ludovici* Worthen is a large, nearly orthocline shell which is seemingly correctly referred to *Myalina.*

Superfamily PECTINACEA

Family AVICULOPECTINIDAE

Genus AVICULOPECTEN McCoy, 1851, amend. Newell, 1937

1937. *Aviculopecten.* Newell, Kansas Geol. Survey, v. 10, pt. 1, p. 43–46.

Diagnosis.—Erect to oblique pectinoids with the right valve less convex than the left and ornamented with subequally strong costae which increase by implantation. Costae on left valve increase by bifurcation. Right valve with concentric ornamentation on the ears only.

Remarks.—Newell (1937) has presented an exhaustive account of some Paleozoic pectinoids from which systematic and morphologic details can be obtained.

Aviculopecten? sp.

Plate 12, figures 31, 32

Lacking adequate material, the writer has been unable to identify the following species more closely than as *Aviculopecten?* sp. The largest specimen is 4 cm high.

Material.—33 specimens. Figured specimens USNM 118853 and 118854. Other material in USGS collections.

Occurrence.—Heath formation, localities 13367, 13402, 13413, 13414, and 13425. Cameron Creek formation, localities 13361, 13362, and 13382.

Genus LIMIPECTEN Girty, 1904

1904. *Limipecten* Girty, U.S. Natl. Mus. Proc., v. 27, p. 721.
1937. *Limipecten.* Newell, Kansas Geol. Survey, v. 10, pt. 1, p. 67.

Diagnosis.—Like *Aviculopecten* but with intercalated costae on both valves and with chevronlike concentric lamellae crossing the costae.

Remarks.—*Acanthopecten* resembles *Limipecten* in ornamentation but has very strong costae of about equal strength.

Limipecten otterensis Easton, n. sp.

Plate 12, figures 28–30

Description.—Shells of moderate size with very slight forward obliquity. Internal molds reflect external ornamentation.

A left valve 28 mm long has a hinge line 21.5 mm long. The posterior ear is sharply pointed, concave posteriorly, and bears about 15 radial costae intersected by almost equally spaced concentric lirae to give a reticulated pattern. Anterior ear set off by a shallow byssal notch and bearing about 10 costae in addition to concentric lirae. Ears not sharply differentiated from rest of shell. Main portion of the valve bears about 6 rounded costae in 5 mm alternating with wide flat-floored interspaces which each bears a low costa. Sharp lamellae which occur 6 in 2 mm, loop up and dorsally over both orders of costae, forming curved flanges which project farther on the costae than on the interspaces.

Right valve similar to left valve but with costae subequal size and less strong, and with much weaker concentric lamellae.

The right valve of a paratype is 19 mm along the hinge line, 16.5 mm long, and 16 mm high. Two left valves are 27 and 18 mm along the hinge line and 32 and 22 mm high.

Comparison.—This species is characterized by the lack of ventral angularity of lamellae in the interspaces and by the wide interspaces.

Limipecten wewokanus Newell, 1937, from the Lower Pennsylvanian, has much narrower interspaces than this species has.

Limipecten docens (McCoy), the only other species known to the writer from the Lower Carboniferous (of England), also lacks the broad interspaces of *L. otterensis*, and the ventral sags of the lamellae are pointed instead of rounded.

Material.—24 specimens. Holotype, USNM 118855. Paratype, 118856 A, B. Other specimens in USGS collections.

Occurrence.—Otter formation, localities 13374 and 14227.

577887 O—61——5

Remarks.—This is the earliest species of *Limipecten* yet described from North America, the others being of Pennsylvanian and Permian age.

Although the specimens are all flattened and too few are complete enough to enable statistical study, the singular nature and early appearance of the species enable its differentiation from other species of the genus.

Lamellar patterns in this species are more like those of *Limipecten* than of *Aviculopecten*. In the latter genus lamellae may protrude over costae as in *L. otterensis*, but the intercostal trace is straight or even dorsally curved, whereas in *Limipecten* the trace is ventrally curved or even acutely angular. Actually, the genotype of *Limipecten* (*L. texanus* Girty) before me has some curved and some angular lamellae, but all are ventrally directed.

Superfamily PINNACEA

Family PINNIDAE

Genus SULCATOPINNA Hyatt, 1892

1892. *Sulcatopinna* Hyatt, Boston Soc. Nat. History Proc., v. 25, p. 341.
1915. *Sulcatipinna.* Girty, U.S. Geol. Survey Bull. 593, p. 87.

Original diagnosis.—*Sulcatopinna* is a new genus proposed for those Carboniferous forms having extremely elongated shells, like *Aviculopinna*, with a straight hinge line, umbones approximately terminal, valves ridged on the dorsal area. (Hyatt, 1892, p. 341).

Remarks.—The sulcus for which the genus was named extends along the cardinal margin but is commonly separated therefrom by a convex area also parallel with the cardinal margin. Similar features are not only also known in *Aviculopinna* but may be absent in both genera.

Sulcatopinna is really characterized by the presence of radial ridges on its surface, and *Aviculopinna* has only concentric wrinkles and growth lines.

Sulcatopinna ludlovi (Whitfield, 1876)

Plate 13, figure 6

1876. *Pinna Ludlovi* Whitfield *in* Ludlow, Report of reconnaissance from Carroll, Montana Territory, on the upper Missouri, to the Yellowstone National Park and return, etc.: War Department, p. 113, 142, pl. 1, figs. 6, 7, [quarto]. (Limestones of Coal Measures [Big Snowy group]).
1876. *Pinna Ludlovi.* Whitfield *in* Ludlow, U.S. War Dept. Chief Engineer's Ann. Rept. (1876), app. NN, p. 696, pl. 1, figs. 6, 7, [octavo]. (44th Cong., 2d sess., H. Ex. Doc. 1, pt. 2, v. 2, pt. 3). Reissued with different pagination, p 128, pl. 1, figs. 6, 7, [octavo]).
1892. *Sulcatopinna ludlovi.* Hyatt, Boston Soc. Nat. History Proc., v. 25, p. 342.
1909. *Sulcatipinna ludlowi.* Girty *in* Calvert, U.S. Geol. Survey Bull. 390, p. 18. (Quadrant formation).
1927. *Sulcatipinna ludlowi.* Girty, U.S. Geol. Survey Prof. Paper 152, p. 68. (Brazer limestone, Idaho).

Original description.—Shell elongate-triangular, very gradually increasing in width from the beaks toward the base; the dorsal and byssal margins diverging at an angle of but little more than twenty degrees. Dorsal margin straight, as long as, or longer than the body of the shell; basal margin, judging from the lines of growth, nearly at right angles to the dorsal margin for a short distance, then directed, with a rapidly increasing curvature, to the byssal border. Apex and umbones unknown. Surface of the valves angularly convex, the left one the most ventricose, and the angularity quite perceptible. Both valves are marked, except for a narrow space along the byssal margin, by numerous, very distinct, and somewhat flexuous radiating ribs, strongest in the middle of the shell, and decreasing in strength toward each margin; about twenty-two to twenty-four of the ribs may be counted across the middle of the shell on the specimen figured, most of which are marked along the middle by a distinctly-depressed line. Concentric lines distinctly marked and often forming undulations in crossing the radii. Evidence of minute, scattered, spine-like projections exists upon the surface of the radii. Transverse section across the closed valves angularly elliptical; the relative diameters about as one and two.

The strongly-radiated surface and duplicated ribs are features that will readily distinguish this from other described species.

Formation and locality.—In limestones of the Coal Measures, in the cañon of the Musselshell, Montana. (Whitfield *in* Ludlow, 1876, p. 143).

Comparison.—*Sulcatopinna ludlovi* is characterized by having grooves on the midline of most of the ribs.

Sulcatopinna missouriensis Swallow, 1862, which is common in the Chester seriês, is very similar to this species in size and number of ribs, but has an apical angle of 15° instead of 20°, and has only some instead of most of the ribs grooved. The two species probably intergrade with each other through specimens such as that figured by Butts (1917, pl. 28, fig. 14) which have numerous grooved ribs but have an apical angle of 15°.

Material.—2 specimens. Holotype, Peabody Museum (Yale University) 6837. Other specimen in USGS collection.

Occurrence.—Heath formation, locality 13424. The types probably come from the Cameron Creek formation, or from the Alaska Bench limestone near Delpine in sec. 14, T. 9 N., R. 10 E., Meagher County, Mont.

Remarks.—The greatest length (almost complete) is 8.2 cm, and where the thickness is 17 mm, the height is 34 mm. Six grooved ribs occur in 1 cm near the anterior end.

Although it was hoped that reexamination of the fauna Dana and Grinnell (Ludlow, 1876, p. 113) cited as being associated with *Sulcatopinna ludlovi* would help identify the formation from which *S. ludlovi* came, it appears that the fossils might have come from almost anywhere in the Heath, Cameron Creek, or Alaska

Bench formations. Dr. Karl M. Waagé of Peabody Museum at Yale University made available the specimens accompanying the type of *Sulcatopinna ludlovi* and on which Whitfield based his faunal list. As identified by the author, these specimens are:

Aulopora sp.
Unidentified simple corals
Polypora sp.
Nix angulata
Echinoconchus angustus
"*Dictyoclostus*" *inflatus*
"*Dictyoclostus*" *inflatus* subsp. *spinolinearis*
"*Dictyoclostus*" *richardsi*
"*Buxtonia*" sp.
Unidentified brachiopod fragments
Sulcatopinna ludlovi

An original label accompanying the specimens reads "Musselshell Cañon a short distance from the Forks of the Musselshell. The limestone is very thick bedded." Limestone matrix attached to the type of *S. ludlovi* is light gray like that of the Cameron Creek and Alaska Bench. Other limestone in the collection resembles that of the upper Heath. It is highly likely that the collection contains fossils from several formations but that the types of *S. ludlovi* came either from limestone in the Cameron Creek formation, or from somewhere in the Alaska Bench limestone. The Heath formation is a bare possibility.

Superfamily PTERIACEA

Family CONOCARDIIDAE

Genus CONOCARDIUM Bronn, 1835

Conocardium latifasciatum Branson, 1942

Plate 12, figure 37

1937. *Conocardium orientale* Branson, Jour. Paleontology, v. 11, no. 8, p. 657, pl. 89, fig. 23. (Sacajawea formation, Wyoming). [not *C. orientale* Janischewski, 1909].

1942. *Conocardium latifasciatum* Branson, Jour. Paleontology, v. 16, no. 3.

Diagnosis.—*Conocardium* with 4 strong nodose ribs on the truncated posterior portion and at least 15 fine ribs on the gaping anterior portion. The median portion is raised slightly and bears as many as 5 strong ribs, of which the posterior one is much the strongest. On the lower half of the median area, 1 or 2 fine radial lirae lie between major ribs. Fine concentric lirae cross the median and anterior portions to make a reticulate pattern. The incomplete shell is 9.4 mm high (essentially complete), 7.2 mm wide, 5 mm long (incomplete), and the median portion is 3.0 mm wide at the venter.

Comparison.—This species is characterized by the 5 strong radial ribs in the medial portion.

Conocardium latifasciatum differs from the other species from the Big Snowy group in having raised, strong, median ribs instead of being equally smooth all over.

Conocardium mesialis Weller, 1916 and *C. chesterensis* Weller, 1920 are very similar to *C. latifasciatum*, but the lateral contour of *C. chesterensis* merges gradually into the posterior portion instead of being angular along the strongest rib. *C. mesialis* has 6 ribs on the median portion instead of 4 or 5 and has more and finer posterior ribs than does *C. latifasciatum.*

Material.—2 specimens. Hypotype, USNM 118857. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13414 (cf.). Cameron Creek formation, locality 13420.

Remarks.—The holotype is much smaller than this specimen, less complete, and is seemingly a juvenile specimen. Paleontologists have been uncertain as to orientation of these shells, as a result of which, for instance, Branson's original description of this species (1937) uses anterior in the sense that posterior is used subsequently (1942).

Conocardium glabratum Easton, n. sp.

Plate 12, figure 36

Description.—*Conocardium* with very convex nearly smooth valves. Beaks are low with steep posterior sides, and are enrolled to meet the straight cardinal margins at about midlength. Lateral outlines converge at 65° toward the anterior end whose gaping margin then flares slightly. Lateral outlines converge at 125° toward the posterior margin. The hinge line is produced posteriorly into a prominent spinose extension 5 mm long.

The surface is devoid of ribs, but is covered with minute concentric striae, of which 8 or 9 occur in 2 mm. Traces of simple ribs which are visible through the surface layer or are revealed at eroded places occur 4 in 2 mm along the venter and total about 36 in the length of the valve. The buried ribs over the umbo are broader than those elsewhere.

The holotype is 17.6 mm long, 10.7 mm high, 10.6 mm wide, the anterior gape is 5.6 mm wide, and the beaks stand 2.0 mm above the hinge line.

Comparison.—This species is characterized by the smooth surface and lack of a raised, median, ribbed portion.

Conocardium glabratum differs from *C. latifasciatum* Branson in being smooth instead of ribbed. Even on weathered portions, there are no extra-strong ribs and no reticulated ornament.

Material.—2 specimens. Holotype, USNM 118858. Other specimen in USGS collections.

Occurrence.—Heath formation, locality 13414.

Order EULAMELLIBRANCHIA

Superfamily TRIGONIACEA

Family TRIGONIIDAE

Genus SCHIZODUS King, 1844

Schizodus? sp.

Plate 12, figure 26

Material.—4 specimens. Figured specimen, USNM 118859. Other material in USGS collections.

Occurrence.—Cameron Creek formation, localities 13361 and 13362.

Remarks.—Some quadrate shells are referred to this genus but are not well enough preserved even to warrant further tentative identification. They are 25 mm and 14 mm long, respectively. Both have fine concentric ornamentation and a few coarse concentric wrinkles.

Superfamily CYPRICARDIACEA

Family PLEUROPHORIDAE

Genus PLEUROPHORUS King, 1844

Pleurophorus sp.

Plate 12, figure 33

The internal mold has the beaks nearly at the anterior end and has a vertical ridge behind the anterior muscle scar.

Material.—3 specimens. Figured specimen, USNM 118860. Other specimens in USGS collections.

Occurrence.—Otter formation, locality 13374?. Heath formation, locality 13366?. Alaska Bench limestone, locality 13404.

Genus CYPRICARDELLA Hall, 1858

Cypricardella sp. A.

Plate 12, figure 35

Material.—4 specimens. Figured specimen, USNM 118861. Other specimens in USGS collection.

Occurrence.—Heath formation, locality 13414. Cameron Creek formation, locality 13421.

Remarks.—Triangular shells referred here are 10 to 12 mm long, equivalved, and inequilateral, and have prominent beaks surmounting a decidedly concave anterior outline. Greatest length well ventral of midheight. An elongate, inflected, escutcheonal area is bounded by a narrow ridge which extends the curved cardinal margin posteriorly to make a wing-like extension to the shell. Lunule deeply inflected. Surface with prominent narrow concentric ridges occurring 2 or 3 in 3 mm and separated by wide interspaces.

This species is much larger than *C. brazerianus* Girty, 1927, but otherwise resembles it generally.

Cypricardella sp. B.

Plate 12, figure 34

Material.—1 specimen. Figured specimen, USNM 118862.

Occurrence.—Alaska Bench limestone, locality 13399.

Remarks.—This single left valve resembles *Cypricardella* sp. A, but has a rounded posterior end, less erect beaks, and finer ornamentation.

Superfamily ANATINACEA

Family PHOLADELLIDAE

Genus ALLORISMA King, 1844

Allorisma walkeri Weller, 1897

Plate 13, figures 1, 2

1897. *Allorisma walkeri* Weller, New York Acad. Sci. Trans., v. 16, p. 265, pl. 20, figs. 6, 7. (Batesville sandstone, Arkansas).

1915. *Allerisma walkeri.* Girty, U. S. Geol. Survey Bull. 593, p. 108, pl. 10, figs. 1, 2 (not 3). (Batesville sandstone, Arkansas).

1915. *Allerisma walkeri.* Snider, Oklahoma Geol. Survey Bull. 24, p. 114, pl. 7, figs. 4, 5. (Mayes, Fayetteville, and Pitkin formations, Oklahoma).

1920. *Allorisma clavata.* Weller (not McChesney), Illinois Geol. Survey Bull. 41, p. 207, 377, pl. 11, figs. 3, 4, Menard limestone, Illinois).

1946. *Allorisma walkeri.* Sloss, Montana Bur. Mines Geology Mem. 24, p. 9, (Amsden formation, Montana).

Diagnosis.—Rather large and subquadrate *Allorisma* with the low beaks about one-quarter or less of the distance from the nearly semicircular anterior end of the shell. Ventral margin straight or slightly indented, depending upon whether or not a very faint and very broad sulcus passes obliquely ventrally and posteriorly from the beaks. The greatest length is at or slightly above midheight. About 20 principal concentric undulations and numerous finer ones surmounting or interspersed with the larger ones lie parallel with the shell outline and only recurve anteriorly behind the beaks when very close to the cardinal margin. Undulations are coarsest as they cross a slight and very broad ridge which extends ventrally and obliquely backward along the median sulcus.

Mature specimens are commonly 6 to 8 cm long, 3 or 4 cm high, and 2 to 3 cm thick.

Comparison—This species is characterized by the large size, rather truncate posterior margin, low beaks, and tendency of the concentric ornamentation to be sharply recurved near the cardinal margins.

Allorisma sulcata, which is of about the same size, has higher beaks and the greatest length is distinctly ventral of midheight.

Material.—20 specimens. Hypotypes, USNM 118863 A, 118863 B. Other specimens in USGS collections.

Occurrence.—Cameron Creek shale formation, localities 13362 and 13363 (cf.).

Remarks.—The beaks lie proportionately closer to the anterior margin as age progresses, owing to the failure of the shell to grow anteriorly as fast as it grows either ventrally or posteriorly.

Allorisma inflata Easton, n. sp.

Plate 13, figure 5

Description.—Very elongate *Allorisma* with inflated umbones. The enrolled beaks lie far forward, being only one-tenth of the distance from the anterior margin in the holotype. The cardinal margin is straight. The free margin slopes ventrally and anteriorly at about 45° from the cardinal margin and then slopes posteriorly on a long low curve to a point about two-thirds of the length; it then slopes dorsally around the posterior margin and back to the cardinal margin behind the beaks so that the posterior outline is parabolic. Valves are widest at about one-third the length. The greatest length is at midheight. Concentric undulations are finer anteriorly and ventrally than they are along the inflated region running ventrally and posteriorly from each beak. Undulations at midlength occur 6 or 7 in 1 cm and are surmounted and interspersed with much finer concentric lirae. Undulations recurve sharply anteriorly along the smooth cardinal margin.

The holotype is 7.7 cm long, 2.5 cm high, and 3.2 cm wide. The width may be exaggerated a bit by distortion.

Comparison.—This species is characterized by the very elongate shape, inflated valves, and very anterior beaks.

Allorisma inflata differs from *A. walkeri* Weller, with which it occurs, in being much more elongate, having much more anterior beaks, sharply recurved ornament anteriorly along the cardinal margin, and finer ornamentation.

The beaks in *A. inflata* are proportionately farther anterior than are those in any other species known to the writer.

Material.—12 specimens. Holotype, USNM 118864. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13414 (cf.). Cameron Creek formation, localities 13360 and 13362 (type locality).

Allorisma? sp.

Material.—3 specimens in USGS collections.

Occurrence.—Otter formation, locality 14227.

Remarks.—These fragmentary specimens are about half as large as *Allorisma walkeri* and have fewer and stronger concentric wrinkles at similar growth sizes of the respective shells. They are not complete enough to warrant figuring but are cited as further evidence of the genus in the fauna.

Genus SPHENOTUS Hall, 1885

Diagnosis.—Equivalved but inequilateral subquadrate pelecypods with prominent prosogyrate or orthogyrate beaks located well forward. A generally prominent ridge extends posteriorly and laterally from the umbo, and a very broad sulcus descends from the umbo to the midventral margins where it may cause a reentrant in the ventral margin. Hinge line nearly straight with a long narrow ligamental groove. Two cardinal teeth present beneath the beak.

Comparison.—*Sphenotus* differs from *Allorisma*, which it resembles closely, in having cardinal teeth, but their presence is hard to demonstrate. Lacking evidence of dentition, shells with elongate shape, a median sulcus, a posterior umbonal ridge, a narrow groove, a sloping instead of flat or inflected posterior cardinal margin, and fine concentric ornamentation are generally referred to *Sphenotus*.

Sphenotus altidorsatus Easton, n. sp.

Plate 13, figures 3, 4

Description.—*Sphenotus*-like shells with the hinge line continued directly backward so that the posterior dorsal termination is high and wedgelike. The umbonal ridge is only moderately acute and the median sulcus is not always distinct. Beaks slightly prosogyrate and situated one-third of the distance from the anterior end, which is sharply rounded and located at or ventral to midheight below a concave slope from the beak. Ornamentation consists of a few coarse concentric wrinkles and numerous fine growth lines. The average dimensions of 10 single valves are 24.7 mm long, 14.2 mm high, and 6.1 mm wide. Among these, corresponding measurements of the most squarish specimen are 23.7, 15.9, and 9.2 mm; of the most elongate specimen are 17.5, 9.2, and 4.4 mm. Length-to-height ratio is 1.75.

Internal features not seen in detail, but the long, narrow, sharply concave ligamental groove is commonly preserved. One husky oblique posterior tooth is also visible in the paratype (a left valve).

Comparison.—This species is characterized by the high postero-dorsal extension of the valve.

Sphenotus washingtonensis Girty, 1910, is rather similar to this species but has a much sharper umbonal ridge, more anteriorly situated beaks, and a more elongate shape (length-to-height ratio of the holotype is 2.5), and has a less elevated posterior dorsal margin.

Numerous other species known to the writer from Carboniferous rocks all lack the high posterior dorsum of *S. altidorsatus*.

Material.—63 specimens. Holotype, USNM 118865. Paratype, USNM 118866. Other specimens in USGS collection.

Occurrence.—Heath formation, locality 13414 (cf.). Cameron Creek formation, locality 13361 (type locality).

Class GASTROPODA

Order ARCHAEOGASTROPODA

Superfamily BELLEROPHONTACEA

Family BELLEROPHONTIDAE

Genus BELLEROPHON Montfort, 1808

Bellerophon sp.

Plate 13, figure 7

Several smooth-surfaced shells and steinkerns are provisionally referred to *Bellerophon*. The aperture of the figured specimen is 20 mm wide.

Material.—4 specimens. Figured specimen, USNM 118867. Other material in USGS collections.

Occurrence.—Otter formation, locality 14227. Heath formation, localities 13412, 13414. Alaska Bench limestone, localities 13363, 13404.

Genus RETISPIRA Knight, 1945

1945. *Retispira* Knight, Jour. Paleontology, v. 19, no 4, p. 334.

Retispira sp.

Plate 13, figure 8

Material.—2 specimens. Figured specimen, USNM 118868. Other specimen in USGS collection.

Occurrence.—Heath formation, locality 13391. Cameron Creek formation, locality 13361.

Remarks.—Although this species has the reticulate ornamentation of the surface and the smooth inductura covering it posteriorly, it is not well enough preserved to warrant reference to any named species. The genus ranges from Devonian to Permian.

Genus EUPHEMITES Warthin, 1930

Euphemites sacajawensis C. Branson, 1937

Plate 13, figures 9, 10

1918. ?*Bucanopsis* or *Bellerophon* E. Branson and Greger, Geol. Soc. America Bull., v. 29, p. 324, pl. 19, figs. 9, 10. ("Amsden" formation, Wyoming)

1937. *Euphemites sacajawensis* C. Branson, Jour. Paleontology, v. 11, no. 8, p. 658, pl. 89, figs. 24, 25, 33 [not 26], (Sacajawea formation, Wyoming)

Remarks.—The holotype designated by C. Branson (1937, explanation of pl. 89) is illustrated by figures 25 and 33 on plate 89. This specimen lacks the smooth anterior portion of the shell which carries the slit. Twenty-three carinae with rounded summits occupy the surface of the shell between umbilici and are separated by smooth interspaces about twice as wide as a carina. Details of the slit band cannot be observed. Growth lines are lacking. The shell is 6 mm wide and 6.5 mm long.

The paratype (C. Branson, 1937 pl. 89, fig. 24) has been eroded or corroded over most of the surface until the 22 carinae are reduced to slender threads only about one-fourth as wide as the interspaces. Growth lines show up well on the stripped surface, however, so that their arcuate deflection toward the slit band is readily traced. The slit band shows not only the lunulae (growth lines) but also bears three carinae between the carinae bounding the slit band, one of which is added by implantation near the end of the carinate portion. Much of the smooth apertural part of the shell is preserved. Although the slit is missing the slit band is delineated by a reduced carina on each side. The specimen is 7 mm wide and 8.5 mm long.

An unfigured paratype with 22 carinae is very similar to the holotype. It has a new carina added to the persistent one in the slit band by implantation.

The extant specimen figured by E. Branson and Greger is a steinkern, as are five of those studied by C. Branson.

Of the two specimens collected by the writer, one (pl. 13, fig. 9) retains the slit and half the apertural margin. Its 21 or 22 carine are rounded and spaced as in the holotype; one of the two carina in the slit band is resorbed anteriorly. The umbilical sides are smooth. The aperture is 9.0 mm wide and the shell is 9.0 mm long.

The other specimen is very similar to the first but lacks the apertural margin. It has 18 carinae of which one of the two in the slit band is added by implantation. The parietal inductura (inner lip) shows as a welt which sags slightly and posteriorly along the midplane.

The hypotypes differ from the primary types only in being slightly larger and in having one or two carinae in the slit band instead of one to three. These differences are in part due to equality of preservation, but are in any case not of specific value.

Material.—2 specimens, USNM 118869A, B. C. Branson's 7 specimens are collection 6631 and E. Branson and Greger's specimen is No. 2660, both lots being in the University of Missouri collections.

Occurrence.—Heath formation, locality 13391.

Superfamily EUOMPHALACEA

Family EUOMPHALIDAE

Genus STRAPAROLLUS Montfort, 1810

Subgenus EUOMPHALUS Sowerby, 1814

Straparollus (Euomphalus), n. sp. A

Plate 13, figure 14

Description.—The four whorls of the spire are depressed into a concave surface above which the carinae stand in bold relief. The periphery of the body whorl slopes outward at an angle of 30° to the plane of coiling. Growth lines are very prominent on the upper surface of the body whorl. The lines are deflected posteriorly near the carina then swing anteriorly and posteriorly on the sloping periphery to make very open **S**-shaped figures. Growth lines on the carina proper are so coarse as to merit being called rugae.

Poor preservation and some crushing prevent accurate recognition of some features, but the umbilicus is apparently wide and shallow, and the lower surfaces of the whorls are rounded where not crushed. Aperture and whorl profile deformed. The specimen is 32 mm in diameter.

Material.—2 specimens. Figured specimen, USNM 118870. Other material in USGS collections.

Occurrence.—Heath formation, localities 13359 and 13367.

Remarks.—This large euomphalid is easily distinguished from other known species by its strong growth lines, rugose carina, and large size.

Straparollus (Euomphalus), n. sp. B

Plate 13, figure 15

Description.—The shell of at least 4 whorls is notably biconcave, the apical surface being less concave than the basal. Volutions on the spire are delineated by a slight shoulder which rises in relief in the outer two whorls until it is surmounted by a strong carinae. Umbilicus broad and deep, lined by whorls whose lower surface is convex on the inner part and concave on the outer part. The lower whorl surface in the last volution ends at the sharp shoulder in a vertical, flangelike, slightly nodose carina.

Material.—14 specimens. Figured specimen, USNM 118871. Other material in USGS collections.

Occurrence.—Cameron Creek formation, localities 13361, 13373?, and 14222. Alaska Bench limestone locality 13371?.

Remarks.—This specimen exhibits the notably bicarinate whorl profile which is used by some systematists to differentiate the genus *Schizostoma*. The writer, after studying various suites of specimens at the U.S. National Museum, agrees with Knight (1934, p. 144) that *Schizostoma* is transitional with *Euomphalus*. This specimen is referable to the *Euomphalus catilloides* group as segregated by Knight (1934, p. 145). Although the shell is very close to *E. subrugosus* Meek and Worthen, it can be distinguished from their species by its base being more concave than its spire and by its apparently unique flangelike lower carina.

Superfamily PLEUROTOMARIACEA

Family PLEUROTOMARIIDAE

Genus ANGYOMPHALUS Cossman, 1915

Angyomphalus? excavatus Easton, n. sp.

Plate 13, figure 16

Description.—Shell of at least 4 volutions, flat spired, and with a very sharply angulated shoulder. Slit band 1.0 mm wide, precisely overlapped by a thick inner margin of the next succeeding whorl. A series of elliptical or barlike transverse ridges 1 mm apart lie on the thick margin overlapping the slit band and barely extending on to the preceding whorl, the whole being about 2.0 mm wide at maturity. Base deeply umbilicate, the latest whorl enveloping preceding whorls. Whorl profile slightly convex on upper surface, slightly concave in slit band, evenly rounded on lower surface, and semicircular at aperture. The holotype is 20 mm in diameter and 6 mm high.

Material.—32 specimens. Holotype, USNM 118872. Topotypes and other specimens in USGS collections.

Occurrence.—Heath formation, localities 13366 and 13414. Cameron Creek formation, locality 13361 (type locality).

Remarks.—All specimens are molds, but the shell substance was so thin that great fidelity of detail is shown by the specimens.

Paleontologists sometimes separate *Angyomphalus*, which has ridged ornamentation and an open umbilicus surrounded by a shelf, from *Trepospira*, which has nodose ornamentation and lacks the open umbilicus. The specimens at hand lack the shelf, possibly because they are molds, but are otherwise like *Angyomphalus*. In comparative collections studied by the writer only one lot of Pennsylvanian *Trepospira* (from the Boggy shale) had even a slightly open umbilicus, but several Mississippian forms have distinct umbilici. The writer refers this species to *Angyomphalus* with question because it has ridged ornamentation and seemingly lacks a shelf in the umbilicus. It may eventually require a new genus to accommodate it. If it is assumed that the callus closing the umbilicus of *Trepospira* is acquired progressively in evolution, then this species could be ancestral to the typical Pennsylvanian forms of *Trepospira*.

Genus GLABROCINGULUM Thomas, 1940

Glabrocingulum? sp.

Plate 13, figure 12

Material.—3 specimens. Figured specimen, USNM 118887. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13414.

Superfamily LOXONEMATACEA

Family LOXONEMATIDAE

Genus PSEUDOZYGOPLEURA Knight, 1930

Pseudozygopleura contains high-spired gastropods with a transversely costate nucleus and subsequent whorls ornamented by transverse costae only, which do not cross the nonumbilicate base.

Subgenus PSEUDOZYGOPLEURA Knight, 1930

Pseudozygopleura with evenly convex whorl profiles and coarse costae on all whorls.

Pseudozygopleura (Pseudozygopleura) aff. P. scitula (Meek and Worthen, 1860)

Plate 13, figure 11

Only 5½ whorls are preserved in the specimen at hand, the nucleus being broken off. Costae are curved and oblique, opposite ends of a costa being offset as far as a costa is wide. Ten costae on the next to the last whorl can be seen from a single lateral viewpoint. The shell is 18 mm long and 8 mm wide.

Material.—2 specimens. Figured specimen, USNM 118873. Other specimen in USGS collection.

Occurrence.—Cameron Creek formation, locality 13363.

Remarks.—This specimen differs from *P. scitula* only in having slightly less coarse costae than that species has, there being 8 instead of 10 costae on *P. scitula* in the same span.

Superfamily NERITACEA

Family NERITIDAE

Genus NATICOPSIS McCoy, 1844

Naticopsis contains roughly globular shells without an umbilicus and with transverse ornamentation on the early whorls, if at all.

Naticopsis cf. N. remex White, 1876

Plate 13, figure 13

1876. *Naticopsis remex* White *in* Powell, Report on the geology of the eastern portion of the Uinta Mountains, chapt. 3, p. 109 (lower Aubrey group, Utah).

1883. *Naticopsis remex*. White, U.S. Geol. Geog. Survey Terr., 12th Ann. Rept., Pt. I. (Hayden, 1878). Contr. Invert. Paleontology no. 6, p. 139, pl. 34, fig. 6a.

Description.—Shell of at least 4 volutions with an apical angle of 120°. Whorl profiles almost semicircular, each whorl only extending about halfway up preceding whorl so that the spire in side view consists of sharply recessed units. Ornamentation of fine ribs occurring about 5 in 1 mm and directed posteriorly and down. Ribs are confined to the very convex upper margin of the whorl just below the deeply grooved sutures of all but the last smooth whorl. Growth lines are straight. The figured specimen is 15 mm high and 15 mm wide. Inner lip not seen.

Material.—6 specimens. Holotype, USNM 8063. Figured specimen, USNM 118874. Other specimens in USGS collections.

Occurrence.—Heath formation, locality 13368. Cameron Creek formation, locality 13363. Lower Aubrey group, Utah (USNM 8063).

Remarks.—This species lacks the flattened or concave upper half of the body whorl, but otherwise resembles *Naticopsis meeki* Knight rather closely. A specimen from the Amsden formation is doubtfully referred to this species. The holotype lacks the diagonal ribs but is too poorly preserved to show them if they were there.

Order NEOGASTROPODA

Superfamily SUBULITACEA

Family SUBULITIDAE

Genus BULIMORPHA Whitfield, 1882

Fusiform smooth-surfaced shells with a siphonal notch and one columellar fold. (Simplified from Knight, 1931, p. 193).

Bulimorpha elegans Girty, 1927

Plate 13, figures 17, 18

1927. *Bulimorpha elegans* Girty, U.S. Geol. Survey, Prof. Paper 152, p. 432, pl. 25, figs. 31, 32. (Brazer limestone).

Five or 6 whorls remain on the specimens at hand. The body whorl is about half as long as the entire shell, which is 12 mm long, the apex being lost.

Material.—4 specimens. Hypotypes, USNM 118875 and 118876?.

Occurrence.—Heath formation, locality 13414. Alaska Bench limestone, locality 13399?.

Remarks.—*B. elegans* is larger and seemingly had more volutions than did *B. bulimiformis* (Hall). Members of the genus are so similar, however, that they are difficult to tell apart.

Genus SOLENISCUS Meek and Worthen, 1860

Soleniscus sp.

Plate 13, figure 19

A smooth fusiform shell with a distinct siphonal notch is referred here but is not specifically identifiable.

Material.—1 specimen, USNM 118877.

Occurrence.—Heath formation, locality 13414.

Class SCAPHOPODA

Family DENTALIIDAE

Genus PLAGIOGLYPTA Pilsbry and Sharp, 1897

Original diagnosis.—Shell circular or elliptical in section, without longitudinal sculpture, with close and fine obliquely encircling wrinkles throughout or on the posterior portion (Pilsbry and Sharp, 1897, p. xxxii).

Remarks.—Girty (1903, p. 452, 453) reviewed the late Paleozoic scaphopods briefly. A nomenclatural summary of supraspecific scaphopod names was published by Emerson (1952, p. 296–303).

Plagioglypta subannulata Easton, n. sp.

Plate 13, figures 20, 21

Shell slightly curved, circular except where seemingly crushed, gradually tapering from a diameter of 1.8 mm to 3.3 mm over a length of 28 mm in the holotype. Largest fragment observed has a maximum diameter of 5.5 mm. Wall very thick, being 0.6 mm thick at a diameter of 3 mm. Surface ornamented with fine encircling ridges occurring 22 in 5 mm and inclined posteriorly at an angle of 15° to the convex profile of the shell; ridges are not reflexed into sinuses in their courses around the shell but represent the traces of oblique conic sections.

Comparison.—*Plagioglypta subannulata* resembles *P. annulistriata* (Meek and Worthen) most closely of known American species, differing from it in being much larger, having finer ridges, and having more ridges in a given distance.

Material.—10 specimens. Holotype and paratype on one block, USNM 118878. Other specimens in USGS collections.

Occurrence.—Alaska Bench limestone, locality 13399.

Class CEPHALOPODA

Order ORTHOCHOANITES

Family TRIBLOCERATIDAE

Genus APHELAECERAS Hyatt, 1884

1884. *Aphelaeceras* Hyatt, Boston Soc. Nat. History Proc., v. 22, pt. 3, p. 293.

Aphelaeceras? sp.

Plate 13, figure 26

The fragment at hand appears to about one-fifth of a volution. It has a trapezoidal cross section (pl. 13, fig. 26b) with flat lateral slopes and seemingly flat venter, but with a convex dorsum which seemingly lacks an impressed zone. Sutures are as for the genus.

Material.—1 specimen. USNM 118879.

Occurrence.—Cameron Creek formation locality 13361.

Remarks.—The generic assignment was suggested by Mackenzie Gordon, Jr. Uncertainty as to whether the venter might locally be concave necessitates using a query with the assignment.

Family PLEURONAUTILIDAE

Genus TYLONAUTILUS Pringle and Jackson, 1928

1928. *Tylonautilus* Pringle and Jackson, Naturalist, no. 863, p. 373.

Tylonautilus sp.

Plate 13, figure 35

Material.—1 specimen. Figured specimen, USNM 118902.

Occurrence.—Otter formation, locality 14227.

Remarks.—The fragment at hand was probably about 2 cm in diameter when complete. The greatest whorl height is about 6 mm. Sutures are straight and transverse. Four distinct ridges occupy the dorsal slope and a row of large rounded nodes occurs midway down the lateral slope with their centers spaced about 2.5 mm distant. Shell surface is not preserved, nor were the whorl profile or the nature of the siphuncle seen.

The genus is characteristic of the *Eumorphoceras* zone of Europe and has been reported from the Fayetteville shale and Caney shale of the United States (Miller and Furnish, 1955, p. 462, 463). Mackenzie Gordon, Jr. (written communication, May 18, 1956) considers the genus to range from near the bottom to near the top of the Chester.

Order CYRTOCHOANITES

Family SACTOCERATIDAE

Genus MOOREOCERAS Miller, Dunbar, and Condra, 1933

Mooreoceras? sp.

Plate 13, figure 22

1933. *Mooreoceras* Miller, Dunbar, and Condra, Nebraska Geol. Survey, ser. 2, Bull. 9, p. 85.

Material.—1 specimen. Figured specimen, USNM 118880.

Occurrence.—Heath formation, locality 13414.

Remarks.—The single specimen does not show siphuncular details and is not long enough apically to indicate whether or not there is a slight curve. If there is, then the specimen would be referable to *Pseudorthoceras* (Miller, Dunbar, and Condra, 1933, p. 78).

Order EXTRASIPHONATA

Family METALEGOCERATIDAE

Genus CRAVENOCERAS Bisat, 1928

1937. *Cravenoceras.* Plummer and Scott, Texas Univ. Bull. 3701, p. 259.
1949. *Cravenoceras.* Youngquist, Jour. Paleontology, v. 23, no. 3, p. 290.

Cravenoceras hesperium Miller and Furnish, 1940

Plate 13, figures 33, 34

1940. *Cravenoceras hesperium* Miller and Furnish, Jour. Paleontology, v. 14, no. 4, p. 374, text fig. 16B; pl. 49, figs. 1–8. (White Pine shale, Nevada).

Description.—The single excellent specimen at hand is subglobular, with a broadly rounded venter. The umbilicus is deep and narrow (measuring 5 mm in diameter) with shoulders of successive whorls visible as steps on the umbilical wall. The surface is covered with the typical imbricate ornamentation of the genus in which 3 to 5 growth lines occur in 5 mm. Sutures are not visible. The conch is 23 mm in greatest diameter and is 15 mm wide.

Material.—1 specimen. Hypotype; USNM 118899.

Occurrence.—Heath formation, locality 14101.

Remarks.—Only the original description is cited above. *Cravenoceras* is diagnostic in Europe of lower Namurian strata.

Cravenoceras sp.

Plate 13, figure 25

1949. *Cravenoceras?* sp. Miller, Downs, and Youngquist, Jour. Paleontology, v. 23, no. 6, p. 612. (Heath shale, Montana).

Description.—Two fragments of a seemingly subglobose shell bear the highly characteristic surface ornamentation of *Cravenoceras.* Almost straight smooth bands which give the appearance of overlapping plates cross the surface transversely and occur about 4 in 2 mm where they are widest near the venter.

Material.—2 specimens. University of Illinois X–1451. Rubber mold figured herein, USNM 118881.

Occurrence.—Heath formation, probably from the base of bed 8 of Scott's section of the type locality of the Heath shale (Scott, 1935b, p. 1025) which is probably the lower part of bed 16 of the same section in this report.

Family GIRTYOCERATIDAE

Genus GIRTYOCERAS Wedekind, 1918

1940. *Girtyoceras.* Miller and Furnish, Jour. Paleontology, v. 14, no. 4, p. 363.

Girtyoceras aff. G. meslerianum (Girty, 1909)

Plate 13, figures 23, 24

1949? *Girtyoceras meslerianum.* Youngquist, Jour. Paleontology, v. 23, no. 3, p. 302. (White Pine shale, Nevada; Caney shale, Oklahoma; Barnett formation, Texas; Floyd shale, Alabama; Upper Viséan of England and Europe).
1949. *Girtyoceras* aff. *G. meslerianum.* Miller, Downs, and Youngquist, Jour. Paleontology, v. 23, no. 6, p. 611, text-fig. 4, pl. 99, figs. 1–4. (Heath shale, Montana).

Description.—These small specimens, of which the largest is 12.7 mm in greatest diameter and 7.0 mm in greatest width, have rounded venters, flat, lateral slopes, and are deeply impressed. The umbilicus is 2.8 mm wide, is deep, and has sloping walls. Four transverse constrictions have a median lobe, ventro-lateral saddle, lateral lobe, and terminate at the umbilical shoulder. Sutures have a moderately deep and bifid median lobe, a nearly semicircular first lateral saddle, a narrowly round first lateral lobe, a low and broadly rounded second lateral saddle, and a sharply rounded lobe whose apex is just onto the umbilical wall. Growth lines are parallel with the transverse constrictions, having a narrower median sinus than lateral sinus.

Comparison.—This species has a narrower median lobe, lower first lateral lobe, and smoother ventral slope of the second lateral saddle than has typical *G. meslerianum.*

Material.—12 specimens. Figured specimens, University of Illinois X–1450. Other material, University of Illinois X–1452, X–1453.

Occurrence.—Heath formation, from the same locality as *Cravenoceras* sp. where it is associated with *Cranaena? circularis* Easton. Also from 304 feet above the base of the Big Snowy group (Heath formation), 4 miles due west of Judith Gap, Wheatland County, Mont.

Remarks.—Data concerning this species were largely drawn from Miller, Downs, and Youngquist (1949, p. 611, 612).

ARTHROPODA

Class CRUSTACEA

Subclass TRILOBITA

Order OPISTHOPARIA

Family PROETIDAE

Genus AMEURA Weller, 1936

Ameura? sp.

Plate 13, figures 27, 28

Description.—The cranidium (pl. 13, fig. 27) is smooth except for very faint ridges parallel with the margin of the rim. Basal furrows with straight central portions separate depressed basal lobes from the glabella. The glabella is as wide or slightly wider between the eyes than it is elsewhere. It is 4 mm long. The foregoing features are more like *Ameura* than like *Paladin*, although sharing features of the latter.

Associated with the foregoing cranidium are pygidia which agree in all but one respect with the generic characters listed by Weller for *Ameura* (1936, p. 713, 714); namely the surface of one specimen (pl. 13, fig. 28b) is clearly pustulose. Both well-preserved pygidia at hand have 21 axial segments and 12 or 13 pleural segments. The axial lobe is strongly elevated and internal molds of it are flat topped (pl. 13, fig. 28a), whereas its outer surface is arched. The larger specimen is 11 mm long and 13 mm wide.

Pygidia from different localities have 11 axial and 20 plural segments, 10 axial and 18 pleural, and 12 axial and 16 pleural segments. These range from 2 mm to 6 mm in length.

The distinct pygidial flange, elevated axial lobe, absence of subsidiary furrows, and large eyes all agree with an advanced evolutionary development as proposed by Weller (1937).

Material.—8 specimens. Figured specimens, USNM 118882A, 118882B. Other specimens in USGS collections.

Occurrence.—Heath formation, localities 13414 and 13425. Cameron Creek formation, locality 13362. Alaska Bench limestone, locality 13385.

Genus PALADIN Weller, 1936

Paladin? sp.

Plate 13, figure 29

Description.—A pustulose pygidium with 9 axial segments and 13 pleural segments and with an elevated axial lobe has faint traces of furrows on the anterior part of the flange. The specimen is 11 mm long.

Material.—3 specimens. Figured specimen, USNM 118883.

Occurrence.—Cameron Creek formation, locality 13420.

Undetermined

Fragments of trilobites were collected from the Cameron Creek formation at localities 13386 and 14221.

Subclass OSTRACODA

Material.—Many specimens were seen by the writer and some beds were sampled and deposited in the paleontological laboratories of the U.S. Geological Survey in Washington.

Occurrence.—Although the following list does not even begin to convey the widespread occurrence of ostracodes in central Montana, it at least records actual samples known to contain ostracodes: Otter formation, localities 13358, 13376, 13377, 13379, 13390, 13400, 13401, and 14227. Heath formation, localities 13387, 13402, 13416. Cameron Creek formation, localities 13361, 13380, 13381, 13420, 14221, 14224, and 14226. Alaska Bench limestone, localities 13372, 13399, 13403, and 13405.

Remarks.—Although ostracodes are unusually abundant in the formations studied by the writer, no attempt is made herein to study these organisms. Their very abundance is such as to discourage efforts of less than major proportions to work with them. A characteristic assemblage from the Otter formation and a small assemblage from the Heath formation have been reported upon by Scott (1942a).

Subclass MALACOSTRACA

Order STOMATOPODA

Family SQUILLIDAE

Genus SQUILLITES Scott, 1938

Squillites spinosus Scott, 1938

Plate 13, figure 30

This creature is among the rarest of fossils. Its principal significance lies in its being the oldest known stomatopod.

Material.—The two known specimens were collected by Scott. The holotype (not seen) is University of Illinois X–1219.

Occurrence.—Heath formation, on Spring Creek, 2 miles south of Heath, Mont. Said by Scott (1938, p. 508) to be from the lower part of the Heath "at or near" the *Leiorhynchus carboniferum* zone.

CHORDATA

Locally, as, for instance, in the Heath formation, "fish scales" are abundant, but identifiable vertebrate material is rare.

One cochliodont shark tooth (pl. 13, fig. 31) 1 cm long occurred in the Alaska Bench limestone at locality 13399 (Romer, 1947, p. 73).

Ctenacanthus-like spines (Newberry and Worthen, 1866, p. 118) less than 1 mm in diameter and less than 1 cm long were found in the Heath formation at localities 13359 and 13414. These longitudinally ribbed, oval, curved spines (pl. 13, fig. 32) are referable either to the placoderms or to the sharks and are loosely called ichthyodorulites (Davis, 1883).

A few minute shark teeth of the *Cladodus* and *Dittodus* types were obtained from the Heath formation at locality 13414.

Three kinds of fish scales were observed. Shiny, amber to gray, ganoine-covered, rhombic and petaloid, slightly striate scales about 1 mm long were obtained from the Heath formation at localities 13394, 13396 and 13414; from the Cameron Creek formation at locality 13380; and from the Alaska Bench limestone at locality 13399.

Thick, subovate, amber-colored, deeply fluted scales about 1 mm long represent acanthodian fish from the Heath formation at locality 13414.

CONODONTS

Incertae sedis

Conodonts were first mentioned as occurring in the Big Snowy group by Scott (1935b, p. 1029), who reported them to be very abundant in the basal part of the Heath formation. Subsequently Scott (1942b) described some assemblages of these conodonts under the names *Lochriea montanaensis*, *Lochriea bigsnowyensis*, and *Lewistownella agnewi*. Inasmuch as conodonts have been elsewhere described according to the characteristics of individual units either making up assemblages or occurring separately, it would be necessary to render Scott's species in terms of the more generally practiced organ-genus usage before the names would convey much in a faunal list. Scott subsequently referred briefly (1950, p. 47) to the presence of conodonts in the Heath. Subsequently Gardner and others (1945; 1946, p. 5) referred to the mere presence of conodonts in the Heath formation.

Insoluble residues of samples from calcareous strata in the Heath formation at locality 13414 contain conodonts. Although reports cited above indicate that conodonts are locally abundant in the Heath formation, their presence is not generally characteristic of the formation. Assiduous search at numerous localities failed to produce a single specimen, although an occasional specimen was seen at other localities.

The conodonts are not treated systematically in this report because this study would require additional field work and probably the efforts of a specialist in their discrimination.

REFERENCES CITED

Agatston, R. S., 1954, Pennsylvanian and lower Permian of northern and eastern Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 38, no. 4, p. 508–583.

Bacon, C. S., Jr., 1948, Geology of the Confusion Range, west-central Utah: Geol. Soc. America Bull., v. 59, no 10, p. 1027–1052.

Barnes, T. R., 1952, The Williston basin—a new province for oil exploration: Billings Geol. Soc., Guidebook 3d Ann. Field Conf., p. 96–117. Reprinted in Am. Assoc. Petroleum Geologists Bull., v. 37, no. 2, p. 340–354 (1953).

Bauer, C. M., and Robinson, E. G., 1923, Comparative stratigraphy in Montana: Am. Assoc. Petroleum Geologists Bull., v. 7, no. 2, p. 159–178.

Beekly, E. K., 1954, The Heath-Amsden boundary on the central Montana uplift at Big Wall field: Billings Geol. Soc., Guidebook, 5th Ann. Field Conf., p. 111–120.

Bennison, A. P., 1954, Target limestone, new member of Springer formation, Carter County, Oklahoma: Am. Assoc. Petroleum Geologists Bull. v. 38, no. 5, p. 913, 914, fig. 1 on p. 915.

Bond, G., 1942, Species and variation in British and Belgian Carboniferous Schizophoriidae: Geologists' Assoc. London Proc., v. 52, pt. 4, p. 285–303.

Bonnet, Pierre, and Bonnet, N. M. 1947, Description géologique de la Transcaucasie méridionale: Soc. Géol. France Mém., new ser., v. 25 (Mém. 53), 263 p., illust.

Branson, C. C., 1936, Carboniferous stratigraphy of Wyoming [abs.]: Geol. Soc. America Proc. for 1935, p. 391.

——— 1937, Stratigraphy and fauna of the Sacajawea formation, Mississippian, of Wyoming: Jour. Paleontology, v. 11, no. 8, p. 650–660.

——— 1939, Pennsylvanian formations of central Wyoming: Geol. Soc. America Bull., v. 50, no. 8, p. 1199–1226.

——— 1942, Correction of homonyms in the lamellibranch genus *Conocardium*: Jour. Paleontology, v. 16, no. 3, p. 387–393.

——— 1948, Bibliographic index of Permian invertebrates: Geol. Soc. America Mem. 26, 1049 p.

Branson, E. B., and Branson, C. C., 1941, Geology of Wind River Mountains, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 25, no. 1, p. 120–151.

Branson, E. B., and Greger, D. K., 1918, Amsden formation of the east slope of the Wind River Mountains of Wyoming and its fauna: Geol. Soc. America Bull., v. 29, no. 2, p. 309–326.

Burk, C. A., 1954, Faunas and age of the Amsden formation in Wyoming: Jour. Paleontology, v. 28, no. 1, p. 1–16.

Butts, Charles, 1917, Descriptions and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, Mississippian formations of western Kentucky, Frankfort, 119 p., illust.

Calvert, W. R., 1909, Geology of the Lewistown coal field, Montana: U.S. Geol. Survey Bull. 390, 83 p., map.

Carruthers, R. G., 1910, On the evolution of *Zaphrentis delanouei* in Lower Carboniferous times: Geol. Mag. (Great Britain), v. 66, pt. 4, p. 523–538.

Chao, Y. T., 1928, Productidae of China, Part II: Palaeontologia Sinica, ser. B, v. 5, fasc. 3.

Chi, Y. S., 1931, Weiningian (Middle Carboniferous) corals of China: Palaeontologia Sinica, ser. B, v. 12, fasc. 5.

Clark, T. H., 1917, New blastoids and brachiopods from the Rocky Mountains: Harvard Coll. Mus. Comp. Zoology Bull., v. 61, no. 9, p. 361–380.

Cloud, P. E., Jr., 1942, Terebratuloid Brachiopoda of the Silurian and Devonian: Geol. Soc. America Spec. Paper 38, 182 p., 26 pls., 17 figs.

——— 1944, *in* King, R. E., and others, Geology and paleontology of the Permian area northwest of Las Delicias, southwestern Coahuila, Mexico—Part III, Permian brachiopods: Geol. Soc. America Spec. Paper 52, p. 49–69.

——— 1948, Notes on Recent brachiopods: Am. Jour. Sci., v. 246, p. 241–250.

Condra, G. E., Reed, E. C., and Scherer, O. J., 1940, Correlation of the formations of the Laramie Range, Hartville Uplift, Black Hills, and western Nebraska: Nebraska Geol. Survey Bull. 13, 52 p., 1 pl., 14 figs.

Cooper, C. L., 1941, Chester ostracodes of Illinois: Illinois Geol. Survey Rept. Inv. 77, 101 p.

——— 1946, Upper Kinkaid (Mississippian) microfauna [abs.]: Am. Assoc. Petroleum Geologists Joint Ann. Meeting Program, April 2–4.

——— 1947, Upper Kinkaid (Mississippian) microfauna from Johnson County, Illinois: Jour. Paleontology, v. 21, no. 2, p. 81–94. Reprinted Illinois Geol. Survey Rept. Inv. 122.

——— 1948, Kinderhook micropaleontology: Jour. Geology, v. 56, no. 4, p. 353–366.

Cooper, G. A., and Muir-Wood, H. M., 1951, Brachiopod homonyms: Washington Acad. Sci. Jour., v. 41, no. 6, p. 195, 196.

Coryell, H. N., and Johnson, S. C., 1939, Ostracoda of the Clore limestone, Upper Mississippian, of Illinois: Jour. Paleontology, v. 13, no. 2, p. 214–224.

Crickmay, C. H., 1952, Nomenclature of certain Devonian brachiopods: Imperial Oil Limited, Calgary, Canada, published by the author, 2 p.

Croneis, C., and Funkhouser, H. J., 1938, New Ostracodes from the Clore formation: Denison Univ. Sci. Lab., Bull., v. 33, p. 331–363.

Cumings, E. R., 1901, The use of Bedford as a formational name: Jour. Geology, v. 9, p. 232–233.

Darrow, G. F., 1951, Melstone oil field, Musselshell County, Montana: Billings Geol. Soc. Guidebook 2d Ann. Field Conf. p. 70–74.

Davis, J. W., 1883, On the fossil fishes of the Carboniferous limestone of Great Britain: Royal Dublin Soc. Sci. Trans., ser. 2, v. 1, p. 327–600.

Davis, W. M., 1886, Relation of the coal of Montana to the older rocks: Dept. Interior, Tenth Census, v. 15, Rept. Mining Industries, p. 697–737.

Demanet, Felix, 1938, La faune des couches de passage du Dinantien au Namurien dans le synclinorium de Dinant: Mus. royale historie nat. Belgique Mém. 84, 201 p., 14 pls., 39 figs.

Dobrolyubova, T. A., 1940, The *Rugosa* corals of the Upper Carboniferous of the Moscow Basin: Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 9, no. 3.

——— 1941, Stratigraphical distribution and evolution of the *Rugosa* corals of the Middle and Upper Carboniferous of the Moscow Basin: Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 11, no. 4.

Dorn, C. L., 1949, Developments in Rocky Mountain region in 1948: Am. Assoc. Petroleum Geologists Bull., v. 33, no. 6, p. 827–836.

Dresser, Hugh, 1954, Contributions to knowledge of the Brazilian Paleozoic—no. 1, B. Notes on some brachiopods from the Itaituba formation (Pennsylvanian) of the Tapajos River, Brazil: Bull. Am. Paleontology, v. 35, no. 149, p. 15–68, illust.

Dunbar, C. O. and Condra, G. E., 1932, Brachiopoda of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey, ser. 2, Bull. 5.

Easton, W. H., 1945a, Corals from the Otter formation (Mississippian) of Montana: Jour. Paleontology, v. 19, no. 5, p. 522–528.

——— 1945b, Amplexoid corals from the Chester of Illinois and Arkansas: Jour. Paleontology, v. 19, no. 6, p. 625–632. (Reprinted as Illinois Geol. Surv. Rept. Inv. 133).

——— 1951, Mississippian cuneate corals: Jour. Paleontology, v. 25, no. 3, p. 380–404.

Easton, W. H., and others, 1953, Revision of the stratigraphic units in the Great Basin: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 1, p. 143–151, 2 figs.

Elias, M. K., 1957, Late Mississippian fauna from Redoak Hollow formation of southern Oklahoma: Jour. Paleontology, v. 31, no. 2, p. 39–50; no. 3, p. 487–527; no. 4, p. 737–784.

Emerson, W. K., 1952, Generic and subgeneric names in the molluscan Class Scaphopoda: Washington Acad. Sci. Jour., v. 42, no. 9, p. 296–303.

Fisher, C. A., 1909, Geology of the Great Falls coal field, Montana: U.S. Geol. Survey Bull. 356, 85 p., map.

Fredericks, G., 1916, The palaentological notes. On some Upper Palaeozoic Brachiopoda of Eurasia: Russia, Geol. Kom. Trudy, novaia ser., no. 156.

Freeman, O. W., 1922, Oil in the Quadrant formation in Montana: Eng. Mining Jour.—Press, v. 113, no. 19, p. 825–827.

Gardner, L. S., 1950, Geology of the Button Butte-Forest Grove area, Fergus County, Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 106.

——— 1959, Revision of the Big Snowy group in central Montana: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 2, p. 329–349.

Gardner, L. S., Hendricks, T. A., Hadley, H. D., and Rogers, C. P., Jr., 1945, Mesozoic and Paleozoic formations in south-central Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Chart 18.

——— 1946, Stratigraphic sections of upper Paleozoic and Mesozoic rocks in south-central Montana: Montana Bur. Mines and Geology Mem. 24, p. 1–6, 12–100.

Geinitz, A. B., 1866, Carbonformation and Dyas in Nebraska. Dresden.

George, T. N., 1927a, Studies in Avonian Brachiopoda—I. The genera *Brachythyris and Martinia*: Geol. Mag. (Great Britain), v. 64, p. 106–119.

——— 1927b, Studies in Avonian Brachiopoda—II. The genus *Camarophoria:* Geol. Mag. (Great Britain), v. 64, p. 193–201.

——— 1931, *Ambocoelia* Hall and certain similar British Spiriferidae: Geol. Soc. London Quart. Jour., v. 87, pt. 1, p. 30–61.

——— 1932, The British Carboniferous reticulate Spiriferidae: Geol. Soc. London Quart. Jour., v. 88, pt. 4, p. 516–575.

——— 1933, Principles in the classification of the Spiriferidae: Annals and Mag. Nat. History, ser. 10, v. 11, no. 64, p. 423–456.

Gerth, H., 1919, Über die Entwicklung der Septalapparates bei den paläozoischen Rugosen und bei lebenden Korallen: Zeitschr. Induktive Abstammungs—und Vererbungslehre, v. 21, no. 4, p. 201–215.

Girty, G. H., 1903, The Carboniferous formations and faunas of Colorado: U.S. Geol. Survey Prof. Paper 16.

Girty, G. H., 1908, The Guadalupean fauna: U.S. Geol. Survey Prof. Paper 58.

——— 1910, New genera and species of Carboniferous fossils from the Fayetteville shale of Arkansas: New York Acad. Sci. Annals, v. 20, p. 189–238.

——— 1911, The fauna of the Moorefield shale of Arkansas: U.S. Geol. Survey Bull. 439, 148 p., illust.

——— 1915, The fauna of the Batesville sandstone of northern Arkansas: U.S. Geological Survey, Bull. 593, 170 p., illust.

——— 1935, An unrecorded structure in certain semireticulate *Producti:* Jour. Paleontology, v. 9, no. 1, p. 7–9.

Gordon, Mackenzie, Jr., 1944, Moorefield formation and Ruddell shale, Batesville district, Arkansas: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 11, p. 1626–1634.

Grabau, A. W., 1928, Paleozoic corals of China, Part I. Tetraseptata: Palaeontologia Sinica, ser. B, v. 2, pt. 2.

Gunnell, F. H., 1932, The Brazer formation of northern Utah and its telotremate brachiopods: Am. Midland Naturalist, v. 13, no 5, p. 282–301.

Hadley, H. D., 1950, The Charles problem: Billings Geol. Soc. Guidebook 1st Ann. Field Conf., p. 44–46.

Hadley, H. D., Gardner, L. S., and Rogers, C. P., Jr., 1945, Graphic sections of Mesozoic and Paleozoic rocks that underlie the basin areas in south-central Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Chart 19.

Hadley, H. D., and Smith, G. W., 1952, Developments in Montana, North Dakota, and South Dakota in 1951: Am. Assoc. Petroleum Geologists Bull., v. 36, no 6, p. 1014–1022.

Hague, Arnold, 1877, Northern Wahsatch Region: U.S. Geol. Explor. 40th Parallel (King), v. 3, chap. 3, sec. 4, p. 393–419.

——— 1883, Geology of the Eureka district: U.S. Geol. Survey Ann. Rept. 3, p. 237–290.

Hall, James, and Clarke, J. M., 1893, 1894, An introduction to the study of the genera of Paleozoic Brachiopoda: New York Geol. Survey, Paleontology v. 8, pt. 1, p. 1–367 (1893); pt. 2, p. 1–394 (1894).

Hall, James, and Whitfield, R. P., 1877, Paleontology: U.S. Geol. Explor. 40th Parallel (King), v. 4, p. 197–302.

Hammer, A. A., and Lloyd, A. M., 1926, Notes on the Quadrant formation of east-central Montana: Am Assoc. Petroleum Geologists Bull., v. 10, no. 10, p. 986–996.

Henbest, L. G., 1946, The Morrow group, Pennsylvanian, of Washington County, Arkansas [abs.]: Am. Assoc. Petroleum Geologists Joint Ann. Meeting Program, April 2–4.

——— 1947, The Morrow group of northwest Arkansas [abs.]: Washington Acad. Sci. Jour., v. 37, no. 10, p. 373.

——— 1954, Pennsylvanian Foraminifera in Amsden formation and Tensleep sandstone, Montana and Wyoming: Billings Geol. Soc. Guidebook 5th Ann. Field Conf., p. 50–53.

Heritsch, Franz, 1939, Karbon und Perm in dem Südeuropa: Geol. Rundschau, v. 30, no. 5, p. 529–588.

Hernon, R. M., 1935, The Paradise formation and its fauna: Jour. Paleontology, v. 9, no. 8, p. 653–696.

Hill, Dorothy, 1938–1941, A monograph on the Carboniferous rugose corals of Scotland: Palaeontogr. Soc. Mon., pts. 1–4.

Honkala, F. S., 1951, Notes on the Amsden formation in southwestern Montana: Billings Geol. Soc. Guidebook 2d Ann. Field Conf., p. 61.

Hudson, R. G. S., 1935, On the Lower Carboniferous corals—*Rhopalolasma*, gen. nov. and *Cryptophyllum*, Carr.: Yorkshire Geol. Soc. Proc., v. 23, pt. 2, p. 91–102.

——— 1942, *Fasciculophyllum* Thomson and other genera of the "*Zaphrentis*" *omaliusi* group of Carboniferous corals: Geol. Mag. [Great Britain], v. 79, no. 5, p. 257–263.

Hudson, R. G. S., and Fox, T., 1943, An upper Viséan zaphrentoid fauna from the Yoredale beds of north-west Yorkshire: Yorkshire Geol. Soc. Proc., v. 25, pt. 2, p. 101–126.

Hudson, R. G. S., and Turner, J. S., 1933, Correlation of Dinantian and Namurian in Western Europe: Leeds Philos. Lit. Soc. Proc., Sci. Sec., v. 2, pt. 10, p. 467–482.

Hyatt, Alpheus, 1892, Remarks on the Pinnidae: Boston Soc. Nat. History Proc., v. 25, p. 335–346.

Imlay, R. W., Gardner, L. S., Rogers, C. P., Jr., and Hadley, H. D., 1948, Marine Jurassic formations of Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Chart 32.

Ivanova, E. A., 1951, New data on productid systematics (Genus *Kutorginella*): Akad. Nauk, SSSR, Doklady, novaia ser., v. 77, no. 2, p. 329–331.

Kiderlen, Helmut, 1937, Die Conularien. Über bau und Leben der ersten Scyphozoa: Neues Jahrb., Beilage-Band, Abt. B, p. 113–169.

King, R. E., 1930, The geology of the Glass Mountains, Texas, Part II: Texas Univ. Bull. 3042.

Knight, J. B., 1931, The gastropods of the St. Louis, Missouri, Pennsylvanian outlier—The Subulitidae: Jour. Paleontology, v. 5, no. 3, p. 177–229.

——— 1934, The gastropods of the St. Louis, Missouri, Pennsylvanian outlier—VII. The Euomphalidae and Platyceratidae: Jour. Paleontology, v. 8, no. 2, p. 139–166.

——— 1937, *Conchopeltis* Walcott, an Ordovician genus of the Conulariida: Jour. Paleontology, v. 11, no. 3, p. 186–188.

Licharew, Boris, 1936, The interior structure of *Camarophoria* King: Am. Jour. Sci., 5th ser., v. 32, no. 185, p. 55–69.

Love, J. D., 1939, Geology along the southern margin of the Absaroka Range, Wyoming: Geol. Soc. America Spec. Paper 20, 134 p., 17 pls., 3 figs.

Love, J. D., Denson, N. M., and Botinelly, T., 1949, Geology of the Glendo area, Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 92.

Ludlow, William, 1876, Report of a reconnaissance from Carroll, Montana Territory, on the upper Missouri, to the Yellowstone National Park and return made in the summer of 1875: Washington, 141 p. *Also in* U.S. (War Dept.) Chief Engineer's, Ann. Rept. (U.S. 44th Cong., 2d sess., H. Ex. Doc. 1, pt. 2, v. 2, pt. 3), app. NN, p. 569–699.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U.S. Geol. Survey Prof. Paper 152, 409 p., 63 pls., 46 figs.

Meek, F. B., 1877, Paleontology: U.S. Geol. Explor. 40th Parallel (King), v. 4, pt. 1, 197 p.

Mellen, F. F., 1947, Black Warrior Basin, Alabama and Mississippi: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 10, p. 1801–1816.

Miller, A. K., Downs, H. R., and Youngquist, W., 1949, Goniatites from the Heath formation of Montana *in*, Some Mississippian Cephalopods from central and western United States: Jour. Paleontology, v. 23, no. 6, p. 611, 612.

Miller, A. K., Dunbar, C. O., and Condra, G. E., 1933, The Nautiloid cephalopods of the Pennsylvania system in the mid-continent region: Nebraska Geol. Survey, ser. 2, Bull. 9.

Miller, A. K., and Furnish, W. M., 1955, The Carboniferous guide fossil, *Tylonautilus*, in America: Jour. Paleontology, v. 29, no. 3, p. 462–464.

Miloradovich, B. V., 1945, Some data on the morphology of productid shells: Akad. Nauk. SSSR, Izv. Ser. Biol. (1945), no. 4, p. 485–500.

Moore, R. C., 1938, The use of fragmentary crinoidal remains in stratigraphic paleontology: Denison Univ., Sci. Lab., Bull., v. 33, p. 165–250.

Moore, R. C., and Jeffords, R. M., 1941, New Permian corals from Kansas, Oklahoma, and Texas: Kansas Geol. Survey, Bull. 38, p. 65–120.

——— 1945, Description of Lower Pennsylvania corals from Texas and adjacent states: Texas Univ. Bull., no. 4401, p. 77–206.

Moore, R. C., Lalicker, C. G., and Fisher, A. G., 1952, Invertebrate fossils: New York, McGraw-Hill Book Co., 766 p., illust.

Moore, R. C., and others, 1944, Correlation of Pennsylvanian formations of North America: Geol. Soc. America Bull., v. 55, no. 6, p. 657–706.

Moore, R. C., and Plummer, F. B., 1940, Crinoids from the Upper Carboniferous and Permian strata in Texas: Texas Univ. Pub., no. 3945, p. 9–468.

Morey, P. S., 1935, Ostracoda from the Amsden formation of Wyoming: Jour. Paleontology, v. 9, no. 6, p. 474–482.

Muir-Wood, H. M., 1927, Two new species of Lower Carboniferous Brachiopoda from Northumberland: Annals and Mag. Nat. History, ser. 9, v. 19, p. 286–291.

——— 1928, The British Carboniferous Producti, pt. II: Great Britain Geol. Survey Mem., Paleontology, v. 3, pt. 1, p. 1–217.

——— 1930, The classification of the British Carboniferous brachiopod subfamily Productinae: Annals and Mag. Nat. History, ser. 10, v. 5, p. 100–108.

——— 1948, Malayan lower Carboniferous fossils and their bearing on the Visean palaeogeography of Asia: British Mus. (Nat. History), London, 118 p., 17 pls., 3 figs.

Mundt, P. A., 1956, Heath-Amsden strata in central Montana: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 8, p. 1915–1934.

Newberry, J. S., and Worthen, A. H., 1866, Descriptions of new species of vertebrates, etc.: Illinois Geol. Survey, v. 2, sec. 1, p. 11–134.

Newell, N. D., 1937, Late Paleozoic pelecypods—Pectinacea: Kansas Geol. Survey, v. 10, pt. 1, 123 p., 20 pls., 38 figs.

——— 1942, Late Paleozoic pelecypods—Mytilacea: Kansas Geol. Survey, v. 10, pt. 2, 115 p., 15 pls., 22 figs.

Nieschmidt, C. L., 1953, Subsurface stratigraphy of the Heath shale and Amsden formation in central Montana: U.S. Geol. Survey Oil and Gas Inv. Chart OC 50.

Nolan, T. B., Merriam, C. W., and Williams, James Steele, 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geol. Survey Prof. Paper 276, 77 p.

Ogden, Lawrence, 1951, Mississippian and Pennsylvanian stratigraphy, Confusion Range, west-central Utah: Am. Assoc. Petroleum Geologists Bull., v. 35, no 1, p. 62–82.

Paeckelmann, W., 1930, Die Brachiopoden des deutschen Unterkarbons, part 1: Preuss. Geol. Landesanstalt Abh., N. F., v. 122.

——— 1931, Versuch einer zusammenfassenden Systematik der Spiriferidae King: Neues Jahrb., Beilage-Band 67, Abt. B, p. 1–64.

Parks, J. M., Jr., 1951, Corals from the Brazer formation (Mississippian) of northern Utah: Jour. Paleontology, v. 25, no. 2, p. 171–186.

Percival, E., 1944, A contribution to the life history of the brachiopod *Terebratella inconspicua* Sowerby: Royal Soc. New Zealand Trans., v. 74, pt. 1, p. 1–23.

——— 1953, Orientation of telotrematous Brachiopoda: Nature, v. 171, no. 4349, p. 436.

Perry, E. S., 1951, The northward termination of the Big Snowy and Amsden strata in central Montana: Billings Geol. Soc. Guidebook 2d Ann. Field Conf., p. 55–57.

Perry, E. S., and Sloss, L. L., 1943, Big Snowy Group—Lithology and correlation in the northern Great Plains: Am. Assoc. Petroleum Geologists Bull., v. 27, no. 10, p. 1287–1304.

Pilsbry, H. A., and Sharp, Benjamin, *in* Tryon, G. W., 1897, Manual of Conchology, ser. 1, v. 17, pt. 65, p. v–xxxii, 1–80.

Rader, M. T., Lorenz, H., Marland, L. E., Gardner, L. S., and Hadley, H. D., 1951, First day of field conference: Billings Geol. Soc. Guidebook 2d Ann. Field Conf., p. 9–22.

Ramsbottom, W. H. C., 1952, The fauna of the Cefn Coed marine band in the coal measures at Aberbaiden, near Tondu, Glamorgan: Great Britain Geol. Survey, Bull. 4, p. 8–30.

Rea, H. C., 1948, Developments in Rocky Mountain region in 1947: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 6, p. 886–892.

Reeves, Frank, 1926, Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana: U.S. Geol. Survey Bull. 786–B, p. 39–95.

——— 1931, Geology of the Big Snowy Mountains, Montana: U.S. Geol. Survey Prof. Paper 165–D, p. 135–149, 4 pls., 1 fig.

Rogers, C. P., Jr., Gardner, L. S., and Hadley, H. D., 1945, Maps showing thickness and general distribution of Mesozoic and Paleozoic rocks in south-central Montana: U.S. Geol. Survey Oil and Gas Prelim. Map 43.

Romer, A. S., 1947, Vertebrate paleontology: 2d ed., Chicago, University of Chicago.

Sarycheva, T. G., 1949, Morphology, ecology, and evolution of Carboniferous productids near Moscow (Genera *Dictyoclostus*, *Pugilis*, and *Antiquatonia*): Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 18, 304 p.

Sarycheva, T. G., and Sokolskaia, A. N., 1952, Index of Paleozoic brachiopods from the submoscovian basin: Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 38, 307 p.

Schenck, H. G., 1939, Revised nomenclature for some nuculid pelecypods: Jour. Paleontology, v. 13, no. 1, p. 21–41.

Schuchert, Charles, 1897, A synopsis of American fossil Brachiopoda including bibliography and synonymy: U.S. Geol. Survey Bull. 87, 464 p.

Schuchert, Charles, and Cooper, G. A., 1932, Brachiopod genera of the suborders Orthoidea and Pentameroidea: Peabody Mus. Nat. History Mem., v. 4, pt. 1, 270 p., illust.

Scott, H. W., 1935a, Upper Mississippian and Lower Pennsylvanian stratigraphy in Montana [abs.]: Geol. Soc. America Proc., 1934, p. 367.

——— 1935b, Some Carboniferous stratigraphy in Montana and northwestern Wyoming: Jour. Geology, v. 43, no. 8, p. 1011–1032.

——— 1938, A Stomatopod from the Mississippian of central Montana: Jour. Paleontology, v. 12, no. 5, p. 508–510.

——— 1942a, Ostracodes from the Upper Mississippian of Montana: Jour. Paleontology, v. 16, no. 2, p. 152–163.

——— 1942b, Conodont assemblages from the Heath formation, Montana: Jour. Paleontology, v. 16, no. 3, p. 293–300.

——— 1945a, Age of the Amsden formation [abs.]: Geol. Soc. America Bull., v. 56, no. 12, pt. 2, p. 1195.

——— 1945b, Pennsylvanian stratigraphy in Montana and northern Wyoming [abs.]: Geol. Soc. America Bull., v. 56, no. 12, pt. 2, p. 1196.

Scott, H. W., 1950, The Big Snowy Group: Billings Geol. Soc. Guidebook 1st Ann. Field Conf., p. 47, 48.

Seager, O. A., 1942, Test on Cedar Creek anticline, southeastern Montana: Am. Assoc. Petroleum Geologists Bull., v. 26, no. 5, p. 861–864.

Severy, C. L., and McNarty, D. M. E., 1950, Developments in Rocky Mountain region in 1949: Am. Assoc. Petroleum Geologists Bull., v. 34, no. 6, p. 1032–1042.

——— 1951, Developments in Rocky Mountain region in 1950: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 6, p. 1160–1172.

Shaw, A. B., and Bell, W. G., 1955, Age of Amsden formation, Cherry Creek, Wind River Mountains, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 3, p. 333–337.

Shimer, H. G., and Shrock, R. R., 1944, Index fossils of North America: New York, John Wiley and Sons.

Sinclair, G. W., 1952, A classification of the Conularida: Fieldiana Geology, v. 10, no. 13, p. 135–145.

Slater, I. L., 1907, A monograph of the British Conulariae: Palaeontogr. Soc. Mon., v. 61, no. 7.

Sloss, L. L., 1945, Corals from the post-Osage Mississippian of Montana: Jour. Paleontology, v. 19, no. 3, p. 309–314.

——— 1946, Faunas of the Amsden and Heath formations: Montana Bur. Mines and Geology, Mem. 24, p. 6–11.

——— 1951, The central Montana uplifts in relation to late Mississippian stratigraphy: Billings Geol. Soc. Guidebook 2d Ann. Field Conf., p. 64–66.

——— 1952, Introduction to the Mississippian of the Williston basin: Billings Geol. Soc. Guidebook, 3d Ann. Field Conf., p. 65–69.

——— 1953, The significance of evaporites: Jour. Sedimentary Petrology, v. 23, no. 3, p. 143–161.

Sloss, L. L., and Moritz, C. A., 1951, Paleozoic stratigraphy of southwestern Montana: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 10, p. 2135–2169.

Snider, L. C., 1915, The paleontology of the Chester group in Oklahoma: Oklahoma Geol. Survey Bull. 24, p. 67–122, illust.

Sokolov, B. S., 1939, Rôle of the *Rugosa* and *Tabulata* corals in the stratigraphy of the lower Carboniferous of the Moscow Basin (northern part): Akad. Nauk SSSR, Doklady, novaiâ ser., v. 25, no. 2, p. 134–137.

Sokolskaia, A. N., 1941, Lower Carboniferous and Devonian-Carboniferous brachiopods of the Moscow Basin (Tschernyschino, Upa, and Malevka—Murajevnia beds), pt. 1, Spiriferidae: Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 12, no. 2.

Soshkina, E., Dobrolyubova, T., and Porfiriev, G., 1941, Permskie *Rugosa* evropeiskoi chasti SSSR: Akad. Nauk SSSR, Paleont. Inst., Paleontologia SSSR, v. 5, pt. 3, no. 1.

Stehli, F. G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo: Am. Mus. Nat. History Bull., v. 105, art. 3, p. 257–358.

Stoyanow, A. A., 1926, Notes on recent stratigraphic work in Arizona: Am. Jour. Sci., 5th series, v. 12, p. 316–320.

Sutton, A. H., 1938, Taxonomy of Mississippian Productidae: Jour. Paleontology, v. 12, no. 6, p. 537–569.

Thompson, M. L., 1948, Studies of American fusulinids: Kansas Univ. Paleont. Contr., Protozoa, art. 1, p. 1–184.

Thompson, M. L., and Scott, H. W., 1941, Fusulinids from the type section of the lower Pennsylvanian Quadrant formation: Jour. Paleontology, v. 15, no. 4, p. 349–353.

Tolmachoff, I. P., 1931, Faune du calcaire carbonifère du bassin houiller de Kousnetzk, pt. 2, p. 321–663: Glavnoe geologorazvedochnoe upravlenie. (Part 1 is published in Geologicheskiĭ Komitet, Materialy po obshcheĭ i prikladnoĭ geologii, no. 25, 1924.)

Trautschold, H., 1867, Einige Crinoideen und andere Thierreste des jüngeren Bergkalks in Gouvernment Moskau: Imp. soc. naturalistes Moscou Bull., [1st ser.], v. 40, no. 3, p. 1–49.

——— 1879, Die Kalkbrüche von Mjatschkowa. Eine Monographie des oberen Bergkalks: Imp. soc. naturalistes Moscou Nouv. Mém., v. 14, liv. 1.

Vine, J. D., and Hail, W. J., Jr., 1950, Geologic map of the Hobson area, central Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 108.

Walton, P. T., 1946, Ellis, Amsden, and Big Snowy group, Judith Basin, Montana: Am. Assoc. Petroleum Geologists Bull., v. 30, no. 8, p. 1294–1305.

Weed, W. H., 1892, Two Montana coal fields: Geol. Soc. America Bull., v. 3, p. 301–330.

——— 1899a, Description of the Fort Benton quadrangle, Montana: U.S. Geol. Survey Geol. Atlas Folio 55.

——— 1899b, Description of the Little Belt Mountains quadrangle, Montana: U.S. Geol. Survey Geol. Atlas, Folio 56.

——— 1899c, Geology of the Little Belt Mountains, Montana * * *: U.S. Geol. Survey Ann. Rept. 20, pt. 3, p. 257–595.

Weller, J. M., 1931, Mississippian fauna: Kentucky Geol. Survey, ser. 6, v. 36, p. 249–290.

——— 1936, Carboniferous trilobite genera: Jour. Paleontology, v. 10, no. 8, p. 704–714.

——— 1937, Evolutionary tendencies in American Carboniferous trilobites: Jour. Paleontology, v. 11, no. 4, p. 337–346.

Weller, J. M., and others, 1948, Correlation of the Mississippian formations of North America: Geol. Soc. America Bull., v. 59, no. 2, p. 91–196.

Weller, Stuart, 1914, The Mississippian Brachiopoda of the Mississippi Valley Basin. Illinois Geol. Survey, Mon. 1, 508 p., illust.

White, C. A., 1877, Report upon the invertebrate fossils, etc.: U. S. Geog., Explor. W. 100th Mer. Rept., v. 4, pt. 1.

Williams, James Steele, 1948, Mississippian-Pennsylvanian boundary problems in the Rocky Mountain region: Jour. Geology, v. 56, no. 4, p. 327–351.

——— 1949, Diverse concepts of the Amsden formation [abs.]: Geol. Soc. America Bull., v. 60, no. 12, pt. 2, p. 1928, 1929.

Williams, J. Stewart, 1943, Carboniferous formations of the Uinta and northern Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 54, no. 4, p. 591–624.

Williams, J. Stewart, and Yolton, J. S., 1945, Brazer (Mississippian) and lower Wells (Pennsylvanian) section at Dry Lake, Logan quadrangle, Utah: Am. Assoc. Petroleum Geologists Bull., v. 29, no. 8, p. 1143–1155.

Willis, Bailey, 1902, Stratigraphy and structure, Lewis and Livingston Ranges, Montana: Geol. Soc. America Bull., v. 13, p. 305–352.

Wright, James, 1939, The Scottish Carboniferous Crinoidea: Royal Soc. Edinburgh Trans., v. 60, pt. 1, no. 1, p. 1–78.

——— 1951, A monograph on the British Carboniferous Crinoidea, pt. 3: Palaeont. Soc. London Mon., v. 105, p. 47–102.

Zeller, D. E. N., 1953, Endothyroid Foraminifera and ancestral fusulinids from the type Chesterian (Upper Mississippian): Jour. Paleontology, v. 27, no. 2, p. 183–199.

Zeller, E. J., 1950, Stratigraphic significance of Mississippian endothyroid Foraminifera: Kansas Univ. Paleont. Contr., Protozoa, Art. 4, p. 1–23.

LOCALITY LIST

Locality (or collection or sample) numbers refer to the "blue" series of the late Paleozoic files of the Paleontology and Stratigraphy Branch of the U. S. Geological Survey, Washington, D. C.

13358 At 2 feet above the base of unit 18 of the measured section at Delpine, Meagher County, Mont., Sec. 14, T. 9 N., R. 10 E.

Can be reached from a point about 23 miles east of White Sulphur Springs or 32 miles west of Harlowtown by going about ¼ mile north from State Road 6 along a gravel road to the second ranch house; walk about 200 yards north, across the irrigation ditch on the hillside. The collection was made in the L-shaped gully.

Otter formation.

13359 From unit 10 of the measured section at Delpine, Meagher County, Mont. Sec. 14, T. 9 N., R. 10 E.

Collected from north bank of irrigation ditch and northward along the strike from the prominent overturned outcrops 100 yards northeast of the ranch house mentioned in 13358.

Heath formation.

13360 From basal 1 foot of unit 8 of the measured section at Delpine, Meagher County, Mont.

Same location as 13359.

Cameron Creek formation.

13361 From 2 to 3 feet above the base of unit 7 of the measured section at Delpine, Meagher County, Mont.

Same location as 13359.

Cameron Creek formation.

13362 From 4 feet above the base of unit 7 of the measured section at Delpine, Meagher County, Mont.

Same location as 13359.

Cameron Creek formation.

13363 From the upper 4 feet of unit 7 of the measured section at Delpine, Meagher County, Mont.

Same location as 13359.

Cameron Creek formation.

13364 From unit 3 of the measured section at Delpine, Meagher County, Mont.

Same location as 13359.

Alaska Bench limestone.

13365 From top of embankment of black fissile shale 50 feet east of the road at a point 100 feet north of the house at the north end of the gypsum plant 1.3 miles south of Heath, Fergus County, Mont. SE cor., sec. 2, T. 14 N., R. 19 E.

Upper part of Heath formation.

13366 From various horizons in three conspicuous road cuts on east side of road south of Heath near the top of the hill. Center of E½ sec. 35, T. 14 N., R. 19 E., Fergus County, Mont.

Black fissile shale overlain by numerous thin siltstone and limestone beds in the upper part of the Heath formation.

13367 From base and 6 feet above the base of the silty and thin-bedded black shale 0.3 mile south of the bridge over Tyler Creek, a few miles southeast of Heath. SE cor. SW¼ sec. 26, T. 14 N., R. 20 E., Fergus County, Mont.

Upper part of the Heath formation.

Approximately the same beds as 13366.

13368 From black shale and thin, black, brown-weathering limestone in the gully washed out from the artesian well on the hill north of Hanover; or almost beneath the old tramway from the cement plant. SE¼SW¼ sec. 22, T. 16 N., R. 17 E., Fergus County, Mont.

Reached by entering field 50 feet west of west end of railway siding at southwest end of cement plant property, then driving 0.5 mile north up grade, bearing east to where old tramway crosses road, collections came from 11 feet of section starting 25 feet south of north artesian well.

Heath formation.

13369 From brown-weathering limestone 34 feet stratigraphically above 13368.

This locality is on the east side of the washed-out gully about 100 feet due east of the south artesian well. SE¼SW¼ sec. 22, T. 16 N., R. 17 E., Fergus County, Mont.

Heath formation.

13370 Limestone below the gypsum bed on the hill south of the Stewart ranch buildings, south of Heath.

Reached by going 4.1 miles south-southwest of the gypsum plant along Spring Creek road; turn west down hill to the Stewart ranch house; go through barnyard and 0.8 mile southwest along field road; turn southeast and go 1.3 mile up hill; go eastward 0.2 mile along flat top of hill and descend slope to fence and railroad rail marking diamond-drill hole A–5. Locality is 150 yards southeast diagonally down slope across field to slight bench on north side of west-trending valley.

Basal limestone in the Heath formation. Probably just below gypsum bed.

13371 From prominent south-facing bluff of limestone at south end of flat hill mentioned in 13370. Dense, gray, platy-weathering limestone about 10 feet below top of Alaska Bench limestone.

From locality 13370 south of Stewart ranch, continue southward, through fences, a total of 1.5 miles to the southwest corner of the large field. The outcrops are about 50 feet beneath the rim of the cliff.

Dense, gray, platy-weathering limestone about 10 feet below the top of the Alaska Bench limestone or 5 feet above the red silty shale of the Cameron Creek formation.

13372 From prominent cliff on south side of large flat-topped hill mentioned in 13371.

Same location as 13371, only 200 yards west of corner of field.

Red-weathering, calcareous, silty shale about 15–17 feet below the top of the Alaska Bench limestone.

577887 O—61——8

13373 Below limestone cliff on south side of large flat-topped hill mentioned in 13371.

Same location as 13371, only 200 yards west of corner of field.

Red silty Cameron Creek formation 2 feet below massive 4-foot-thick reddish-stained Alaska Bench limestone.

13374 From black shale in small quarry on the west side of the road at the top of the hill 0.5 mile south of the school house in Otter Creek valley. SW¼ sec. 7, T. 16 N., R. 9 E., Judith Basin County, Mont.

Reached from Geyser on U.S. Highway 87 west of Stanford, by going 6.4 miles west on Highway 87; turn south and go 2.0 miles; turn east up Otter Creek valley and go 5.9 miles to school house with "1902" on plaque.

About the middle of the Otter formation. Associated with intrusive rocks.

13375 On the west side of the road at the cliffs cut in the intrusion by Otter Creek, in a road cut-and-stripped area. Center of E½ sec. 7, T. 16 N., R. 9 E., Judith Basin County, Mont.

Reached by going 0.2 mile north of school mentioned in 13374.

In green shale in the upper third of the Otter formation, about 10–15 feet above the intrusion.

13376 From hard black shale in unit 8 of the measured section on the West Fork of Judith River, 2 feet above prominent cliff at last exposure eastward of the cliff-making limestone along road on the north side of the river. SW¼ sec. 19, T. 13 N., R. 12 E., Judith Basin County, Mont.

Reached by going about ½ mile past vivid green outcrop about 11 miles west of Utica on Judith River road. Ascend cliff northwest of two minor anticlines on its face to stripped upper surface of limestone.

Otter formation.

13377 From oolitic limestone in unit 11 of the measured section on the West Fork of Judith River. About 25 feet below cliff along road up Judith River. NE¼ sec. 25, T. 13 N., R. 11 E., Judith Basin County, Mont.

Same location as 13376.

Otter formation.

13378 From unit 8 of the measured section on the West Fork of Judith River on the southwest side of a rounded hill on the north side of a broad valley draining eastward into Judith River. Center W½ sec. 19, T. 13 N., R. 12 E., Judith Basin County, Mont.

Reached by going about 11 miles west of Utica on road up valley of West Fork of Judith River to vivid green hillside; continue about ½ mile along road to concrete culvert; walk westward up dry creek about ¼ mile and thence up gully to northward.

From black shale in Otter formation about 10 feet above limestone in gully bottom.

13379 From unit 8 of the measured section on the West Fork of Judith River, Judith Basin County, Mont. Center W½ sec. 19, T. 13 N., R. 12 E.

Same location as 13378.

From 6-inch thickness of yellowish-weathering shale and limestone in the Otter formation just below the prominent bluff ¼ mile west of the road.

13380 From the upper 3 feet of unit 17 of the measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

The locality can be reached by going 11.5 miles south and east of the gypsum plant at Heath, taking the road to the beacon; stop on the grade 0.2 mile north of the intersection of the gravel road and the dirt road leading to the beacon; walk about 100 yards west, descending the bluff on a round spur.

Cameron Creek formation.

13381 From the upper half of unit 16 of the measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

Same location as 13380.

Cameron Creek formation.

13382 From unit 15 of the measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

Same location as 13380.

Cameron Creek formation.

13383 From the middle of unit 13 of the measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

Same location as 13380.

Sandstone bluff in the Cameron Creek formation.

13384 From unit 3 of the measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

Same location as 13380.

Alaska Bench limestone.

13385 Random collections, mostly float, from measured section at the north end of the bluff near the beacon south of Heath, Fergus County, Mont. NE¼SW¼ sec. 25, T. 13 N., R. 19 E.

Same location as 13380.

Undifferentiated limestone of the Cameron Creek and Alaska Bench formations.

13386 From the basal 6 inches of shale in unit 15 of the measured section below the beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.

The locality can be reached by going 11.5 miles south and east of the gypsum plant at Heath, taking the road up on to Alaska Bench, then driving south along the brink of the cliff to the beacon. The section is most readily approached by descending the south end of the cliff and working back on to the cliff face.

Cameron Creek formation.

13387 From unit 19 of the measured section below the beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.

Same location as 13386.

Uppermost bed of the Heath formation. This is the type section of the Heath shale.

13388 From unit 24 of the measured section below the beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.

Same location as 13386.

Heath formation (type locality).

From 2-inch ironstone band 5 feet below top of unit.

13389 From the upper 10 feet of unit 1 of measured section at the north end of the cliff near the beacon south of Heath, Fergus County, Mont. SW¼ sec. 25, T. 13 N., R. 19 E.

Along the top of the cliff southward ½ mile from 13386.

Top of Alaska Bench limestone.

13390 From the bottom 6 inches of unit 33 of the measured section at Potter Creek Dome, Fergus County, Mont. Center N½ sec. 8, T. 13 N., R. 21 E.

Reached by going to the last good outcrop on the north side of the grade 8.1 miles southeast of Forest Grove on the Little Snowies Road, at a point about 0.2 mile west (downgrade) from the summit.

Otter formation.

13391 From about the upper 20 feet on slope of unit 24 of measured section at Potter Creek Dome, Fergus County, Mont. SW¼SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

From point 7.4 miles southeast of Forest Grove along the Little Snowies Road, walk across field and along ridge crest immediately east of two old houses ¼ mile north of road; locality is 550 to 600 feet north along the ridge from the last outcrop of green shale.

Heath formation.

13392 From unit 23 of the measured section at Potter Creek Dome, Fergus County, Mont. SW¼SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

Same location as 13391.

Heath formation.

13393 From unit 21 of the measured section at Potter Creek Dome, Fergus County, Mont. SW¼SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

Same location as 13391.

Heath formation.

13394 From unit 16 of the measured section at Potter Creek Dome, Fergus County, Mont. SW¼SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

Same location as 13391, but 300 feet farther north along the ridge.

Heath formation.

13395 From unit 14 of the measured section on Potter Creek Dome, Fergus County, Mont. SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

From the second short spur east of locality 13394, about 200 yards.

Heath formation.

13396 From upper 51 feet of unit 9 of measured section on Potter Creek Dome, Fergus County, Mont. SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

Located 300 to 400 feet north along the spur from which came 13395.

Heath formation.

13397 From unit 11 of the measured section on Potter Creek Dome, Fergus County, Mont. SE¼SW¼ sec. 5, T. 13 N., R. 21 E.

From the fifth ridge east of the two old houses mentioned in 13391 and on a shoulder occupied by a cairn.

Heath formation.

13398 From unit 2 of the measured section on Potter Creek Dome, Fergus County, Mont. Center SW¼ sec. 5, T. 13 N., R. 21 E.

From base of prominent cliff north of two old houses mentioned in 13391.

Alaska Bench limestone.

13399 From vertical limestone cliff just west of the beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.

Same location as 13386.

Undifferentiated limestone in the Alaska Bench limestone.

13400 From unit 67 of the measured section on Durfee Creek Dome, Fergus County, Mont. NW¼NW¼ sec. 19, T. 12 N., R. 23 E.

The locality is reached by going 7.3 miles southeast of N Bar Ranch, then turning south through the yard of a white ranch house; after crossing yard, turn west in field and go a total of 0.5 mile from county road; turn south along east side of fence and go 1.4 miles, ascending bluff with fence along crest; turn west at fence and go 2.6 miles along faint tracks to gorge of Durfee Creek. Go up east fork on south side of gorge and walk to earth dam about ¼ mile. Locality is on northeast-facing dip slope beyond second gully.

Algal(?) limestone in Otter formation.

13401 From unit 69 in measured section on Durfee Creek Dome, Fergus County, Mont. NW¼NW¼ sec. 19, T. 12 N., R. 23 E.

Location is in first gully and ridge east of dam mentioned in 13400.

Otter formation.

13042 From unit 44 of measured section on Durfee Creek Dome, Fergus County, Mont. NE¼NW¼ sec. 19, T. 12 N., R. 23 E.

Location is 240 yards east of earth dam mentioned in 13400.

Heath formation.

13403 From unit 23 of measured section on Durfee Creek Dome, Fergus County, Mont. S. line, SE¼SW¼ sec. 18, T. 12 N., R. 23 E.

Located on the west side of the gorge of Durfee Creek mentioned in 13400.

Base of limestone bluffs in the Alaska Bench limestone.

13404 From unit 11 of measured section on Durfee Creek Dome, Fergus County, Mont. S. line, SE¼SW¼ sec. 18, T. 12 N., R. 23 E.

Located on both sides of the gorge of Durfee Creek mentioned in 13400.

Alaska Bench limestone.

13405 From unit 21 of the measured section on Durfee Creek Dome, Fergus County, Mont. S. line, SE¼SW¼ sec. 18, T. 12 N., R. 23 E.

Located on the west side of the gorge of Durfee Creek mentioned in 13400.

Lower part of limestone succession in the Alaska Bench limestone.

13406 From gorge of Durfee Creek, in units 5 to 24 of measured section on Durfee Creek Dome, Fergus County, Mont. S. line, SE¼SW¼ sec. 18, T. 12 N., R. 23 E.

Located on the sides of the gorge of Durfee Creek mentioned in 13400.

Alaska Bench limestone.

13407 From the upper surface of the lowest of three short bluffs at the gorge near the head of Hopley Creek, about 20 miles northwest of Harlowtown, Wheatland County, Mont. Probably N½ sec. 8, T. 10 N., R. 13 E. Section measured by Gardner and others (1946, p. 38, basal 37 foot bed of Amsden).

Can be reached by going up Hopley Creek to where the good road rises out of the gully on the west banks. Continue up faint track in center of valley to narrow gorge in limestone.

Alaska Bench limestone.

13408 From cut on east side of road south of Heath, Fergus County, Mont.

Locality is 0.7 mile north of Mountain View School and 0.1 mile north of the small bridge.

Upper part of Heath formation.

13409 From summit of road grade at north end of hill south of Heath, Fergus County, Mont.

Locality is in black shale and 4-inch limestone beds in the ditches and stripped area west of road 1.8 miles south of Mountain View School.

About 100 to 150 feet above the base of the Heath formation.

13410 From summit of south grade on hill south of Heath, Fergus County, Mont.

Locality is in the ditch on the east side of the road 2.5 miles south of Mountain View School and 0.2 mile north of the vivid green road cut on the hill.

Probably about 50 feet above the base of the Heath formation in black shale and brown-weathering thin limestone beds.

13411 From unit 65 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality can be reached by walking up Stonehouse Canyon from ranch house at mouth of canyon to the earth dam or by driving into Stonehouse Canyon through Road Canyon to the west 1 mile. Outcrops are about 200 yards east of dam in trenchlike gully on east side of valley.

Lower brown-weathering limestone stringers in the Heath formation.

13412 From unit 64 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is the same as 13411.

Lower part of the Heath formation.

13413 From unit 58 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the north side of the deep gully about 500 yards east of the earth dam mentioned in 13411, near the bottom of the gully.

Heath formation.

13414 From unit 46 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the rounded shoulder on the north side of the deep gully 500 yards east of the earth dam mentioned in 13411.

Heath formation.

13415 From unit 44 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the north wall near the top of the deep gully about 500 yards east of the earth dam mentioned in 13411.

Heath formation.

13416 From unit 44 of measured section in Stonehouse, Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is about 200 feet northwest of 13415 and on the far north wall of the gully.

Heath formation.

13417 From unit 41 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the north side of the deep gully about 500 yards east of the earth dam mentioned in 13411.

Heath formation.

13418 From lower 4 feet of unit 33 of measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the bench above the steep slope cut by gullies about 500 yards east of the earth dam mentioned in 13411.

Sandstone in the Cameron Creek formation.

13419 From unit 29 through the upper half of unit 32 of the measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of N. line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the slopes below the limestone ledges capping the hill about 700 yards east of the earth dam mentioned in 13411.

Cameron Creek formation.

13420 From unit 28 of the measured section in Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the reddish slump-exposed face on the east side of the valley about 200 feet north of the north end of the gorge.

Cameron Creek formation.

13421 From unit 22 of the measured section in Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is in the east wall of the north end of the gorge, in unresistant beds making a reentrant beneath the hard limestones.

Cameron Creek formation.

13422 From unit 19 of the measured section on Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is on the east wall of the gorge in limestone at a minor bluff.

Alaska Bench limestone.

13423 From unit 11 of the measured section in Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is at the top of the resistant limestone sequence on a dip slope on the east wall of the gorge.

Alaska Bench limestone.

13424 From unit 46 of the measured section in Stonehouse Canyon, Golden Valley County, Mont. Center of north line, NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is in the third major gully north of the earth dam mentioned in 13411.

Heath formation.

13425 From unit 50 in the measured section in Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.

Locality is in the stream bank on the east side of the dry creek bed about 300 yards north of the north end of the gorge, in a bluff about 10 feet high.

Heath formation.

13426 From unit 53 of measured section on Durfee Creek Dome, Fergus County, Mont. NE¼NW¼ sec 19, T. 12 N., R. 23 E.

Location is 240 yards east of earth dam mentioned in

13400, thence south near base of north slope.
Otter formation.

14100 From limestone in the valley wall at the water fall about 2 miles south of Becket, Mont. E½ sec. 21, T. 14 N., R. 22 E., Fergus County, Mont.
Collected by H. D. Hadley and W. Saalfrank and mentioned by Gardner and others (1946) as their locality 45–38–14, in cherty dolomite 6 to 12 feet below top of the Alaska Bench limestone.

14101 Probably the same as 13395.
Collected by Gardner and others (1946) as their locality 45–58–41B.
Heath formation.

14102 Same as 13411 and 13412 combined.
Collected by Gardner and others (1946) as their locality 44–37–138.
Heath formation.

14103 From the ridge 1 mile west of Eustis. Sec. 7 or 8, T. 2 N., R. 2 E., Broadwater County, Mont.
Collected by Gardner and others (1946) as their locality 44–15–5.
Heath formation.

14146 From units 28 and 29 of measured section in Scott (1935b, p. 1024). Located in reddish shale and limestone beneath the beacon on the hillside south of Heath, probably in sec. 36, T. 13 N., R. 19 E., Fergus County, Mont.
Collected by H. W. Scott. Same as USGS f 9712.
Cameron Creek formation.

14220 From unit 7 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14221 From unit 9 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14222 From the top of unit 10 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14223 From the base of unit 10 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14224 From the upper 10 inches of unit 11 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14225 From an 8-inch-thick nodular limestone whose base lies 1.5 feet below the top of unit 11 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14226 From just below the nodular limestone mentioned in 14225 at a point about 1.5 to 2 feet below the top of unit 11 of the measured section at Alaska Bench near the aerial beacon south of Heath, Fergus County, Mont. SW¼ sec. 36, T. 13 N., R. 19 E.
Same location as 13386.
Cameron Creek formation.

14227 From calcareous streaks in unit 11 of the measured section on Belt Creek in sec. 11, T. 17 N., R. 6 E., Cascade County, Mont.
Located on the bluffs on the east side of U.S. Highway 89 at the spring 8.5 miles south of U.S. Highway 87 or 1.6 miles north of Riceville.
Otter formation.

16180 Probably from unit 7 or 9 of the measured section at Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.
From gray dolomite about half way up the hill on the west side of gorge and above southern edge of outcrop of Alaska Bench limestone. Collected by M. Gordon.
Devils Pocket formation.

16185 From base of unit 1 of the measured section on Potter Creek Dome, Fergus County, Mont. Center SE¼ sec. 5, T. 13 N., R. 21 E.
From cherty limestone about 30 feet above the base of the formation. Collected by P. E. Cloud, Jr., M. Gordon, and R. Ross.
Alaska Bench limestone.

16700 (USGS foraminiferal collection f-12308.) From about 1 mile west of Stonehouse Ranch in Road Canyon, Golden Valley County, Mont. Sec. 31, T. 11 N., R. 21 E.
From angular chert fragments in breccia at top of the formation. Collected by P. E. Cloud, Jr.
Devils Pocket formation.

16701 (USGS foraminiferal collection f-12309.) From same locality as 16700.
From massive chert nodule, not brecciated, in breccia at top of the formation. Collected by P. E. Cloud, Jr.
Devils Pocket formation.

16702 (USGS foraminiferal collection f-12307.) From unit 5 of the measured section at Stonehouse Canyon, Golden Valley County, Mont. SE¼NW¼ sec. 31, T. 11 N., R. 21 E.
From 38 feet below top of the Devils Pocket formation in carnelian nodules contained in chert matrix sand along crest of west bank of gorge of creek. Collected by P. E. Cloud, Jr.
Devils Pocket formation.

17389 (USGS foraminiferal collection f-9772.) From Golden Valley County, Mont. NW¼ sec. 31, T. 11 N., R. 21 E.
From chert fragments and matrix near the base of breccia. Collected by G. H. Norton.
Devils Pocket formation ("Amsden formation", top.)

17390 (USGS foraminiferal collection f-9785.) From Road Canyon, Golden Valley County, Mont. NE¼ sec. 36, T. 11 N., R. 20 E. (Probably the same locality as 17389, but higher in the 15-foot breccia or conglomerate unit.)
From chert 2 to 4 feet below top of 8-foot limestone bed which lies at top of 15-foot chert breccia or conglomerate (?) zone in the uppermost part of the formation. Collected by P. W. Richards, R. P. Kunkel, and H. R. Smith.
Devils Pocket formation. ("Amsden formation", uppermost part.)

17391 (USGS foraminiferal collection f-9786.) From same locality as 17390.

From 4 feet below top of 8-foot limestone bed. Collected by P. W. Richards, R. P. Kunkel, and H. R. Smith.

Devils Pocket formation. ("Amsden formation", uppermost part.)

17392 (USGS foraminiferal collection f-9788.) From Road Canyon, Golden Valley County, Mont. Near center E½ sec. 31, T. 11 N., R. 21 E.

From chert at top of 14-foot breccia described by Gardner and others (1946, p. 50) as base of "Chugwater(?) formation." Collected by P. W. Richards, R. P. Kunkel, and H. R. Smith.

Devils Pocket formation. ("Amsden formation.")

MEASURED SECTIONS

Because the sections measured in detail by Gardner and others (1946) are well known to geologists in Montana, the writer has used them as a basis for collections referred to herein. In addition, however, the writer measured some other sections not contained in the aforementioned reference. Also, some parts of previously measured sections have been remeasured or condensed somewhat, in which case these portions are indicated below.

Numbers such as 13415 in the measured sections are "blue" U.S. Geological Survey locality numbers. Numbers such as 44–37–115 are collection numbers used by Gardner and others (1946).

Measured section No. 1 of the Big Snowy group, Belt Creek section

Located in the valley of Belt Creek on the north slope of the Little Belt Mountains, mostly in secs. 1 and 11, T. 17 N., R. 6 E., Cascade County, Mont. (pl. 2, figs. B, C).

The section is a composite of outcrops, of which units 1–11 were measured along the cliffs on the east side of U.S. Highway 89 1.9 miles north of Riceville or 8.5 miles south of U.S. Highway 87 at a spring; units 12–16 were measured in the cliffs on the west side of the valley at the second bridge over Belt Creek 6.6 miles south of U.S. Highway 87 or 3.5 miles north of Riceville. The total thickness of the Kibbey sandstone is taken from Weed (1899a).

The Otter formation was originally described from exposures in or near this section. Measured by W. H. Easton and P. B. Easton.

	Feet
JURASSIC SYSTEM	
ELLIS GROUP	
1. Sandstone, yellowish, fine-grained, slump	--
MESOZOIC OR PALEOZOIC ROCKS	
2. Covered, probably shale (estimated)	25
MISSISSIPPIAN SYSTEM	
BIG SNOWY GROUP	
Otter formation:	
3. Shale, mostly greenish-gray, some purple, blocky, in part fissile and calcareous; lower 6 ft with limestone (algal?) nodules, nonresistant	49
MISSISSIPPIAN SYSTEM	
BIG SNOWY GROUP—Continued	
Otter formation—Continued	
4. Limestone, light-gray, fine-grained; wavy laminations; algal(?) in part	1
5. Limestone, saccaroidal, dolomitic, gray, calcareous, slightly resistant, medium-grained; and conglomerate	1
6. Limestone, light-gray, argillaceous, resistant, platy-weathering; wavy laminations	4
7. Shale, greenish-gray; some reddish and purplish, some calcareous; nonresistant	49
8. Limestone, light-gray, very fine grained, argillaceous, vugular, resistant; wavy laminations	6
9. Shale, reddish, some greenish and purplish, calcareous, nonresistant	8
10. Limestone, buff to gray, very fine grained, vugular, heavy-bedded, resistant; ostracodes	8
11. Shale, reddish-brown, some green-speckled, calcareous; some very calcareous streaks or limestone nodules are very fossiliferous. Loc. 14227	18
12. Limestone, very argillaceous, gray, very fine grained, platy-weathering, resistant bluff-maker, algal(?) in part; 3-in. dark-brown chert band near base; ostracodes	12
13. Shale, mostly gray-green, nonresistant; 20 percent of the lower half contains limestone beds 2-in. to 2-ft thick limestone; some reddish beds of shale with rounded sand grains overlie lower half and are succeeded by strata which grade into unit 12	42
Total Otter formation	198
Kibbey sandstone:	
14. Conglomerate and sandstone, gray-green, coarse- and round-grained with some limestone clasts, massive, resistant; rounded outcrops	2
15. Siltstone, maroon with green specks, calcareous, nonresistant	6
16. Sandstone, siltstone, and shale, interbedded, mostly reddish with some green beds; beds as thick as 1 ft; calcareous, slightly resistant; weathers platy to hackly	38
17. Mostly sandstone, reddish, fine-grained, rather resistant; some gypsum present in beds; basal portion shaly and very poorly exposed; thickness computed to make total thickness equal to the figure of 153 ft given by Weed (1899a)	101
Total Kibbey sandstone	147
Total Big Snowy group	345
MADISON GROUP	
Mission Canyon limestone:	
18. Limestone, blue-gray, fine-grained; massive beds, resistant cliff-maker	?

Measured section No. 2 of Big Snowy group, Delpine section

Located on the prominent spur on the north side of Musselshell River at the east end of the narrows at Delpine, sec. 14, T. 9 N., R. 10 E., Meagher County, Mont.

Reached from a point about 23 miles east of White Sulphur

Springs or 32 miles west of Harlowtown by going about ¼ mile north from State Highway 6 along a gravel road to the second farmhouse; walk about 200 yards north to the irrigation ditch on the hillside. The section was measured in part in the L-shaped gully 200 yards north of the farmhouse and in part along the excavated north bank of the irrigation ditch about 100 yards northeast of the farmhouse. Measured by W. H. Easton, J. Smedley, and Kasetre Phitaksphraivan.

Approximately this same section was published by Gardner and others (1946, p. 33–36).

JURASSIC SYSTEM

ELLIS GROUP

	Feet
1. Sandstone, orange-brown, fine-grained, calcareous; 4-in. to 10 in. beds; interbedded with minor beds of limestone, brownish, fine-grained, sandy; some beds of fossil trash at the base; slickensides abundant	20+

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM

UPPER PART OF BIG SNOWY GROUP

	Feet
Alaska Bench limestone:	
2. Mostly covered; limestone float, gray, fine-grained; limestone, gray, fine-grained, argillaceous; upper 1 ft limestone, gray, fine-grained, slightly nodular	16
3. Limestone, gray, fine-grained, slightly nodular; interbedded with poorly exposed argillaceous limestone; beds from 1 in. to 10 in. thick, mostly about 6 in. Loc. 13364	35
Total Alaska Bench limestone	51
Cameron Creek formation:	
4. Covered; red soil and reddish limestone float	6
5. Limestone, light-gray, fine-grained, resistant	2
6. Mostly covered; reddish silty shale, siltstone, limestone	18
7. Limestone, buff, pinkish, gray, weathering light gray, fine-grained, 2-in. to 12-in. beds; weathers reddish in upper half; 1 ft above base is 2-in. black chert band; 12 ft above base is base of 2-ft limestone bed with brown nodular chert. Loc. 13361 from 2 ft to 3 ft above base; 13362 from 4 ft above base; 13363 from top 4 ft	20
8. Limestone, as in unit 7; small amount of shale, reddish-weathering, fissile. Loc. 13360 in basal 1 ft	19
Total Cameron Creek formation	65

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP

	Feet
Heath formation:	
9. Shale and limestone, interbedded; 2- to 18-in. beds; shale, black fissile, calcareous, unresistant; limestone, dark-gray to black, very fine grained, argillaceous, weathering light-gray	10
10. Shale, black, fissile, very calcareous, unresistant. Loc. 13359	4
11. Limestone, dark-gray, weathering pinkish-gray, fine-grained, massive	1
12. Shale, black, fissile, poorly exposed; thickness arbitrarily made to agree with Gardner and others (1946, p. 36)	22
Total Heath formation	37

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

	Feet
Otter formation:	
13. Shale, green and reddish, fissile, poorly exposed	25
14. Limestone, light-gray, very fine grained, slightly resistant; wavy beds	2
15. Shale, green, black, reddish, fissile, poorly exposed	29
16. Limestone, light-gray with grains of green shale, resistant	1
17. Shale, mostly green, fissile; some reddish beds, upper part poorly exposed	44
18. Shale, black, fissile, calcareous. Loc. 13358 at 2 ft above base	8
19. Limestone, gray, very fine grained, platy-weathering, resistant; wavy beds	2
20. Shale, black, fissile, unresistant; basal 2 ft green	6
21. Limestone, light-gray, white-weathering sublithographic, subnodular	5
22. Shale, black, reddish, gray, silty, calcareous, very unresistant; some platy weathering	14
23. Limestone, pinkish-gray, lithographic	1
24. Shale, green, black, brown, fissile, unresistant	5
25. Limestone, weathering buff, very silty, unresistant; wavy beds, shaly partings	3
26. Limestone, gray, fine-grained, resistant	1
27. Shale, gray-green, silty, weak	2
28. Limestone, pinkish-gray, fine-grained, hard, resistant	1
29. Shale, black, fissile, calcite veins, unresistant	6
30. Siltstone, orange to buff, very calcareous, unresistant	2
31. Interbedded shale, siltstone, limestone, unresistant, poorly exposed; shale, green, black, gray, fissile, some silty, some calcareous; siltstone, buff, blocky, calcareous, slightly resistant; limestone, blue-gray, very fine grained; wavy bedding planes, 8-in. resistant bed	30
Total Otter formation	187
Kibbey sandstone:	
32. Interbedded standstone, shale, limestone; 2- to 18-in. beds, poorly exposed; sandstone, buff, fine to very fine grained, calcareous, partly cherty, subangular grains; shale, greenish-gray, fissile, platy, some with black specks, some with calcite veins; limestone, purple and buff, very argillaceous, siliceous, hackly rubble from weathering, slickensides	23
Total Kibbey sandstone	23
Total Big Snowy group	363

MADISON GROUP

	Feet
Mission Canyon limestone:	
33. Limestone, gray, weathering light gray, very fine grained; upper contact poorly exposed	?

Measured section No. 3 of the Big Snowy group, Judith River section

Located along the west and north valley walls of the South

Fork of Judith River, extending from NW¼SE¼ sec. 25, T. 13 N., R. 11 E., to center of W½ sec. 19, T. 13 N., R. 12 E., Judith Basin County, Mont.

Reached by going 13.2 miles west of Utica, to a Y-intersection, then about 300 yards southwest to the contact of the Madison Canyon limestone and the Kibbey sandstone in a gully. The section was measured along the hills bordering the road by W. H. Easton, J. Smedley, and Kasetre Phitaksphraivan.

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP

Otter formation:

	Feet
Top not exposed.	
1. Shale, mostly green, some purplish, blocky, some silty, unresistant	75
2. Shale, brown, unresistant	12
3. Shale, brown, silty, slightly resistant	12
4. Shale, dark-brown, dark brownish-gray, some fissile, some blocky, calcareous, unresistant	21
5. Limestone, gray, fine-grained, platy-weathering, resistant	2
6. Mostly covered; lower third consists of shale, green, purplish-gray, fissile, calcareous	72
7. Limestone conglomerate, brownish-gray; 6-in. beds, very resistant bluff-forming	14
8. Shale, black, fissile, calcareous. Loc. 13379 from top 6 in.; 13378 from 10 ft above base; 13376 from 2 ft above base	49
9. Limestone conglomerate, brownish-gray, massive, 2 ft bed; grades upward into limestone, gray, platy, 2-in. to 2-ft bedded; makes very prominent bluff capping the hills north of the road	16
10. Shale, dark-gray, weathering yellowish-orange; upper third shale, yellow, calcareous, soft, vugular, with limestone stringers	24
11. Limestone, orange to brown, weathering white to brown, platy, oolitic, resistant. Loc. 13377	3
12. Limestone, dark-gray, fine-grained; 2- to 6-in. beds, weathering into plates; slightly argillaceous, bluff-maker	4
13. Limestone, dark-gray, fine-grained; basal 3 ft platy, argillaceous; interbedded with shale, dark-gray, fissile, 2- to 18-in. beds	11
14. Shale, dark-gray, weathering greenish gray, fissile	75
15. Limestone, light-gray, weathering brownish, sublithographic, slightly resistant	2
16. Shale, dark-gray, blocky, weathering greenish gray, fissile	7
17. Limestone, light gray-buff, weathering white, nodular to botryoidal, algal(?), platy on upper surface	1
18. Shale, dark-gray, weathering greenish gray, fissile	8
19. Limestone, black, weathering white, platy, argillaceous; interbedded with black, fissile shale, ¼-in. to 12-in. beds; one slightly cherty limestone bed in middle of unit; slightly resistant	7
20. Shale, dark gray, greenish-gray, brown, fissile, mostly greenish gray when weathered; one 4-in. limestone bed about half way through unit	55
21. Shale, lavender, blocky-weathering, silty	2
Total Otter formation	472

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

Kibbey sandstone:

	Feet
22. Sandstone, pale-lavender, very fine grained, friable, calcareous, unresistant	9
23. Siltstone and very fine grained sandstone, gray and greenish-gray; 1- to 12-in. beds, white blotches; calcareous, very hard	12
24. Siltstone, red, gray, purple, shaly, unresistant; interbedded with siltstone of similar colors but nonshaly, resistant; unit forms steep slope	26
25. Siltstone, purple with white blotches, shaly, calcareous, resistant	4
26. Siltstone, red with white blotches, shaly, very unresistant	17
27. Sandstone, red with white blotches, very fine grained, irregularly bedded, shaly, punky, slightly resistant; angular grains	7
28. Siltstone and sandstone, red with white blotches; irregular beds as thick as 18 in., poorly exposed	56
29. Siltstone, red, orange to buff, shaly, irregular beds from 3 to 18 in. thick, bench and bluff topography	7
30. Covered; red soil with float of siltstone, red, blocky; sandstone, red	10
31. Covered; brown soil with occasional fragments of red siltstone and sandstone, especially in the upper half	28
32. Covered; red soil; yellow shaly siltstone and silty shale dug up	64
Total Kibbey sandstone	241
Total Big Snowy group measured	713

MADISON GROUP

Mission Canyon limestone:

	Feet
33. Limestone, dark-gray, lithographic to fine- and medium-grained; 2-in. to 2-ft. beds, weathering light gray; slightly resistant, crumpled, exhumed dip slope	?

Composite measured section No. 4 of the Big Snowy group, Alaska Bench section

Located along the prominent cliff (pl. 1, fig. A) forming the west end of Alaska Bench (locally called "Beacon Hill") extending from the NE¼SW¼ sec. 25, T. 13N., R. 19E., to the SW¼ sec. 36, T. 13N., R. 19E., and thence continued downhill to the NE¼ sec. 1, T. 12N., R. 19E., Fergus County, Mont.

This section can be reached by going 11.5 miles south of the gypsum plant at Heath, taking the road toward the beacon and stopping on the grade 0.2 mile north of the intersection of the gravel road eastward along Alaska Bench with the unimproved dirt road to the beacon. The upper approximately 400 feet of section through the thick sandstone (bed 20) was mostly measured here. The rest of the section can be reached from above by descending the hillside southwestward below the beacon, or from below by going 12 miles south of the gypsum plant at Heath to a point 0.3 mile south of the boundary of Lewis and Clark National Forest. The Madison group crops out about 100 yards west of the foregoing point and the rest of the section lies along a line of sight northeastward toward the beacon. An unimproved road branches off from the next road going eastward (about ½ mile south of the starting point) and leads toward the base of the cliff. Measured by W. H. Easton.

This is the type section of the Big Snowy group and of the Heath formation as originally proposed.

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM

UPPER PART OF BIG SNOWY GROUP

	Feet
Alaska Bench limestone:	
Top is on a dip slope.	
1. Limestone, light gray, sublithographic, 2-in. to 6-in. beds, grading upward into limestone, brownish-gray, 2 ft to 3 ft beds; cliffmaker; locs. 13389, 13399	24
2. Limestone, yellowish-weathering, fine-grained, massive	3
3. Shale, green and red; with limestone, yellowish, argillaceous, resistant; loc. 13384	1
4. Limestone, gray to buff, sublithographic to fine-grained, 1-ft to 2-ft beds, crystalline, hard; shale, yellow, green, in partings to beds 1-ft thick; forms prominent bluff; cross sections of productid brachiopods present	38
Total Alaska Bench limestone	66
Cameron Creek formation:	
5. Shale, purplish-brown and gray-brown, calcareous, nonresistant	1
6. Limestone, gray, massive, resistant, fine-grained	2
7. Shale and shaly limestone, gray, 6-in. beds, hackly weathering and rather nonresistant; loc. 14220	2
8. Limestone, gray, fine-grained, vugular, massive with laminated wavy minute beds	3
9. Shale, maroon, fissile, calcareous, with limestone nodules; 14221	3
10. Limestone, gray-brown, fine-grained, wavy laminations; forms resistant ledge; loc. 14223 from base; 14222 from top	4
11. Shale, maroon or reddish-brown, calcareous, fissile, nonresistant slope former; base of an 8-in. impure nodular limestone lies 1.5 ft from the top of the unit; loc. 14226 just beneath the nodular limestone; 14224 from the uppermost shale	10
12. Limestone, gray, sublithographic, hard, very resistant	1
13. Sandstone, yellowish-buff, stained red on surface, very fine grained, calcareous, prominent cliff-maker; loc. 13383 in middle of bed	7
14. Siltstone, pinkish to purplish, weathering white, shaly, calcareous; platy and wavy beds; surfaces covered with wormlike purplish lines and with spots	15
15. Shale, greenish-gray, weathering red, fissile; 13382, 13386	9
16. Dolomite, light-gray, very fine grained, calcareous, hard, resistant; sinuous vertical vugs in lower half; grades up into limestone, dark brownish gray, very fine grained matrix with pebbly limestone grains, very hard, resistant; loc. 13381 in upper half	5
Cameron Creek formation—Continued	
17. Shale; basal 5 ft calcareous, weathering yellow; upper 3 ft black, fissile; 4 in. limestone 3 ft from top; loc. 13380 in upper 3 ft	21
Total Cameron Creek formation	83

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

	Feet
Heath formation:	
18. Limestone, light-gray to buff, very fine grained, seminodular, vugular, very hard, resistant	3
19. Shale and clay, yellow, greenish-gray, red, very weak (exposure dug out); 13387	10
20. Limestone, buff with purple mottling, very fine grained dolomitic, laminated, platy-weathering, cliff-maker	4
21. Shale, black, fissile; weathers to green clay at base and to red clay at top; plant fragments near base	28
22. Sandstone, light-brown, fine-grained, 2-in. beds of alternating clean porous beds and shaly beds; subangular grains; slightly resistant	9
23. Shale, black and dark-gray, fissile	28
24. Sandstone, buff; weathering yellowish brown; fine-grained calcareous, porous, crossbedded, ripple-marked, 2-in. to 2 ft beds; forms prominent bluff; 13388 in 2-in. ironstone band 5 ft below top	14
25. Shale, black, brown, and gray, fissile; poorly exposed on steep slope	108
26. Sandstone, buff to brown, fine-grained, crossbedded, friable, calcareous, massive, cliff-making	48
(The section continues southwestward from the aerial beacon.)	
27. Sandstone, brownish, conglomeratic; only basal part seen; estimated thickness is average (83 ft) of Reeves' (1926, p. 53, 54) and Scott's (1935b, p. 1024) total possible thicknesses of associated sandy and covered units less thickness of item 26 above	36
28. Limestone, black, argillaceous, hackly-weathering, slightly resistant	10
29. Covered; probably black or dark-brown shale; Illinois cephalopod locality near base	56
30. Limestone, black, argillaceous, hackly-weathering	10
Total Heath formation	364
Otter formation:	
31. Covered; probably greenish-gray shale	83
32. Shale, greenish gray; interbedded with argillaceous limestone; steep slope	42
33. Shale, greenish-gray to black; float of gray limestone slabs containing *Spirorbis* near top	28
34. Covered; probably shale	14
35. Limestone conglomerate, platy	5
36. Covered; probably shale	28
37. Mostly covered, upper part shale, greenish, some silty, with thin beds of oolitic limestone; limestone float to base of unit	90
Total Otter formation	290

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

Kibbey sandstone:	Feet
38. Covered; soil is brown, silty, becoming reddish in lower part	23
39. Covered; soil reddish or reddish-brown; float of sandstone, red, very fine grained, calcareous, flaggy	82
Total Kibbey sandstone	105
Total Big Snowy group	908

MADISON GROUP

Mission Canyon limestone:	
40. Limestone, dark brownish gray, very fine grained; 1-in. beds in upper few feet but largely massive, hackly-weathering to blocky; forms prominent bluff	---

Measured section No. 5 of the Big Snowy group, Potter Creek Dome section

Located on the northwest flank of Potter Creek Dome. The section goes upward from exposures in the short valley along the west line of the SW¼NW¼ sec. 8; thence uphill along the road cuts in center of N½ sec. 8; thence up various ridge crests separating valleys draining the escarpment in SW¼ sec. 5, all in T. 13 N., R. 21 E., Fergus County, Mont.

The section can be reached by going to Sure Enough summit on the Little Snowies road located 8.3 miles southeast of Forest Grove. The Kibbey sandstone was measured in the valley south of the road from a point 0.7 mile west of the summit at the foot of the grade; the Otter formation was measured in the road cuts on the north side of the road going upgrade from a point 0.5 west of the summit; the rest of the section was measured in the system of gullies north of the road and beginning at a point 100 yards southeast of two abandoned houses located about ¼ mile north of a point 0.9 mile west of the summit. Measured by W. H. Easton, J. Smedley, and Kasetre Phitaksphraivan.

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM

UPPER PART OF BIG SNOWY GROUP

Alaska Bench limestone:	Feet
Top of section a dip slope.	
1. Limestone, gray, poorly exposed; loc. 16185 in base	52
2. Limestone, gray to buff, fine- to medium-grained; 6-in. to 2-ft beds, forms very prominent cliff; 13398 in soft layer 5 ft above base	22
Total Alaska Bench limestone	74
Cameron Creek formation:	
3. Limestone and shale, interbedded; 6-in. to 12-in. beds, poorly exposed; shale, reddish-weathering, clayey; limestone, gray fine- to medium-grained, hard	46
4. Mostly covered: shale, black, fissile; clay, red; yellow when dug out or seen in burrows	86
5. Siltstone, yellowish-buff, punky, arigillaceous, calcareous, platy; 2-in. to 1 ft beds; some sandstone, buff, fine-grained, calcareous, hard; resistant unit	20
Total Cameron Creek formation	152

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

Heath formation:	Feet
6. Covered; brown soil, probably shale	77
7. Limestone conglomerate containing yellowish stained clasts 1 in. to 3 in. in diameter, yellow clay matrix, unresistant rubbly slope except for hard top bed 1.4 ft thick	18
8. Limestone, gray; weathers light gray, silty, platy; siltstone, light-gray weathering; makes upper white streak on hill, platy-weathering, calcareous, slightly resistant	6
9. Shale, dark grayish brown; weathers gray, poorly exposed; 13396 from upper 51 ft along slope	92
10. Shale, black, fissile, very gypsiferous	6
11. Shale, black, fissile, unresistant; a tree stump, upright in upper 2 ft at loc. 13397; poorly exposed in lower part	40
12. Sandstone, buff to reddish-brown, fine-grained, porous, calcareous, crossbedded; grains subrounded to subangular; locally very resistant bluff-maker	50
13. Shale, black, fissile; with thin stringers of dark-gray, limestone, weathering buff to orange; poorly exposed; unit is perhaps only 5 percent limestone	41
14. Limestone, dark-gray, silty, argillaceous, hackly weathering; with shaly partings; major source of loc. 13395 which was also collected on the slope of the next lower unit	14
15. Shale, black, fissile; mostly covered	63
16. Limestone, gray, weathering light gray, silty, dolomitic, laminated, platy-weathering, slightly resistant; loc. 13394 in middle of unit; lower white streak along hillside	15
17. Covered, brown soil; becomes black fissile, shale; 2-in. gray limestone stringer near top	60
18. Limestone conglomerate, brown, hackly-weathering; containing ¼-in. pebbles; poorly exposed	7
19. Shale, black, fissile, unresistant	16
20. Mostly covered; brown soil with black fissile shale in burrows	55
21. Limestone, gray, fine-grained, nodular-weathering; interbedded with shale; poorly exposed, loc. 13393	7
22. Shale, black, fissile; weathering into brown soil; poorly exposed	20
23. Limestone, brown, sublithographic; 13392	1
24. Shale, black, fissile; weathers brown and some light gray; interbedded with 3 stringers of limestone, brown, argillaceous, hard, about 1 ft thick; 13391 from shale in upper 20 ft	80
25. Limestone, brown with red, green, and black mottlings, argillaceous, hard, nodular-weathering; lower 2 ft are gray, fine-grained, hard, and flaggy; slightly resistant unit	8
26. Covered; brown soil; probably black shale	164
Total Heath formation	840
Otter formation:	
27. Shale, bright-green, fissile	47
28. Shale, purple, fissile	5
29. Shale, green, slightly silty, unresistant	18

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

	Feet
Otter formation—Continued	
30. Limestone conglomerate, gray, dolomitic, wavy-bedded, platy-weathering, resistant	4
31. Shale, slightly silty, unresistant, green; with some silt-stone, green, unresistant	40
32. Limestone, buff, weathering orange, sublithographic, very hard; prominent resistant marker-bed	1
33. Siltstone and shale, green, calcareous, platy-weathering; slightly resistant slope-maker; 13390 from basal 6 in. which is black but weathers rusty brown to orange	24
34. Limestone, gray, silty, nodular; weathers light gray	2
35. Shale, black, fissile	1
36. Limestone conglomerate, wavy to botryoidal, brownish-gray, hard, resistant	2
37. Shale, greenish gray; black near top, fissile, weathers brownish	22
38. Limestone, dark-gray, sublithographic, nodular, argillaceous, wavy-bedded, very hard, resistant	6
39. Shale, mostly black, but some greenish gray, fissile	34
40. Limestone, buff, medium-grained, algal(?) and oolitic; 3-in. to 12-in. beds; interbedded with black shale	4
41. Limestone, gray, fine-grained, laminated; with wavy beds, stringers of dark-gray chert, and partings of shale	4
42. Limestone conglomerate, gray, botryoidal base	1
43. Limestone, light brownish gray, fine- to medium-grained, 4-in. to 18 in. beds, vugular, shaly and silty layers range from partings to 6-in. layers; forms prominent bluff	10
44. Shale, black, fissile, clayey	11
45. Limestone, dark-gray, sublithographic, subnodular; 18-in. beds	2
46. Shale, greenish-gray with some dark-gray layers; float of limestone, weathering buff, argillaceous and silty	66
47. Limestone, buff, algal (?) and oolitic, hard, slightly resistant; has botryoidal upper surface with lumps ½ in. in diameter	1
48. Interbedded shale, siltstone, and limestone; weathering buff to gray, slightly resistant slope-former, poorly exposed	51
Total Otter formation	356
Kibbey sandstone:	
49. Sandstone, white to buff, fine-grained, calcareous; subrounded grains	10
50. Siltstone; red in lower part, gray in upper part, argillaceous, calcareous; lower fourth covered with brown silty soil; poorly exposed	272
Total Kibbey sandstone	282
Total Big Snowy group	1,704

MADISON GROUP

Mission Canyon limestone:

51. Limestone, gray, massive, resistant; contact approximate.

Measured section No. 6 of Big Snowy group, Durfee Creek Dome, Mont.

Located on the northeast flank of Durfee Creek Dome in the gorge and headwaters of Durfee Creek; the section extends from the NE¼ sec. 24, T. 12 N., R. 22 E., into adjacent parts of the SW¼ sec. 18, and the NW¼ sec. 19, both in T. 12 N., R. 23 E., Fergus County, Mont.

The section can be reached by going 7.3 miles southeast of the N Bar Ranch to the ranchhouse south of the road in center of E½E½ sec. 16, T. 12 N., R. 23 E.; turn south through yard and then turn west through field a total of 0.5 mile from the county road; turn south and go 1.4 miles along the east side of the fence and ascend bluff of Cretaceous; turn right at fence and head toward mouth of Durfee Creek, bearing 293°; go 2.6 miles from fence at top of preceding bluff, always bearing away from fence line. (See pl. 2, figs. A, D).

This section was originally published by Gardner and others (1946, p. 59–63). The section was originally measured by H. D. Hadley and C. P. Rogers, Jr. The section was collected again by W. H. Easton, J. Smedley, and Kasetre Phitaksphraivan. Units 39–45 and 86–90 were remeasured. Some original descriptions are modified somewhat.

JURASSIC SYSTEM

ELLIS GROUP

	Feet
Not measured	
1. Sandstone, greenish-gray, fine-grained except upper 2 ft., coarse-grained glauconitic, noncalcareous	13
2. Sandstone, light-gray to brownish-gray, fine- to medium-grained, calcareous, glauconitic; 6-in. to 1-ft. beds	39
3. Siltstone, tan and gray, calcareous	7
Total Ellis group measured	59

PENNSYLVANIAN SYSTEM

UPPERMOST PART OF BIG SNOWY GROUP

Devils Pocket formation:	
4. Sandstone, light-gray to white, calcareous, porous; beds about 8 in. thick; grains well-rounded, fine, clean	7
5. Limestone, light-gray to yellowish-gray, dense, dolomitic; faint bedding as much as 3 in. thick; basal part dolomite	4
6. Dolomite, gray to brown, finely crystalline, basal 7 ft brecciated, porous, grading laterally into sandstone, fine- to medium-grained, calcareous, cream-colored	16
7. Covered; soil is red, silty, with dolomite fragments; unit probably is dolomite and siltstone	25
8. Limestone, gray, finely crystalline, dolomitic; beds 2 in. to 6 in. thick, fetid odor; contains occasional partings of siltstone and the poorly exposed base may be largely reddish siltstone	22
9. Interbedded limestone and dolomite, gray and purplish gray, dense to finely crystalline	4
10. Covered	2
Total Devils Pocket formation	80

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM

BIG SNOWY GROUP—Continued

	Feet
Alaska Bench limestone:	
11. Limestone, gray, finely crystalline, 1-ft beds, weathers light gray with reddish-brown splotches; loc. 13404	11
12. Limestone, gray to greenish-gray and reddish-brown, dense to finely crystalline; beds mostly a few inches thick, some sandy, some poorly exposed, some fossiliferous	18
13. Covered; soil is reddish brown	4
14. Limestone, gray to purplish-gray, dense to finely crystalline	15
15. Covered	6
16. Limestone, gray to purplish and greenish-gray, dense to finely crystalline; some dolomitic beds, mostly a few inches thick	25
17. Limestone, light-gray to gray, dense to finely crystalline; beds as thick as 1 ft; bluff-maker	17
18. Limestone, gray, finely crystalline; some sandy and porous, some hackly weathering	13
19. Covered	16
20. Limestone, gray, finely crystalline; lower 4 feet has fetid odor	9
21. Limestone, gray to black, dense; weathered surface laminated; loc. 13405	1
22. Chert, reddish-brown to black	1
23. Limestone, variegated reddish-brown, green, and purple, sandy, massive; 13403	3
24. Limestone, gray, dense, 3-in. beds	4
Total Alaska Bench limestone	143
Cameron Creek formation:	
25. Covered; soil is gray to greenish-gray; probably shale or siltstone	54
26. Sandstone, reddish-brown, fine-grained, crossbedded, calcareous; grains angular, poorly sorted; upper 10 feet in 2-in. beds; remainder in 4-in. to 2-ft beds; resistant	24
27. Covered	34
28. Sandstone, gray and light- to dark-brown, fine- to medium-grained, cross-bedded, sun-cracked; weathers purplish to reddish brown; grains poorly sorted, range from quartz sand to clay; magnetite and hematite clasts as much as ¼ in. in diameter; beds 4 in. to 1 ft; basal 1 ft of sandstone, well rounded, fairly well sorted; prominent cliff-maker	32
29. Covered; probably shale	77
30. Shale, black, fissile; weathers purplish and reddish	8
31. Sandstone, white to light-gray, fine- to medium-grained; 1- to 2-ft beds; grains well rounded, well sorted; resistant bluff-maker	38
32. Sandstone, coarse-grained, grading downward into conglomerate, rusty brown, weathering purple, porous; subrounded to angular fragments black chert, quartz, and iron oxide; beds 2 to 6 in. thick, poorly stratified, slabby-weathering; forms very prominent bluff; lower 4 ft poorly exposed	15
Total Cameron Creek formation	282

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

	Feet
Heath formation:	
33. Shale, dark greenish gray to black, fissile, silty; very poorly exposed on clayey soil-covered slope	29
34. Limestone, gray, weathering light brown, finely crystalline, dolomitic	1
35. Shale, greenish-gray to black, fissile	9
36. Limestone, dark-gray, dense; beds 1-in. to 3-in. thick; many veinlets and vugs filled with calcite and limonite	1
37. Shale, greenish-gray to black, fissile, fossiliferous; interbedded with shale containing 20 percent limestone, black, dense, in 2-in. to 1-ft beds	33
38. Limestone, black, weathering gray to black, dense, brittle, earthy and crumbly; fetid odor; 3-in. beds	6
39. Limestone conglomerate, gray to yellowish and purplish-gray; earthy matrix with 1-in. limestone fragments; makes steep slope	8
40. Limestone, black to dark-gray, some buff, sublithographic to fine-grained, argillaceous, hackly- to platy-weathering; 3 in. of black chert stringers at top; 1-in. to 18-in. beds; forms steep slope or low bluff	33
41. Covered; soil is brown	91
42. Limestone, black, weathering light-gray; 1 ft beds	4
43. Shale, black, fissile, gypsiferous, unresistant	15
44. Limestone, black weathering brown, fine-grained, 1-in. to 6-in. beds, slabby, argillaceous; 13402	5
45. Shale, black to brown, weathering light grey and brown	8
46. Shale, black, fissile, poorly exposed; lower part covered	27
Total Heath formation	270
Otter formation:	
47. Limestone, gray, finely crystalline; contains crinoid columnals, some of which are pentagonal	1
48. Shale, light greenish brown and gray; lower few feet gray to black; contains limestone, light-gray to gray, finely crystalline, well-bedded; with light brown to purple splotches; contains microfossils	61
49. Limestone, gray with green and purple tints, weathering light gray; dense to finely crystalline, 3-in. to 6-in. beds; contains abundant microfauna	7
50. Shale, greenish-gray to brown, poorly exposed	28
51. Limestone, gray with purple tint, dense, poorly bedded, somewhat crumbly; interbedded with 50 percent shale, greenish-gray, fissile; limestone weathers into 2-in. to 6-in. blocks	14
52. Covered; soil is greenish gray	43
53. Limestone, conglomeratic, light-gray, dense, dolomitic, well-bedded, blocky weathering; fragments subrounded; loc. 13426	1
54. Limestone, gray, silty, earthy, unresistant	2

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

Otter formation—Continued	Feet
55. Shale, green, fissile, noncalcareous; interbedded with 10 percent limestone, gray to greenish-gray, finely crystalline, dolomitic; beds 3 in. to 1 ft thick	31
56. Limestone, black, weathering light brown, dense, laminated; beds 2 to 3 in. thick	3
57. Shale, black, fissile, noncalcareous	1
58. Claystone, greenish-gray to greenish-brown, weathing green, noncalcareous, shaly at base	6
59. Limestone, light-gray, weathering light-brown, finely crystalline, shaly bedded with occasional layers of green shale	1
60. Shale, greenish-gray, fissile	2
61. Limestone, light-gray, weathering light-brown, finely crystalline, shaly bedded	1
62. Shale, greenish-gray, silty, calcareous, thin-bedded	8
63. Limestone, light-gray to bright reddish yellow, vertically jointed; conspicuous marker-bed	2
64. Shale, blue-green, fissile	1
65. Limestone, gray to greenish-gray, mostly fine-grained, very thin-bedded; loc. 13411 in basal 1 ft	7
66. Shale, greenish-gray, fissile, poorly exposed	9
67. Limestone, dark-gray, dense; weathers light gray, 4- to 6-in. beds, botryoidal upper surface algal(?); loc. 13400	1
68. Limestone, gray to greenish-gray, fine- to medium-grained; partings of greenish gray shale, some earthy	26
69. Limestone, gray, oolitic, botryoidal, 1-in. beds; loc. 13401	3
70. Covered; some siltstone, gray, punky; middle half a bed of gypsum, white, punky, slightly resistant	43
71. Limestone, gray to black, fine-grained; top half earthy and punky and calcitic; lower half shaly bedded	2
72. Shale, greenish-gray, noncalcareous, thin-bedded; float of mammillary chert from this unit	4
73. Dolomite, gray, earthy, locally calcitic; 2-in. beds	7
74. Shale, greenish-gray, silty, noncalcareous; yellowish green at base	14
Total Otter formation	329
Kibbey sandstone:	
75. Sandstone and siltstone, gray to brown; some calcareous, some porous, good to poor sorting, subangular to rounded, thin-bedded; some poorly exposed	16
76. Covered	44
77. Sandstone, light-brown to reddish-brown, calcareous, porous, fine- to medium-grained, poorly cemented; grains angular, poorly sorted	5
78. Covered; soil is reddish brown	9
79. Sandstone, light-brown, fine-grained, silty, calcareous, poorly bedded	1
80. Claystone, purple, calcareous; grades downward into light-brown siltstone	9

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

Kibbey sandstone—Continued	Feet
81. Sandstone, red, medium-grained, very calcareous, porous, poorly cemented; 4-in. to 2 ft beds; grains subangular quartz to well-rounded chert	11
82. Siltstone, light-brown; some reddish and sandy, some calcareous, 3-in. to 1 ft beds	11
83. Gypsum, white with some variegated red and green, fine-grained, massive, occasionally crystalline, somewhat impure; has some beds of calcareous gray shale	24
84. Siltstone, reddish-brown, very gypsiferous; gypsum fine-grained, fibrous, and crystalline, in thin stringy beds; contains several 2- to 6-in. brownish-red sandstone beds	20
85. Shale and shaly sandstone, pale yellow, silty, gypsiferous; contains some 1-in. beds of pure gypsum	17
Total Kibbey sandstone	167
Total Big Snowy group	1,264

BIG SNOWY GROUP OR MADISON GROUP

Kibbey(?) sandstone or Charles(?) formation:	Feet
86. Limestone, gray, platy; mostly 2-in. beds; ostracodes(?) and brachiopod fragments; gypsiferous, resistant, locally collapse breccia	8
87. Sandstone and sandy limestone, yellowish; platy, ripple-marked, argillaceous; irregular thin beds weathers readily	12
88. Shale, yellowish, sandy, calcareous; collapse structures	3
89. Gypsum, massive white beds with some shale partings; locally leached away	14
Total Kibbey(?) sandstone or Charles(?) formation	37

MADISON GROUP

Mission Canyon limestone:

90. Limestone, blue-gray, fine-grained, hard, massive; some weathers to hackly rubble, resistant.

Measured section No. 7 of the Big Snowy group, State Road 25 and Stonehouse Canyon sections

Located along an east-southeastward trending line from the first prominent red outcrops of Kibbey formation in road cuts along State Road 25 where it ascends into the Big Snowy Mountains, through Stonehouse Canyon; the section extends from the center of the west line, sec. 25, T. 11 N., R. 20 E., across sec. 30 and into SW¼SW¼ sec. 29, thence down the dry canyon running southward across N½NW¼ sec. 31, T. 11 N., R. 21 E., Golden Valley County, Mont.

Most of the section is exposed in Stonehouse Canyon. This can be reached by going 0.5 mile west of the intersection of the Lavina road (State Road 25) with State Road 6 at a point about 1 mile north of Lavina, then going north along State Road 25 toward the Big Snowy Mountains. Bear left and downhill at the first Y intersection; go 26.0 miles, always taking the better road when a choice is necessary and making some right-angle turns, to a road crossing; continue north

1.0 mile to a cattle guard. By bearing right at this point, the road leads to the stone ranch house at the mouth of Stonehouse Canyon; entry to the top of the Paleozoic strata is possible through the fence on the west side of the creek 150 feet west of the house. By bearing left at the cattle guard, one can drive onto the Otter formation in the upper reaches of Stonehouse Canyon; from the cattle guard bear left and continue roughly northward 0.8 mile to a T-intersection; turn right, crossing fence line just east of intersection; go downhill and swing northward a total of 0.3 mile; bear left on faint vehicle tracks, going 0.6 mile to northwest corner of fenced field; cross fence line, and immediately turn northward up valley (called Road Canyon in Gardner and others, 1946, p. 49), going 0.3 mile to fence; cross fence line, bear eastward into dry wash and go a total of 0.4 mile up wash to earth dam; continue around west end of dam, swinging eastward up grade, crossing low summit, and descending the grade into Stonehouse Canyon at another earth dam, a total of 0.9 mile.

Most of beds 1–102 may be studied east of the second earth dam or south (downstream) from it. The Otter formation and the Heath formation are best exposed to the east; younger beds are best exposed to the south.

Beds 1–33 were originally (Gardner and others, 1946, p. 52–54) published as part of the Stonehouse Canyon section; beds 34–102 were originally published (Gardner and others, 1946, p. 46) as part of the State Road 25 section. The sections were originally measured by L. S. Gardner, H. D. Hadley, and C. P. Rogers, Jr. The section was sampled again by W. H. Easton, J. Smedley, and Kasetre Phitaksphraivan.

JURASSIC SYSTEM

ELLIS GROUP

	Feet
1. Sandstone, brown, glauconitic, friable, impure, resistant	5
Total Ellis group	5

PENNSYLVANIAN(?), PERMIAN(?), OR TRIASSIC(?) SYSTEM

Unamed formation:	
2. Siltstone, dark-red to brown, shaly, calcareous	10
3. Covered; red soil; 200 ft to east red siltstone, is in upper 13 ft of unit	16
Total unnamed formation	26

PENNSYLVANIAN SYSTEM

UPPERMOST PART OF BIG SNOWY GROUP

Devils Pocket formation:	
4. Sandstone, white to mottled grey and pink, clean, porous, noncalcareous, poorly bedded; made up of medium-grained, well-sorted, clean, quartz sand; locally quartzitic to cherty, but upper 6 ft is friable and nodular; this interval in Road Canyon, about 1 mile to the west, contains 14 additional ft of breccia with Pennsylvanian fusulinids	18
5. Interbedded sandstone, siltstone, and dolomite; sandstone, white, grey, pink, and purple, fine- to medium-grained, mostly calcareous, friable, unresistant; siltstone, red, unresistant; dolomite, white, light-brown, and grey with pink tint, some sandy, some with chert nodules; beds as much as 5 in. thick	35

PENNSYLVANIAN SYSTEM—Continued

UPPERMOST BIG SNOWY GROUP—Continued

Devils Pocket formation—Continued	Feet
6. Covered: soil is light purple	2
7. Dolomite, mottled gray and pink, dense to finely crystalline, siliceous, chalky brittle, poorly bedded	4
8. Covered	21
9. Dolomite, white to gray, sandy textured; beds to 1 ft thick	5
10. Covered, red soil on steep slope	58
Total Devils Pocket formation	143

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM

BIG SNOWY GROUP—Continued

Alaska Bench limestone:	
11. Limestone, light-gray, dense to finely crystalline; 6-in. to 2-ft beds; top of resistant sequence forming dip slopes; loc. 13423 from upper 2 ft; colln. 44–37–69	9
12. Covered; soil is red and pink, silty and clayey	5
13. Limestone, gray; 2-in. to 8 in. beds, some fossils; interbedded with dolomite, gray and pink, mottled, silty or sandy, in middle 4 ft	7
14. Silstone, red, shaly, calcareous, locally nodular	6
15. Limestone, gray, some pinkish and purplish, dense to finely crystalline, beds 2 in. to 2 ft thick, sparsely fossiliferous, resistant; base of shaly interval 4 ft thick is 9 ft from base	20
16. Covered	6
17. Limestone, gray, some mottled with pink, stylolitic, 3-in. to 2-ft beds, fossiliferous	47
18. Shale, purplish-red; siltstone, red, very calcareous, unresistant, in a few thin beds	6
19. Limestone, mottled gray and pink, finely crystalline; 1-in. to 6-in. beds; partings of red, calcareous shale; sparsely fossiliferous; loc. 13422	5
20. Limestone, dark-gray, dense, massive, veinlets of silica on weathered surfaces	1
21. Interbedded limestone and shale, mottled gray and pink	5
22. Siltstone, mottled gray and purple, argillaceous, very calcareous, probably with some beds actually of impure limestone, very fine grained, beds mostly 1 in. to 6 in. thick, some shaly partings; loc. 13421, colln. 44–37–83	10
Total Alaska Bench limestone	127
Cameron Creek formation:	
23. Covered: soil, reddish, silty	35
24. Limestone conglomerate, gray, dense, hard, tough, massive; vugs with quartz linings	2
25. Covered; soil reddish	18
26. Shale, red, very calcareous, silty, locally sandy; with thin layers of white to greenish-gray siltstone and sandstone; unresistant	6
27. Limestone, gray, dense, massive, with calcite veins	2
28. Interbedded shale and siltstone, red, very calcareous, with nodules of bluish-gray limestone, unresistant; loc. 13420; colln. 44–37–80 from siltstone	16

MISSISSIPPIAN OR PENNSYLVANIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

Cameron Creek formation—Continued	Feet
29. Covered; soil is red, silty	27
30. Shale, red, fissile to brittle, unresistant; with lenses and laminae of pale-yellow siltstone	26
31. Conglomerate, dark-red, very calcareous, massive; clasts angular, of red claystone, ferruginous chert, and silstone, having diameters as much as 3 in.; matrix silt and clay, calcareous	3
32. Shale, mostly reddish, some purplish-gray, fissile, unresistant; lower 16 ft. claystone, silty, gray, outcrops dug out; 2 ft of interbedded siltstone and shale with limestone nodules 41 ft from base yielded colln. 44-37-94	66
33. Sandstone, white, gray, and brownish, fine- to medium-grained, half calcareous; top 6 ft mud cracked and ripple marked, ½-in. to 6-in. beds; bottom 4 ft massive, porous, crossbedded; loc. 13418 in basal 4 ft; mostly poorly exposed	21
Total Cameron Creek formation	222

MISSISSIPPIAN SYSTEM

BIG SNOWY GROUP—Continued

Heath formation:	Feet
34. Covered; soil is dark gray	5
35. Shale, dark greenish gray to very dark brownish gray, slightly calcareous, fissile, poorly exposed	20
36. Mostly covered; some black, fissile, shale, poorly exposed; some dark-gray soil that is presumably weathered shale	75
37. Conglomerate, mottled yellow and gray, very calcareous, hard; contains subrounded limestone fragments, 2 in. in diameter, in fine-grained sandstone matrix; poorly exposed	1
38. Mostly covered; shale, black, fissile, fossiliferous, alternating with siltstone, brown to medium-gray, calcareous; upper 51 ft gray soil on low slope, probably weathered shale	72
39. Siltstone, brown to gray, very calcareous, grading upward into limestone, black, silty to sandy, earthy, porous, poorly exposed	3
40. Covered	5
41. Shale, black, fissile, calcareous, poorly exposed; 13417	3
42. Covered; soil is dark gray; probably shale, black, fissile, unresistant	25
43. Siltstone, mottled gray and yellowish gray, calcareous, massive, contains some plant fragments; overlies shale, black, fissile, poorly exposed, 1 ft thick	3
44. Siltstone or claystone, dark-gray, weathers yellowish gray, slightly resistant; locs. 13415, 13416, colln. 44-37-115	1
45. Covered; soil is gray; digging yields gray-buff shaly siltstone	10
46. Limestone, dark-gray to black, dense to finely crystalline, well-bedded, locally laminated; 2-ft layer 3 ft above base is siltstone, gray calcareous, shaly, poorly exposed; 13414; 13424; 44-37-117 from upper 14 ft	19

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

Heath formation—Continued	Feet
47. Shale, black, weathering gray, fissile, calcareous, poorly exposed	1
48. Limestone, dark-gray, hard	2
49. Covered; digging yielded sandstone, light-gray, calcareous, platy	9
50. Limestone, dark-gray to black, dense, brittle, beds as thick as 2 ft; 13425, 44-37-123	6
51. Covered; soil is dark gray	20
52. Limestone, dark-gray to black, dense	3
53. Covered; soil is dark gray	5
54. Dolomite, black to brownish-gray, dense, massive	3
55. Shale, dark-gray to black, fissile, silty, poorly exposed	12
56. Limestone, dark-gray to black, dense, massive, very fossiliferous	2
57. Covered; digging yielded shale, dark-gray to black, fissile, silty	6
58. Limestone, black to dark-gray, very silty, fossiliferous; platy beds as much as ¼ in. thick, interbedded with shale, black, carbonaceous; 13413	5
59. Shale, black, fissile; upper 33 ft. poorly exposed	48
60. Shale, dark-gray, fissile, gypsiferous, fossiliferous, poorly exposed	11
61. Siltstone, greenish-gray, calcareous, poorly exposed	17
62. Covered; soil is black and contains flakes of black, fissile shale	3
63. Covered; soil is gray	6
64. Shale, black, fissile, noncalcareous; contains nodules and thin lenticular layers of limestone, gray to brown, finely crystalline; 13412, 44-37-138	9
65. Limestone, dark-gray to brown, silty, sandy textured, poorly bedded; interbedded with greenish-gray, silty shale; 13411, 44-37-138	3
66. Shale, dark-gray or black, noncalcareous, locally limonitic; paper-thin beds, interbedded with greenish-gray mudstone or claystone; plant fragments	10
Total Heath formation	423

Otter formation:	Feet
67. Shale, light-green to greenish-gray, fissile; some layers of limestone, silty, nodular; upper half poorly exposed; lower half with selenite on slope	10
68. Shale, green to yellow, fissile, unresistant, poorly exposed; contains basal 1-ft. bed and other beds at 8 to 12-ft. intervals of limestone, gray, dense, brittle, some laminated; contains some shale, gray, calcareous	45
69. Covered; soil is light greenish gray	3
70. Limestone, light greenish gray, finely crystalline, silty, porous, locally pebbly; ostracodes	2
71. Claystone and shale, green, silty, very calcareous, with thin layers of greenish-gray, finely crystalline	37
72. Covered; soil is greenish gray	11

MISSISSIPPIAN SYSTEM—Continued

BIG SNOWY GROUP—Continued

		Feet
Otter formation—Continued		
73.	Siltstone, light yellowish green, shaly, unresistant; upper 1 ft. sandstone, yellow to brown, calcareous, clayey, poorly sorted, clasts fine-grained sand to angular sandstone	6
74.	Limestone, gray to white, medium crystalline; basal 6 ft. interbedded with siltstone, light-green and white, thin-bedded	9
75.	Covered; soil is greenish gray	13
76.	Limestone, light-gray to light-brown, dense to finely crystalline, dolomitic; weathers to knobby surfaces; forms resistant hogback; algal(?)	2
77.	Covered; soil is gray, silty	10
78.	Limestone, medium-gray, medium crystalline, slabby, fairly resistant; colln. 44-37-156	1
79.	Covered; soil is gray to greenish gray, silty, with some float of limestone, gray, fine-grained; forms wide valley floor and rounded hogback	172
80.	Limestone, gray to white, finely crystalline, massive to poorly bedded, tufalike; contains some sandy lenses; vugs with calcite crystals	4
81.	Siltstone, light greenish gray, shaly, poorly exposed; interbedded with stringers of black shale; sandy near top	9
82.	Limestone, light greenish gray, dense; beds ½-in. to 1-in. thick	4
83.	Claystone, dark greenish gray, silty, shaly at top; agate fragments in the soil probably weather from this unit	16
84.	Limestone, dark-gray to black, weathering gray to white, dense, shaly-bedded	2
85.	Shale, yellowish-brown, silty, fissile, poorly exposed	5
86.	Siltstone, greenish-gray, shaly to platy	13
	Total Otter formation	374
Kibbey sandstone:		
87.	Sandstone, gray to yellowish and brown, fine- to medium-grained; some calcareous in lower half, partly friable, porous; beds as thick as 3 ft	23
88.	Covered	1
Kibbey sandstone—Continued		
89.	Sandstone, yellow to gray with pink mottlings, calcareous, impure; beds 1 in. to 2 ft thick; fine- to medium-grained, poorly sorted quartz sand	16
90.	Covered	12
91.	Sandstone, mottled pink and yellowish-gray, calcareous, porous; beds 6 in. to 18 in. thick; medium-grained, poorly sorted quartz sand	28
92.	Covered	19
93.	Sandstone, greenish-yellow and brown, calcareous, impure; medium-grained, poorly sorted quartz sand; beds 6 in. to 1 ft thick	3
94.	Covered	6
95.	Sandstone, yellow or mottled red, gray, and yellow, friable, porous, unresistant, beds 2 in. to 1 ft thick; very fine- to medium-grained; some grains rounded and frosted	19
96.	Covered	10
97.	Sandstone, yellow, calcareous, fine-grained; beds 1 in. to 8 in. thick; upper three-fourths of unit grades upward from light-brown to purple, calcareous, shaly siltstone into impure, fine-grained sandstone	21
98.	Covered	6
99.	Sandstone, light-yellow to light-brown, fine-grained, calcareous, mostly with black spots that may be dried oil	12
100.	Covered	6
101.	Siltstone, reddish-brown, calcareous, locally shaly, gray-splotched; becomes progressively more sandy upward, top of unit being resistant 1-ft bed	38
	Total Kibbey sandstone	220
	Total Big Snowy group	1,491

MADISON GROUP

		Feet
Mission Canyon formation:		
102.	Limestone, gray with yellow and blue tints, very fine grained; top 1 ft is intraformational breccia	----

INDEX

[Italic numbers indicate descriptions]

PLATES 3–13

PLATE 3

[All figures × 1 unless otherwise indicated]

FIGURES 1–3. *Millerella* n. sp. ? (p. 27)

1. Equatorial section, × 50. USNM 119218 from USGS f 9712; Cameron Creek formation, loc. 14146.
2. Equatorial section, × 50. USNM 119219 from USGS f 9712; Cameron Creek formation, loc. 14146.
3. Axial section showing evolute shape, × 50. USNM 119220 from USGS f 9712; Cameron Creek formation, loc. 14146.

4. *Millerella* aff. *M. chesterensis* Cooper (p. 27)

Equatorial section, × 50. USNM 119221 from USGS f 9726; Otter formation, loc. 14227.

5, 6. *Endothyra* aff. *E. excentralis* Cooper (p. 28)

5. Equatorial section of a skew-coiled individual, × 50. USNM 119222 from USGS f 9712(8); Cameron Creek formation, loc. 14146.
6. Equatorial section of a planispiral individual, × 50. USNM 119223 from USGS f 9712(9); Cameron Creek formation, loc. 14146.

7. *Clionolithes* sp. (p. 28)

Borings in *Composita*, × 2. USNM 118720; Heath formation, loc. 13415.

8. *Triplophyllites* cf. *T. spinulosus* (Milne-Edwards and Haime) (p. 29)

Calyx. USNM 118721; Cameron Creek formation, loc. 13363.

9–12. *Bradyphyllum clavigerum* Easton, n. sp. (p. 31)

9. a, Transverse section, middle maturity, × 3; b, transverse section, early youth, × 5; c, transverse section, early maturity, × 3; d, transverse section, late maturity, × 3. Holotype, USNM 118722; Cameron Creek formation, loc. 13420.
10. Transverse section, late youth. Paratype, USNM 118723B; Cameron Creek formation, loc. 13420.
11. Longitudinal section. Paratype, USNM 118723C; Cameron Creek formation, loc. 13420.
12. a, Corallite, side view; b, calyx, late maturity, with rudimentary septa in the left-hand one of two buds, × 2. Paratype, USNM 118723A; Cameron Creek formation, loc. 13420.

13–17. *Fasciculiamplexus contortus* Easton, n. gen. and n. sp. (p. 32)

13. a, Transverse section, late maturity, × 3; b, transverse section, middle maturity, × 3; c, transverse section, early youth, × 5; d, transverse section, early middle maturity, × 3; e, transverse section, very late maturity, × 3. Holotype, USNM 118724; Cameron Creek formation, loc. 13420.
14. Transverse section, middle maturity, × 3. Paratype, USNM 118725B; Cameron Creek formation, loc. 13420.
15. Corallite, side view. Paratype, USNM 118725A; Cameron Creek formation, loc. 13420.
16. Corallite, side view. Paratype, USNM 118725D; Cameron Creek formation, loc. 13420.
17. Longitudinal section, × 3. Paratype, USNM 118725C; Cameron Creek formation, loc. 13420.

18–20. *Caninia montanensis* Easton, n. sp. (p. 33)

18. Natural longitudinal section. Ideotype, USNM 118727; Heath formation, loc. 13414.
19. Transverse section, late maturity, × 2. Ideotype, USNM 118726; Heath formation, loc. 13424.
20. a, Transverse section, early maturity, × 2; b, longitudinal section, × 2; c, transverse section, middle maturity, × 2; d, longitudinal section; e, transverse section, old age, × 2. Syntypes from Sloss (1945, pl. 48); Montana School of Mines collection; Yakinakak limestone of Willis (1902), Yakinakak Creek, Flathead County, Mont.

21–23. *Longiclava tumida* Easton, n. gen. and n. sp. (p. 34)

21. a, Transverse section, early maturity, × 3; b, transverse section, late maturity, × 3. Holotype, USNM 118729; Otter formation, loc. 13390.
22. a, Transverse section, early youth, × 5; b, transverse section, early youth at a rejuvenated stage, × 5. Paratype, USNM 118730A; Otter formation, loc. 13390.
23. a, Corallite, side view, with *Crania* encrusting it; b, calyx, × 2. Paratype, USNM 118730B; Otter formation, loc. 13390.

24. *Koninckophyllum*? sp. (p. 33)

Transverse section, × 3. USNM 118728; Heath formation, loc. 13424.

BIG SNOWY GROUP FORAMINIFERA, SPONGES, AND CORALS

PLATE 4

[All figures × 1 unless otherwise indicated]

FIGURE 1. *"Conularia"* n. sp. (p. 35)

a, External mold of parts of two faces; b, external mold of center of a face, × 5. USNM 118731; Cameron Creek formation, loc. 13362.

2, 3. *Echinocrinus* sp. (p. 38)

2. a, Spine, × 5; b, spine base, × 5. USNM 118738; Alaska Bench limestone, loc. 13372.
3. Spine. USNM 118739; Alaska Bench limestone or Cameron Creek formation, loc. 13385.

4, 5. *Dicromyocrinus granularis* Easton, n. sp. (p. 36)

4. a, Posterior of cup; b, basal view of cup. Paratype, USNM 118733; Alaska Bench limestone, loc. 14100.
5. Calyx, anterior view. Holotype, USNM 118732; Alaska Bench limestone, loc. 14100.

6–11. Crinoid plates (p. 37)

6. Columnal, circular with two orders of crenellae, × 5. USNM 118736A; Cameron Creek formation, loc. 13361.
7. Columnal, pentagonal with chevron arrangement of crenellae at angles, × 5. USNM 118736B; Cameron Creek formation, loc. 13361.
8. Columnal, star-shaped with chevron arrangement of crenellae at angles, × 5; USNM 118737; Alaska Bench limestone, loc. 13372.
9. a, Calyx plate, inner surface, × 2; b, calyx plate, outer surface, × 2. USNM 118734A; Heath formation, loc. 13414.
10. Columnal, circular with pentameral petaloid canal, × 2. USNM 118734B; Heath formation, loc. 13414.
11. Columnal, × 2. USNM 118735; Otter formation, loc. 13390.

12. *Lingula* cf. *L. carbonaria* Shumard (p. 38)

Surface, × 2. USNM 118740; Cameron Creek formation, loc. 13380.

13. *Orbiculoidea wyomingensis* Branson and Greger (p. 39)

Internal mold of pedicle valve superimposed on inner surface of opposite valve, × 2. Hypotype, USNM 118741; Alaska Bench limestone, loc. 13399.

14–16. *Orbiculoidea interlineata* Easton, n. sp. (p. 39)

14. Exterior of pedicle valve, exfoliated, × 2. Holotype, USNM 118742A; Heath formation, loc. 13367.
15. Ornamentation on surface of pedicle valve, × 10. Paratype, USNM 118742C; Heath formation, loc. 13367.
16. Exterior of brachial valve, × 2. Paratype, USNM 118742B; Heath formation, loc. 13367.

17, 30. *Orthotetes* (*Derbyia*) sp. (p. 43)

17. Internal mold of pedicle valve, × 1. USNM 119717; Devils Pocket formation, loc. 16180.
30. Internal mold of pedicle valve showing positions of dental lamellae, × 3. USNM 119717; Devils Pocket formation, loc. 16180.

18. *Crania* cf. *C. modesta* White and St. John (p. 40)

Specimen cemented onto surface of a *"Dictyoclostus,"* × 2. USNM 118744; Heath formation, loc. 13391.

19–23. *Schizophoria depressa* Easton, n. sp. (p. 85)

19. Pedicle view, × 3. Paratype, USNM 118745; Heath formation, loc. 13387.
20. Interior of pedicle valve, × 3. Ideotype, USNM 118748B; Cameron Creek formation, loc. 13421.
21. Brachial hinge features, × 3. Holotype, USNM 118746; Heath formation, loc. 13387.
22. Posterior, × 2. Ideotype, USNM 118747; Otter formation, loc. 13378.
23. Exterior of pedicle valve. Ideotype, USNM 118748A; Cameron Creek formation, loc. 13421.

24–27. *Stenoscisma obesa* (Clark) (p. 41)

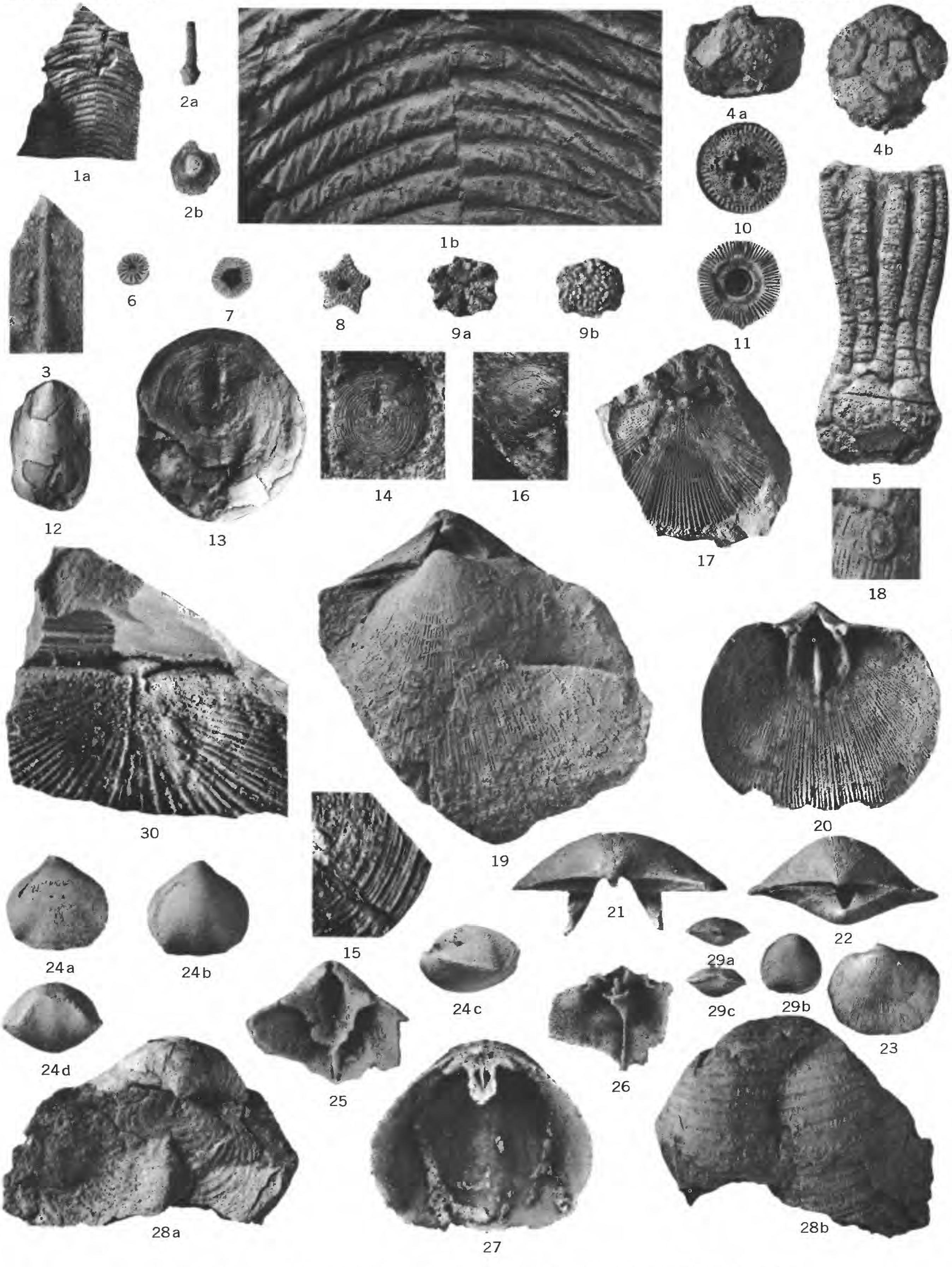
24. a, Brachial view, × 2; b, pedicle valve, × 2; c, side, × 2; d, anterior, × 2. Hypotype, USNM 118749A; Heath formation, loc. 13414.
25. Interior of pedicle valve, showing spondylium, × 5. Hypotype, USNM 118749B; Heath formation, loc. 13414.
26. Interior of brachial valve, slightly oblique, × 5. Hypotype, USNM 118749D; Heath formation, loc. 13414.
27. Interior of brachial valve, × 5. Hypotype, USNM 118749C; Heath formation, loc. 13414.

28. *Echinoconchus* aff. *E. alternatus* (Norwood and Pratten) (p. 48)

a, Brachial view; b, pedicle valve. USNM 118760; Alaska Bench limestone or Cameron Creek formation, loc. 13385.

29. *Rhipidomella* n. sp. (p. 86)

a, Posterior, showing cardinal areas; b, pedicle valve; c, anterior. USNM 118900; Heath formation, loc. 14102



BIG SNOWY GROUP CONULARIDS, ECHINODERMS, AND BRACHIOPODS

PLATE 5

[All figures × 1 unless otherwise indicated]

FIGURES 1–5. *Orthotetes* (*Orthotetes*) sp. (p. 42)

1. Pedicle valve, internal mold. Hypotype, USNM 118751C; Otter formation, loc. 13375.
2. Brachial valve, internal mold with distinct impressions of crural ridges. Hypotype, USNM 118751B; Otter formation, loc. 13375.
3. Cardinal process, outer side, × 5. Hypotype, USNM 118751D; Otter formation, loc. 13375.
4. a, Pedicle valve, internal mold; b, pedicle valve, posterior view of internal mold, × 2; c, pedicle valve, oblique posterior view showing fusion of median septum with dental lamellae, × 2. Hypotype, USNM 118751A; Otter formation, loc. 13375.
5. Pedicle interarea, × 2. Hypotype, USNM 118750, Alaska Bench limestone, loc. 13422.

6, 7. *Schuchertella* sp. (p. 43)

6. a, Pedicle interarea, × 2, USNM 118752A; b, pedicle valve, internal mold, × 2, USNM 118752B. Heath formation, loc. 13365.
7. Interior of brachial valve. USNM 118753; Heath formation, loc. 13414.

8–13. *Chonetes pseudoliratus* Easton, n. sp. (p. 44)

8. a, Posterior, × 2; b, pedicle exterior, corroded on lower right surface to show false lirae, × 2; c, brachial view, × 2; d, side, × 2. Holotype, USNM 118754; Cameron Creek formation, loc. 13420.
9. Exterior of pedicle valve, × 3. Paratype, USNM 118755E; Cameron Creek formation, loc. 13420.
10. Interior of brachial valve, × 2. Paratype, USNM 118755A; Cameron Creek formation, loc. 13420.
11. Interior of brachial valve, × 2. Paratype, USNM 118755B; Cameron Creek formation, loc. 13420.
12. Interior of pedicle valve, × 2. Paratype, USNM 118755C; Cameron Creek formation, loc. 13420.
13. Interior of pedicle valve, × 2. Paratype, USNM 118755D; Cameron Creek formation, loc. 13420.

14–20. *Nix angulata* Easton, n. gen. and n. sp. (p. 46)

14. Interior of brachial valve, × 3. Holotype, USNM 118756; Heath formation, loc. 13414.
15. a, Exterior of pedicle valve, × 2; b, side, × 2; c, brachial view, × 2. Ideotype, USNM 118896; Heath formation, loc. 13425.
16. Interior of brachial valve, × 2. Ideotype, USNM 118897; Heath formation, loc. 13425.
17. Interior of pedicle valve, × 3. Paratype, USNM 118757A; Heath formation, loc. 13414.
18. Interior of pedicle valve, × 3. Paratype, USNM 118757B; Heath formation, loc. 13414.
19. Interior of pedicle valve, × 3. Paratype, USNM 118757C; Heath formation, loc. 13414.
20. Interior of brachial valve, × 3. Paratype, USNM 118757D; Heath formation, loc. 13414.

21. *Chonetes geinitzianus* Waagen (p. 44)

Interior of brachial valve, showing indefinite ridge in place of median septum, × 2. Topotype, USNM 123391a; Pennsylvanian system of Nebraska. Shown for comparison.

22. *Nix loganensis* (Hall and Whitfield) (p. 46)

Pedicle valve, partly an internal mold, × 2; right cardinal extremity is rounded. Shown for comparison. Holotype, USNM 14237; "Lower Carboniferous," Logan Canyon, Utah.

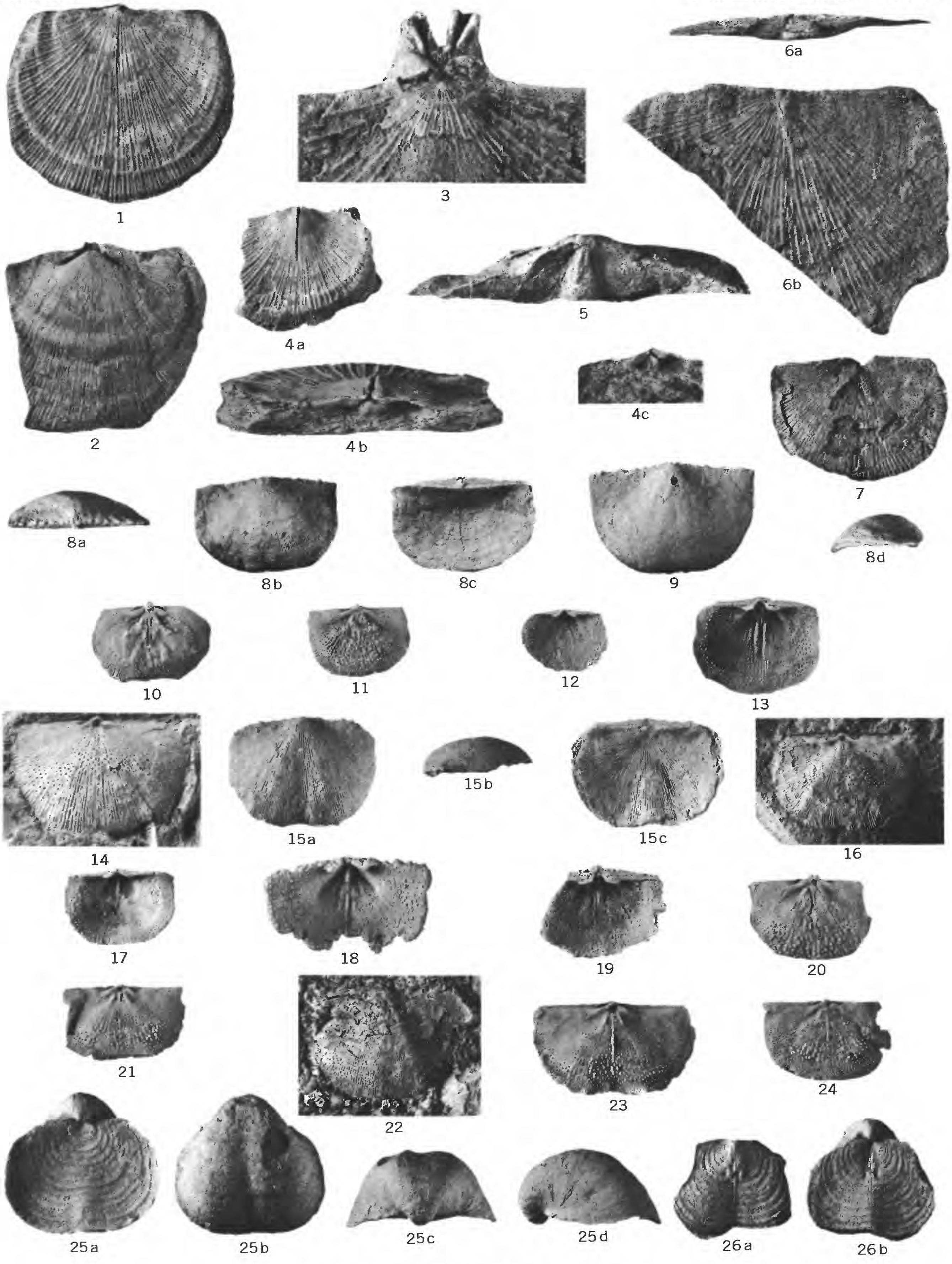
23, 24. *Chonetes* sp. (p. 44)

23. Interior of brachial valve showing good median septum, × 2. USNM 123392a; Pennsylvanian system of Nebraska.
24. Interior of brachial valve showing good median septum, × 2. USNM 123392b; Pennsylvanian system of Nebraska.

These two specimens are associated with *C. geinitzianus* at its type locality and are shown here for comparison.

25, 26. *Echinoconchus angustus* Easton, n. sp. (p. 47)

25. a, Brachial view; b, exterior of pedicle valve; c, posterior; d, side. Holotype, USNM 118758; Cameron Creek formation, loc. 13362.
26. a, Interior of brachial valve, artificial mold; b, brachial view showing partly exfoliated brachial valve. Paratype, USNM 118759; Cameron Creek formation, loc. 13362.



BIG SNOWY GROUP BRACHIOPODS

PLATE 6

[All figures $\times$ 1 unless otherwise indicated]

FIGURES 1–5. *Productus fasciculatus* McChesney (p. 48)

1. a, Pedicle valve; b, specimen in fig. 1a orientated as before but separated along crack to show coarse radial ridges and finely striate diaphragm around margin of brachial valve. Hypotype, USNM 118763B; Heath formation, loc. 13425.
2. Pedicle valve, internal mold showing muscle scars. Hypotype, USNM 118763A; Heath formation, loc. 13425.
3. a, Brachial valve, artificial mold reproducing internal surface; b, cardinal process, external view, $\times$ 5; c, cardinal process, internal view, $\times$ 5. Hypotype, USNM 118762; Heath formation, loc. 13414.
4. a, Brachial view showing external ornamentation of brachial visceral disc and diaphragm; b, pedicle valve. Hypotype, USNM 118763C; Heath formation, loc. 13425.
5. a, Side, showing cluster of spine bases; b, pedicle view of specimen with visceral area of pedicle valve broken away to show median septum and muscle scars of inner surface of brachial valve, $\times$ 2. Hypotype, USNM 118761; Heath formation, loc. 13409.

6–8. *Linoproductus nodosus* (Newberry) n. subsp. (p. 50)

6. Exterior of pedicle valve. USNM 118766A; Cameron Creek formation, loc. 13362.
7. Brachial valve, exfoliated away from posterior margin. USNM 118766B; Cameron Creek formation, loc. 13362.
8. a, Pedicle valve, side view of internal mold; b, pedicle valve, anterior view of internal mold. USNM 118765; Cameron Creek formation, loc. 13383.

9. *Linoproductus croneisi* Branson (p. 50)

Exterior of pedicle valve, $\times$ 2. Hypotype, USNM 118767; Heath formation, loc. 13395.

10–12. *Linoproductus*? *duodenarius* Easton, n. sp. (p. 51)

10. a, Pedicle exterior; b, side. Holotype, USNM 118768; Heath formation, loc. 13416.
11. Brachial valve, external mold, $\times$ 2. Ideotype, USNM 118770; Alaska Bench limestone, loc. 13403.
12. Brachial valve, external mold. Paratype, USNM 118769A; Heath formation, loc. 13416.

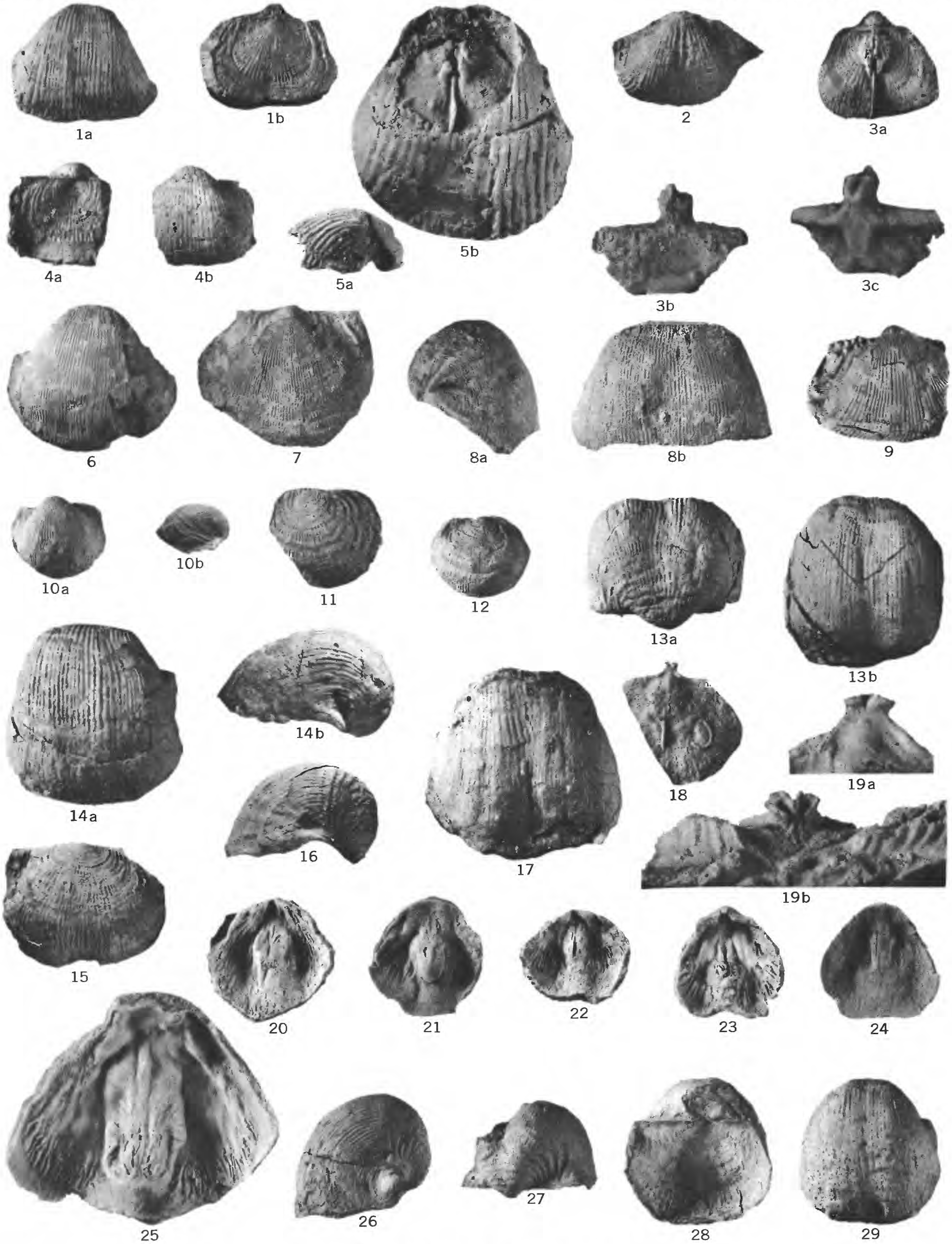
13–24. "*Dictyoclostus*" *inflatus* subsp. *spinolinearis* Easton, n. subsp. (p. 54)

13. a, Exterior of pedicle valve, posterior view; b, exterior of pedicle valve, anterior view. Holotype, USNM 118772; Heath formation, loc. 13368.
14. a, Exterior of pedicle valve, anterior view; b, exterior of pedicle valve, side view showing spine bases. Paratype, USNM 118773A; Heath formation, loc. 13368.
15. Brachial valve, exfoliated but showing row of nodes on upper right edge. Ideotype, USNM 118775; Heath formation, loc. 13410.
16. Exterior of pedicle valve, side view showing spine bases. Ideotype, USNM 118776; Heath formation, loc. 13402.
17. Exterior of pedicle valve, anterior slope showing smooth lower margin. Ideotype, USNM 118777; Cameron Creek formation, loc. 13362.
18. Brachial valve, artificial mold of internal surface. Paratype, USNM 118773D; Heath formation, loc. 13368.
19. a, Cardinal process, inner side, $\times$ 5; b, cardinal process, outer side, $\times$ 5. Paratype, USNM 118773B; Heath formation, loc. 13368.

20–24. Interiors of pedicle valves. The five specimens show much variation in shape and strength of adductor muscle platforms and of diductor muscle fields. Ideotypes, USNM 118774; Heath formation, loc. 13359.

25–29. "*Dictyoclostus*" *inflatus* subsp. *obsoletus* Easton, n. subsp. (p. 55)

25. Interior of pedicle valve, $\times$ 2. Ideotype, USNM 118781; Heath formation, loc. 13402.
26. Exterior of pedicle valve, side view. Paratype, USNM 118779; Heath formation, loc. 13402.
27. Exterior of pedicle valve, oblique side view. Ideotype, USNM 118780; Heath formation, loc. 13370.
28. Brachial view. Holotype, USNM 118778; Heath formation, loc. 13402.
29. Exterior of pedicle valve of specimen in figure 28.



BIG SNOWY GROUP BRACHIOPODS

PLATE 7

[All figures × 1 unless otherwise indicated]

FIGURES 1, 2. "*Dictyoclostus*" *confluens* Easton, n. sp. (p. 55)

1. a, Exterior of pedicle valve; b, brachial view; c, side; d, anterior. Holotype, USNM 118782; Cameron Creek formation, loc. 13362.
2. a, Brachial valve, side view of external mold; b, brachial valve, external mold. Paratype, USNM 118783A.

3–5. "*Dictyoclostus*" *richardsi* (Girty) (p. 56)

3. Exterior of pedicle valve, side view, × 2. Hypotype, USNM 118784A; Heath formation, loc. 13414.
4. a, Brachial valve, external mold, × 2; b, brachial valve, side view of external mold, × 2. Hypotype, USNM 118784B; Heath formation, loc. 13414.
5. Exterior of pedicle valve, × 2. Hypotype, USNM 118784C; Heath formation, loc. 13414.

6–8. *Antiquatonia pernodosa* Easton, n. sp. (p. 58)

6. a, Exterior of pedicle valve; b, pedicle exterior, side view; c, posterior view; d, brachial view. Holotype, USNM 118785; Cameron Creek formation, loc. 13362.
7. Pedicle valve, internal mold. Paratype, USNM 118786; Cameron Creek formation, loc. 13362.
8. a, Exterior of pedicle valve, side view; b, pedicle exterior, oblique side view. Ideotype, USNM 118787; Heath formation, loc. 13395.

9, 10. *Antiquatonia* n. sp. (p. 59)

9. Exterior of pedicle valve. USNM 118788B; Heath formation, loc. 13362.
10. Exterior of pedicle valve, side view. USNM 118788A; Heath formation, loc. 13362.

11–15. *Rugoclostus nivalis* Easton, n. gen. and n. sp. (p. 60)

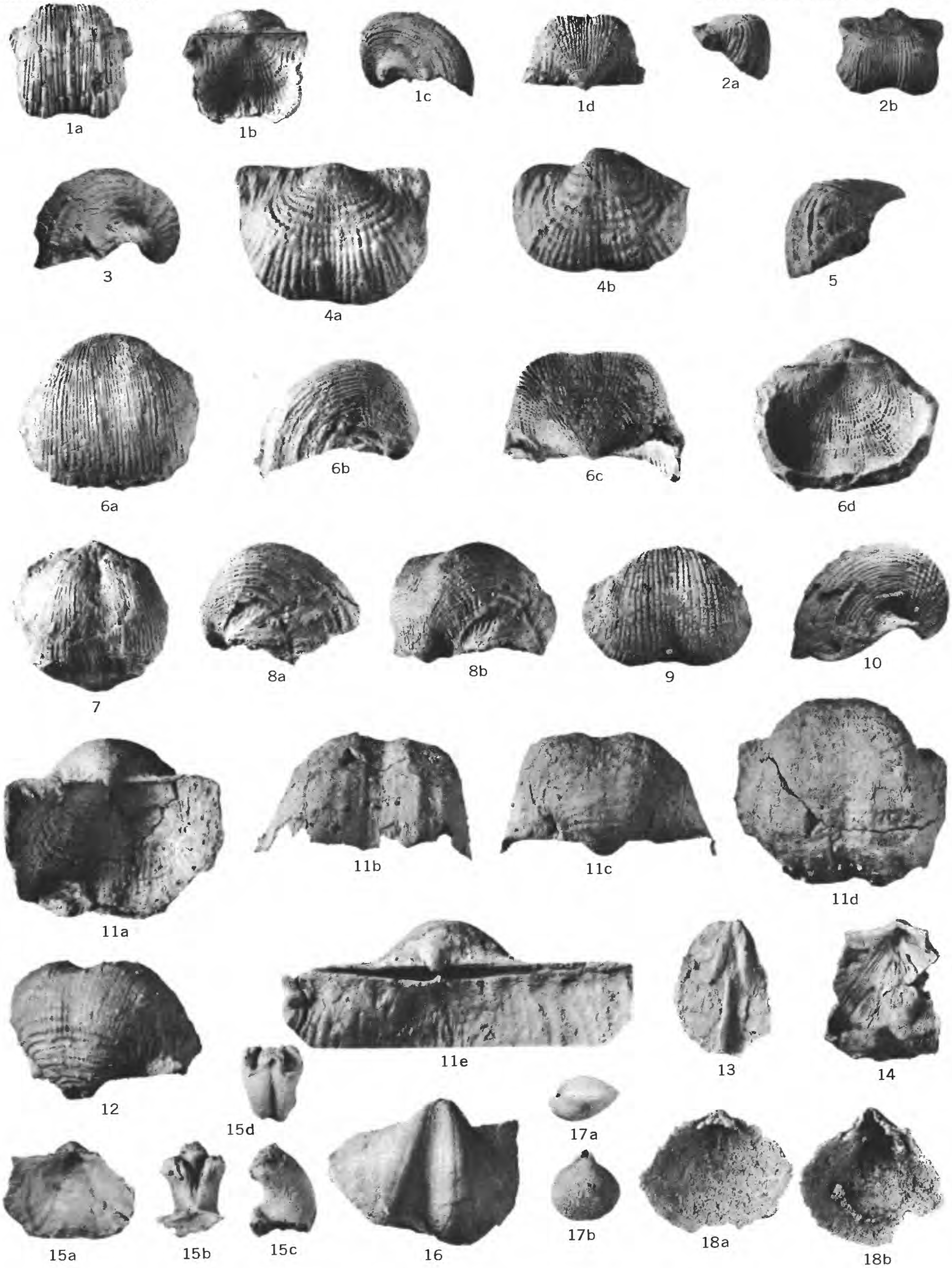
11. a, Brachial view; b, pedicle valve, anterior view; c, pedicle valve, posterior view; d, pedicle valve; e, brachial view of hinge region showing narrow elogate cardinal area just above articulating hinge surface of pedicle valve, × 3. Holotype, USNM 118789; Cameron Creek formation, loc. 13420.
12. Pedicle valve, oblique side view. Paratype, USNM 118790D; Cameron Creek formation, loc. 13420.
13. Interior of brachial valve, fragment showing adductor muscle scars and median septum, × 2. Paratype, USNM 118790A; Cameron Creek formation, loc. 13420.
14. Interior of pedicle valve, mature shell. Paratype, USNM 118790C; Cameron Creek formation, loc. 13420.
15. a, Interior of pedicle valve, immature shell; b, cardinal process, inner surface, × 3; c, cardinal process, side view with inner surface to left, × 3; d, cardinal process, end view, × 3. Paratype, USNM 118790B; Cameron Creek formation, loc. 13420.

16. *Brachythyris* sp. (p. 72)

Exterior of pedicle valve. USNM 118813; Cameron Creek formation, loc. 13362.

17, 18. *Crurithyris* n. sp. (p. 75)

17. a, Side, × 2; b, brachial view, × 2. USNM 118814A; Heath formation, loc. 13414.
18. a, Interior of brachial valve, × 3; b, interior of pedicle valve, × 3. USNM 118814B; Heath formation, loc. 13414.



BIG SNOWY GROUP BRACHIOPODS

PLATE 8

[All figures × 1 unless otherwise indicated]

FIGURES 1–3. "*Buxtonia*" sp. (p. 62)

1. a, Interior of brachial valve, showing slightly grooved median septum and bifid inner surface of cardinal process, × 5; b, interior of brachial valve; c, cardinal process, outer side, × 5. USNM 118792; Heath formation, loc. 13412.
2. Exterior of pedicle valve, × 2. USNM 118793A; Heath formation, loc. 13366.
3. Exterior of brachial valve, × 2; USNM 118793B; Heath formation, loc. 13366.

4. *Buxtonia scabricula* (Martin) (p. 61)

a, Brachial view showing bifid outer side of cardinal process and lower side of cleft median septum (matrix picked out of groove by the writer) where shell is exfoliated, × 5; b, cardinal process from posterior showing bifid inner side, × 5. Hypotype, USNM 123388; Carboniferous, Viséan, D2, Chrome Hill, Derbyshire, England.

5, 6. "*Buxtonia*" *arizonensis* Hernon (p. 62)

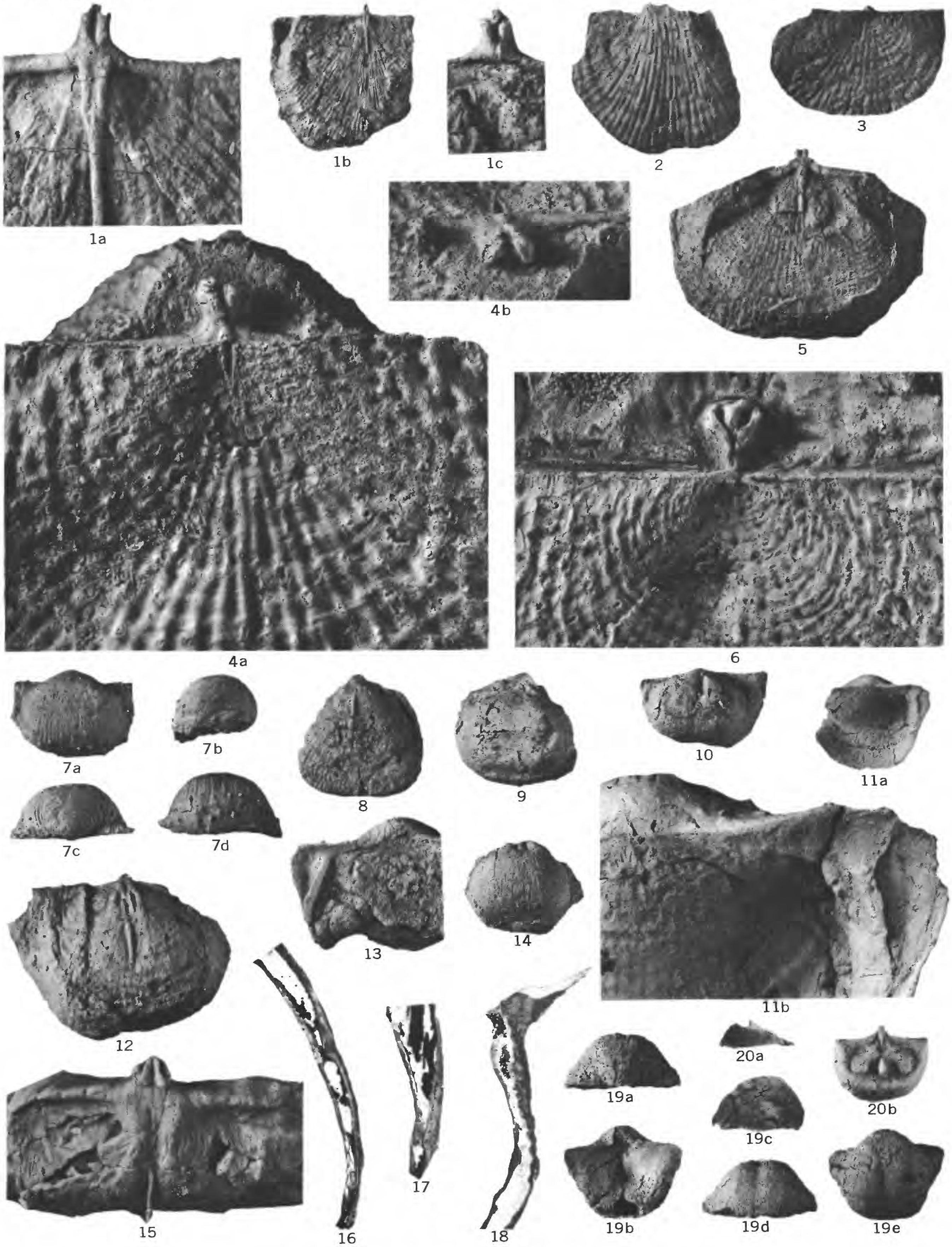
5. Interior of brachial valve of visceral disc with exterior of pedicle valve forming anterior and lateral margins. Hypotype, USNM 118791A; Heath formation, loc. 13370.
6. Brachial view showing trifid outer side of cardinal process, × 5. Hypotype, USNM 118791B; Heath formation, loc. 13370.

7–18. "*Marginifera*" *planocosta* Easton, n. sp. (p. 63)

7. a, Pedicle valve; b, side; c, posterior; d, anterior. Holotype, USNM 118794; Cameron Creek formation, loc. 13420.
8. Interior of brachial valve, showing marginal ridge on right posterior margin, × 2. Paratype, USNM 118795E; Cameron Creek formation, loc. 13420.
9. Pedicle valve, internal mold, showing strong girdle at anterior margin. Paratype, USNM 118795B; Cameron Creek formation, loc. 13420.
10. Pedicle valve, internal mold, showing slight girdle near right anterior margin. Paratype, USNM 118795C; Cameron Creek formation, loc. 13420.
11. a, Brachial view; b, brachial view of an ear with brachial valve overlapping the ear, × 5. Paratype, USNM 118795A; Cameron Creek formation, loc. 13420.
12. Interior of brachial valve with exterior of pedicle valve in place on left third of figure, showing slight ridge around anterior margin of brachial visceral disc, × 2. Paratype, USNM 118795J; Cameron Creek formation, loc. 13420.
13. Brachial view of ear of pedicle valve with brachial valve absent, showing concavity of ear, × 2. Paratype USNM 118795G; Cameron Creek formation, loc. 13420.
14. Pedicle valve, internal mold, showing vascular markings. Paratype, USNM 118795D; Cameron Creek formation, loc. 13420.
15. Interior of brachial valve, showing hinge features, × 5. Paratype, USNM 118795F; Cameron Creek formation, loc. 13420.
16. Radial section through anterior-lateral slope, showing ridges of brachial (left) and pedicle valves in contact and also showing separate laminae of shell margins, × 5. Paratype, USNM 118888A; Cameron Creek formation, loc. 13420.
17. Radial section through anterior slope, showing ridges of brachial (left) and pedicle valves in contact, × 5. Paratype, USNM 118888B; Cameron Creek formation, loc. 13420.
18. Radial section through ear, showing secondary deposit of ear and overlap of brachial valve to leave a separate chamber outside the visceral cavity, × 5. Paratype, USNM 118888C; Cameron Creek formation, loc. 13420.

19, 20. "*Marginifera*" *adairensis* (Drake) (p. 64)

19. a, Posterior; b, brachial view; c, side; d, anterior; e, pedicle valve. Holotype, Stanford University Paleontology Type Collection 818; "Boston group" [probably Mayes formation and Fayetteville shale] near Adair, Okla.
20. a, Brachial valve, side view; b, interior of brachial valve. Paratype, Stanford University Paleontology Type Collection 819; "Boston group" [probably Mayes formation and Fayetteville shale] near Adair, Okla.



BIG SNOWY GROUP BRACHIOPODS

PLATE 9

[All figures × 1 unless otherwise indicated]

FIGURES 1–8. *Leiorhynchus carboniferus* (Girty) (p. 65)
1. Pedicle valve, mostly internal mold. Hypotype, USNM 118798; Heath formation, loc. 13408.
2. Exterior of pedicle valve. Hypotype, USNM 118800A; Heath formation, loc. 13365.
3. Exterior of brachial valve. Hypotype, USNM 118800B; Heath formation, loc. 13365.
4. Brachial valve, internal mold. Hopotype, USNM 118799B; Heath formation, loc. 13414.
5. Brachial valve, hinge features, × 2. Hypotype, USNM 118797; Heath formation, loc. 13417.
6. Pedicle valve, side view. Hypotype, USNM 118799A; Heath formation, loc. 13414.
7. Interior of pedicle valve, × 2. Hypotype, USNM 118796; Heath formation, loc. 13359.
8. Brachial valve, internal mold. Syntype, USNM 118890; Moorefield formation, Spring Creek, Ark.

9. *Leiorhynchus quadracostatus* (Vanuxem) (p. 64)
Brachial valve, internal mold. Genotype, USNM 123390; base of New Albany shale (Devonian), Lexington, Ind.

10, 11. *Pugnoides quinqueplecis* Easton, n. sp. (p. 67)
10. a, Posterior; b, side; c, brachial view; d, pedicle valve; e, anterior. Holotype, USNM 118801; Cameron Creek formation, loc. 13420.
11. Oblique anterior view, × 2. Paratype, USNM 118802; Cameron Creek formation, loc. 13420.

12, 13. *Pugnoides parvulus* Girty (p. 67)
12. a, Pedicle valve; b, side; c, anterior; d, brachial view; all × 2. Hypotype, USNM 118803A; Otter formation, loc. 13390.
13. Anterior of thick specimen, × 2. Hypotype, USNM 118803B; Otter formation, loc. 13390.

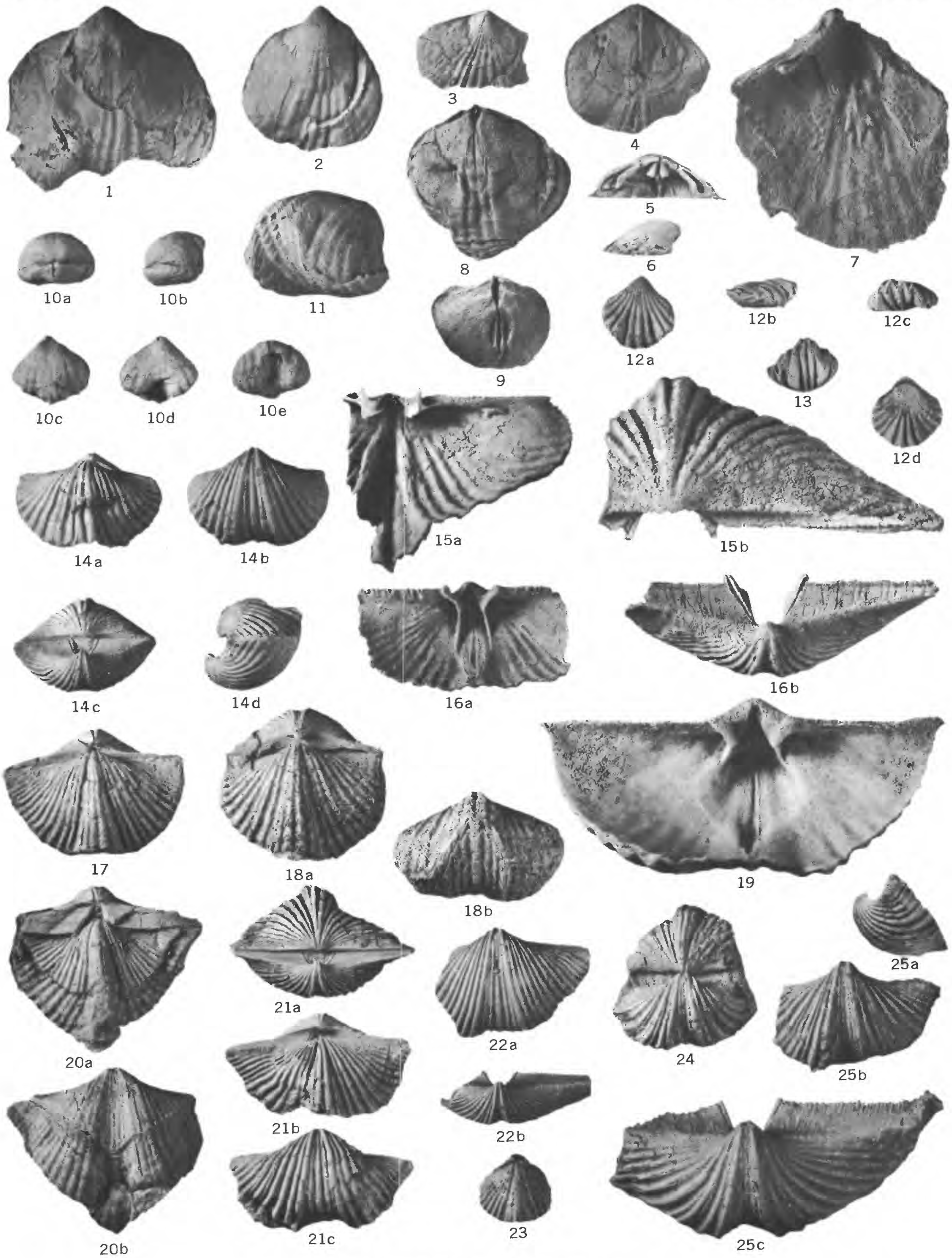
14–19. *Spirifer curvilateralis* Easton, n. sp. (p. 68)
14. a, Brachial view; b, pedicle valve; c, posterior; d, side. Holotype, USNM 118804; Heath formation, loc. 13395.
15. a, Interior of brachial valve, view from anterior at low angle, × 2; b, brachial valve, posterior view, × 3. Ideotype, USNM 118806C; Cameron Creek formation, loc. 13363.
16. a, Interior of pedicle valve, × 2; b, pedicle valve, posterior view, × 3. Ideotype, USNM 118806B; Cameron Creek formation, loc. 13363.
17. Brachial view of a transverse specimen. Paratype, USNM 118805B; Heath formation, loc. 13395.
18. a, Brachial view of an elongate specimen; b, anterior. Paratype, USNM 118805A; Heath formation, loc. 13395.
19. Interior of pedicle valve, × 2. Ideotype, USNM 118806A; Cameron Creek formation, loc. 13363.

20. *Spirifer increbescens* Hall (p. 70)
a, Brachial view; b, pedicle valve. Hypotype, USNM 118807; Cameron Creek-formation, loc. 13420.

21, 22. *Spirifer shoshonensis* Branson and Greger (p. 70)
21. a, Posterior; b, brachial view; c, exterior of pedicle valve. Hypotype, USNM 118808; Heath formation, loc. 13395.
22. a, Exterior of pedicle valve; b, pedicle valve, posterior view. Hypotype, USNM 118809; Cameron Creek formation, loc. 13382.

23. *Spirifer welleri* Branson and Greger (p. 70)
Brachial view. Hypotype, USNM 118810; Alaska Bench limestone, loc. 13404.

24, 25. *Neospirifer praenuntius* Easton, n. sp. (p. 71)
24. Posterior, valves swung apart along hinge line. Holotype, USNM 118811; Heath formation, loc. 13409.
25. a, Pedicle valve, side view; b, pedicle exterior; c, pedicle valve, posterior view, × 2. Paratype, USNM 118812A; Heath formation, loc. 13409.



BIG SNOWY GROUP BRACHIOPODS

577887 O—61——7

PLATE 10

[All figures $\times$ 1 unless otherwise indicated]

FIGURES 1–3. "*Martinia*" sp. A (p. 72)

1. a, Exterior of pedicle valve; b, exterior of pedicle valve, side view. USNM 118815C; Heath formation, loc. 13409.
2. Interior of pedicle valve, showing vascular markings, $\times$ 2. USNM 118815A; Heath formation, loc. 13409.
3. Pedicle valve, showing hinge features and fibrous shell substance, $\times$ 2. USNM 118815B; Heath formation, loc. 13409.

4. "*Martinia*" sp. B (p. 73)

Pedicle valve, showing delthyrium and cardinal areas, $\times$ 2. USNM 118816; Heath formation, loc. 13409.

5. *Eumetria* cf. *E. vera* (Hall) (p. 85)

Brachial view, $\times$ 2. USNM 118822; Otter formation, loc. 13390.

6–11. *Punctospirifer transversus* (McChesney) (p. 80)

6. a, Brachial view; b, pedicle valve; c, posterior. Hypotype, USNM 118819; Heath formation, loc. 13414.
7. Interior of brachial valve, $\times$ 2. Hypotype, USNM 118817C, Cameron Creek formation, loc. 13420.
8. Interior of pedicle valve, showing median septum and dental lamellae engulfed in apical callous, $\times$ 2. Hypotype, USNM 118817D; Cameron Creek formation, loc. 13420.
9. Pedicle view of a transverse specimen. Hypotype, USNM 118817A; Cameron Creek formation, loc. 13420.
10. a, Pedicle valve, $\times$ 2; b, brachial view, $\times$ 2; c, left tip of figure 10b enlarged to show spines, $\times$ 10. Hypotype, USNM 118818; Cameron Creek formation, loc. 13382.
11. Interior of brachial valve, $\times$ 5. Hypotype, USNM 118817B; Cameron Creek formation, loc. 13420.

12–16. *Reticulariina spinosa* (Norwood and Pratten) (p. 83)

12. a, Brachial view of specimen with spines broken off; b, pedicle valve; c, side; d, anterior. Hypotype, USNM 118820; Heath formation, loc. 13414.
13. Interior of brachial valve, $\times$ 2. Hypotype, USNM 118821D; Heath formation, loc. 13414.
14. a, Interior of brachial valve, $\times$ 2; b, brachial interior of same specimen enlarged, $\times$ 5. Hypotype, USNM 118821C; Heath formation, loc. 13414.
15. Interior of pedicle valve, $\times$ 2. Hypotype, USNM 118821A; Heath formation, loc. 13414.
16. Interior of pedicle valve, oblique view $\times$ 2. Hypotype, USNM 118821B; Heath formation, loc. 13414.

17. *Nucleospira superata* Easton, n. sp. (p. 73)

a, Brachial valve, $\times$ 2; b, brachial valve, slightly oblique, enlarged to show minute spines covering surface, $\times$ 5; c, anterior, $\times$ 2; d, posterior, showing small cardinal area, $\times$ 2; e, side, $\times$ 2; f, pedicle valve, $\times$ 2. Holotype, USNM 118823; Cameron Creek formation, loc. 13420.

18. *Cleiothyridina* aff. *C. sublamellosa* (Hall) (p. 75)

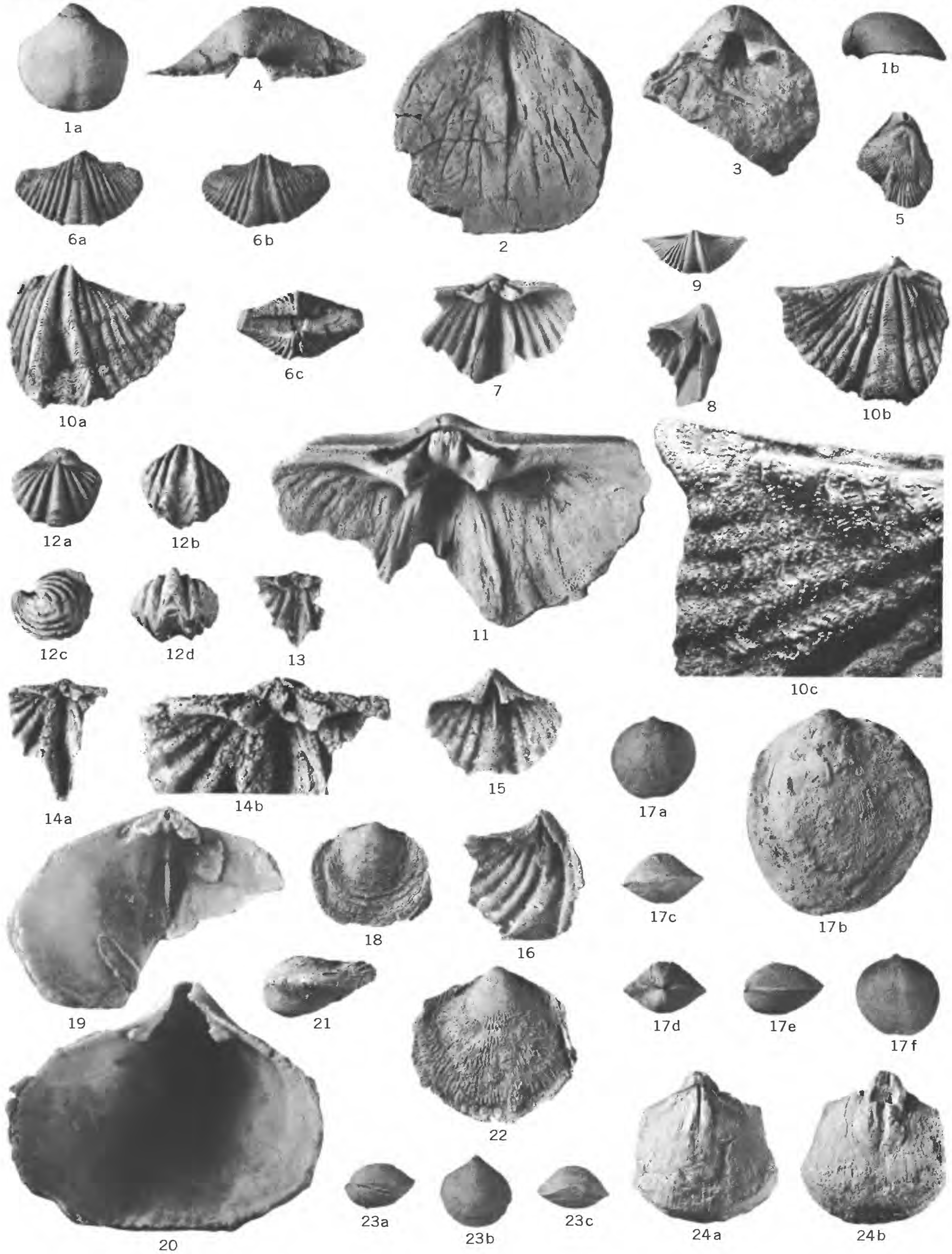
Pedicle valve, showing spinose surface. USNM 118827; Heath formation, loc. 13359.

19–22. *Cleiothyridina hirsuta* (Hall) (p. 74)

19. Interior of brachial valve, $\times$ 5. Hypotype, USNM 118826B; Alaska Bench limestone, loc. 13423.
20. Interior of pedicle valve, $\times$ 5. Hypotype, USNM 118826A; Alaska Bench limestone, loc. 13423.
21. Side, $\times$ 2. Hypotype, USNM 118825A; Cameron Creek formation, loc. 13420.
22. Pedicle valve, showing spinose surface, $\times$ 2. Hypotype, USNM 118825B; Cameron Creek formation, loc. 13420.

23, 24. *Cleiothyridina atrypoides* (Girty) (p. 75)

23. a, Side; b, brachial view; c, anterior. Holotype, USNM 118718; Fayetteville shale, Arkansas.
24. a, Brachial view of internal mold, $\times$ 2; b, pedicle view of internal mold, $\times$ 2. Hypotype, USNM 118828; Heath formation, loc. 13393.



BIG SNOWY GROUP BRACHIOPODS

PLATE 11

[All figures × 1 unless otherwise indicated]

FIGURES 1, 2. *Composita laevis* Weller (p. 76)

1. a, Brachial view; b, pedicle valve; c, side; d, anterior. Hypotype, USNM 118829A; Heath formation loc. 13395.
2. a, Brachial view; b, anterior. Hypotype, USNM 118829B; Heath formation, loc. 13395.

3, 4. *Composita* cf. *C. lateralis* (Girty) (p. 77)

3. a, Brachial view; b, pedicle valve; c, anterior. Hypotype, USNM 118830; Heath formation, loc. 13414.
4. a, Brachial view; b, pedicle valve, somewhat exfoliated; c, side; d, anterior. Shown for comparison. Holotype, USNM 118719; Fayetteville shale, Arkansas.

5–7. *Composita ozarkana* Mather (p. 77)

5. a, Brachial view; b, pedicle valve; c, anterior; d, side. Hypotype, USNM 118831A; Heath formation, loc. 13395.
6. Spiralia and brachial hinge structures seen from pedicle side, × 2. Hypotype, USNM 118831C; Heath formation, loc. 13395.
7. a, Brachial view; b, anterior. Hypotype, USNM 118831B; Heath formation, loc. 13395.

8, 9. *Composita sulcata* Weller (p. 77)

8. a, Brachial view; b, pedicle valve; c, side; d, anterior. Hypotype, USNM 118832A; Heath formation, loc. 13395.
9. a, Anterior; b, pedicle valve. Hypotype, USNM 118832B; Heath formation, loc. 13395.

10–18. *Composita subquadrata* (Hall) (p. 78)

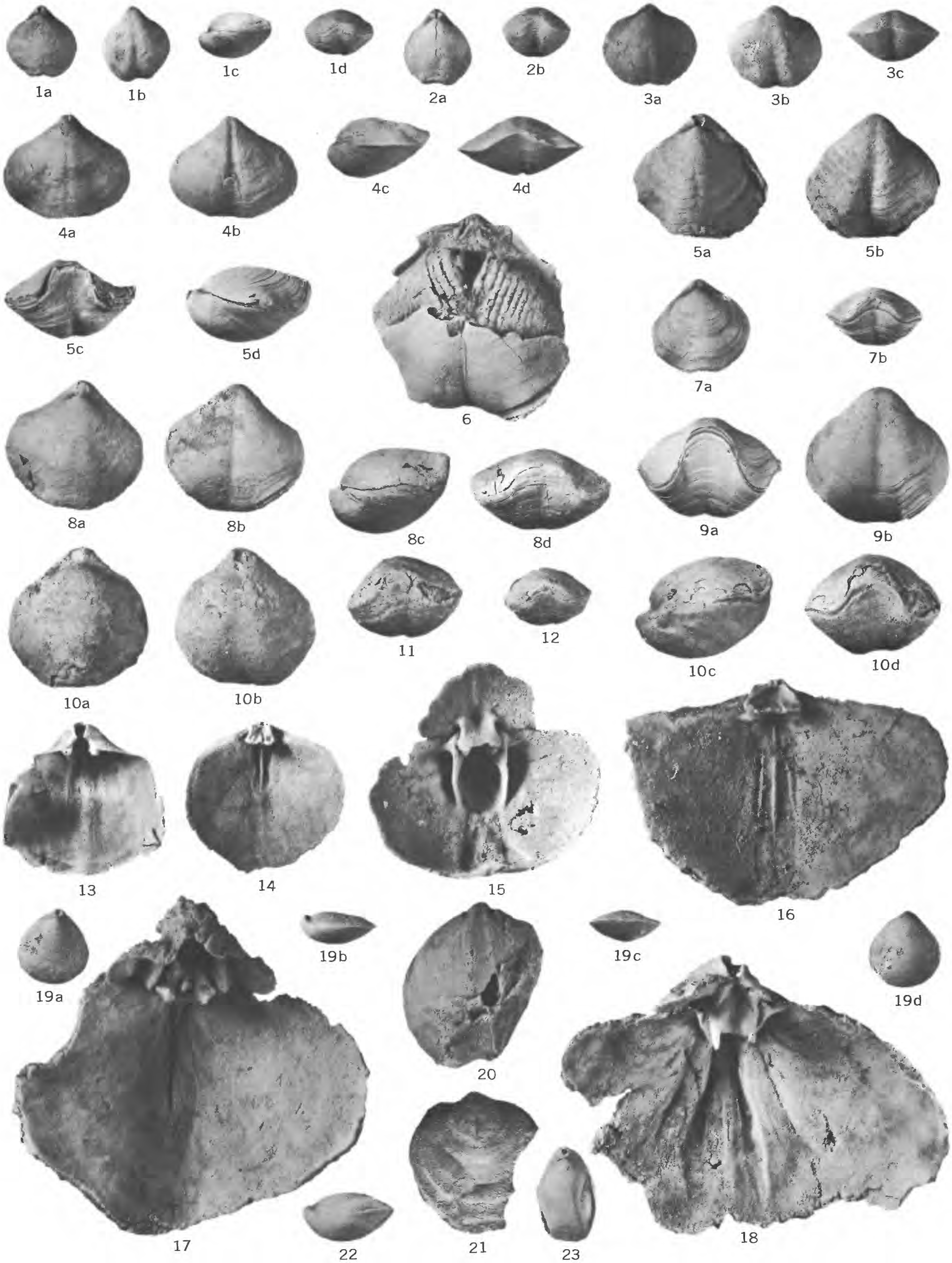
10. a, Brachial view; b, pedicle valve; c, side; d, anterior. Hypotype, USNM 118833A; Alaska Bench limestone, loc. 13404.
11. Anterior. Hypotype, USNM 118833B; Alaska Bench limestone, loc. 13404.
12. Anterior. Hypotype, USNM 118833C; Alaska Bench limestone, loc. 13404.
13. Interior of pedicle valve, × 2. Hypotype, USNM 118833D; Alaska Bench limestone, loc. 13404.
14. Interior of brachial valve, × 2. Hypotype, USNM 118833E; Alaska Bench limestone, loc. 13404.
15. Articulated hinge structures, × 3. Hypotype, USNM 118833F; Alaska Bench limestone, loc. 13404.
16. Interior of brachial valve, × 3. Hypotype, USNM 118833G; Alaska Bench limestone, loc. 13404.
17. Interior of brachial valve with pedicle hinge structures at upper side of figure, × 3. Hypotype, USNM 118833H; Alaska Bench limestone, loc. 13404.
18. Interior of pedicle valve with brachial hinge structures at upper side of figure, × 3. Hypotype, USNM 118833I; Alaska Bench limestone, loc. 13404.

19–21. *Cranaena*? *circularis* Easton, n. sp. (p. 88)

19. a, Brachial view; b, side; c, anterior; d, pedicle valve. Holotype, USNM 118835; Heath formation, loc. 13425.
20. Pedicle valve, internal mold, × 2. Paratype, USNM 118836; Heath formation, loc. 13425.
21. Interior of brachial valve, × 2. Ideotype, USNM 118837; Otter formation, loc. 13375.

22, 23. *Cranaena*? n. sp. (p. 89)

22. Side view, × 2. USNM 118904; Otter formation, loc. 14227.
23. Brachial view, × 2. USNM 118904; Otter formation, loc. 14227.



BIG SNOWY GROUP BRACHIOPODS

PLATE 12

[All figures × 1 unless otherwise indicated]

FIGURES 1–6. *Girtyella woodworthi* Clark (p. 87)

1. a, Side; b, pedicle valve; c, anterior; d, brachial view. Hypotype, USNM 118834A; Heath formation, loc. 13425.
2. a, Brachial view; b, anterior. Hypotype, USNM 118834B; Heath formation, loc. 13425.
3. a, Brachial view; b, anterior. Hypotype, USNM 118834C; Heath formation, loc. 13425.
4. Brachial view with internal mold of brachial valve, × 2. Hypotype, USNM 118834D; Heath formation, loc. 13425.
5. Interior of brachial valve, slightly oblique, showing brachial support on right side, × 5. Hypotype, USNM 118834F; Heath formation, loc. 13425.
6. Pedicle interior, × 5. Hypotype, USNM 118834F; Heath formation, loc. 13425.

7. *Girtyella wellsvillensis* Gunnell (p. 87)
a, Side; b, brachial view; c, anterior. Shown for comparison. Holotype, USNM 123393; Brazer limestone, Wellsville Mountains, Utah.

8. *Hamburgia*? cf. *H.*? *walteri* (Branson) (p. 88)
a, Cardinal region, × 11. USNM 118839; Heath formation, loc. 13414. b, Brachial view, × 3. USNM 118838; Heath formation, loc. 13414.

9, 10. *Spirorbis* aff. *S. moreyi* C. Branson (p. 89)

9. Basal view, × 5. USNM 118840A; Otter formation, loc. 13390.
10. Side view, showing impression of attachment, × 5. USNM 118840B; Otter formation, loc. 13390.

11. *Spirorbis* sp. (p. 89)
Apical view, × 5. USNM 118841; Heath formation, loc. 13387.

12. *Cornulites* sp. (p. 90)
Fragments of conical tubes on *Spirifer curvilineatus* and associated with *Spirorbis*, × 5. USNM 118842; Heath formation, loc. 13395.

13–16. *Nuculopsis* (*Palaeonucula*) *montanensis* Easton, n. sp. (p. 90)

13. Left valve, × 3. Paratype, USNM 118844B; Heath formation, loc. 13391.
14. Right valve, × 2. Holotype, USNM 118843; Heath formation, loc. 13391.
15. Dorsal margin, × 2. Paratype, USNM 118844A; Heath formation, loc. 13391.
16. Left valve, interior, × 3. Paratype, USNM 118844A; Heath formation, loc. 13391.

17, 18. *Nuculana biangulata* Easton, n. sp. (p. 91)

17. a, Left valve, × 2; b, anterior of left valve, × 2. Holotype, USNM 118845; Cameron Creek formation, loc. 13361.
18. Right valve, dorsal margin, × 2. Paratype, USNM 118846; Cameron Creek formation, loc. 13361.

19. *Nuculana* sp. A (p. 91)
Left valve, × 2. USNM 119964; Alaska Bench limestone, loc. 13399.

20, 21 *Nuculana rugodorsata* Easton, n. sp. (p. 91)

20. a, Left valve, × 4; b, posterior, × 4; c, dorsal margin, × 4. Holotype, USNM 118847; Heath formation, loc. 13391.
21. Interior of left valve, × 4. Paratype, USNM 118848; Heath formation, loc. 13391.

22. *Myalina* (*Myalina*) *parallela* Easton, n. sp. (p. 92)
a, Side of left valve; b, anterior of left valve. Holotype, USNM 118849; Otter formation, loc. 13390.

23–25. *Septimyalina* n. sp. (p. 92)

23. Left valve, × 2. USNM 118852A; Cameron Creek formation, loc. 13363.
24. Dorsal margin viewed slightly from anterior, showing notch left in internal mold of left beak by septum, × 2. University of Missouri 2658; Sacajawea formation of Branson (1936) near Lander, Wyo.
25. Interior of beak region of right valve, tilted slightly down on left side, showing septum in plane of valve, × 2. USNM 118852B; Cameron Creek formation, loc. 13363.

26. *Schizodus*? sp. (p. 96)
a, Left valve; b, hinge features of left valve. USNM 118859; Cameron Creek formation, loc. 13362.

27. *Myalina* (*Orthomyalina*) sp. (p. 92)
Left valve. USNM 118851; Cameron Creek formation, loc. 13421.

28–30. *Limipecten otterensis* Easton, n. sp. (P. 93)

28. Right valve, internal mold. Paratype, USNM 118856B; Otter formation, loc. 13374.
29. Left valve, internal mold. Holotype, USNM 118855; Otter formation, loc. 13374.
30. Left valve, surface ornamentation, × 5. Paratype, USNM 118856A; Otter formation, loc. 13374.

31, 32. *Aviculopecten*? sp. (p. 93)

31. Interior of left valve of a small specimen. USNM 118854; Heath formation, loc. 13367.
32. Internal mold of right valve of a small specimen. USNM 118853; Cameron Creek formation, loc. 13367.

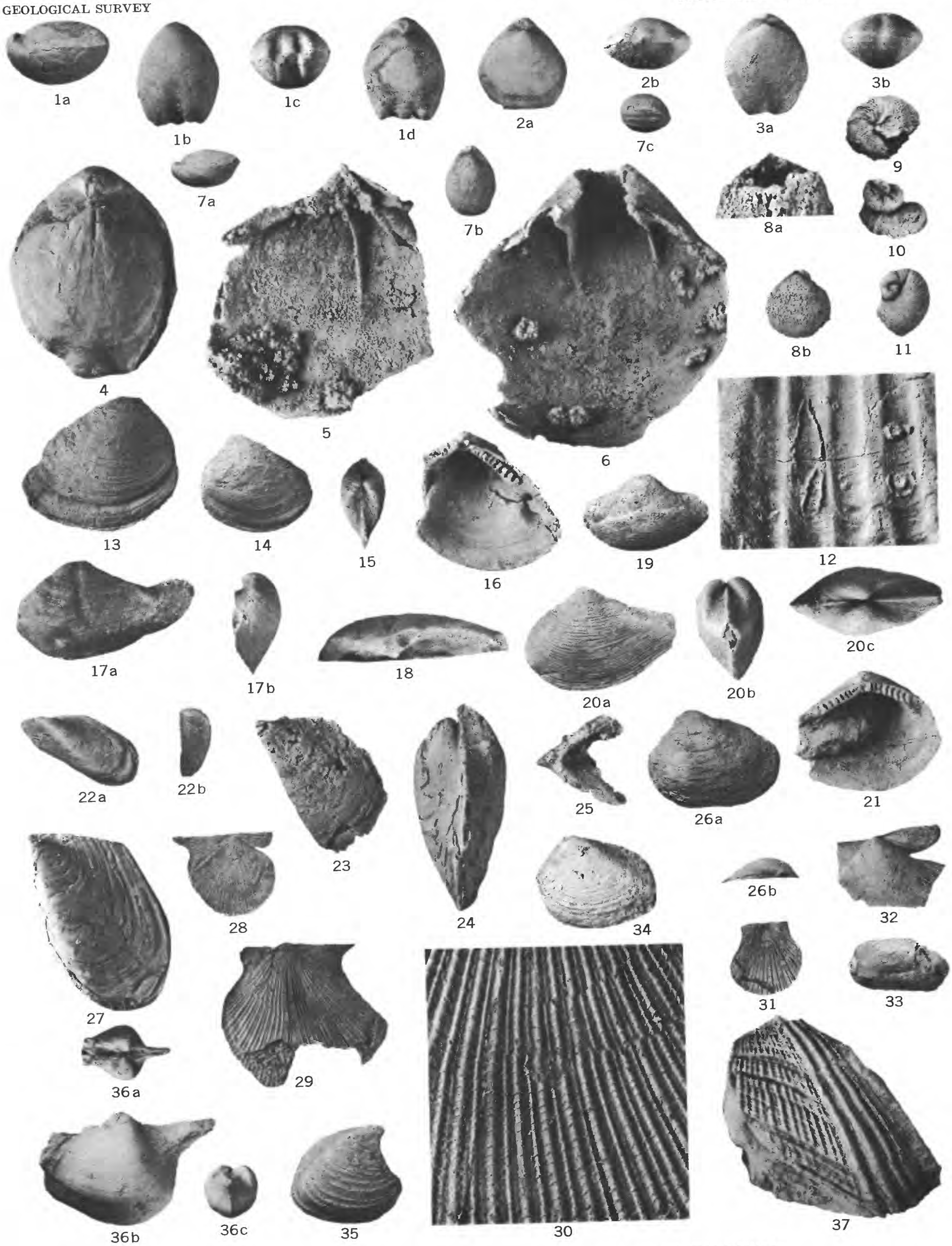
33. *Pleurophorus* sp. (p. 96)
Internal mold of left valve. USNM 118860; Alaska Bench limestone, loc. 13404.

34. *Cypricardella* sp. B (p. 96)
Left valve, × 2. USNM 118862; Alaska Bench limestone, loc. 13399.

35. *Cypricardella* sp. A (p. 96)
Left valve, × 2. USNM 118861; Heath formation, loc. 13414.

36. *Conocardium glabratum* Easton, n. sp. (p. 95)
a, Dorsal margin; b, left valve, × 2; c, posterior. Holotype, USNM 118858; Heath formation, loc. 13414.

37. *Conocardium latifasciatum* Branson (p. 95)
Fragment of left valve, × 5; Hypotype, USNM 118857; Cameron Creek formation, loc. 13420.



BIG SNOWY GROUP BRACHIOPODS, MOLLUSKS, AND WORM TUBES

PLATE 13

[All figures × 1 unless otherwise indicated]

FIGURES 1, 2. *Allorisma walkeri* Weller (p. 96)

1. Left valve, oblique side view of anterior portion. Hypotype, USNM 118863B; Cameron Creek formation loc. 13362.
2. Left valve. Hypotype, USNM 118863A; Cameron Creek formation, loc. 13362.

3, 4. *Sphenotus altidorsatus* Easton, n. sp. (p. 97)

3. a, Left valve, side view; b, left valve, anterior end; c, left valve, dorsal view. Holotype, USNM 118865; Cameron Creek formation, loc. 13361.
4. Left valve, dorsal margin, × 3. Paratype, USNM 118866; Cameron Creek formation, loc. 13361.

5. *Allorisma inflata* Easton, n. sp. (p. 97)

a, Right valve, side view; b, dorsal view. Holotype, USNM 118864; Cameron Creek formation, loc. 13362.

6. *Sulcatopinna ludlovi* (Whitfield) (p. 94)

Left valve. Holotype, Yale University (Peabody Museum) 6837; Alaska Bench limestone or Cameron Creek formation, near Delpine, Mont.

7. *Bellerophon* sp. (p. 98)

a, Apertural view; b, side view. USNM 118867; Heath formation, loc. 13414.

8. *Retispira* sp. (p. 98)

Side, showing reticulate shell ornamentation, × 3. USNM 118868; Heath formation, loc. 13391.

9, 10. *Euphemites sacajawensis* C. Branson (p. 98)

9. Anterior, × 2. Hypotype, USNM 118869A; Heath formation, loc. 13391.
10. a, Posterior, × 2; b, side, × 2; Hypotype, USNM 118869B; Heath formation, loc. 13391.

11. *Pseudozygopleura* (*Pseudozygopleura*) aff. *P. scitula* (Meek and Worthen) (p. 100)

Dorsal view, × 2. USNM 118873; Cameron Creek formation, loc. 13363.

12. *Glabrocingulum*? sp. (p. 100)

Apertural view, × 2. USNM 118887; Heath formation, loc. 13414.

13. *Naticopsis* cf. *N. remex* White (p. 100)

a, Apertural view; b, apical view, × 2; c, apical view, × 5. USNM 118874; Heath formation, loc. 13368.

14. *Straparollus* (*Euomphalus*) n. sp. A (p. 99)

Apical view. USNM 118870; Heath formation, loc. 13359.

15. *Straparollus* (*Euomphalus*) n. sp. B (p. 99)

a, Apical view, × 2; b, basal view, × 2; c, apertural view, × 2. USNM 118871; Cameron Creek formation, loc. 13361.

16. *Angyomphalus*? *excavatus* Easton, n. sp. (p. 99)

a, Apical view, × 2; b, apertural view; c, basal view. Holotype, USNM 118872; Cameron Creek formation, loc. 13361.

17, 18. *Bulimorpha elegans* Girty (p. 100)

17. *Bulimorpha* cf. *B. elegans* Girty, dorsal view, × 2. USNM 118876; Alaska Bench limestone, loc. 13399.
18. Apertural view, × 2. USNM 118875; Heath formation, loc. 13414.

19. *Soleniscus* sp. (p. 101)

Apertural view, × 2. USNM 118877; Heath formation, loc. 13414.

20, 21. *Plagioglypta subannulata* Easton, n. sp. (p. 101)

Types on one block, USNM 118878; Alaska Bench limestone, loc. 13399.

20. Side, near apertural end, × 2. Holotype.
21. Side, near distal end, × 1. Paratype.

22. *Mooreoceras*? sp. (p. 101)

Side. USNM 118880; Heath formation, loc. 13414.

23, 24. *Girtyoceras* aff. *G. meslerianum* (Girty) (p. 102)

23. Side, young specimen, × 2. University of Illinois collections X–1450; near base of Heath formation at its type section near Heath, Mont.
24. Side, very young specimen, showing growth lines, × 5. University of Illinois collections X–1450; near base of Heath formation at its type section near Heath, Mont.

25. *Cravenoceras* sp. (p. 102)

Surface sculpture, × 5. University of Illinois collections X–1451 (rubber mold, USNM 118881); near base of Heath formation at its type section near Heath, Mont.

26. *Aphelaeceras*? sp. (p. 101)

a, Side view, fragment of internal mold, × 3; b, whorl section, × 3. USNM 118879; Cameron Creek formation, loc. 13361.

27, 28. *Ameura*? sp. (p. 103)

27. Cranidium, × 3. USNM 118882A; Cameron Creek formation, loc. 13362.
28. a, Pygidium, oblique posterior view of internal mold, × 2; b, pygidium, dorsal view of internal mold. × 2; USNM 118882B; Cameron Creek formation, loc. 13362.

29. *Paladin*? sp. (p. 103)

Pygidium, dorsal view, × 2. USNM 118883; Cameron Creek formation, loc. 13420.

(*Continued on back of plate 13*)

BIG SNOWY GROUP MOLLUSKS, ARTHROPODS, AND VERTEBRATES

PLATE 13—Continued

30. *Squillites spinosus* Scott (p. 103)
    Dorsal surface, × 5; from Scott (1938, p. 509). Holotype, University of Illinois collections X–1219; basal Heath formation, 2 miles south of Heath, Mont.
31. Cochliodont shark tooth (p. 103)
    × 2. USNM 118884; Alaska Bench limestone, loc. 13399.
32. Ichthyodorulites (fish spine) (p. 104)
    × 5. USNM 118886; Heath formation, loc. 13414.

33, 34. *Cravenoceras hesperium* Miller and Furnish (p. 102)
- 33. Side, showing surface sulpture and umbilical characters. Hypotype, USNM 118899; Heath formation, loc. 14101.
- 34. Anterior view, showing whorl profile. Hypotype, USNM 118899; Heath formation, loc. 14101.

35. *Tylonautilus* sp. (p. 101)
    Side view. USNM 118902; Otter formation, loc. 14227.