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INTRODUCTION

ABSTRACT

THE PERMIAN-TRIASSIC SUCCESSION in the Middle Rockies of North America records one of the major gaps in the history of fossil invertebrates. Bivalve mollusks are the only invertebrates that are major components of both the Permian and the Eotriassic faunas. Seventy taxa, including two new genera and seven new species, are described from Permian rocks of the Park City group. Twenty-one taxa, including one new species, are described from Lower Triassic rocks.

A proper interpretation of the magnitude of the local faunal break depends on the accurate dating of both the Permian and the Triassic sequences. Rocks of Park City age are subdivided into two age groups on the basis of bivalve correlations. Age group I, consisting of the basal members of the Park City and Phosphoria formations, is correlated with rocks of Upper Leonardian-Lower Wordian age in the West Texas standard Permian marine section. Age group II, including the remaining nine members of the Park City, Phosphoria, and Shedhorn formations, is correlated with rocks of Upper Wordian-Capitanian age in West Texas. This suggests an upper age limit of Kazanian (Capitanian) for the Park City group and indicates that the youngest Permian marine strata (Tartarian, Ochoan) are not locally represented. The Eotriassic Dinwoody formation is of early Scythian age.

The nature of the Permian-Triassic contact indicates that, at least locally, weathering and erosion took place and suggests a withdrawal of Permian seas and a period of emergence prior to transgression of the early Eotriassic sea.

Generic and specific diversification in the Permian bivalves suggests that major evolutionary changes occurred in normal marine, shallow-water, carbonate facies. Latest Permian and earliest Triassic marine deposits are very restricted over the world and are notable for a general lack of calcareous facies. It seems that a major regression of the seas closed the Permian, which was followed by an early Triassic transgression in all of the known sequences. Perhaps the ecological changes recorded by these events were responsible for the revolutionary paleontological changes at this time rather than a very long time hiatus.

Although bivalves are abundant in both the Permian and the Eotriassic faunas, only two species, out of 91 noted in the two local sequences, are closely comparable. Lower Eotriassic rocks contain an impoverished, intermediate fauna, which does not closely resemble younger Triassic faunas. The latter do not become established until the return of normal marine, clastic-free, carbonate facies in later Eotriassic time.

PURPOSE OF INVESTIGATION

The close of the Permian period, last chapter in the Paleozoic era, witnessed the most profound alteration in marine faunas in all history. Many great groups of invertebrate animals inexplicably died out near or at the very end of the Permian and were replaced in the earliest Triassic by quite a different fauna. Thus a well-defined gap in the history of invertebrates marks the Permo-Triassic boundary in all parts of the known world.

The Middle Rocky Mountain region of North America contains one of the few widespread and well-known records of the critical Permian-Triassic sequence. There is no other area of such great extent in the world where upper Permian is overlain by Lower Triassic. In the local sequence, and in other known successions, fossil bivalve mollusks are conspicuous and important members of both the late Permian and early Triassic marine faunas.

The purpose of the present study is (1) to describe and document the occurrence of the large, diversified, bivalve fauna of the local Permian-Eotriassic succession; (2) to correlate the Permian fauna with similar faunas, especially with those of the standard section of West Texas, and thereby to determine the relative age of the Permian strata and the relative magnitude of the faunal gap; and (3) to define in detail the nature of the Permian-Triassic break in terms of faunal differences, emphasizing the bivalves, and in terms of the physical nature of the stratigraphic interval containing the Permian-Triassic contact.

PREVIOUS WORK

A complete review of the work on which the present understanding of the geologic history of the Middle Rockies is based is beyond the scope of this paper. It is pertinent, however, to mention briefly a few of the major contributions that have made the local succession one of the best-known Permian-Triassic sequences in the world.

Our knowledge of the Permian stratigraphy is the product of many years of research, a major part of which has been done by the United States Geological Survey in connection with the development of economic phosphate and trace metal deposits. The basis for much of the recent work in southern Idaho is the comprehensive earlier work done in this area by Mansfield (1927). Early paleontologic work was done by Girty (1910), who described the fauna of the phosphate beds and associated Permian strata of western Wyoming and southeastern Idaho, and by Branson (1930), who described a large Permian fauna based principally on collections from the Wind River and Owl Creek Mountains in west-central Wyoming.

Present interpretations of the Lower Triassic stratigraphy are based on the regional study of the Eotriassic sequence by Newell and Kummel (1942), in which they described important elements of the molluscan and brachiopod fauna. A more detailed account of the Lower Triassic stratigraphy of the area, with emphasis on the ammonite faunas, is given by Kummel (1954).

REGIONAL SETTING

The area encompassed in the present study, referred to herein as the Middle Rockies province, includes western Wyoming, south-central Montana, southeastern Idaho, and northeastern Utah (fig. 1). Exposures of the rocks in this region are generally discontinuous and largely restricted to the numerous mountain ranges. The exposures are commonly more complete and laterally extensive in western Wyoming, southern Montana, and northern Utah. The Idaho localities show generally poor exposures, many of which have been artificially created in connection with sampling procedures and mine operations.

The general tectonic setting is also shown in figure 1. The Permian and Triassic marine rocks follow the general depositional pattern of earlier Paleozoic strata in this area. Each of the two systems is a few hundred feet thick in the eastern part of the area and thickens rapidly to about 2000 feet to the west of an approximately north-south line separating the craton, to the east, from the miogeosyncline, to the west.

Most of the area was affected by late Mesozoic and Cenozoic regional tilting and faulting, particularly the Wyoming-Idaho border area, which contains several major thrust sheets.

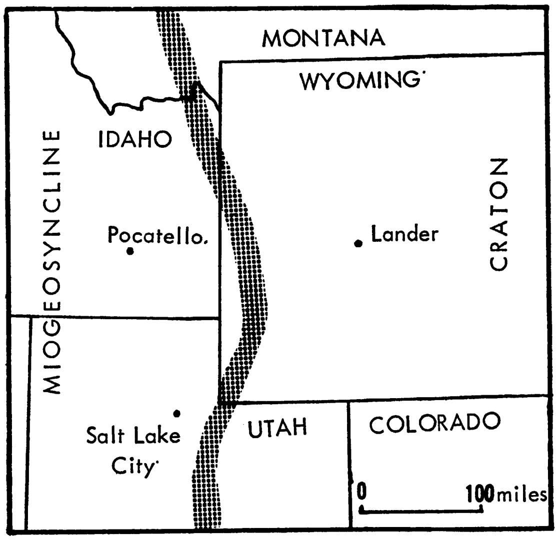

FIG. 1. Index map of the area included in the present report. The pattern shows the approximate dividing line between craton and miogeosyncline (Kay, 1951).

FIELD WORK AND LABORATORY STUDY

Field work for this study was done in the summers of 1959 and 1960. Twelve short stratigraphic sections were measured and sampled across the Permian-Triassic contact. The contact was studied at numerous other localities. Fossils were collected to supplement collections lent to the writer for this study.

Laboratory research was done during the academic years 1960–1961 and 1961–1962, and during the summer of 1961. Research and library facilities of both Columbia University and the American Museum of Natural History were used extensively. In addition, several weeks were spent in making preliminary observations and procuring loans of the Permian collections at the United States Geological Survey and United States National Museum in Washington, and Triassic collections at the Museum of Comparative Zoölogy at Harvard University, in Cambridge.

ACKNOWLEDGMENTS

Field work was supported by a National Science Foundation Summer Fellowship in 1959 and by a research grant from the Columbia University Kemp Memorial Fund in the summer of 1960. The laboratory phases of the study were aided by a National Science Foundation Cooperative Fellowship during the academic year 1959–1960, a Columbia University Fellowship during the academic year 1960–1961, and by a research grant from the Kemp Memorial Fund in the summer of 1961.

The laboratory work was done at the American Museum of Natural History under cooperative programs of Columbia University and the American Museum. Much aid was received from Mr. G. R. Adlington there, who instructed the writer in photography of specimens and made facilities available for all the photographic work.

An essential part of the work is a revision of many species. To this end several persons made type specimens of their institutions available on loan. These were Dr. G. A. Cooper, United States National Museum; Dr. R. L. Batten, University of Wisconsin; and Dr. A. G. Unklesbay, University of Missouri.

The collections that form the major basis of the study are those of the United States Geological Survey, Harvard University (Museum of Comparative Zoölogy), and the American Museum of Natural History. Most of the reference material needed was already available at the last-named institution; consequently, the study could not have well been undertaken elsewhere.

Dr. Alfred Fischer, Princeton University, and Dr. Bernhard Kummel, Harvard University, provided data on field localities. Dr. Ellis Yochelson, United States Geological Survey, who was undertaking a broad survey of the Permian faunas, provided stimulating discussion in field and office and expedited the study of the extensive Survey collections.

The study was guided jointly by Profs. N. D. Newell and John Imbrie, but the writer assumes the whole responsibility for its imperfections as well as its conclusions.

Finally, I extend grateful thanks to my wife, Annette, for substantial aid in the field and in the preparation of the final manuscript, and for her encouragement throughout this study.

ABBREVIATIONS AND DEFINITIONS

The following abbreviations are used in the tabulations of measurements:

AAC, number of costae on anterior auricle
Angle α, angle between posterior umbonal ridge and cardinal margin (in myalinids)
Angle β, posterodorsal angle between rear margin and cardinal margin (in myalinids)
B, bivalved specimen
C, bivalved convexity
½C, convexity of single valve
GD, greatest linear dimension (in myalinids)
H, height of shell
HGL, length of hinge
H/L, height/length ratio
HS, number of hinge spines
L, length of shell
Lt, left valve
PAC, number of costae on posterior auricle
PCF, number of primary concentric fila
PDA, posterodorsal angle
PR, number of primary ribs
Rt, right valve
SC, total number of shell costae
UA, umbonal angle near beak

The following abbreviations refer to the permanent locations of catalogued specimens:

A.M.N.H., the American Museum of Natural History
M.C.Z., Museum of Comparative Zoölogy of Harvard College, Cambridge, Massachusetts
U.M., University of Missouri, Columbia, Missouri
U.S.N.M., United States National Museum, Washington, D. C.

In the discussions of occurrence, the terms "rare," "common," and "abundant," with regard to the frequency of any species at a single locality, have the following quantitative meaning:

Rare, 1 to 5 specimens
Common, 6 to 15 specimens
Abundant, 16 or more specimens

The term "topoparatype" is used as defined by Newell (1949). It refers to specimens of an original type lot from the same locality and horizon, thus presumably members of the same population, as the holotype.

The term "limestone," as used in this paper, includes dolomitic carbonates and calcium carbonate sediments in which the original texture, particularly the grain size, has been obscured. The terms "calcarenite," "calcisiltite," and "calcilutite" are used when grain size was determined by megascopic or casual microscopic observation.

STRATIGRAPHY

A DETAILED ACCOUNT or analysis of the Permian and Lower Triassic stratigraphy of the Middle Rockies is beyond the scope of the present study. The stratigraphic framework utilized here is based entirely on previous work. The interpretations of the Permian relationships are those of the United States Geological Survey (McKelvey and others, 1959). The Triassic interpretations adopted are based on the works of Newell and Kummel (1942) and Kummel (1954). This procedure is followed because a majority of the bivalves studied here are from collections that are documented in terms of the above interpretations. A diagrammatic representation of the physical relationships of the Permian-Triassic sequence is shown in figure 2. (The Shedhorn formation, which intertongues from the north, is not shown in fig. 2, but its position in the sequence is indicated in fig. 4.)

PERMIAN

Physical Relationships and Nomenclature

A brief summary of the Permian sequence is given by McKelvey and others (1959, p. 9): "Three intertonguing lithic units are recognized as formations and defined as follows: (1) the Park City formation, consisting of carbonate rocks and subordinate sandstone; (2) the Phosphoria formation, consisting of phosphatic, carbonaceous, and cherty rocks; and (3) the Shedhorn sandstone. The Park City formation is best developed in central and eastern Utah and in southwestern and west-central Wyoming, but tongues extend to eastern Idaho and Montana as well. The Phosphoria formation is best developed in eastern Idaho, northern Utah, western Wyoming, and southwestern Montana, but tongues extend over a much wider area. The Shedhorn sandstone is best developed in the general vicinity of Yellowstone National Park, but tongues extend over much of southwestern Montana and northwestern Wyoming. These three formations can be regarded as end-member types that interfinger over much of the area of the western phosphate field. In areas where they are best developed, however, the Park City and Shedhorn formations contain a thin tongue of the Phosphoria, so that even in their type areas continuous sections of the Park City and Shedhorn end-member lithologies do not exist.

"Eleven subdivisions of these formations are recognized as members. Members of the Park City formation are designated the Grandeur member, the Franson member, and the Ervay carbonate rock member. Those belonging to the Phosphoria formation are the Meade Peak phosphatic shale member (the phosphatic shale member of Richards and Mansfield), the lower chert member, the Rex chert member, the cherty shale member, the Retort phosphatic shale member, and the Tosi member. Subdivisions of the Shedhorn are the lower and upper members."

For a more detailed account of the inferred physical relationships, the reader is referred to the nomenclatural chart and composite correlation chart in McKelvey and others (1959, pls. 2 and 3). It must be emphasized that the formations and members are identified and correlated solely on the basis of lithologic criteria, and as such are subject to revision and modification as the extensive, but poorly known faunas of the sequence are properly studied. Evidence of interrelationships based on a study of the bivalves is presented below in this report.

Age Relationships

Regional and world-wide correlation of the Permian sequence is very difficult. Fusulinids, universally used in Permian correlations, are extremely rare in rocks of Park City age (the writer here follows the procedure of referring to the three formations and 11 members of the Permian sequence of the Middle Rockies collectively as the Park City group) and are confined to rocks questionably referred to the Grandeur member (fig. 2) in southwestern Montana. Frenzel and Mundorff (1942) described *Pseudoschwagerina montanensis* and *Schwagerina laxissima* Dunbar and Skinner from a tongue of the Grandeur near Three Forks, Montana, and considered the rocks to be of Wolfcampian age. James Steele Wil-

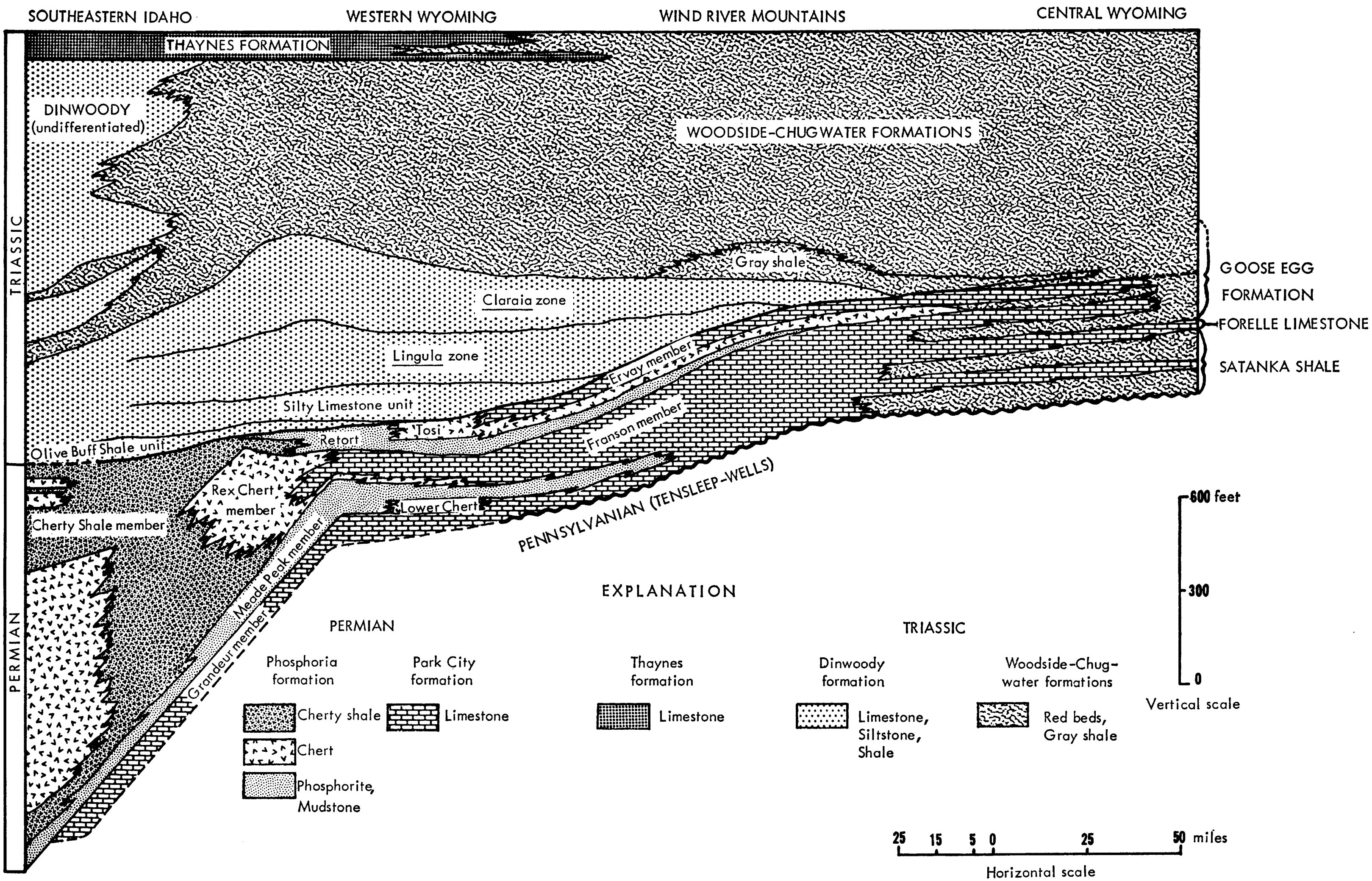

FIG. 2. Diagrammatic representation of stratigraphic relationships of Permian and Triassic rocks in Idaho and Wyoming (modified from McKelvey and others, 1959, and from Newell and Kummel, 1942).

liams (*in* McKelvey and others, 1959) indicates that Thompson and others (1946) believe that the fusulinids there may be younger than fusulinids from the type section of the Wolfcamp, and Henbest (written communication to Williams, 1954) believes that the fusulinids may be as young as early Leonard. Ellis Yochelson, R. W. Swanson, and the writer returned to the Three Forks locality, in August, 1959, to establish the field relationships of the fusulinid-bearing strata to the overlying Permian beds but were unable to locate any fusulinids. It seems quite probable that the fusulinid-bearing strata actually lie stratigraphically below beds that are now included in the Grandeur member. Rocks in southeastern Idaho that underlie the Grandeur member have yielded early Permian fusulinids, thereby helping to establish a lowermost age for the Grandeur of this region. Henbest (written communication to Williams, 1954) identified *Schubertella kingi* Dunbar and Skinner, *Triticites notus* Thompson, and *T. ventricosus* (Meek and Hayden) var., considered to be of early Wolfcampian age, from the upper Wells formation in Caribou County, Idaho.

The Meade Peak member (fig. 2), basal unit of the Phosphoria formation, has been dated primarily on the basis of cephalopods. Miller and Cline (1934) described *Vidrioceras girtyi* as very similar to a species from the Sosio beds of Italy, correlated by them on other evidence with the Word formation of West Texas. *Stacheoceras*, *sensu stricto*, and certain species of *Pseudogastrioceras* in the Meade Peak member indicate Leonardian or Wordian affinities, or both. More recently, Miller, Furnish, and Clark (1957) considered the ammonoid assemblage in the Meade Peak of Idaho and Utah to be of Leonardian age.

A Meade Peak fish fauna, originally identified as Pennsylvanian by E. B. Branson in 1916, was referred to the Permian, probably pre-Wordian, by E. B. Branson and C. C. Branson (1941).

The age of the Park City rocks above the Meade Peak is not well established in spite of the fact that the upper two members of the Park City formation, the Franson and Ervay, are probably the most fossiliferous units in the local sequence. These members contain abundant, generally poorly preserved brachiopods, bryozoans, and mollusks. The brachiopods appear to resemble faunas of Wordian age in West Texas. G. A. Cooper (personal communication, 1961) believes that the Park City forms are, without exception, specifically distinct from the West Texas forms but bear a general resemblance to those of Word Number 2 limestone and Word Number 4 limestone.

Newell's (1948) description of a critical Permian section in the Confusion Range of northwestern Utah shows that beds lithologically and faunally similar to the Kaibab limestone of Arizona, believed to be equivalent to the Upper Leonardian of West Texas (Dunbar and others, 1960), underlie rocks identified with the Park City group. A similar relationship in north-central Utah was described by Baker and Williams (1940). This evidence would suggest a Wordian age (probably younger than the Word Number 1 limestone) for at least part of the Park City group. Hose and Repenning (1959) defined the Gerster formation in the Confusion Range and correlated this formation with the Franson member of the Park City formation on the basis of brachiopod similarities. Dunbar (*in* Dunbar and others, 1960, p. 1775) states that the Gerster fauna has been correlated by Mackenzie Gordon with other faunas in the west which contain ammonites of Capitan age (Repenning and McKelvey, personal communication to Dunbar). Such correlation would extend the range of the Park City beds to upper Guadalupian (Capitanian).

Normal marine faunas of post-Wordian age, which might be compared to younger Park City faunas, are poorly known because of the widespread occurrence of reefy facies and other atypical marine beds in the upper part of the West Texas sequence. The faunas of the upper part of the Delaware Mountain formation described by Girty (1909) are poorly documented, and much of the described material is fragmentary and incomplete, making specific comparison with other forms very difficult.

The intercontinental correlation of the Park City group was discussed by Williams (*in* McKelvey and others, 1959) who stated that the brachiopods of the Meade Peak member and of the upper beds of the Park City formation have a greater resemblance to the Irghina brachiopods (top of the Russian Artinskian) than to any other faunal division of the Russian type area. He emphasized, however, that the correlation was based on general impressions, not on identical and restricted genera and species.

Newell (1955) has suggested a close paleoclimatic relationship among the Zechstein of Europe, Upper Permian of Greenland, and the Permian of the Middle Rockies. These areas appear to contain faunas characteristic of and restricted to high latitudes and show a common lack of fusulinids and hermatypic organisms probably representative of warmer climatic conditions.

In summary, sparse and often indirect faunal evidence has led to the present interpretation of the age of the Park City group as spanning Upper Leonardian through Guadalupian time, with questionable upper and lower age limits throughout the Middle Rockies (Dunbar and others, 1960, correlation chart 7). In terms of the Russian type area, the Park City group would span the Lower-Upper Series boundary, extending from approximately the base of the Kungurian Stage, through the Ufimian and Kazanian, and well into the Tartarian Stage (the latter does not contain marine fossils and exact equivalency with marine sections has not been established).

The age relationships that are suggested by the bivalves are discussed below (p. 23; see also fig. 3).

TRIASSIC

Physical Relationships and Nomenclature

The Permian sequence in the Middle Rockies is overlain by rocks of Lower Triassic age except locally in southern Montana where the Ellis formation, of Jurassic age, lies directly on the youngest Permian. A detailed account of the physical nature of the Permian-Triassic contact, of great importance because it records the physical break suggested by the faunal gap, is discussed below in this report (p. 32).

The lower Eotriassic (the term "Eotriassic" is here used for rocks of Scythian age) of the Middle Rockies is represented by the Dinwoody and Woodside formations. The Dinwoody formation, named and defined by Blackwelder in 1918, was redefined by Newell and Kummel (1942) at the type locality, Dinwoody Lakes, Wyoming, to include only the dominantly silty strata between the "Phosphoria" and the top of a resistant siltstone about halfway to the top of the original Dinwoody. As redefined, it is about 90 feet thick and overlain by gray shales. Elsewhere it is generally overlain by red shales and siltstones of the Woodside formation.

The Woodside formation, named by Boutwell in 1907, consists of about 1000 feet of maroon and red, shaly siltstones at its type area, Woodside Gulch, in the Park City mining district of northern Utah. It is unfossiliferous and overlies the "Phosphoria" formation and underlies the Thaynes formation. The interrelationships of the Dinwoody and Woodside formations and their relationship to adjacent strata are shown in figure 2.

Kummel (1954, p. 168) has summarized the regional picture of the Dinwoody as follows: "Along an arcuate belt from southwestern Montana, the Idaho-Wyoming boundary, and swinging westward in northern Utah, an intertonguing sequence of nonred Dinwoody and red Woodside formations lies between the Permian Phosphoria formation and the Thaynes formation. West of this arcuate belt the percentage of red Woodside rocks decreases rapidly, and east and south of it the red Woodside thickens rapidly and only a small part of the nonred Dinwoody formation is present in central Wyoming and none at all in the Wasatch and Uinta Mountains, Utah." A detailed interpretation of the physical relationships of the Lower Triassic sequence is shown in a composite correlation diagram and in correlations of columnar sections (Kummel, 1954, pls. 34–37).

The Dinwoody formation has been subdivided into several units based on both lithologic and faunal evidence. Newell and Kummel (1942) recognized three major units of areal extent in western Wyoming: the basal siltstone unit (now called the Silty limestone unit), the *Lingula* zone, and the *Claraia* zone. The *Lingula* zone is lithologically heterogeneous but is characterized by abundant, well-preserved specimens of *Lingula*. The genus also occurs less commonly above and below this unit. The *Claraia* zone, the most extensive unit, is also lithologically heterogeneous but contains abundant molds of *Claraia* and *Unionites*. Newell and Kummel have demonstrated a progressive overlap of these units, from west to east, with the *Claraia* zone thinning and lying directly on Permian rocks in the southern Wind River Mountains of Wyoming. *Claraia*, also, is not restricted to the *Claraia* zone but is most abundant in that unit.

In southeastern Idaho and southern Montana, the three units defined above are generally not recognizable. Here, the section tends to be considerably thicker and is roughly divisible into two major units: a lower shale unit, and an upper calcareous siltstone and gray limestone that grade into each other along strike. The lower shaly section is correlative with the basal silty limestone to the east and part of the *Lingula* zone of western Wyoming (Kummel, 1954). The upper part of the sequence contains a few poorly preserved fossils and is believed to be equivalent in part to the *Claraia* zone, but largely to the red Woodside formation as indicated by the fact that the Dinwoody, in its westernmost exposures, is overlain by the basal *Meekoceras*-bearing Thaynes limestones which overlie the Woodside at many places.

The Woodside formation has not been subdivided. It is believed to pass laterally into the Red Peak member of the Chugwater formation to the east and north in central Wyoming. The intertonguing relationships of the red beds generally referred to the Chugwater formation with Permian and Triassic sediments containing marine fossils in central Wyoming is discussed by Burk and Thomas (1956). They defined the Goose Egg formation to include an interval of intertonguing Permian-Triassic marine and non-marine beds which contain feather-edges of the upper carbonate members of the Park City formation and a marine tongue of the Dinwoody formation.

Age Relationships

Zoning of the Lower Triassic, as in other Mesozoic rocks, has been done primarily on the basis of ammonites. Kummel (1954) has revised the zonation of the Eotriassic, established by Spath, and the following Eotriassic subdivisions are currently recognized:

Upper Eotriassic
- Prohungaritan
- Columbitan
- Owenitan

Lower Eotriassic
- Flemingitan
- Gyronitan
- Otoceratan

The Otoceratan and Gyronitan age of part of the Dinwoody was established by Newell and Kummel (1942). Kummel (1954) demonstrated the Flemingitan age of the upper Dinwoody and the presence of all three of the upper Eotriassic subdivisions in the overlying Thaynes formation. Thus a complete Eotriassic (Scythian) section is recorded in the Middle Rockies.

Five species referred to the genus *Ophiceras* have been reported from the lower shale unit of the Dinwoody in Montana and the Silty limestone and *Lingula* units in western Wyoming and southeastern Idaho. These species are present in the *Ophiceras* beds (of Otoceratan age) of east Greenland. In addition, other members of a cosmopolitan and remarkably homogeneous Eotriassic molluscan fauna such as *Promyalina putiatensis*, *Promyalina spathi*, and *Claraia stachei* are recorded from the *Lingula* unit. Thus, although the ceratite *Otoceras*, which characterizes the lowest Scythian zone in the Salt Range and east Greenland, has not been found in the Middle Rockies, other elements of the associated fauna confirm an Otoceratan age. Kummel (1954, p. 183) states that the lower Dinwoody fauna indicates an upper Otoceratan age. The only other Otoceratan faunas known, in addition to the three mentioned above, are from the Ussuri district of eastern Siberia and the Canadian Arctic.

Kummel reports two new ammonite faunas from limestone-siltstone beds overlying the lower shale unit in southwestern Montana. Species of *Prionolobus* and *Koninckites*, from a bed about 60 feet above the shale, establish the Gyronitan age of this horizon. Seventy feet above the *Prionolobus*-bearing beds were found species of *Kymatites*, *Koninckites*, and *Xenodiscoides* which indicate a Flemingitan age for this horizon.

The ammonities, although poorly preserved and generally difficult to identify specifically, suggest that all three subdivisions of the lower Eotriassic are present in the Dinwoody. Kummel has further established that all three subdivisions of the upper Eotriassic are represented by five ammonite faunas, from bottom to top (*Meekoceras*, *Anasibrites*, *Tirolites*, *Columbites*, and *Prohungarites* zones) in the Thaynes formation.

Although bivalves have not been extensively used in formal zonation of the Lower Triassic, many species appear to be cosmopolitan in distribution and to have restricted vertical ranges, and may serve as excellent guide fossils. They are frequently more abundant and more easily identifiable than the ammonites. Species of the genera *Claraia*, *Eumorphoris*, *Unionities*, and *Promyalina* are widespread and common in the lower Eotriassic, and forms such as *Gervilleia*, *Monotis*, and a poorly known apparently equivalved pectinoid are widespread and may be useful in the correlation of upper Eotriassic and younger Triassic marine strata.

PALEONTOLOGY

THE PERMIAN-TRIASSIC FAUNA

THE PERMIAN-TRIASSIC SEQUENCE of the Middle Rockies is of primary paleontological interest because it records one of the major gaps in the history of invertebrate life. The mass extinctions at the close of the Permian and the subsequent absence or extreme scarcity of entire phyla such as the echinoderms, coelenterates, bryozoans, and sponges in the Lower Triassic have long been known but remain poorly understood. Lowermost Triassic faunas are remarkably cosmopolitan and homogeneous (although only a few are known). They consist almost exclusively of mollusks and a few brachiopods, in general opposition to the late Paleozoic faunas in which brachiopods are generally dominant over mollusks.

An over-all picture of the faunal changes at the Permian-Triassic boundary is well illustrated by Newell (1962, fig. 6) in a comprehensive study of major faunal gaps throughout the fossil record. Sharp increases in the percentage of extinction of existing families are shown in the corals, brachiopods, and gastropods. Other groups, including some of the vertebrates (fishes), show relatively high percentages of extinction at this critical time.

The nature of the Permian-Triassic faunal break in the Salt Range of Pakistan has been studied in detail by Schindewolf (1954, tables 2, 3). In the Salt Range sequence only five genera are common to both the Upper Productus Limestone and the Lower Eotriassic. These forms include *Pseudomonotis*, *Stachella*, *Naticopsis*, *Episageceras*, and "*Rhychonella*." In the Chhidru sequence, only the long-ranging *Bellerophon* is common to the Permian and Triassic.

Other Permian-Triassic sequences, in which Permian and Triassic faunas have been separately studied, in east Greenland, Siberia, and the Canadian Arctic, show similar sharp faunal changes.

Insufficient taxonomic knowledge of the Permian fauna of the Middle Rockies makes comparison of the Permian and Triassic faunas on a generic or specific level presently impossible. However, the important faunal contrasts are clearly shown at a higher categorical level, generally at superfamilial rank, in table 1. Foraminifera, Porifera, Coelenterata?, and Bryozoa are known only from the Permian. Four of 10 superfamilies of brachiopods (the inarticulate Lingulacea and the articulate Rhynchonellacea, Spiriferacea, and Terebratulacea) continue into the early Triassic, but the inarticulates are considerably more abundant than the articulates, which were major components of the Permian fauna. Ammonoids are represented by six superfamilies, but three are restricted to the Permian and three to the Triassic, with none crossing the boundary. Nautiloids, belemnoids, and scaphopods are known only from the Permian. One of four Permian superfamilies of gastropods (Bellerophontacea) occurs in the Triassic. Bivalves, represented by 13 superfamilies, show seven superfamilies (Ctenodontacea, Nuculacea, Nuculanacea, Solemyacea, Parallelodontacea, Crassatellacea, and Pholadomyacea) restricted to the Permian. Five superfamilies (Mytilacea, Pteriacea, Pectinacea, Trigoniacea, and Carditacea) are found in both the Permian and Triassic of the local sequence. Echinoderms, arthropods, and conodonts are poorly known but are apparently restricted to the Permian. Sharks are known from both the Permian and Triassic, and one subholostean and one questionable coelocanth occurrence are reported from the Triassic.

It is necessary to emphasize that the relationships shown in table 1 are those not of the taxonomic categories in their total aspect, but only as they are known to occur in the Permian-Triassic succession in the Middle Rockies. The compilation is based on preliminary observations, especially with regard to the Permian occurrences, and specific changes will undoubtedly occur as the large faunas are intensively studied. However, it is improbable that the major pattern of sharp, high-level changes across the Permian-Triassic boundary will be altered significantly in total aspect.

Particularly significant in a study of a faunal break as shown here is a careful study of the forms that do cross the boundary. In

TABLE 1

Known Occurrence of Higher Categories of Fossils of Permian and Lower Triassic Age in the Middle Rockies

Higher Category	Permian	Lower Triassic	Higher Category	Permian	Lower Triassic
Foraminifera			Belemnoid hooks	x	—
Fusulinidae	?	—	Gastropoda		
Porifera			Bellerophontacea	x	x
Lithistida	x[a]	—	Euomphalacea	xx	—
Coelenterata?			Pleurotomariacea	xx	—
Conularidae	x	—	Neritacea	xx	—
Bryozoa			Bivalvia		
Cryptostomata	xxx	—	Ctenodontacea	x	—
Trepostomata	xxx	—	Nuculacea	xxx	—
Cyclostomata	?	—	Nuculanacea	xx	—
Brachiopoda			Solemyacea	x	—
Lingulacea	x	xxx	Parallelodontacea	x	—
Orbiculoidea	x	—	Mytilacea	x	xx
Chonetacea	x	—	Pectinacea	xxx	xxx
Orthotetacea	xx	—	Pteriacea	x	x
Productacea	xxx	—	Unionacea	—	xx
Rhynchonellacea	xxx	x	Trigoniacea	xxx	x
Rostrospiracea	xx	—	Crassatellacea	xx	—
Spiriferacea	xxx	x	Carditacea	xx	x
Strophalosacea	xxx	—	Pholadomyacea	xx	—
Terebratulacea	xx	x	Scaphopoda		
Ammonoidea			Dentaliidea	xx	—
Agathiceratceae	x	—	Echinodermata		
Cyclobaceae	x	—	Echinoid spines	x	—
Goniatitaceae	x	—	Crinoid columnals	xx	—
Otocerataceae	—	xx	Arthropoda		
Noritaceae	—	x	Ptychopariida	x	—
Ceratitaceae	—	xx	Ostracoda	x	—
Nautiloidea			Conodonta	x	—
Tainoceratidae	x	—	Chordata		
Tribloceratidae	x	—	Chondrichthyes	xx	x
Orthoceratidae	?	—	Subholostei	—	x
Belemnoidea			Coelacanthini	—	?

[a] x, uncommon; xx, common; xxx, widespread.

the present case, a thorough study of the brachiopods and bivalves that occur in the sequence is necessary for the biological and environmental changes that occurred to be assessed and for the nature of the mechanisms inducing the changes to be postulated. By gaining an insight into the "case histories" of the surviving forms, one may simultaneously hope to learn more about the causes of mass extinctions recorded in the same interval.

The occurrence of four superfamilies of brachiopods in the Permian and Lower Triassic is somewhat misleading, as it greatly overemphasizes the role of the brachiopods in the Triassic fauna. To my knowledge, each of the superfamilies is represented by only a single genus in the local Triassic sequence. Similarly, only one genus (*Bellerophon*) represents known Lower Triassic gastropods. Bivalves, however, are highly diversified and important components of both the Permian and Eotriassic of the Middle Rockies and in other Permian-Triassic sequences in east Greenland, eastern Siberia, and the Salt Range. Therefore, a careful study of this group, which apparently was more successful in surmounting a major crisis in invertebrate history, is a logical beginning to an understanding of the magnitude and general nature of the local faunal break.

The apparent success of the bivalves may be related to the natural adaptation of the class to a burrowing existence and thereby an apparently more uniform and less fluctuating habitat. Yonge (1961) states that bivalves, by the nature of their basic morphology, appear "irrevocably committed to infaunal life," either as suspension or deposit feeders. However, of the five superfamilies common to the local Permian-Triassic sequence, three (the Mytilacea, Pectinacea, and Pteriacea) are generally byssate members of the marine epifauna. Conversely, burrowers such as the Nuculanacea, Nucluacea, Ctenodontacea, Solemyacea, and Pholadomyacea, present in the Permian sequence, have not been found in the local Triassic. Factors other than the adult habitat of the groups, such as relative mobility and adaptive potential, may have been of great importance to the groups that crossed the local boundary.

THE BIVALVE FAUNA

Relative Abundance of Bivalves

Seventy species of bivalves are currently described from rocks of Park City age in the Middle Rockies, which is over twice the number previously described by Girty (1910) and C. C. Branson (1930). The 70 species are assigned to 34 genera. The total number of specimens examined by the present writer is probably fewer than 2000, a relatively small number for the large number of taxa. Yet these specimens represent collections accumulated over a period of about 15 years by many members of United States Geological Survey field crews, and several smaller collections, including the type collections of Girty and Branson, and individual collections of R. E. King, Alfred Fischer, and the writer. Of the 70 species described, only seven are named as new species. Six of these are based on silicified collections.

These statistics are presented to point out the generally poor quality of preservation and the great lack of specifically identifiable material in the faunas of the Park City group. Many of the forms previously unrecorded from this region are now represented by only a few specimens, often in small collections of silicified material. The majority of the forms identified are incompletely and poorly preserved, making specific identification and, in some cases, generic identification very uncertain. Such uncertainty is shown by the fact that 22 forms are either believed to represent new species but are inadequately known for characterization, or can be identified only at a generic level.

Twenty-one species, assigned to nine genera, are described from the lower Eotriassic. Only one new species is described. Here again, the preservation is generally poor, and, although forms of many of the genera such as *Claraia* and *Unionites* are abundantly represented, specifically identifiable specimens are generally rare. Silicified forms have not been found in the local lower Eotriassic and, to my knowledge, are not known at this level anywhere in the world. (A single silicified fauna has been collected from the upper Eotriassic Thaynes formation in northern Utah by N. D. Newell, and is currently being studied by N. D. Newell and the writer, but is not included in this report.)

The relative importance of bivalves as members of the Permian and Triassic invertebrate macrofaunas can be estimated in terms of both taxonomic and absolute abundance. In the Permian fauna, the 70 bivalve taxa constitute an important segment of the total number of species present. Based on a general survey of the fauna, it seems reasonable to estimate that the total number of macroinvertebrate species is on the order of 200 to 250. Thus the bivalves may constitute 25 per cent or more of the total number of species. Numerically, however, bivalves are very sparsely represented, which is indicated by the nature of the known silicified collections, in which brachiopods and bryozoans are clearly dominant. Only in a single silicified collection, that containing the new genus *Pseudopermophorus*, are bivalves dominant. It is reasonable to estimate that bivalves constitute fewer than 5 per cent of the total number of invertebrate individuals in the fauna.

In the lower Eotriassic fauna the 21 species of bivalves are both taxonomically and numerically of great importance. Probably fewer than 40 invertebrate species are known from the Dinwoody and Woodside formations, the bivalves thus constituting about 50 per cent of the total. With the exception of *Lingula*, bivalves are generally numerically more abundant than other mollusks and brachiopods and may well comprise 50 per cent or more of the total number of macroinvertebrate individuals in the fauna.

Taxonomic Character and General Occurrence

Aviculopectinids are the most prominent and widespread bivalve group in the Permian sequence. Nine genera and 19 species are identified. They occur most commonly in carbonate rocks in Wyoming and Utah, but one form [*Streblochondria? montpelierensis* (Girty)] is abundant in the phosphatic and carbonaceous beds of the Meade Peak member in Idaho. Four of the nine genera (*Camptonectes?*, *Limipecten?*, *Girtypecten*, and *Obliquipecten*) have a very limited distribution and are known only from the upper carbonate members in the Wind River Mountains of Wyoming. The form identified as *Annuliconcha?* sp. is known from a single locality in southern Montana. *Aviculopecten*, *Cyrtorostra*, *Streblochondria?*, and *Acanthopecten* are more widespread, but well-preserved specimens are rare.

The myophoriids are taxonomically diverse but numerically uncommon. Seven species of *Schizodus* and two forms of *Costatoria* are recognized. The externally similar, but internally distinct, forms identified with *Scaphellina*, represented by two species, are placed in a new family but have a similar occurrence as the myophoriids. Representatives of these families are frequently found in coarser, often sandy, carbonates and arenites, with the exception of *Schizodus ferrieri* Girty, which is restricted to the carbonaceous sediments of the Meade Peak member. Individuals are rare, and generally fewer than 10 identifiable specimens are known in each of the 11 species in these groups.

Nuculoids are widespread, locally important members of the fauna. Three genera (*Nuculopsis*, *Polidevcia*, and *Paleoneilo*), represented by 10 taxa, are currently differentiated. They are most common in the phosphatic and carbonaceous rocks of the Phosphoria formation but are widespread and locally abundant throughout much of the Permian sequence.

Permophorids are represented by four genera and six species. They are widespread in the sandy and carbonate facies but, with the exception of the new form *Pseudopermophorus annettae*, are generally poorly preserved and locally rare.

The remaining 15 genera and 26 species are generally uncommon and inconspicuous members of the fauna, usually locally restricted, and often confined to a single horizon or a single locality, or both.

The Eotriassic bivalves are also dominated by pectinoids. Three genera (*Eumorphotis*, *Claraia*, and *Monotis?*), representing three families and including 11 species, comprise more than 50 per cent of the bivalve fauna. Individuals of the species of *Eumorphotis* and *Monotis?* are numerically uncommon, represented by fewer than 10 identifiable specimens for each of the four taxa. They generally occur in silty limestones and calcareous siltstones. Forms of *Claraia* are widespread and locally abundant, but poor preservation makes specific identification difficult. Only *C. stachei* Bittner is widely recognizable. Species of *Claraia* do not appear to be limited to characteristic lithologies and occur throughout the various shales, siltstones, and limestones of the Dinwoody.

The mytiloids are represented by two genera and three species. Although locally abundant, they are not generally widespread. *Promyalina spathi* (Newell and Kummel) is known from only one locality, and *Mytilus? postcarbonica* (Girty), from two localities. These forms occur primarily in highly silty beds and are most common near the peripheral areas of the marine seas, apparently preferring shallow water and a fine, detrital, bottom sediment.

The unionids, represented by four species of *Unionites*, are widespread and numerically abundant. They are almost exclusively preserved as internal molds, and recognition of specific characters is generally difficult. They

TABLE 2

STRATIGRAPHIC DISTRIBUTION AND FREQUENCY OF PERMIAN BIVALVES

Species	Park City Formation			Shedhorn Formation		Phosphoria Formation					
	Er[a]	Fr	Gr	Up	Lo	To	Rt	Cs	Rx	Mp	Lc
Paleoneilo mcchesneyana (Girty)	—	—	r[b]	—	—	—	—	—	—	c	—
Paleoneilo? parviradiatus Ciriacks, new species	—	r	—	—	—	—	—	—	—	—	—
Nuculopsis sp. a	—	—	—	—	—	—	—	—	—	r	—
Nuculopsis sp. b	—	—	r	—	—	—	—	—	—	—	—
Nuculopsis sp. c	—	—	—	—	—	—	r	—	—	r	—
Nuculopsis montpelierensis (Girty)	—	—	?	—	—	—	—	—	—	a	—
Nuculopsis poposiensis (Branson)	—	r	r	r	—	—	r	?	—	?	—
Polidevcia bellistriata (Stevens)	—	—	r	r	—	—	r	—	r	r	—
Polidevcia obesa (White)	r	r	r	r	r	r	r	r	r	r	r
Solemya sp.	r	—	—	—	—	—	—	—	—	—	—
Parallelodon cf. *multistriatus* Girty	r	—	—	—	—	—	—	—	—	—	—
Parallelodon? sp.	—	—	r	—	—	—	—	—	—	—	—
Goniophora? sp.	r	—	—	—	—	—	—	—	—	—	—
Myalina sinuata Branson	r	—	—	—	—	—	—	—	—	—	—
Myalina wyomingensis thomasi Newell	r	r	—	—	—	—	—	—	—	—	—
Myalina meeki Dunbar	—	—	—	—	—	r	—	—	—	—	—
Bakevellia? sp.	—	r	r	—	—	—	—	—	—	—	—
Cassianella sexradiata (Branson)	r	—	—	—	—	—	—	—	—	—	—
Aviculopinna sp. a	—	—	—	—	—	r	—	—	—	—	—
Aviculopinna sp. b	?	—	—	—	—	r	—	—	—	—	—
Aviculopecten phosphaticus Girty	—	—	—	—	—	—	—	—	—	r	—
Aviculopecten girtyi Newell	—	—	r	—	—	—	—	—	—	—	—
Aviculopecten gryphus Newell	r	—	—	—	—	—	—	—	—	—	—
Aviculopecten cf. *vanvleeti* Beede	c	c	—	—	—	?	—	—	—	—	—
Aviculopecten cf. *kaibabensis* Newell	r	—	—	?	—	?	—	—	—	—	—
Aviculopecten cf. *basilicus* Newell	r	r	—	—	—	—	r	—	—	—	—
Aviculopecten sp.	—	r	r	—	—	—	—	—	—	—	—
Monotis? landerensis (Branson)	r	—	—	—	—	r	—	—	—	—	—
Limipecten? sp.	r	r	—	—	—	—	—	—	—	—	—
Acanthopecten coloradoensis (Newberry)	r	c	r	r	—	r	—	—	—	—	—
Acanthopecten cf. *delawarensis* (Girty)	—	—	r	—	—	—	—	—	—	—	—
Annuliconcha? sp.	—	—	?	—	—	—	—	—	—	—	—
Girtypecten sublaqueatus (Girty)	—	r	—	—	—	—	—	—	—	—	—
Streblochondria? cf. *guadalupensis* (Girty)	r	—	—	—	—	—	—	—	—	—	—
Streblochondria? tubicostata Ciriacks, new species	—	r	—	—	—	—	—	—	—	—	—
Streblochondria montpelierensis (Girty)	—	—	—	—	—	—	—	—	—	a	—
Obliquipecten sp.	r	—	—	—	—	—	—	—	—	—	—
Camptonectes? sculptilis Girty	—	r	—	—	—	—	—	—	—	—	—
Cyrtorostra varicostata Branson	c	c	—	r	—	r	?	—	r	—	—
Pseudomonotis sp.	c	c	—	—	—	—	r	—	—	r	—
Schizodus bifidus Ciriacks, new species	r	r	?	r	—	—	?	—	—	—	?
Schizodus canalis Branson	—	—	r	—	—	—	—	—	—	r	—
Schizodus subovatus Ciriacks, new species	—	—	r	—	—	—	—	—	—	—	—
Schizodus ferrieri Girty	—	—	—	—	—	—	—	—	—	a	—
Schizodus sp. a	r	—	—	—	—	—	—	—	—	—	—
Schizodus cf. *oklahomensis* Beede	—	?	?	r	—	—	—	—	—	?	—
Schizodus sp. b	r	r	r	—	—	—	—	—	—	—	—
Costatoria sexradiata	c	?	—	?	—	—	—	—	—	—	—
Scaphellina phosphoriensis (Branson)	r	r	?	r	—	—	—	—	—	—	—

TABLE 2—(*Continued*)

Species	Park City Formation			Shedhorn Formation		Phosphoria Formation					
	Er	Fr	Gr	Up	Lo	To	Rt	Cs	Rx	Mp	Lc
Scaphellina concinnus (Branson)	—	—	r	—	—	—	—	—	—	—	—
Astartella subquadrata Girty	—	—	r	—	—	—	—	—	—	—	—
Astartella sp.	—	r	r	—	—	—	r	—	—	—	—
Eoastarte subcircularis Ciriacks, new genus and species	—	—	r	—	—	—	—	—	—	—	—
Oriocrassatella sp.	—	—	r	—	—	—	—	—	—	—	—
Permophorus albequus (Beede)	—	r	c	—	—	—	—	—	—	—	—
Permophorus pricei (Branson)	r	—	—	—	—	—	—	—	—	—	—
Permophorus? sp.	r	—	—	—	—	r	—	—	—	—	—
Pseudopermophorus annettae Ciriacks, new genus and species	—	r	—	—	—	—	r	—	—	—	—
Celtoides unioniformis Newell	—	c	—	—	—	—	—	—	r	—	—
Stutchburia sp.	r	c	r	—	r	—	—	—	—	—	r
Wilkingia wyomingensis (Branson)	—	r	—	—	—	—	—	—	—	—	—
Wilkingia? sp.	r	—	—	—	—	—	—	—	—	—	—
Sanguinolites? elongatus Ciriacks, new species	—	—	r	—	—	—	—	—	—	—	—
Sanguinolites? sp.	r	r	—	—	—	—	—	—	—	—	—
Sanguinolites carbonaria (Girty)	—	—	—	—	—	—	—	—	—	r	—
Edmondia gibbosa Swallow	—	—	r	—	—	—	—	—	—	—	—
Edmondia phosphatica Girty	—	—	—	—	—	—	—	—	—	c	—
Edmondia sp.	—	—	—	—	—	r	—	—	—	—	—

[a] Members: Er, Ervay; Fr, Franson; Gr, Grandeur; Up, upper Shedhorn; Lo, lower Shedhorn; To, Tosi; Rt, Retort; Cs, Cherty shale; Rx, Rex; Mp, Mead Peak; Lc, lower chert.

[b] Frequency: r, rare (one to three localities); c, common (four to six localities); a, abundant (seven or more localities).

frequently occur in "*Unionites* beds" and are most common in silty limestones of the *Claraia* zone.

The three remaining genera (*Gervilleia*, *Myophoria*, and *Permophorus?*) are relatively rare and inconspicuous members of the Eotriassic fauna.

A detailed study of the paleoecology of individual species was not undertaken. A proper understanding of the physical and biological interrelationships requires an analysis of all the available evidence and cannot be based on the study of only one group, particularly if the group is not numerically abundant. Important paleoecological conclusions of individual species are reported in the discussions under the systematic descriptions where pertinent. Yochelson (MS) reports a large number of natural faunal assemblages based on a general study of the occurrence of all fossils reported in the Park City group.

General Distribution of Permian Bivalves

The stratigraphic distribution and relative abundance of each of the 70 species in the 11 Permian members is shown in table 2. A tabulation of the interrelationships between the members is indicated in table 3, which shows the number of species each member has in common with every other member and the relative similarity among members (this represents only similarities between two individual members that are being compared, and does not compare two or more members simultaneously to one or more other members). A condensation and interpretation of the data presented in tables 2 and 3 is given in table 4. This represents an objective attempt to show the amount of intermingling of the bivalves, possible stratigraphic age relationships between members, and the relative influence of facies as opposed to time (since the members are defined strictly on lithologic criteria, it is

TABLE 3

NUMBER OF BIVALVE SPECIES IN COMMON AND RELATIVE SIMILARITY BETWEEN PERMIAN MEMBERS

Member	E	F	G	U	L	T	Rt	Cs	R	M	Lc
Ervay	—	14	6	7	2	8	5	1	2	3	2
Franson	.49	—	11	7	2	4	8	2	3	5	2
Grandeur	.21	.39	—	7	2	2	5	2	2	7	2
Upper	.41	.42	.42	—	1	4	5	2	3	4	2
Lower	.26	.27	.27	.23	—	1	1	1	1	2	1
Tosi	.40	.23	.11	.39	.21	—	2	1	2	1	1
Retort	.29	.48	.30	.50	.23	.19	—	2	3	5	2
Cherty shale	.13	.27	.27	.45	.50	.21	.45	—	1	2	1
Rex	.18	.28	.19	.48	.36	.30	.48	.36	—	2	1
Meade Peak	.14	.23	.33	.32	.36	.08	.40	.36	.25	—	1
Lower chert	.26	.27	.27	.45	.50	.21	.45	.50	.36	.18	—

Measure of similarity based on the equation:

$$\cos\theta = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}}$$

(Imbrie and Purdy, 1962), in which x and y represent numbers of species in members being compared. Complete similarity is represented by 1.00; no similarity, by 0.00.

assumed that they reflect general facies differences).

The following conclusions are drawn from the data presented in tables 2, 3, and 4:

1. Thirty-nine of 70 species are restricted to individual members.

2. The Ervay member is most similar to the Franson (facies control) but is more similar to the Tosi and upper members than to the Grandeur member (age control).

3. The Franson member, stratigraphically between the Ervay and Grandeur, shows nearly equal similarity to both (facies control) and is also

TABLE 4

TOTAL NUMBER OF SPECIES, NUMBER OF RESTRICTED SPECIES, AND NUMBER OF SPECIES SHARED BETWEEN INDIVIDUAL PERMIAN MEMBERS

Member	A	B	A-B	C
Ervay	29	10	19	Franson, 14 (74%); Tosi, 8
Franson	28	6	22	Ervay, 14 (64%); Grandeur, 12
Grandeur	28	13	15	Franson, 11 (73%); Meade Peak, 7
Upper	10	0	10	Ervay, Franson, Grandeur, 7 (70%)
Lower	2	0	2	Ervay, Franson, Grandeur, Meade Peak, 2 (100%)
Tosi	11	3	8	Ervay, 8 (100%); Franson, 4
Retort	10	0	10	Franson, 8 (80%); Ervay, Grandeur, Upper, Meade Peak, 5
Cherty shale	2	0	2	Franson, Grandeur, Upper, Retort, Meade Peak, 2 (100%)
Rex	4	0	4	Franson, Upper, Retort, 3 (75%)
Meade Peak	16	7	9	Grandeur, 7 (78%); Retort, Franson, 5
Lower chert	2	0	2	Ervay, Franson, Grandeur, Upper, Retort, 2 (100%)

A Total number of species in each member.
B Number of species restricted to each member.
A-B Number of species in each member that occur in other members as well.
C Members having most species in common with each member, number of species shared, and percentage of unrestricted species shared with most similar member.

similar to the nearly stratigraphically equivalent Retort member.

4. The Grandeur member is most similar to the Franson member (facies control) but is more similar to the overlying Meade Peak member than to the Ervay carbonate member (age control). It contains the highest percentage of species restricted to a single member.

5. The upper and lower members show strong, equal similarity to the three carbonate members, which implies that bivalves in the sandstone facies are long-ranging and have little stratigraphic significance.

6. The Tosi member is very similar to the overlying Ervay member and shows little resemblance to any of the other members of the Phosphoria formation.

7. The Retort member is most like the underlying Franson member and shows equal similarity to other carbonate and sandstone members as well as the lithologically similar Meade Peak member.

8. The Meade Peak member more closely resembles the underlying Grandeur member than the lithologically similar, but younger, Retort member. It contains a high percentage of restricted species.

9. The Cherty shale, Rex, and lower chert members contain sparse but widespread bivalves common throughout most of the sequence.

In the carbonate members of the Park City formation, which contain the greater majority of the known species (only 10 of the 70 species are not known from one or more of the carbonate members), there is generally a strong similarity between stratigraphically adjacent members (Grandeur-Franson, Franson-Ervay), which implies a facies control of fossils. The differences between the Ervay and Grandeur members, however, are greater than between these members and stratigraphically closer members of a different lithology (Ervay-Tosi, Grandeur-Meade Peak), which implies that age differences are more important than facies similarities with increasing distance of vertical separation in the stratigraphic column.

The members of the Phosphoria formation generally show a greater resemblance to adjacent members in other formations (Tosi-Ervay, Retort-Franson) than to lithologically similar members of the same formation, which suggests a stronger age control of fossils in the Phosphoria formation. Such a suggestion is supported by the high percentage of restricted species (39%) in the Meade Peak member.

Another objective measure of facies control as opposed to age control of bivalves within the sequence was obtained by tabulating the distribution of bivalve species in the three formations (without regard to the subdivided members). Since the formations are separated on lithologic criteria, they are essentially a more accurate reflection of the three major types of Permian facies than the members, which represent stratigraphic recurrences of the major facies. The results are shown in table 5.

TABLE 5

NUMERICAL DISTRIBUTION OF BIVALVE SPECIES IN PERMIAN FORMATIONS

Formation	Total Number of Species	Number of Restricted Species	Number of Species Shared
Park City	59	37	22
Phosphoria	31	10	21
Shedhorn	11	0	11

Of the total of 70 Permian species, 20 occur in both the Park City and Phosphoria formations, 11 in both the Park City and Shedhorn, and seven in both the Phosphoria and Shedhorn formations. Nine species are found in all three formations.

Conclusions drawn from the study of distribution of species in the three formations are: (1) 37 of the 70 species (53%) are restricted to the Park City formation, and (2) 37 of the total of 59 species (63%) found in the Park City formation are restricted to it, while only 10 of 31 species (32%) of the Phosphoria species are restricted to that formation, and none of the 11 Shedhorn species are confined to that formation. These conclusions suggest a decreasing influence of facies control of bivalve distribution from the carbonate, to the chert-phosphate-mudstone, to the sandstone facies.

An additional treatment of the distribution data, in which generic as opposed to specific interrelationships between Permian formations were recorded, in general reflects the same relationships as the specific distribution. However, it shows a somewhat greater influ-

TABLE 6

STRATIGRAPHIC DISTRIBUTION AND FREQUENCY OF EOTRIASSIC BIVALVES

Species	Silty Limestone	Dinwoody Formation *Lingula* Zone	Dinwoody Formation *Claraia* Zone	Woodside Formation Undivided Unit	Thaynes Formation Undivided Unit
Mytilus? postcarbonica (Girty)	—	—	r[a]	—	—
Promyalina putiatensis (Kiparisova)	—	r	r	—	—
Promyalina spathi (Newell and Kummel)	—	c	c	—	—
Gervilleia cf. *ussurica* Kiparisova	—	—	c	—	—
Eumorphotis multiformis (Bittner)	—	—	c	—	r
Eumorphotis multiformis regularaecosta (Kiparisova)	—	—	r	—	—
Eumorphotis amplicostata Ciriacks, new species	—	—	r	—	—
Claraia clarai (Emmrich)	—	—	r	—	—
Claraia extrema (Spath)	—	—	—	—	r
Claraia mulleri Newell and Kummel	—	—	r	—	—
Claraia stachei Bittner	r	r	a	—	r
Claraia sp. a	—	—	—	—	r
Claraia sp. b	—	—	—	r	—
Claraia? sp.	—	—	r	—	—
Monotis? thaynesiana (Girty)	—	—	—	r	r
Unionites breviformis (Spath)	—	—	r	—	—
Unionites canalensis (Catullo)	—	—	a	—	—
Unionites fassaensis (Wissman)	—	—	r	—	—
Unionites? sp.	—	—	r	—	?
Myohoria laevigata (Ziethen)	—	—	c	—	—
Permophorus? bregeri (Girty)	r	—	r	—	—

[a] Frequency: r, rare (one to three localities); c, common (four to six localities); a, abundant (seven or more localities).

ence of facies control in the carbonates and a lesser emphasis of facies in the other rocks. Nine genera are restricted to individual members of the Park City formation. Thirteen, of a total of 34 (38%), are restricted to the Park City formation considered as a unit. No genera are restricted to either the Phosphoria formation or the Shedhorn formations, which suggests that the bivalve species restricted to the Phosphoria formation (10), and the chert-phosphorite-mudstone facies it represents, are somewhat specialized forms of genera which are, without exception, present in the more normal marine carbonate facies of the Park City formation.

GENERAL DISTRIBUTION OF EOTRIASSIC BIVALVES

The stratigraphic distribution and relative abundance of Eotriassic bivalve species are shown in table 6. The relationships between the units involved is considerably less complex than in the Permian, and the data do not require condensation and quantitative treatment to emphasize important points. All the forms recognized in the Silty limestone and *Lingula* zone are present in the overlying *Claraia* zone, which is clearly the most fossiliferous horizon. Two species [*Monotis? thaynesiana* (Girty) and *Claraia* sp. b] are identified from collections reportedly from the Woodside formation, but the matrix adhering to the specimens is not red, and these occurrences are probably from strata that are now considered to be upper Dinwoody (equivalent to the *Claraia* zone). With the exception of two species [*Claraia extrema* (Spath), and *C.* sp. a], the only forms described from the upper Eotriassic Thaynes formation are those that also occur in the underlying lower Eotriassic sequence (available collections of the generally different upper Eotriassic bivalve fauna of the Thaynes formation are inadequate for a proper study).

CORRELATION OF BIVALVE FAUNAS

PERMIAN

Correlation of Members Within the Sequence

Quantitative biological resemblances between various members are discussed above. Many of the similarities involve species that are long-ranging and widespread and cannot be used individually in detailed stratigraphic correlation. Others are restricted to a single member and cannot be closely compared to known species in the local sequence or Permian strata elsewhere. Of the 70 species, only about 30 can be used in local or regional comparisons. A certain amount of subjectivity is required in selecting the species that are most meaningful stratigraphically. Other forms, however, are used objectively as a measure of total similarity between the local Permian fauna and other known Permian bivalve faunas.

The bivalves of the Grandeur member represent a somewhat unique assemblage which is difficult to compare with other members. Thirteen species are restricted to this member. The 11 species in common with the Franson member all range higher in the sequence, with the exception of forms identified as *Permophorus albequus* (Beede). The Grandeur seems most closely allied with the Meade Peak member, basal unit of the Phosphoria formation. Although they have only seven species in common, several of these forms [*Paleoneilo mcchesneyana* (Girty), *Nuculopsis montpelierensis* (Girty), and *Schizodus canalis* Branson] are restricted to these two members. In addition, individual species restricted to either of the two members can be correlated with the same general horizon (Upper Leonard-Lower Word) in the Permian of the southwestern United States. The Grandeur-Meade Peak bivalve assemblage is here designated age group I.

Franson bivalves most resemble those of the Ervay member, and, although only about five species are restricted to these members (considered as a unit), many of the other forms are also found in the Tosi and Retort members of the Phosphoria formation. The bivalves of these four members are characterized by an abundance of aviculopectinids, many of which do not occur lower in the sequence. Forms such as *Cyrtorostra* (also found in the Rex member), *Costatoria*, ribbed species of *Streblochondria*, and the permophorid genera *Pseudopermophorus* and *Celtoides* are restricted to these higher Permian members. All the bivalve species of the Tosi member, except the three restricted forms, occur in the Ervay, and eight of 10 Retort species occur in the Franson. These four members appear to constitute a second age group, designated age group II, which is quite distinct from age group I.

The upper member of the Shedhorn sandstone has seven, of a total of 10, species in common with each of the carbonate members of the Park City formation. However, the presence of *Costatoria* and *Cyrtorostra* suggests affinity with members of age group II. Only five species are known from the Rex chert member, but the occurrence of *Cyrtorostra* and *Celtoides* suggests affinity with units of age group II. The lower member of the Shedhorn sandstone, the Cherty shale member, and the lower chert member each contain only two bivalve species, one of which is the ubiquitous *Polidevcia obesa*. The other species are not distinctive.

Regional Correlations

Two methods are used in the attempt to correlate Permian bivalves of the Middle Rockies with other North American bivalve faunas. Data were compiled by listing closely comparable species of the Middle Rockies fauna with other known faunas, and a percentage of over-all similarity between various faunas was obtained (table 7).

There is a consistent and relatively low degree of similarity between the bivalves of the Middle Rockies and other known faunas. It is particularly striking that only a maximum of eight of a total of 70 species are comparable to any other individual fauna, which does not necessarily imply that many forms are restricted to the Middle Rockies, but more probably reflects inadequate knowledge of

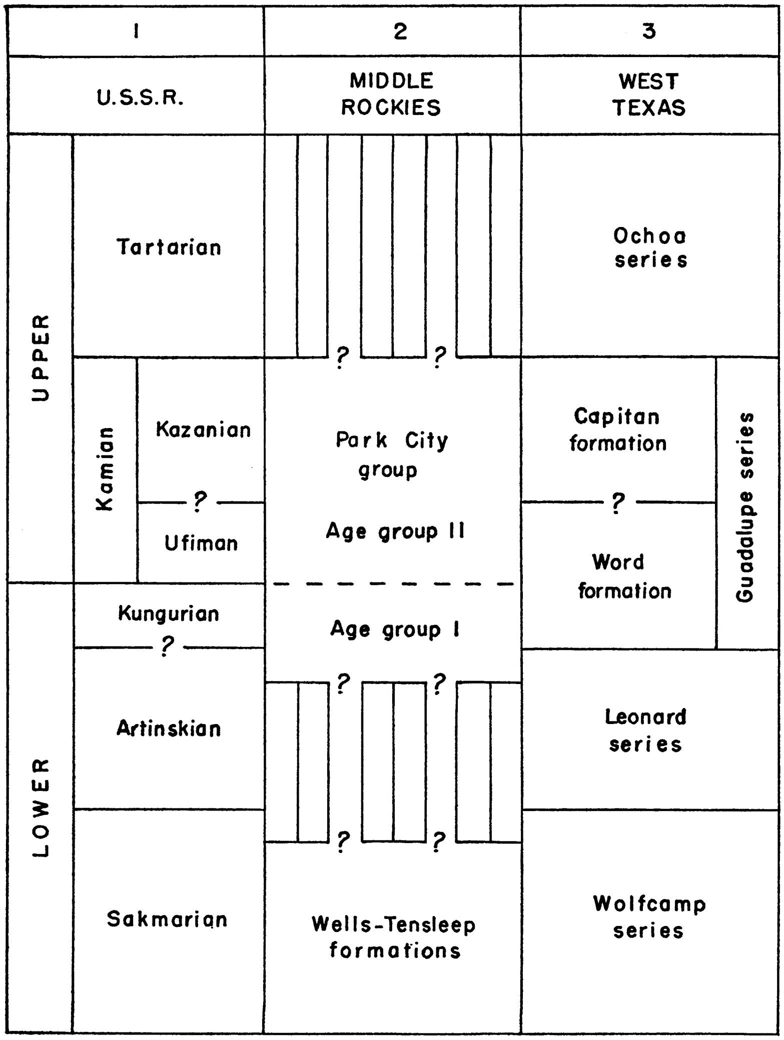

FIG. 3. Faunal correlation of Permian sequence of the Middle Rockies with the Permian sequences of Russia and West Texas. Equivalency of columns 1 and 3 taken from Dutro (1961).

many of the faunas. The low similarity with the Guadalupian fauna of West Texas, in particular, is somewhat misleading. Comparison with this fauna is extremely difficult, because much of Girty's (1908) material is fragmentary and specifically unrecognizable. However, the fact that 24 specifically identifiable taxa are known only from the Middle Rockies suggests that in the bivalves, as well as other groups such as the brachiopods (p. 10), there was a great deal of local speciation in the Permian.

A second method used in correlation of the bivalves is a comparison based on individual, relatively short-ranging species, especially those restricted to one or two members. Middle Rockies species are compared to other known forms and with similar forms in the large undescribed silicified fauna of the standard Permian section of West Texas. Grandeur-Meade Peak species (age group I) of the Middle Rockies are compared with Permian forms of the southwestern United States in table 8.

TABLE 7

SIMILARITY OF NORTH AMERICAN BIVALVE FAUNAS TO MIDDLE ROCKIES FAUNA

Formation and Source	Age	Total No. of Bivalve Species	No. of Comparable Species	Percentage of Comparable Species
Kaibab, (alpha) (Chronic, 1952)	Upper Leonard-Lower Word	26	8	31%
Manzano group (Girty, 1909)	Leonard-Lower Word	29	7	24%
Whitehorse (Newell, 1940)	Capitan	13	3	23%
Guadalupian group (Girty, 1908)	Word and Capitan	45	8	18%

The comparisons indicate a strong similarity between the lower members of the Park City group and Upper Leonardian to Lower Wordian rocks of the southwestern United States. The Kaibab is dated as Upper Leonardian (Dunbar and others, 1960, correlation chart 7). An older age is indirectly suggested by the absence of the genus *Cyrtorostra* in the Middle Rockies age group I sequence. The genus is found in Upper Leonard through Word Number 4 limestone horizons in the Glass Mountains of West Texas. The genus first appears in the Franson member in the Middle Rockies, but these forms closely resemble forms in the Word Number 3 limestone, which suggests that the apparent absence of the genus in the Grandeur member of the Middle Rockies may be fortuitous.

Nuculoids are generally long-ranging forms unsuitable for stratigraphic correlation. However, the nuculids of the Meade Peak member, which constitute a major element of the fauna, are closely similar to Lower Wordian forms of West Texas. Conspicuously larger, undescribed forms, found higher in the west Texas sequence, are unknown in the Middle Rockies, but the largest specimens identified, assigned to *Nuculopsis* sp. c, range up into the Retort member. There may be a parallel trend of increasing size in the Middle Rockies and West Texas forms in this genus.

The only strong comparison with younger Permian rocks is with *Aviculopecten girtyi*, which is locally restricted to the Grandeur member but is very similar to undescribed forms in the Word Number 3 limestone of the Glass Mountains.

Species of age group II that may be useful in correlation are shown in table 9. The comparisons show a strong affinity of the upper members of the Park City group to rocks of Upper Wordian to Capitanian age of the southwestern United States. *Camptonectes? sculptilis*, from the Franson member in Wyoming, is known only from the Capitan limestone of West Texas. Other species of the genus, described by Girty (1908) in association with *C.? sculptilis*, are abundant in the Word formation in the Glass Mountains, but extensive silicified collections of Glass Moun-

TABLE 8

COMPARISONS OF BIVALVE SPECIES OF AGE GROUP I WITH PERMIAN SPECIES OF THE SOUTHWESTERN UNITED STATES

Age Group I Species	Southwestern United States Forms	Age
Nuculopsis sp. a	Undescribed form	Word No. 1 limestone
Aviculopecten girtyi Newell	*A. girtyi*	Word No. 3 limestone
Acanthopecten cf. *delawarensis* (Girty)	*A. delawarensis*	Delaware Mountain
Eoastarte subcircularis Ciriacks, new species	Undescribed form	Word No. 1 limestone
Schizodus canalis Branson	Undescribed form	Word No. 1 limestone
Astartella subquadrata Girty	*A. subquadrata*	Kaibab, alpha
Sanguinolites? elongatus Ciriacks, new species	*S.?* sp.	Kaibab, alpha

TABLE 9

COMPARISONS OF BIVALVE SPECIES OF AGE GROUP II WITH PERMIAN SPECIES OF THE SOUTHWESTERN UNITED STATES

Age Group II Species	Southwestern United States Forms	Age
Aviculopecten gryphus Newell	*A. gryphus*	Word (?No. 3 limestone)
Girtypecten sublaqueatus (Girty)	*G. sublaqueatus*	Leonard-Word No. 3 limestone
Streblochondria? guadalupensis (Girty)	*S.? guadalupensis*	Capitan
Camptonectes? sculptilis Girty	*C.? sculptilis*	Capitan
Cyrtorostra varicostata Branson	Undescribed form	Word No. 3 limestone
Schizodus sp. a	Undescribed form	Kaibab
Costatoria sexradiata (Branson)	Undescribed form	Word No. 3-Word No. 4 limestone
Pseudopermophorus annettae Ciriacks, new species	*Protrete texana* Girty	Word (Capitan?)
Wilkingia wyomingensis (Branson)	Undescribed form	Kaibab
Parallelodon cf. *multistriatus* Girty	*P. multistriatus*	Capitan

tains specimens at the American Museum do not contain *C.? sculptilis*. *Cyrtorostra varicostata*, represented by well-preserved specimens in the Franson and Ervay members, is closely similar to West Texas forms in the Word Nunber 3 limestone of the Glass Mountains. The writer has observed trends of increase in size and the number of ribs in studying several hundred west Texas specimens from Upper Leonard through Word Number 4 limestone horizons. Franson forms in the present collection are essentially inseparable from forms in the Word Number 3 limestone, although several larger specimens are present in the considerably smaller Franson collection. *Costatoria sexradiata*, in the Ervay member, and smaller, more densely plicated forms questionably referred to the species, in the Franson member, are somewhat intermediate in size and ornamentation between undescribed forms in the Word Number 3 and Word Number 4 limestones.

Species of *Cyrtorostra*, *Camptonectes?*, *Streblochondria?*, and *Costatoria* appear to be the most useful stratigraphic guide fossils among Permian bivalves. Other forms such as *Schizodus* and *Cassianella* may become of greater importance as forms in the West Texas sequence are made known.

With the exception of *Wilkingia wyomingensis* and *Schizodus* sp. a, which resemble Kaibab forms, the upper members of the Park City group are most closely correlated with rocks ranging from the Word Number 3 limestone to the Capitan of west Texas. A more refined zonation must await both the description of the rich west Texas bivalve fauna and corroborative evidence from detailed studies of other invertebrate groups in the Park City rocks.

In summary, bivalves support and strengthen the evidence, based on limited observations of other invertebrate groups (p. 11), of essentially an Upper Leonardian and Guadalupian age for rocks of the Park City group (fig. 3). The upper age limit is difficult to establish. Resemblances between Franson and Ervay species and Capitan forms suggest an Upper Guadalupian age for the younger units of the Middle Rockies sequence. Distinctive bivalves of post-Guadalupian age are not known in North America, which makes a regional comparison with the youngest Permian (Ochoan) strata presently impossible.

INTERCONTINENTAL CORRELATIONS

Comparison with the Upper Permian fauna of east Greenland (a Zechsteinian fauna), and the Permian fauna of the Salt Range of Pakistan is critical, because these two areas are believed to contain fossiliferous marine beds of youngest Permian, Tartarian (Ochoan) age. The evidence for the existence of marine Permian of post-Kazanian age is discussed by Dunbar (Dunbar and others, 1960). Two genera, the ammonite *Cyclolobus*, present in the Upper Productus limestone of the Salt Range and the Foldvik Creek formation of east Greenland, and the fusulinid *Yabeina*, widespread in the Orient, are considered to be indicative of post-Kazanian marine deposits.

Four bivalve species in the Middle Rockies are closely comparable with Salt Range forms: *Schizodus canalis* (age group I) resembles *S. emarginatus* Reed of the Upper Productus limestone. *Girtypecten sublaqueatus* (age group II) is compared with *G. chitralensis* (Reed) of the Lower Productus limestone. *Cyrtorostra varicostata* (age group II) resembles *Blandfordina trifurcata* Reed of the upper Middle Productus limestone. *Wilkingia wyomingensis* (age group II) resembles *W. waageni* (Reed) of the Lower Productus limestone. With the exception of the *Cyrtorostra-Blandfordina* comparison (these forms are probably congeneric, see p. 57), the results of the comparisons are somewhat anomalous, in that the Lower Productus limestone bears resemblance to the upper part of the Middle Rockies sequence, and the single comparable species of the Upper Productus limestone most closely resembles a form occurring near the base of the Middle Rockies sequence.

Comparison with the Greenland bivalve fauna shows that approximately 30 per cent of the species described by Newell (1955) are closely comparable with forms in the Park City group. The Greenland bivalve fauna is dated as Kungurian to Kazanian or younger (Zechsteinian of Europe and post-Leonardian of North America) by Newell.

There is a very close resemblance between ribbed aviculopectinids assigned to the genus *Streblochondria?* in the Greenland, West Texas, and Middle Rockies faunas. *Streblochondria? guadalupensis* (Girty) from the Capitan of West Texas and the Ervay member of Wyoming, *S.? tubicostata* Ciriacks, new species, from the Franson member of Wyoming, and *S.? maynci* Newell from the Brachiopodenkalk of Greenland are very closely comparable. Dutro (1961) considers the Brachiopodenkalk to be of Kamian (Ufimian-Kazanian) age on the basis of brachiopods and correlates the Kazanian with the Capitan of west Texas based on ammonite and fusulinid similarities. The resemblance in forms of *Streblochondria?* in the Capitan and Brachiopodenkalk was recognized by Newell (1955). Thus the occurrence of similar forms in the upper members of the Park City formation of Wyoming supports a Kazanian-Capitanian age for the younger part of the sequence and offers a close tie between the Permian of Greenland and that of the Middle Rockies.

The single specimen of *Cyrtorostra* sp., described by Newell from the Martienkalk of Greenland, considered by Dutro to be Tartarian in age, appears closely similar to *C. varicostata* in the Middle Rockies. This is the only bivalve species reported from the Martienkalk. Thus comparison of the Middle Rockies Permian with post-Kazanian beds of Greenland, on the basis of bivalves, is presently not possible.

TRIASSIC

Correlation of Eotriassic Bivalves

As indicated above, the lower Eotriassic fauna is very uniform and highly restricted. The Dinwoody most closely resembles the Greenland fauna described by Spath (1930, 1935). Several species, including *Claraia extrema* (Spath) and *Unionites breviformis* (Spath), are known only from the Middle Rockies and Greenland. Other identical or closely comparable forms include species of *Claraia*, *Eumorphotis*, *Promyalina*, *Gervilleia*, and *Unionites*.

The Dinwoody also shows close resemblance to Eotriassic faunas of the Alps and of Asia.

EVOLUTIONARY OBSERVATIONS

GENERIC DIVERSIFICATION IN PERMIAN BIVALVES

THE LARGE-SCALE taxonomic expansion of many characteristic Paleozoic invertebrates during Permian time has long been known. Groups such as the fusulinids, and productoid and richtofenid brachiopods, are numerically abundant and taxonomically diverse. Many of these forms were apparently reaching their zenith during the Permian, then underwent sudden mass extinction. Bivalves, important members of both the Permian and Eotriassic faunas, show less striking changes at higher taxonomic levels during this period of high extinction rates, but major changes are readily apparent at a generic and specific level.

Bivalves of the Park City group show a wide diversification which generally reflects important universal changes within the group. Many new genera appear in the Permian and are restricted to that period (or only part of the period). Within the aviculopectinids recorded in the local sequence, two genera (*Cyrtorostra* and *Girtypecten*) are known only from the Permian (probably Leonardian-Guadalupian). The three species identified as *Streblochondria?* are unlike earlier forms of the genus and are also confined to the Permian. Several other genera are confined to rocks of Carboniferous and Permian age. Specific diversification characteristic of Permian aviculopectinids is also well shown in the Middle Rockies. Eight species of *Aviculopecten* are differentiated. Especially prominent are the large, heavy-ribbed, spine-bearing species which became widespread in the upper Permian.

Myophoriids are represented by only two genera (*Schizodus* and *Costatoria*). However, seven species of *Schizodus* are locally recognized, and the abundance of known and undescribed forms (observed in American Museum collections by the writer) indicates a great taxonomic expansion of this group during the late Paleozoic. The genus *Scaphellina*, placed in a separate family but bearing general resemblance to the myophoriids, is represented by three North American species, two in the local sequence, and is known only from strata of Leonardian and Guadalupian age.

Astartids, sparsely represented in the North American Paleozoic by a poorly known Ordovician occurrence (*Matheria?*) and the Permocarboniferous genus *Astartella*, show the addition of two new genera in the Permian: *Kaibabella*, in the Kaibab formation of Arizona, and *Eoastarte*, a new genus, in the Grandeur member of Wyoming and Utah.

Permophorid bivalves undergo a great expansion in the Permian. Only one genus, *Pleurophorella* (Upper Pennsylvanian), is known in pre-Permian North American rocks. Permian representatives of the family include *Permophorus*, *Celtoides*, *Stutchburia* (including the forms *Netschajewia* and *Rimmyjimina*), and *Pseudopermophorus*. *Celtoides* and *Pseudopermophorus* are known only from the upper part of the Park City group (age group II), and these two and the forms included in *Stutchburia* are universally confined to rocks of Permian age.

In summary, 10 of the 34 genera recorded in the Permian of the Middle Rockies are universally confined to rocks of Permian age, many of them restricted to only a part of the Permian. The mean survivorship for a bivalve genus has been computed as 78 million years by Simpson (1953). The origination of many new genera, the taxonomic expansion of previously existing forms, and the restricted ranges of many of the genera reflect a trend of taxonomic diversification followed by widespread extinction in Permian bivalves, similar to that shown in the fusulinids and certain groups of brachiopods in the Permian, ammonoids in the Triassic and Cretaceous, and other groups of organisms throughout the geologic column. For unknown reasons, perhaps a broader adaptability and evolutionary plasticity, the changes in the bivalves were confined largely to a generic and lower taxonomic level.

Three of the nine genera recorded in the lower Eotriassic of the Middle Rockies (*Eumorphotis*, *Claraia*, and *Unionites*) are universally restricted to the Triassic. The three genera contain two-thirds of the total number of species in the local fauna. *Claraia* is confined to the Scythian (Eotriassic). Generic diversity is not great in lower Eotriassic bivalves, and the majority of the members of the cosmopolitan fauna are relatively short-ranging, restricted types which do not greatly resemble either the preceding Permian forms or the succeeding younger Triassic and later Mesozoic forms.

SPECIFIC DIVERSIFICATION IN PERMIAN BIVALVES

It is shown above (p. 22) that 13 of the bivalve genera are restricted to the carbonate members of the Park City formation. Although 10 species are confined to individual members of the Phosphoria formation, they are, without exception, representatives of genera that also occur in the carbonate facies, which seems somewhat paradoxical with regard to a normal explanation of the occurrence of new genera in the Permian. It would seem logical to anticipate the appearance of new genera in less normal marine facies represented by the cherty-carbonaceous-phosphatic facies of the Phosphoria members. It would follow that with the disappearance of these somewhat unusual environmental conditions (McKelvey and others, 1959, postulate cold, upwelling currents and reducing conditions in a relatively deep-water embayment as the general depositional environment of the Meade Peak member), many of the highly specialized, narrowly adapted forms might become extinct. This is probably a reasonable, simplified explanation of what happened to species that are restricted to members of the Phosphoria. *Aviculopecten phosphaticus*, an unusual form displaying delicate hinge spines on the right valves only, is dissimilar to other species of the genus. The preservation of the delicate spines and of the relatively thin shells suggests little post-mortem transportation and a quiet, relatively deep-water environment (see discussion of species, p. 46). *Streblochondria? montepelierensis*, *Edmondia phosphatica*, *Sanguinolites carbonaria*, *Schizodus ferrieri*, and *Nuculopsis* sp. a are generally dissimilar to and cannot be closely compared with other species of the genera that occur in the carbonate facies of the local sequence.

Local, atypical, marine environmental conditions and paleoecological anomalies, such as those of the chert-phosphorite-mudstone facies, may account for local speciation in the bivalves. They do not, however, seem important in the factors that led to the appearance and later extinction of the restricted Permian genera. The evidence in the local sequence suggests that the appearance of new genera probably occurred in response to a combination of a wide variety of available habitats and selection pressures operating in the relatively shallow-water areas of carbonate deposition.

EVOLUTIONARY TRENDS IN PERMIAN BIVALVES

Despite the large size and general diversity of the Permian bivalve fauna, evolutionary trends in specific lineages are difficult to demonstrate in the local Permian sequence, owing, no doubt, to the poor preservation, the small number of specimens, and our inadequate knowledge of variation in most of the species.

The following systematic changes are observed: (1) an apparent increase in size, and decrease in number of radial ribs in forms described as *Costatoria sexradiata?*, in the Franson member, and *C. sexradiata*, in the Ervay member; (2) an increase in size and in relative height in *Scaphellina concinnus*, in the Grandeur member, and *S. phosphoriensis*, in the Franson, Ervay, and upper Shedhorn members; and (3) an increase in the number of primary, spine-bearing ribs, and in relative height in *Aviculopecten girtyi*, in the Grandeur member, and *A. gryphus*, in the Ervay member.

The lack of demonstrable change may indicate a relatively short span for the total time interval represented by the Permian of the Middle Rockies. Although a number of trends, such as changes in the number of ribs and in size in forms of *Cyrtorostra*, a general increase in size in the nuculids, and others, have been observed in the undescribed West Texas fauna, these trends are generally discovered only after large numbers of specimens have been carefully studied, which again emphasizes the need of a sufficient number of suitably preserved specimens, which is lacking in the presently available bivalve collections.

Evolutionary trends in Eotriassic bivalves studied here are not evident. Local differences within genera and species cannot be attributed to progressive changes within the local stratigraphic succession.

COMPARISON OF PERMIAN AND EOTRIASSIC BIVALVES

As indicated in table 1, there is more similarity between bivalves of the Permian and those of the lower Triassic than among any other invertebrate groups. In the Middle Rockies, five superfamilies are common to both the Permian and lower Eotriassic. It has been subquently shown that at generic and lower taxonomic levels the similarity of the two bivalve faunas is neglibible. Two species, probably representing a new but inadequately known genus, *Monotis? landerensis* (Branson), from the Ervay and Tosi members near the top of the Permian sequence, and *M.? thaynesiana* (Girty), from the Woodside? and Thaynes formations (probably upper Eotriassic), are closely comparable. The Permian occurrence is the initial appearance of these small, nearly equilateral, and probably equivalved pectinoids which are abundantly represented in the upper Eotriassic of the local sequence. The genus *Permophorus* is reported from both the Permian and the Triassic, but the species are not closely comparable, and the generic affinity of the Dinwoody form, *Permophorus? bregeri* (Girty), is uncertain.

The most dominant members of both the Permian and the lower Eotriassic bivalve faunas are pectinoids. Most closely comparable are the Permian genus *Aviculopecten* and the Triassic genus *Eumorphotis*. Left valves of the two genera are very difficult to separate. The most distinguishing characteristic is the lack of bifurcating radial costae on the right valves of *Eumorphotis*, which are nearly smooth. A new species, *E. amplicostata*, shows distal splitting of ribs on the left valves, a feature unknown in *Aviculopecten*. Although the phylogenetic relationships between the two genera have not been worked out, it seems probable that *Eumorphotis* originated from Permian representatives of *Aviculopecten*. The Eotriassic forms are not greatly advanced from the Permian forms in an evolutionary sense.

The highly characteristic Eotriassic genus *Claraia* is not closely comparable to known Permian genera. It was long thought to be a member of the family Pseudomonotidae, widespread in the Permian, but it is rather unlike *Pseudomonotis*, *sensu stricto*, and its phylogeny is as yet unknown.

A third abundant Eotriassic group, represented by *Unionites*, cannot be compared with known Permian genera. The Eotriassic forms have an occurrence somewhat similar to that of the Permian nuculids and may have occupied a similar ecological niche.

Eotriassic myalinids, represented by *Promyalina*, are generally smaller and more erect than Permian forms of *Myalina*. Closely comparable forms are not observed in the local sequence.

In summary, with the exception of a few forms such as *Monotis?* and *Eumorphotis*, there is very little similarity between genera of families that cross the local Permian-Triassic boundary. Thus an explanation must be sought to account for the nearly total extinction of Permian genera and their replacement by new forms in the earliest Triassic of the local sequence.

The local boundary problem is complicated by the fact that the upper age limit of the Permian sequence is difficult to establish. If it be assumed that the youngest Park City beds are of Upper Guadalupian (Kazanian) age, then a significant interval of time (equivalent to the length of the Ochoan or Tartarian Series) is apparently missing in the local sequence. A lack of diagnostic marine fossils in both the Permian type section in Russia and the standard section of North America has resulted in a poor understanding of the status of the Tartarian and Ochoan, respectively, as series comparable to the older Permian subdivisions, and in the amount of absolute time that they represent. The upper Permian is characterized in many parts of the world by abundant evaporite deposits (Ham, Mankin, and Schleicher, 1961) and continental deposits, which may indicate a rather slow withdrawal of marine seas and relatively hot, dry climatic conditions. The magnitude of the hiatus that separates the Permian and Triassic strata of the Middle Rockies cannot be definitely established, but evidence presented in the subsequent section of this report suggests a complete withdrawal of the marine seas and a period of emergence and erosion throughout the area. The absolute time interval of the hiatus may be estimated to include about one-fifth of the Permian (Ochoan) and a small fraction of the Triassic (lower Otoceratan) and may be on the order of 10 million years.

A second factor, important in explaining faunal differences, is that of dissimilar facies in the Permian and Eotriassic. There is a major difference between the cherty-phosphatic-carbonaceous, coarse sandy, and relatively pure carbonate facies of the Permian, and the silty limestone and shale facies of the Eotriassic. However, many of the Permian species were apparently broadly adapted and distributed in a great variety of lithologic types. Furthermore, the fact that nearly all the Triassic families of bivalves are also found in the underlying Permian suggests at least a general similarity in the respective environments. However, one particular lithology, that of a relatively pure carbonate, free of high percentages of detrital quartz and other clastics, is conspicuously absent in the lower Eotriassic of the local sequence and in the lower Eotriassic throughout its limited known occurrences. Relatively pure limestones do occur in the Dinwoody (*Claraia* zone) but are generally unfossiliferous. Not until the upper Eotriassic Thaynes formation do relatively fossiliferous carbonates become abundant in the sequence. It thus appears that the widespread, shallow-water, carbonate environment of the Permian seas, which may have been the site of much of the rapid differentiation of marine invertebrate life, became restricted and generally disappeared in the upper Permian, was generally absent in early Eotriassic time, and did not again become prominent until the late Eotriassic.

The highly uniform, cosmopolitan, early Eotriassic fauna may be considered as an impoverished, intermediate assemblage of hearty, broadly adapted forms, which do not closely resemble youngest Permian marine faunas or younger Triassic and later Mesozoic faunas. Such a supposition is supported by the fact that bivalves such as *Costatoria* and *Cassianella* are present in the Permian carbonates, then are generally unknown in the early Eotriassic, but reappear in carbonate facies of the younger Triassic. Many other forms, however, were evidently unsuccessful during the time of restricted seas, a general emergence of the continents, and a concurrent reduction in area of formerly widespread epicontinental seas and broad continental shelves. Faunal evidence suggests that conditions of widespread continental emergence persisted for several million years. At this time there was probably excessive crowding on the reduced continental shelves, changes in intensity and direction of selection pressures, and thus relatively rapid evolutionary changes in generally reduced populations. Forms having greater adaptive potential and thus greater evolutionary plasticity survived, while more highly specialized forms either changed radically or became extinct. Mass extinctions were widespread. With the transgression of seas in the early Eotriassic the carbonate facies was relatively barren of organisms, and this environment was only slowly reoccupied by a diminished and greatly changed fauna in late Eotriassic time. In summary, the revolutionary paleontological changes at the Permian-Triassic boundary may be related to pronounced ecological changes concurrent with widespread withdrawal of marine seas in late Permian time, a hiatus of several million years, and a rather slow transgression of the early Eotriassic seas.

THE PERMIAN-TRIASSIC BOUNDARY INTERVAL

REVIEW OF PREVIOUS WORK

ALTHOUGH FAUNAL CONTRASTS in marine strata that are at present called Permian and Triassic are quite pronounced (where fossils occur in the sequence), and although the lithologic changes are generally quite abrupt between the various formations of the Park City group and the overlying Dinwoody, this sequence has frequently been treated as a single, apparently continuous unit. Darton in 1906 gave the name Embar formation to limestones and shales lying between the Pennsylvanian Tensleep sandstone and the Triassic? Chugwater formation in the Owl Creek Mountains of Wyoming. The name was later extended to include similar sequences in the Wind River and Gros Ventre Ranges of western Wyoming (Blackwelder, 1911). In 1918 Blackwelder divided the Embar into an upper unit of Triassic age, called the Dinwoody, and a lower unit, unnamed, correlated with the Park City formation of Permian age. Subsequent work has firmly established the Eotriassic age of the Dinwoody (Newell and Kummel, 1942) but has failed to establish an upper age limit for the underlying Permian rocks.

Because of essentially parallel relationships of the Permian and Eotriassic formations, this sequence superficially appears to be conformable and would thereby be comparable to other reportedly conformable Permo-Triassic units in east Greenland and the Salt Range. Although the upper age limit of the local Permian is not known, it appears that youngest Permian marine equivalents are not present in the Middle Rockies (p. 26). The local Permian may not range quite so high as that of east Greenland or the Salt Range, which contain the post-Kazanian genus *Cyclolobus*, but the age relationships of all these sequences to Eotriassic rocks is uncertain because of the great dissimilarity of the Permian and Triassic faunas.

There is abundant evidence of disconformity between the Permian and Triassic strata in the Middle Rockies. Newell and Kummel (1942) demonstrated a regional overlap of the Dinwoody onto the Permian strata. They cite additional evidence in the local leaching of cherty beds at the top of the Phosphoria formation, and the discovery, by Alfred Fischer, of local truncation of upper Permian beds by beds of the basal Dinwoody. Sheldon (1957) indicates that the Permian sequence of western Wyoming shows a regression from east to west, terminating Permian deposition. Near the close of this regression phosphates were being deposited to the west, cherts centrally, and carbonates to the east, with a tongue of sandstone entering from the north at the close of Permian deposition. The general nature of the Permian regression and Eotriassic transgression is shown in figure 2 of the present report. Owing to lack of sufficient faunal evidence in the Permian sequence the time relations of the intertonguing units involved in the regression are poorly known. The regression is one of facies that may be essentially time equivalent. There is no evidence that the Permian phosphates and mudstones in the western part of the area (southeastern Idaho), representing the final stages of the regression, are any younger than the carbonates and sandstones to the east. The Permian regression cannot be considered as conclusive evidence of unconformity until time relations of the various lithologies can be demonstrated. Bivalves of the upper member of the Shedhorn sandstone indicate a close relationship to the Ervay carbonate member, but fossils are relatively rare in the Tosi, Retort, and Cherty shale members (respectively capping the Permian sequence going westward), and the age relationships of these members are poorly known.

FIELD AND PETROGRAPHIC OBSERVATIONS

The writer has made detailed observations of the Permian-Triassic contact at numerous localities in Wyoming, Idaho, and Montana in search of conclusive evidence with regard to the nature of the local rock sequence. Twelve short sections adjacent to the contact were measured and described (fig. 4; p. 84). The sections are arranged to show the lithologic changes at the contact, generally from east to west, reflecting the progressive change in Permian beds from carbonates to sandstones to cherts to phosphorites and mudstones.

Sections 1 to 4, in the Owl Creek and Wind River Mountains of west-central Wyoming, show evidence of shallow-water limestones overlain by silty limestones and shales of the basal Dinwoody. At Wind River Canyon, hard, crystalline limestone, containing desiccation cracks within a foot of the top of the unit, is overlain by a highly weathered, chalky limestone bed (about 0.2 foot thick), which becomes argillaceous at the top and apparently grades into a soft, brown, iron-rich shale, containing detrital quartz. The shale is considered to be the base of the Dinwoody.

Contacts at Little Popo Agie Canyon, Red Basin, and Dinwoody Canyon, in the Wind River Mountains, are illustrated in plates 1 and 2. The former shows a change from oolitic limestone to a weathered, crystalline limestone, containing microstyolites that may represent old corrosion surfaces similar to those described by Weiss (1954) in Ordovician limestones, to a covered interval about 1 foot in thickness. Trenching revealed an apparently erosional profile of white, chalky, calcareous material, a thin iron oxide band, then a light brown, thin-bedded shale. The contact is placed between the iron band and the shale. The shale is overlain by a fine silty limestone (pl. 3, figs. 3, 5, 7). The Red Basin section shows a recrystallized oolitic limestone, with weathered, rounded joints, which varies laterally in thickness, overlain by platy limestone, considered to be basal Dinwoody. The characteristic basal silty limestone appears about 4 feet above the contact (pl. 3, fig. 1). At Dinwoody Canyon a recrystallized limestone contains joint fillings of a fine quartz arenite, which also overlies the limestone and is considered to be basal Dinwoody (pl. 3, figs. 6, 8). The sandstone, containing detrital fragments of reworked phosphorite, is about 2 feet thick and is overlain by typical Dinwoody silty limestone.

In summary, in west-central Wyoming, shallow-water limestones at the top of the Permian sequence are generally highly weathered, show local evidence of channel and joint filling, and are lithologically distinct from the overlying beds. The Dinwoody beds are also calcareous but contain significant amounts of detrital quartz and locally reworked Permian fragments. All the sections, except at Little Popo Agie Canyon, show Permian scaphopods and bryozoans within 10 feet of the contact and all but one, Wind River Canyon, contain Triassic bivalves within 10 feet of the contact.

At section 5, Cinnabar Mountain, Montana, quartz sandstone of the upper Shedhorn sandstone is overlain by silty limestones and gypsiferous beds of the lower Dinwoody. Fossils are lacking in the sequence, and the boundary is arbitrarily placed at the top of the sandstones and at the base of a silty limestone which shows intraformational contortions. There is no evidence of discontinuity except for the lithologic break.

At Gros Ventre Canyon, in the Gros Ventre Range (section 6), the upper Permian unit is a cherty arenite questionably referred to the Tosi member of the Phosphoria formation. Petrographically, the rock is a quartz arenite, containing 40 per cent to 50 per cent angular quartz in a cherty matrix. The basal Dinwoody is represented by a 6-inch bed of quartz arenite with calcareous matrix, which is finely conglomeratic and basally contains large grains of detrital chert and phosphorite and finer detrital limestone grains. It is overlain by silty limestones and siltstones containing vertical burrow casts and small gastropods typical of the lower Dinwoody. Wanless (Wanless and others, 1955, pl. 8, fig. 3) illustrates deformed chert cylinders at the top of the Permian sequence, beneath an "unconformable contact" with basal conglomerate of the Dinwoody, at Flat Creek, a few miles south of the Gros Ventre Canyon section.

Sections 7 through 10 in western Wyoming and southeastern Idaho are similar. The Retort member, containing a characteristic and widespread hard, coarse-grained phosphorite bed, tends to cap the Permian sequence. The bed is generally about 1 foot thick and is readily recognizable in the field and in thin section (pl. 3, fig. 4). It has been chosen as the top of the Phosphoria formation by field parties of the United States Geological Sur-

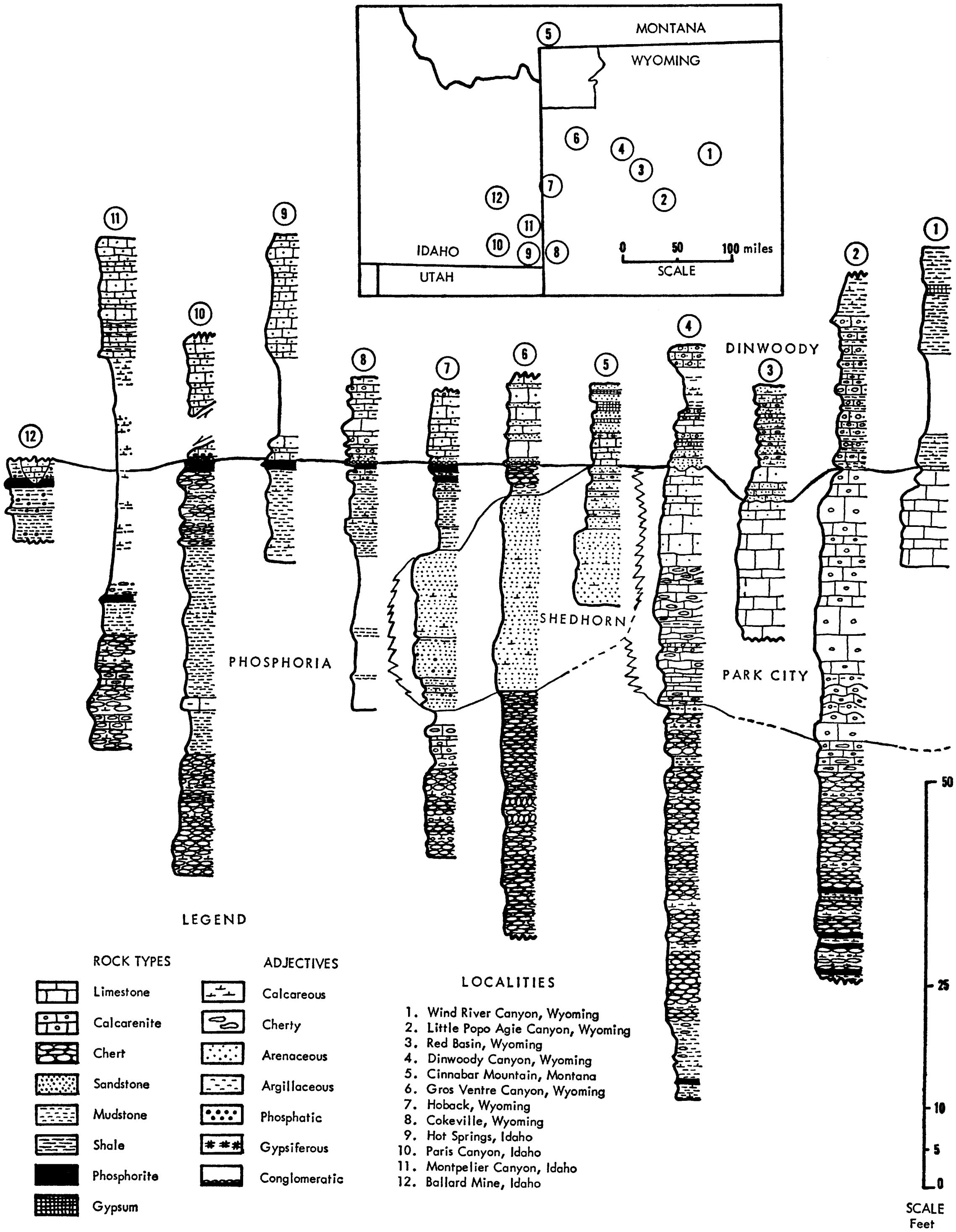

FIG. 4. Stratigraphic sections of Permian-Triassic contact interval in Idaho, Montana, and Wyoming.

vey. Petrographic examination of the bed reveals that it is composed primarily of pellets and large irregular grains of phosphorite, and of smaller grains of detrital quartz, in a cherty or calcareous matrix, or both. The detrital nature of the granular material, and especially the presence of significant amounts of detrital quartz (generally absent in underlying beds), suggests that the bed may be reworked Permian material incorporated in the basal Triassic. However, a productid brachiopod and orbiculoid brachiopods, characteristic of the local Permian, are known from this bed, and its strong chemical affinity with the Permian (high phosphate content), makes it desirable to consider this bed as the top of the Phosphoria formation. This bed is overlain by silty limestones and shales of the basal Dinwoody which, at three localities (Hoback and Cokeville, Wyoming, and Paris Canyon, Idaho) show a basal fine conglomerate of detrital phosphorite, quartz, and chert which transitionally diminishes over an interval of about 1 foot in vertical sequence. Some of the sections show a small amount of microrelief on the hard phosphorite bed. The section at Hot Springs, Idaho (section 9), shows no indication of microrelief or of a basal zone of reworked material but displays a sharp lithologic change and a few detrital phosphorite grains in the basal Dinwoody bed (pl. 3, figs. 2, 4).

At Montpelier Canyon, Idaho (section 11), the phosphorite bed is overlain by beds of the Cherty shale member, and the Permian-Triassic contact is concealed in a covered interval. It is arbitrarily placed between fine-grained limestones, typical of the younger Dinwoody, and a black, calcareous mudstone of the Cherty shale member, revealed in trenching.

The contact interval at Ballard Mine in southeastern Idaho (section 12) is artificially exposed in an old mine pit. Here a hard phosphorite bed is capped by 2.5 feet of dark, calcareous mudstone containing a small amount of detrital phosphorite. This unit is truncated by artificial grading. The dark carbonaceous and phosphatic beds are cut centrally by a channel containing thin-bedded, gray, silty limestone of typical Dinwoody lithology. The channel cuts through both the mudstone and phosphorite beds and into the underlying strata (pl. 2, fig. 1). The contact of the channel fill and underlying rocks is generally obscured by deformation of the soft, weathered, Permian beds.

In summary, the evidence of disconformity in the western Wyoming-southeastern Idaho area is generally that of a sharp lithologic change and local evidence of reworked Permian grains often concentrated in a basal conglomerate. It seems reasonable that the hard phosphorite bed, which caps the Permian over a wide geographic area, may represent a former erosional surface developed after a withdrawal of marine seas at the close of Permian deposition. Late Permian weathering and erosion produced local channels and microrelief features on a broad, relatively flat surface of considerable areal extent. The transgressing early Triassic sea then incorporated resistant, detrital pebbles and fragments in the basal deposits of the Dinwoody formation. The lack of recognition of consistent evidence of relief on a widespread surface of this type is not surprising when it is realized that exposures of the contact in this area are extremely rare and are generally limited to a few feet in lateral extent. Fossils are generally rare in the contact interval of this region, but *Claraia* has been found in Dinwoody beds within a few feet of the contact at Paris Canyon, Idaho (section 10).

The contact has not been studied in detail by the writer in other areas of southern Montana or in northern Utah. In Utah the Dinwoody thins rapidly toward the south and intertongues with the Woodside formation. In the southern Wasatch Mountains the Woodside is separated from the Permian by an angular unconformity and bevels nearly 2000 feet of Permian strata in a horizontal distance of 10 miles (Baker and Williams, 1940). Cressman (1955) comments that, in Montana, the lithologic break between the Permian and Triassic rocks is generally abrupt. Locally, however, near Lima, Montana, the change seems more gradational. Cressman states that varieties of quartz and heavy mineral suites are similar in the Dinwoody and Shedhorn formations, a fact that no doubt reflects the similar general paleogeographic pattern that influenced deposition throughout the Permian and extended into the Triassic. R. W. Swanson (United States Geological Survey) has shown the writer an exposure at Jefferson Canyon, Montana, where the Ellis formation of Jurassic age overlies the Permian Shedhorn sandstone without evidence of angular discordance, weathering, or erosion at the contact. The Dinwoody is absent either because of erosion or non-deposition, in any case implying a considerable hiatus. This case illustrates the known, but frequently overlooked, fact that parallelism of strata, displayed throughout most of the Permian-Triassic sequence of the Middle Rockies and in other places (Pakistan and east Greenland) and between many known discontinuous sequences throughout the geologic column, does not demonstrate conformity. Newell (1962) has suggested that it is a good working hypothesis to consider any stratigraphic sequence as discontinuous unless faunal or lithologic evidence can demonstrate continuity.

The Permian-Triassic boundary in the Middle Rockies is thus represented by a widespread paraconformity on rocks of upper Permian age. This same general relationship persists throughout much of the Colorado Plateau and eastern Basin-Range region of the western United States, which show a generally similar distribution of Permian and Triassic rocks. Baars (1962), in a comprehensive study of the Permian system of the Colorado Plateau, discusses the regional unconformity at the top of the Permian. A hiatus that involves the upper half of the Permian and a part of the Lower Triassic is indicated by faunal evidence. Physically, the Permian-Triassic boundary is characterized by irregular upper Permian surfaces and basal Triassic conglomerates, with only local angular discordance. In some areas, such as the Mogollen Plateau, the top of the Permian is essentially a smooth, planar surface. Baars states that the amount of uplift and erosion was not great, was generally the result of epeirogenic uplift, and that arid climatic conditions permitted the preservation of Permian evaporites and erosional irregularities beneath the unconformity.

SUMMARY

The physical history of the Permian-Triassic sequence can be summarized in terms of the regional relationships of the strata and local evidence at individual localities. Both Ervay and Dinwoody marine strata pinch out eastward and southward and intertongue with non-fossiliferous, presumably non-marine beds of the Chugwater-Woodside-Goose Egg formations. Movements of the strand line are indicated by the intertonguing beds. The proximity to the strand line and the physical evidence of shallow-water seas are indicated by oolitic carbonates locally containing desiccation cracks, in the Ervay member, and by evaporites in the lower Dinwoody. The influx of terrigenous sands from the north suggests proximity to a source area in southern Montana (Sheldon, 1957) which may have persisted into Dinwoody time. Westward, the Permian and Triassic marine units each thicken from several hundred feet, in west-central Wyoming, to about 2000 feet in southeastern Idaho. (These rocks eventually disappear under a thick sequence of Tertiary volcanic deposits of the Snake River Plain of south-central Idaho.) The lithologic character of the upper Permian beds changes toward the west from limestone to chert, phosphorite, and mudstone, presumably reflecting increasing water depth (McKelvey and others, 1959).

An examination of the contact of the Permian and Triassic beds at many places reveals evidence of disconformity, predepositional weathering, channeling, and the reworking of sediments. Thus, in addition to the faunal evidence, field and petrographic observations suggest a complete regression of the Permian seas, a period of emergence and erosion, then subsequent transgressive overlap, with deposition on a relatively flat, paraconformable surface in the early Eotriassic. Only the parallelism of strata above and below the contact supports the concept of continuous deposition, and this alone is known to be an inadequate criterion.

SYSTEMATIC PALEONTOLOGY

PERMIAN BIVALVES

FAMILY CTENODONTIDAE

PALEONEILO HALL, 1870

Paleoneilo mcchesneyana (Girty)

Plate 4, figures 12–16

Yoldia mcchesneyana GIRTY, 1910, p. 39, pl. 4, figs. 4–6.

Nucula mcchesneyana, C. C. BRANSON, 1948, p. 631.

DISCUSSION: This species is characterized by fairly prominent, posteriorly placed beaks, ovate configuration, and nearly smooth surface.

The species cannot be placed with *Yoldia* because the valve margins do not gape. The nearly straight and apparently continuous dentition, shown by a small internal mold with a configuration much like Girty's holotype, suggests that these forms lacked a resilifer and had an external ligament. Accordingly, the species cannot be identified with *Nuculopsis*, but seems to possess the generic characters of *Paleoneilo*.

Similar, but specifically distinct forms occur in the Word formation of West Texas.

MEASUREMENTS (IN MM.), BIVALVED SPECIMENS:

	H	L	C
Holotype	4.8	7.6	2.8
	4.7	7.3	3.5
	7+	10.5	5.0
	2.1	2.9	2.0

OCCURRENCE: Girty reports the species from the Meade Peak member at Thomas Fork, Wyoming, and Montpelier, Idaho. Present collections contain specimens common in the Meade Peak at Raymond Canyon, Wyoming; abundant in the Grandeur member at Mud Spring, Idaho; and questionably identified in rare occurrences in the Meade Peak at Layland Canyon, Wyoming, and Trail Canyon, Snowdrift Mountain, and West Dairy, Idaho.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 1705; hypotype, U.S.N.M. No. 140457.

Paleoneilo? parviradiatus Ciriacks, new species

Plate 4, figures 7–11

DESCRIPTION: Shell gibbose, ovate-elongate, height/length ratio about 3/5, relatively flat, convexity about one-half of shell height; beaks low, strongly prosogyre, located about one-fifth of shell length behind anterior extremity; anterior and posterior margins the same height, broadly rounded, passing uniformly into a very slightly convex ventral margin, dorsal margin nearly straight behind beaks, then concave upward to anterior margin; lunule and escutcheon well defined, lunule short and deep, escutcheon elongate, slender, bounded by an angulation of the postumbonal shell leading to posterodorsal margin; ligament opisthodetic, extending back about one-half of length of escutcheon; surface ornamentated with fine, closely spaced, concentric fila, and about 12 to 15 very faint, but distinct, radiating grooves restricted to anterior half of shell and best developed near the ventral margin; internal features unknown.

MEASUREMENTS (IN MM.), BIVALVED SPECIMENS:

	H	L	C
Holotype	8.5	13	4.5
Topoparatype	6.0	10	3.0

DISCUSSION: The species is represented by two silicified bivalved specimens. The external morphological features, including the ligament, are beautifully preserved. *Paleoneilo? parviradiatus* is characterized and distinguished from all known species of *Paleoneilo* by subdued, anteriorly placed beaks, well-defined lunule and escutcheon, and especially by the faint radial grooves on the anterior region of the shell. Although the internal morphology is unknown and intraspecific variability cannot be presently assessed, the distinctive external features permit the designation of a new species.

The generic placement of the species is extremely difficult. It cannot be closely compared to other late Paleozoic or Mesozoic forms known to the writer. It is questionably assigned to *Paleoneilo* because of a superficial resemblance to undescribed forms of the genus from the basal Word formation in West Texas. The forms are alike in size and general configuration, but the West Texas specimens do not possess a well-defined lunule and show no indication of radial ornamentation.

The species is also generally similar to species of *Unionites*, a common Triassic genus, in size and general shape. The opisthodetic ligament and well-defined escutcheon are common to many heterodont bivalves, which suggests the affinity of the species with forms very distantly separated from *Paleoneilo*. The classification of the species cannot be determined until the internal features are made known.

OCCURRENCE: The two specimens are from the Franson member near the Coulter Ranger Station in northern Utah.

CATALOGUED SPECIMENS: Holotype, U.S.-N.M. No. 140458; topoparatype, U.S.N.M. No. 140459.

FAMILY **NUCULIDAE**

NUCULOPSIS GIRTY, 1911

DISCUSSION: Schenck (1934, p. 30) has indicated that the original designation of the genus *Nuculopsis* was based on erroneous observations which indicated that forms of this group possessed a continuous taxodont dentition and thus an external ligament. The name was retained, however, because it is the first name applied to nuculids with a smooth ventral margin. (The genus *Nucula* possesses a crenulate margin.)

The genotype of *Nuculopsis* is *Nucula ventricosa* Hall, 1858 (*non* Hinds, 1843) = *Nuculopsis girtyi* Schenck, 1934. Schenck designated *Paleonucula* Quenstedt as a subgenus of *Nuculopsis*, but stated that the subgenotypic species, "*Nucula*" *hammeri*, is very similar to *N. girtyi*, differing only in that the former is less opisthogyrate. An examination of Schenck's illustrations of the two subgenotypic species (Schenck, 1934, pl. 2, figs. 19, 20) shows that they possess a very similar subrectangular configuration, with beaks located near the posterior extremity.

Upper Paleozoic rocks frequently contain nuculids that have a smooth ventral margin and dentition like those of *Nuculopsis* but that are subtrigonal in shape, have more centrally placed beaks, and are generally less globose than the forms repesented by the two subgenotypic species discussed above. A representative of the subtrigonally shaped nuculids is the form described as *Paleonucula levatiformis* (Walcott) from the middle Permian of the southwestern United States (see H. Chronic, 1952, pl. 6, figs. 4–9).

Nuculids in the present collection fall into two broad morphological categories, subrectangular and subtrigonal, with one form, *Nuculopsis* sp. c, having a configuration somewhat intermediate between the more extreme forms. The more elongate, subrectangular forms, with posteriorly placed beaks, are collectively treated as group I of *Nuculopsis*. The generally smaller, subtrigonal forms, with more centrally placed beaks, are designated as group II of *Nuculopsis*. The internal structures of available specimens are generally not shown, and the preservation is poor, which make it undesirable to define new subgeneric categories or to modify the existing classification. A detailed study of the well-preserved WestTexas Permianfauna will better show the degree of variability and intergradation within the nuculids and permit a more meaningful classification of the group.

GROUP I

Nuculopsis sp. **a**

Plate 4, figures 17, 18, 23

DISCUSSION: Two specimens of a highly inflated, elongate, subrectangular form are designated as *Nuculopsis* sp. a. The thin shell is ornamented with subdued, in some cases thickened, concentric fila. The beaks are located very near the posterior extremity. Internal structures are not known.

The larger specimen is 11.5 mm. long, 9.5 mm. high, and has a convexity of 6 mm.

Closely similar described species of *Nuculopsis* are unknown to the writer. A new species is not designated because the internal features are unknown, and the nature of variability, especially important in the diagnosis of nuculids, cannot be presently determined. Closely comparable undescribed forms occur in the Word Number 1 limestone of West Texas.

OCCURRENCE: The two bivalved specimens are from the Meade Peak member at Waterloo, Idaho.

CATALOGUED SPECIMEN: Hypotype, U.S.-N.M. No. 140460.

Nuculopsis sp. b

DISCUSSION: Five poorly preserved, bivalved, silicified specimens, from a single locality, cannot be identified with other known species of *Nuculopsis*. Characteristic features of the forms are the relatively great height and the very prominent, strongly opisthogyrate beaks. The surface ornamentation consists of a few coarse concentric fila on the ventral third of the shell, either absent or not preserved dorsally.

The species generally resembles *N. poposiensis* and may be a variant of that species, but it differs in having a greater relative height, slightly more prominent beaks, and a more rectangular lateral profile. From *N.* sp. a the present form differs in having prominent beaks and in being considerably less elongate.

A typical specimen is 9.0 mm. high, 8.0 mm. long, and has a height/length ratio of 1.19 and a convexity of 5 mm.

OCCURRENCE: The five specimens are from the Grandeur member at Mud Spring, Idaho.

Nuculopsis sp. c

Plate 4, figures 19–22

DISCUSSION: Included in this species are relatively inflated, subtrigonal to subrectangular forms with posteriorly placed beaks and relatively coarse, raised concentric fila numbering four or five per millimeter near the posteroventral angle. The configuration is variable in this group, the height/length ratio varying from 0.7 to 0.82. One internal mold, with part of the shell preserved, shows a relatively wide, smooth, marginal shelf and a prominent anterior adductor muscle scar. Dentition and internal features are unknown.

Relatively shorter, subtrigonal specimens are restricted to the Meade Peak member, where they occur in association with *N. montpelierensis*. More elongate specimens occur in association and appear to intergrade with shorter specimens in the Meade Peak but occur as isolated forms in the Retort member.

Although some of the forms here grouped appear as though they could be elongate variants of *N. montpelierensis*, the latter differs in having narrower, well-defined umbones, a more centrally placed beak, and finer surface ornamentation. In addition, internal molds of *N. montpelierensis* do not display the prominent marginal shelf and anterior adductor scar of the present species. *Nuculopsis poposiensis* differs in having a considerably greater relative height and finer, more irregular surface ornamentation.

OCCURRENCE: Forms here included are common in the Meade Peak member at Trail Canyon, Idaho; rare in the Meade Peak at Cokeville and Wheat Creek, Wyoming, and Hot Springs, Mabie Canyon, and Kendall Canyon, Idaho; rare in the Retort member at Cedar Creek, Little Water Canyon, and Sheep Creek, Montana; and questionably identified in the Meade Peak at Woodall Creek and Swan Lake, Idaho.

TABLE 10

MEASUREMENTS (IN MILLIMETERS) OF BIVALVED SPECIMENS OF *Nuculopsis* SP. C

H	L	H/L	C
14.0	20.0	0.70	10
11.5	14.0	0.82	7+
10.0	14.0	0.71	7
10.0	13.0	0.77	6
9.5	13.0	0.73	6
9.5	11.5	0.74	6
7.0	9.0	0.78	5

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140461–140463.

GROUP II

Nuculopsis montpelierensis (Girty)

Plate 4, figures 24–27

Nucula montpelierensis GIRTY, 1910, p. 38, pl. 4, figs. 1–3.

Nucula montpelierensis, C. C. BRANSON, 1930, p. 42, pl. 10, figs. 7–9.

DISCUSSION: This species can be differentiated from closely related forms by the presence of rounded umbonal ridges which define narrow, highly inclined slopes between the main shell body and the dorsolateral margins. The concentric ornamentation, consisting of somewhat regularly alternating coarse and fine concentric fila, is also distinctive. Relative dimensions, such as height/length ratio, may be useful in the identification of internal molds but cannot be used exclusively because of the apparently high variability in configuration and thus overlap among several common species of *Nuculopsis*. Present knowledge of the internal structures and dentition is inadequate, based only on observations of the internal molds.

The holotype of *N. montpelierensis* is 7 mm. long, 6.5 mm. high, and has a convexity of about 3 mm.

Nuculopsis montpelierensis is probably closely related to "*Paleonucula*" *levatiformis*, from the middle Permian of the southwestern United States (Girty, 1910, p. 38). The two forms may be variants of a single species. *Nuculopsis montpelierensis* appears to intergrade in configuration with *N. poposiensis*, making separation of the internal molds very difficult. Well-preserved specimens of *N. poposiensis* are more highly convex, lack the umbonal ridges, and have more irregular concentric ornamentation than does *N. montpelierensis*.

OCCURRENCE: This species has been identified from the Meade Peak member at Montpelier Canyon, Trail Canyon, Hot Springs, Waterloo, East Georgetown, and Kendall Canyon, Idaho, and Coal Canyon, Wyoming. Branson reports the species as abundant in the Franson member in the Wind River Mountains, Wyoming, but internal molds of this horizon are specifically unidentifiable.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 1700; hypotype, U.S.N.M. No. 140464.

Nuculopsis montpelierensis? (Girty)

Plate 4, figures 28, 29

DISCUSSION: A few silicified specimens from the Grandeur member are referred to *N. montpelierensis* which is common in the overlying Meade Peak member. The external features, generally poorly preserved, indicate that present forms are more equilateral and lack the fairly distinct umbonal ridges of *N. montpelierensis*. However, the relative dimensions and surface ornamentation appear to be very similar in the two forms. The internal characters, unknown in *N. montpelierensis*, reveal a dentition of about 20 teeth on large individuals, about eight posteriorly and 12 anteriorly. The resilifer is deep and subtrigonal. The adductor muscle impressions are circular, with the anterior pit being slightly deeper and bounded above by a slight buttress.

TABLE 11

MEASUREMENTS (IN MILLIMETERS) OF *Nuculopsis montpelierensis?* (GIRTY)

H	L	H/L	C
9.0	11.0	0.82	6
7.0	8.5	0.82	4
6.5	7.0	0.93	4
6.0	7.5	0.80	5

The dentition is suggestive of *N. poposiensis* and, in some smaller forms, "*Paleonucula*" *levatiformis*, which indicates a close relationship between these common middle Permian species.

OCCURRENCE: These forms are common in the Grandeur member at Mud Spring, Idaho.

CATOLOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140465, 140466.

Nuculopsis poposiensis (Branson)

Plate 4, figures 30–33

Nucula poposiensis C. C. BRANSON, 1930, p. 42, pl. 10, figs. 1–6.

Nucula pulchella, C. C. BRANSON, 1930, p. 43, pl. 10, figs. 12–14.

Nuculopsis? poposiensis, SCHENCK, 1939, p. 24.

DISCUSSION: Widely varying morphological forms are assigned to *N. poposiensis* on the basis of their common occurrence, and because Branson's syntypes and description of the species indicate high variability. One of the syntypes (pl. 4, fig. 31, this report), here designated the lectotype, is a specimen in which the shell is preserved. It has a height/length ratio of 1.00 and a convexity equal to about two-thirds of the shell height. A second syntype, an internal mold, has a height/length ratio of 0.85 and is distinctly less convex. The configuration of the species, based on the two syntypes from the same horizon and locality, thus varies from relatively short and robust to more elongate and flattened. Additional occurrences of forms resembling the syntypes generally show either the presence of only one morphological type, or the occurrence of forms that fall near the ends of the two morphological extremes indicated above. Very few transitional forms are present. Although two natural groups may be represented here, generally poor preservation and the common occurrence of these forms make it desirable to include all the specimens in a single species.

TABLE 12

MEASUREMENTS (IN MILLIMETERS) OF *Nuculopsis poposiensis* (BRANSON)

	H	L	H/L	C
	9.5	11.2	0.85	4.5 (mold)
	9.5	9.0	1.06	—
	9.5	9.0	1.06	—
	9.0	10.0	0.90	—
Lectotype	8.5	8.4	1.00	5.5
	6.0	7.0	0.86	3.5 (mold)
	5.5	5.5	1.00	—
	4.5	5.0	0.86	—

Branson's hypotype of *Nucula pulchella*, from the same horizon and locality as the types of *N. poposiensis*, is included in the later species because it is specifically unrecognizable and falls within the broad morphological limits of *N. poposiensis*.

Specimens that retain the shells can be distinguished from *N. montpelierensis* by the lack of umbonal ridges and the presence of coarser, more irregular, concentric fila. Two very small specimens have hinges very similar to the hinge of *Paleonucula levatiformis* but do not show external concentric fila. Halka Chronic (1952, p. 6, figs. 5b, 6a, 7–9) illustrates specimens of *Paleonucula levatiformis* that show a wide range in configuration. Apparently *N. montpelierensis*, *N. poposiensis*, and *Paleonucula levatiformis* are highly similar and show considerable morphological overlap. The true relationships, however, cannot be presently evaluated because of the generally poor preservation of available material.

OCCURRENCE: Silicified specimens are abundant in the upper member of the Shedhorn sandstone at Alpine Creek, Montana; common in the Grandeur member at Willow Creek, Wyoming; and rare in the Retort member at Deadline Ridge, Wyoming; Branson's types are from the Franson member at Big Popo Agie Canyon, Wyoming. Internal molds questionably identified as *N. poposiensis* are extremely abundant in the Retort member at Dinwoody Canyon, Wyoming; rare in the Retort at Steer Creek, Wyoming, and in the cherty shale member at Hidden Pastures, Montana. In addition, Branson reports the species from the Franson member and questionably the Meade Peak member throughout the Wind River Mountains, Wyoming.

CATALOGUED SPECIMENS: Lectotype, U.M. No. 5277; hypotypes, A.M.N.H. No. 28307, U.S.N.M. No 140467.

FAMILY NUCULANIDAE

POLIDEVCIA TSCHERNYSCHEW, 1943 (NUCULANA LINCK, 1807, IN PART)

Polidevcia bellistriata (Stevens)?

Plate 4, figures 4–6

Leda bellistriata, C. C. BRANSON, 1930, p. 43, pl. 10, figs. 15–20.

Nuculana bellistriata, C. C. BRANSON, 1948, p. 633.

DISCUSSION: A few internal molds of a small, elongate form are confidently identified as the same species described by Branson. Prominent adductor muscle impressions, the anteriorly located, prosogyre beaks, and especially the small size distinguish this form from *P. obesa*. The details of surface ornamentation and dentition are not known.

A fairly large specimen is 9.5 mm. long, 5.5 mm. high, and has a convexity of about 2 mm. Branson refers to "typical specimens of *Leda bellistriata*" which attain a length of 25 mm., but specimens of this size were not illustrated and have not been observed by the writer. The species is based on a Pennsylvanian form.

OCCURRENCE: *Polidevcia bellistriata* is rare in the Retort member at Big Popo Agie Canyon and Dinwoody Canyon, Wyoming; rare in the Grandeur member at Bull Lake, Wyoming; and rare in the Franson member at Blue Holes Canyon, Wyoming. Branson reports the species from the Retort and Meade Peak members in Wyoming and the Rex member at Fort Hall, Idaho.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28306.

Polidevcia obesa (White)

Plate 4, figures 1–3

Nuculana obesa WHITE, 1879, p. 216.

Leda obesa, GIRTY, 1910, p. 40, pl. 4, figs. 7, 8.

Leda obesa, C. C. BRANSON, 1930, p. 43, pl. 10, figs. 21, 22.

Nuculana obesa, H. CHRONIC, 1952, p. 137, pl. 6, figs. 1a–3.

DISCUSSION: Poorly preserved internal molds of this widespread Permian species are common in southeastern Idaho and adjacent regions. A few silicified specimens differ from the molds in lacking a midumbonal depression on the external surface, but there is an apparent trace of this feature on the internal surface of the shell.

A typical right valve is 31 mm. long, 18 mm. high, has a convexity of about 6 mm., and is ornamented by about 50 regularly spaced concentric fila. The specimen has about 18 anterior and 16 posterior teeth.

A closely related species, *P. speluncaria*, from the Upper Permian of Greenland, the Zechsteinian of Germany, and the Kazanian of Russia, is distinctly smaller than *P. obesa*, but is otherwise similar in shape and ornamentation (Newell, 1955, p. 17).

OCCURRENCE: *Polidevcia obesa* is widespread and common to locally abundant in the Meade Peak member and has been positively identified from every member in the Park City, Phosphoria, and Shedhorn formations. Occurrences in members other than the Meade Peak are relatively rare, however, and generally restricted to one or two localities.

The species is also common in the Kaibab and San Andres formations of the southwestern United States.

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140468, 140469.

FAMILY **SOLEMYIDAE**

SOLEMYA LAMARCK, 1818

Solemya sp.

Plate 5, figures 12, 13

Solenomya radiata?, C. C. BRANSON, 1930, p. 41, pl. 9, figs. 21, 22.

DISCUSSION: A reëxamination of Branson's hypotype fails to show any indication of surface ornamentation. Thus the specimen is insufficiently preserved for specific identification. It possesses the general configuration of *Solemya* and may be tentatively assigned to that genus.

OCCURRENCE: Branson's hypotype is from the Ervay member near Cody, Wyoming. An additional specimen in the present collection is from the same horizon at Burroughs Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, U.M. No. 5275.

FAMILY **PARALLELODONTIDAE**

PARALLELODON MEEK, 1866

Parallelodon cf. **multistriatus** Girty

Plate 5, figure 11

Parallelodon multistriatus GIRTY, 1908, p. 423, pl. 31, figs. 13–14a.

DISCUSSION: A few internal molds of left valves from a single occurrence are referred to Girty's West Texas Capitanian species. Valves are small and elongate; dorsal and ventral margins are essentially parallel; beaks are prosogyre, extending over the hinge line. There is a fairly prominent postumbonal ridge leading toward the posteroventral angle. The surface ornamentation consists of about five widely spaced concentric growth lines and evenly spaced radiating costae, numbering about three per millimeter at the ventral margin. The costae are interrupted by growth lines and are individually discontinuous. That the costae become faint and disappear toward the anterior and posterior margins may be a result of poor preservation.

A nearly complete left valve is 16.5 mm. long and 7.5 mm. high.

The forms at hand differ from Girty's species (described on the basis of a few incomplete specimens) in being slightly more coarsely ornate. The West Texas forms appear to have about five costae per millimeter; the present forms have three. However, similarity in size, general configuration, and concentric ornamentation indicate a close relationship between the Texas and Wyoming forms. They are probably variants of the same, still poorly known species.

OCCURRENCE: *Parallelodon* cf. *multistriatus* has been found only at Dinwoody Canyon, Wyoming, where it occurs rarely in the Ervay member.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28311.

Parallelodon? sp.

Plate 5, figure 9

Allerisma sp., C. C. BRANSON, 1930, p. 51, pl. 14, figs. 4, 5.

DISCUSSION: Two internal molds of an elongate, inequilateral bivalve are questionably assigned to *Parallelodon* on the basis that one of the specimens bears impressions of what may be lateral sockets near the posterior end of the cardinal margin. As Branson points out, these specimens are somewhat like *Wilkingia wyomingensis* (Branson) in shape and the possession of a midumbonal depression. However, they are considerably smaller than the latter species, and do not show evidence of a posterior gape.

A nearly complete mold of a left valve is 40 mm. long, 17 mm. high, and has a convexity of 6 mm.

OCCURRENCE: Branson's hypotypes are from the Grandeur member at Bull Lake, Wyoming. He reports the species from the Grandeur member in the Wind River Mountains, Wyoming, but additional specimens have not been found in subsequent collecting.

CATALOGUED SPECIMEN: Hypotype, U.M. No. 5322.

FAMILY **MODIOLOPSIDAE**

GONIOPHORA PHILLIPS, 1848

Goniophora? sp.

Plate 5, figure 8

DISCUSSION: A single silicified left valve of a small, elongate bivalve is assigned to the predominantly Carboniferous genus *Goniophora*. The lateral profile is subquadrate. A sharp, angular, umbonal ridge leads to the posteroventral angle. The shell surface is ornamented with a few irregularly spaced, concentric, growth lines. The dentition and hinge characters are not preserved.

The specimen bears a superficial resemblance to *Paleomutela trapezoidalis* Amalitzky from the Russian Permian. It is quite unlike the Kaibab form *G. cristata* Chronic.

OCCURRENCE: The single specimen is from the Ervay member at Tosi Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28310.

Family **MYALINIDAE**

MYALINA DE KONINCK, 1844

Myalina (Myalina) sinuata Branson

Plate 5, figures 17, 18

Myalina sinuata C. C. BRANSON, 1930, p. 45, pl. 12, fig. 1.

Myalina (*Myalina*) *sinuata*, NEWELL, 1942, p. 56, pl. 6, figs. 4, 5.

DISCUSSION: Some very large, highly convex, internal molds of myalinid bivalves are identified as *M.* (*M.*) *sinuata*. The holotype has been lost, and good specimens are extremely rare. The species is thus poorly known, but the specimens at hand are very similar to Branson's illustration of the holotype and are undoubtedly members of this distinctive species.

Newell (1942, p. 56) has suggested that the configuration of this species is similar to the Wolfcampian form *M.* (*M.*) *pliopetina* and that the two forms differ primarily in the high convexity of *M.* (*M.*) *sinuata*. Available specimens confirm Newell's observations. In addition, *M.* (*M.*) *sinuata* is considerably more acline than *M.* (*M.*) *pliopetina*.

A relatively complete specimen, here designated the neotype, has a length in excess of 60 mm., a height of 82 mm., and a greatest dimension of about 85 mm. Other fragmentary specimens have a greatest dimension in excess of 110 mm. and a convexity of about 40 mm. of occluded internal molds.

The ontogenetic changes and variability within the species are poorly known, which makes recognition of smaller individuals and juveniles extremely difficult.

OCCURRENCE: Large individuals are common in the Ervay member at Little Dry Creek, Wyoming. Branson's holotype was from the Ervay member at Bull Lake, and smaller, poorly preserved forms from the Ervay at Bull Lake, Bargee, and South Fork Canyon, Wyoming, are questionably identified as *M.* (*M.*) *sinuata*.

The species also occurs in the upper Kaibab formation of northern Arizona.

CATALOGUED SPECIMENS: Neotype, A.M.-N.H. No. 28312; hypotype, A.M.N.H. No. 28313.

Myalina (Myalina) cf. **wyomingensis thomasi** Newell

Plate 5, figures 14, 19, 20

Myalina (Myalina) wyomingensis thomasi Newell, 1942, p. 51, pl. 14, figs, 15, 16.

Discussion: Three poorly preserved internal molds and a few incomplete silicified valves of a relatively oblique myalinid are referred to a subspecies described by Newell, which occurs at the base of the Satanka shale (possibly equivalent to the Grandeur member in age) in central Wyoming. The size, general configuration, and measurements of angle α fall within the limits of *M.* (*M.*) *wyomingensis thomasi.*

The specimens at hand have a greater relative length and a sharper, obtuse, posterodorsal angle than the originally described forms. The present forms occur at a higher horizon than the Satanka subspecies, but they are undoubtedly closely related.

TABLE 13

Measurements (in Millimeters) of *Myalina* (*Myalina*) cf. *wyomingensis thomasi* Newell and Comparison with the Original Hypodigm of the Subspecies

	H	L	GD	Angle α
Lt	43	52	64	53°
Lt	43	46	60	65°
Lt	—	40	—	62°
Rt	45+	57	65+	53°
Average values of subspecies[a]	43	47	56	55°

[a]Taken from Newell (1942, p. 48).

Occurrence: Three internal molds occur in association with *M.* (*M.*) *sinuata* in the Ervay member at Little Dry Creek, Wyoming. The fragmentary silicified specimens are from the Franson member at Washakie Reservoir, Wyoming.

Catalogued Specimens: Hypotypes, A.M.-N.H. Nos. 28314/1:1, 28314/1:2, 28314/2.

Myalina (Myalinella) meeki Dunbar

Plate 5, figures 15, 16

Myalina meeki Dunbar, 1924, p. 201, fig. 3.
Myalina (*Myalinella*) *meeki*, Newell, 1942, p. 60, pl. 14, figs. 7–14.

Discussion: This long-ranging species is characterized by a distinctive angle α. Other important features include a nearly straight umbonal ridge, a greatly reduced anterior lobe, a slightly smaller right valve, and a relatively smooth shell surface. A nearly complete left valve, displaying these characters, has dimensions similar to the average values of representative members of the species (taken from Newell, 1942, p. 61).

Comparative Measurements (in Mm.):

	Lt	Average Values
H	30	22
L	32	26
GD	41	33
Angle α	45°	43°
Angle β	128°	127°

Occurrence: *Myalina* (*M.*) *meeki* is represented by two specimens, one with occluded valves, from the Tosi member at Hogback, Montana.

Newell (1942, p. 16) shows that this species ranges from the Desmoinesian into the Leonardian. The present occurrence suggests that it extended into the Guadalupian. A similar form referred to this species is reported by Newell (1955, p. 26) from the Lower Triassic of Greenland.

Catalogued Specimen: Hypotype, U.S.-N.M. No. 140470.

Family **BAKEVELLIIDAE**

BAKEVELLIA King, 1848

Bakevellia? sp.

Plate 5, figure 10

Discussion: A few internal molds and poorly preserved valves show a configuration suggestive of the common Permian genus *Bakevellia.* A left valve shows a very strong forward obliquity, a moderately extended anterior auricle, and a relatively small posterior auricle. The specific affinities of the available material cannot be determined.

Occurrence: Included in this group are rare occurrences in the Franson member at Fontenelle Creek, Crystal Creek, and Gros Ventre Canyon, Wyoming, and in the Grandeur member at Bear Creek, Idaho.

Catalogued Specimen: Hypotype, U.S.-N.M. No. 140471.

Family CASSIANELLIDAE

CASSIANELLA Beyrich, 1862

Cassianella sexradiata (C. C. Branson)

Plate 5, figures 5–7

Cyrtorostra sexradiata C. C. Branson, 1930, p. 45, pl. 11, figs. 13–15.

Description: Left valves small, highly convex, slightly higher than long; beaks narrow, orthogyre to slightly prosogyre, extended beyond and curving down over hinge; anterior auricle large, ornamented by a prominent ridge which meets the hinge line obliquely, separated from the shell body by a deep sulcus; posterior auricle relatively large and smooth except for fine concentric fila, separated from shell body by angulation formed by posteriormost shell costa; hinge line equal to or slightly exceeding shell body length; shell ornamented with six raised, radiating costae which are separated by deep, broad depressions; closely spaced concentric fila are conspicuous in depressions where they are arched dorsally, then bent ventrally at junctions with costae; right valves and internal characters unknown.

The largest and most complete specimen is 9.5 mm. high, 8 mm. long, and has a half convexity of 3 mm.

Discussion: This species bears generic characters of the predominantly Triassic genus *Cassianella* and is unlike known forms of the genus *Cyrtorostra*. Similar but specifically distinct, undescribed forms occur in the Wordian of West Texas. Also similar is the South American species *Aviculopecten crassispinosus* J. Chronic, which is highly unlike other known species of *Aviculopecten* and should probably be assigned to *Cassianella*. By comparison with these forms, the present species is characterized by its small size and its decussate ornamentation.

Occurrence: *Cassianella sexradiata* is represented by only three left valves, from Branson's original collection, which occur in the Ervay member at Bull Lake, Wyoming. Branson reports the species from the Ervay member in the Wind River Mountains, Wyoming, but subsequent collecting has not revealed additional specimens.

This occurrence, the other two New World occurrences discussed above, and a questionable occurrence of *Cassianella* in the Permian of Italy (Gortani, 1906) indicate that the known range of the genus extends back into the Permian, probably at least as far as the base of the Upper Permian.

Catalogued Specimens: Holotype, U.M. No. 5299; topoparatype, U.M. No. 5299:1.

Family PINNIDAE

AVICULOPINNA Meek, 1867

Aviculopinna sp. **a**

Plate 5, figures 1, 2

Discussion: Poorly preserved and incomplete internal molds of an aviculopinnid are locally abundant at a single locality. Neither the anterior or posterior margins are preserved. Thus the total configuration, the nature of the beaks, and the internal features of these forms are unknown. A fairly complete specimen shows an estimated divergence of about 13 degrees between the dorsal and ventral margins. If the margins are extended anteriorly to an apex, this specimen would have a length of about 70 mm.

Highly characteristic of these forms is the surficial ornamentation which shows a peculiar, irregularly corrugated surface. This may be a post-mortem deformational feature, but the regularity with which it occurs, associated non-distorted fossils, and the fact that the corrugations are best developed posteriorly and near the dorsal margin of the valves suggest that this feature is truly reflective of the original shell sculpture. One right valve shows poorly developed concentric growth lines. A fine cross-hatched pattern exists near the ventral margin where the growth lines intersect the corrugations. The latter generally trend obliquely, at high angles to the ventral and dorsal margins.

Aviculopinna sp. a differs from *A.* sp. b, with which it is associated, in having the corrugated surface and in diverging posteriorly more uniformly and at a lower angle. It cannot be closely compared with other species known to the writer. A new species is not designated because of the poor quality of available material.

Occurrence: The forms are abundant in a single bed of the Tosi member at Bull Lake, Wyoming.

Catalogued Specimens: Hypotypes, A.M.N.H. Nos. 28308:1, 28308:2.

Aviculopinna sp. b

Plate 5, figures 3, 4

DISCUSSION: A few incomplete internal molds and fragments occur associated with the form described above as *A.* sp. a. The present forms differ in being considerably flatter, diverging less uniformly and at a higher angle (estimated at 19°), and in lacking the corrugated surface ornamentation. Forms of *A.* sp. b are nearly smooth but show faintly developed growth lines which emerge nearly parallel to the ventral border, then bend sharply and run across the shell body, terminating essentially perpendicular to the dorsal margin. One external mold shows a slight corrugation effect on the posterior region of the valve.

Aviculopinna sp. b may be similar to forms listed by Thomas (1934, p. 1675) as *Pinna peracuta* Shumard. The present forms are generally similar to a larger species, *A. timanica* Maslennikov, from the Russian Permian (Licheraw and others, 1939, p. 139, pl. 33, figs. 11, 12).

OCCURRENCE: The species is common, associated with *A.* sp. a, in a single bed of the Tosi member at Bull Lake, Wyoming. A very large fragmentary specimen is questionably identified from the Ervay member at South Fork Canyon, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28309:1, 28309:2.

FAMILY **AVICULOPECTINIDAE**

AVICULOPECTEN McCOY, 1851

Aviculopecten phosphaticus Girty

Plate 7, figures 1–6

Aviculopecten phosphaticus GIRTY, 1910, p. 43, pl. 4, fig. 11.

Aviculopecten phosphaticus, NEWELL, 1937, p. 54, pl. 6, fig. 3.

DESCRIPTION: Girty's original description, apparently based on a single specimen, is here supplemented by observations and measurements of additional specimens and by the description of right valves of the species.

The holotype is an external mold of a small (7.5 mm. high), probably juvenile, left valve. The description of the species, however, applies to larger specimens except for details of shape and ornamentation. Second-order costae are added by implantation on the left valves and become more numerous with growth. Mature specimens show variation in obliquity, generally becoming strongly prosocline, but with some remaining nearly acline or becoming slightly opisthocline.

Associated with left valves of *A. phosphaticus* are nearly equally abundant right valves showing beautifully preserved hinge spines. A single right valve, without spines, in occlusion at the hinge with a left valve of *A. phosphaticus,* leaves little doubt that the spine-bearing right valves are of the same species. The absence of spines on the right valve of the occluded specimen can be attributed to the severance of the spines during rotation of the valves around the hinge axis to their present position (pl. 7, fig. 4).

Right valves slightly convex, suborbicular in outline, probably slightly smaller and fitting inside opposite valves; acline to slightly prosocline; auricles well developed, highly extended, right anterior auricle longer than posterior auricle, separated from shell body by a well-defined sinus, posterior auricle more continuous with shell body but distinctly separated by a slight angulation and depression; hinge length greatest linear dimension, hinge containing rounded, tapering spines up to more than 4 mm. in length; spines variable in number, up to about 10 per individual, irregularly to nearly symmetrically disposed on hinge; shell ornamentation consisting of faintly developed radiating costae, generally of a single order, with addition of a few costae, apparently by bifurcation; auricles possessing faint, irregular, concentric growth lines and radiating costae which vary in number and prominence as in left valves.

DISCUSSION: This species is characterized by its relatively small size, the prominence of the auricles, and especially by the presence of delicate hinge spines. The possession of hinge spines is believed to be unique to this species of *Aviculopecten.* The spines are derived by sharp dorsal bending of successive, laterally directed, auricular costae.

The presence of the spines suggests that *A. phosphaticus* was highly immobile, utilizing the spines for attachment in some manner. The low convexity and faint development of costae on the right valve suggest that individuals lay on or were attached by their right valves. There is no evidence of spine develop-

TABLE 14

MEASUREMENTS (IN MILLIMETERS) OF *Aviculopecten phosphaticus* GIRTY

	H	L	HGL	HS	SC	PAC	AAC
Lt	31.5	32.0	—	—	54	—	—
Lt	24.0	23.5	—	—	44	—	—
Lt	19.0	19.0	15+	—	33	?8	—
Lt	17.0	17.5	14+	—	35	7	8+
Lt	16.5	18.0	18.0	—	35	9	12
Lt	16.0	15.5	13+	—	33	7	?6
Lt	15.0	16.0	18.0	—	29	13	15
Lt	8.0	8.5	8.5	—	27	7	9
Lt	7.5	9.0	9.0	—	23	7	9
Lt, holotype	7.5	8.5	9.0	—	21	6	?7
Rt	14.5	15.5	21.5	?10	—	—	—
Rt	14.0	12+	16.0	8	35+	9	6+
Rt	13.0	15.5	21.0	9+	—	—	—
Rt	12.5	10.5	15.0	8	36	—	?3
Rt	11.5	9.5	14.5	8	30+	6+	5+
Rt	10.5	12.5	16.5	6+	—	—	3+
Rt	7.5	8.0	11.0	9+	—	—	—
Rt	7+	8.0	12.5	?8	—	—	—
Rt	7.0	8.0	11.0	9	—	?5	3+
Rt	6.0	5.5	9.0	4	—	—	—

ment on the left valves and no incurving of spines on the right valves to indicate that they were a means of interlocking the dorsal margins of the shells.

Aviculopecten phosphaticus cannot be closely compared with other species known to the writer. The right valves show a remote similarity to those of *A. girtyi* from the Grandeur member in northern Utah.

OCCURRENCE: The species is very abundant in the Meade Peak member at Cokeville, Wyoming; common to abundant in the same horizon at Hot Springs, Idaho; and rare in the Meade Peak at Coal Canyon, Wyoming (the holotype locality).

The restricted geographic and stratigraphic range of this locally abundant species is difficult to explain. The calcareous mudstone matrix in which *A. phosphaticus* occurs is common in the Meade Peak, and also in the Retort and Cherty shale members, over a large geographic area encompassing many localities which have yielded numerous other bivalves. *Aviculopecten phosphaticus* is generally associated with *Edmondia phosphatica*, isolated specimens of *Polidevcia obesa*, and a small gastropod, all of which are widespread forms. This species may have evolved a highly specialized adaptation in a local basin restricted by barriers which prevented its migration and thus limited its occurrence both in space and time.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 1737; hypotypes, U.S.N.M. Nos. 140472–140476.

Aviculopecten girtyi Newell

Plate 6, figures 5–7, 9

Aviculopecten girtyi NEWELL, 1937, p. 58, pl. 5, fig. 4.

DESCRIPTION: Left valves acline to prosocline, suborbicular in form, with extended auricles; radial costae of three or more ranks, with three to five raised primary costae bearing spines at intervals of a few millimeters; auricular folds and sulci straight and relatively shallow.

Right valves nearly flat, suborbicular, with prominent posterior auricles; latter separated from shell body by a slight but distinct angulation, ornamented by about eight radial costae (in two ranks) and well-developed, closely spaced, concentric fila which are poorly displayed on shell body; anterior right auricle unknown; shell body ornamented with faintly developed radiating costae which appear to split distally.

Internal features of the species are unknown.

DISCUSSION: These forms coincide closely with Newell's description and illustrations of Wordian representatives of the species, and with undescribed forms in the Word Number 3 limestone. One specimen (the fourth left valve in table 15) is anomalous in having a relatively greater height, an acline obliquity, and a considerably lower umbonal angle. It is suggestive of such forms as *A. vanvleeti* and *A. gryphus*. The latter is associated with *A. girtyi* in the Word formation in the Glass Mountains of West Texas. *Aviculopecten gryphus*, however, is characterized by a very deep auricular sulcus, which the present anomalous valve does not show. The anomalous valve, if isolated, would probably be referred to *A. vanvleeti*, a common lower Permian species, distinguished from *A. girtyi* on the basis of a narrower beak, greater height, and shorter anterior auricle.

TABLE 15

MEASUREMENTS (IN MILLIMETERS) OF *Aviculopecten girtyi* NEWELL

	H	L	PR	UA
Lt	35.0	—	6+	—
Lt	32.0	32	3	90°+
Lt	31.5	33+	4–5	90°
Lt	24.0	19	?	72°
Rt	22+	21+	—	85°
Rt	20.5	19+	—	88°

It is evident that with limited material, inadequately showing variation, morphotypes will be established based on characters that will become less distinctive as more material is studied. At least five species (*A. girtyi*, *A. gryphus*, *A. vanvleeti*, *A nodocosta*, and *A. kaibabensis*), described from Permian rocks of the southwestern United States, can be morphologically distinguished but possess many similarities. All show the development of a variable number of prominent, spine-bearing, radial costae. The distinctions between species are probably based on individual population differences rather than biologically meaningful specific characters. The present assemblage of seven valves from a single locality shows wide variation in the umbonal angle, the nature of the auricles, and in the number of characteristic primary ribs, which suggests that the characters used to differentiate species may be subject to considerable variation and that all these forms may be representatives of a single, highly variable, widespread species. A better understanding of this group of aviculopectinids must await the description of the large silicified fauna of the Glass Mountains.

There is no direct evidence that the right valves described here are those of *A. girtyi*, but similarity in size, shape, and the extended nature of the auricles, with left valves of the species, strongly suggest that they are opposite valves. In addition, the right and left valves occur in direct association to the exclusion of other similar forms.

OCCURRENCE: *Aviculopecten girtyi* is common in the Grandeur member at Horseshoe Canyon, Utah, and is questionably identified from a rare occurrence in the Grandeur at Fontenelle Creek, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140477–140480.

Aviculopecten gryphus Newell

Plate 6, figure 12

Aviculopecten gryphus NEWELL, 1937, p. 58, pl. 5, figs. 11a, b.

DISCUSSION: A fairly well-preserved left valve and a few incomplete left valves possess characters of *A. gryphus*, originally described from the Word formation of West Texas. Although the pronounced posterior body suclus characteristic of the species is lacking in the present form, other features of ornamentation and configuration are in close agreement. Distinctive features are the strong development, even in the dorsal umbonal area, of a relatively large number (up to 10) of primary, spine-bearing cosate, fairly deep and outcurved auricular sulci, a highly convex and narrow beak, and an umbonal angle of about 80 degrees.

MEASUREMENTS, REPRESENTATIVE LEFT VALVE: Height, 27 mm.; length, 22.5 mm.; hinge length, 22.5 mm.; primary body costae, seven; auricular costae, six anteriorly, 12 posteriorly; umbonal angle, 82 degrees.

As suggested by Newell (1937, p. 58), this species is probably closely related to *A. vanvleeti*. The forms at hand resemble the latter to a greater degree than the Wordian forms of *A. gryphus* in lacking the pronounced sulcus on the posterior shell body. The true relationships between these two species and other closely similar forms cannot be assessed until more is known of their variation and intergradation. (See discussion above under *A. girtyi*.)

OCCURRENCE: *Aviculopecten gryphus* is common in float from the Ervay (?Franson) member at South Fork Canyon, Wyoming, and is questionably identified from a rare occurrence in the Franson member at Crystal Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28318.

Aviculopecten cf. **vanvleeti** Beede

Plate 6, figures 10, 11, 13, 14

Aviculopecten vanvleeti BEEDE, 1902, p. 6, pl. 1, figs. 8–8b.

Deltopecten vanvleeti, C. C. BRANSON, 1930, p. 49, pl. 11, figs. 1, 2.

Aviculopecten vanvleeti, NEWELL, 1937, p. 57, pl. 5, figs. 8–19.

DISCUSSION: Incomplete valves and fragments of large, highly ornate aviculopectinids occur in Park City limestones at many localities in Wyoming. Included in this group (not necessarily a single species) are all forms with prominent spine-bearing costae (often in two or more ranks) that cannot be assigned to known species. Some of these forms attain a height of 80 mm. Also included is Branson's *Deltopecten vanvleeti*, which is too poorly preserved to display diagnostic specific characters.

The present forms are undoubtedly closely related to *A. vanvleeti* and other similar heavy-ribbed Permian species and are referred to the name given here because of Branson's earlier use of the name and because it is the earliest name applied to characteristic Permian aviculopectinids of this type.

Distinctive features of the forms at hand are the differentiation of as many as six ranks of costae on a single mature individual, the pronounced development of heavy spines on the first- and second-order costae, and the relatively large size compared to that of other related species.

OCCURRENCE: These forms are generally rare and have been identified from the Franson member at Washakie Reservoir, Burroughs Creek, and Tosi Creek, Wyoming, North Wadham Spring, Montana, and Strawberry Valley, Utah; from the Ervay member at Bargee, Bull Lake Blue Holes Canyon (the most common occurrence), Red Basin, Dinwoody Canyon, and Bartlett Creek, Wyoming; and questionably identified from the Tosi member at West Fork of Blacktail Creek, Montana.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28317/1, 28317/2, U.S.N.M. No. 140514, U.M. No. 5292.

Aviculopecten cf. **kaibabensis** Newell

Plate 6, figures 3, 4

Aviculopecten kaibabensis NEWELL, 1937, p. 60, pl. 4, figs. 17, 18.

Aviculopecten kaibabensis, H. CHRONIC, 1952, p. 144, pl. 8, figs. 1–7.

DISCUSSION: A few poorly preserved and generally incomplete left valves of this species are identified primarily on the basis of shell ornamentation. Halka Chronic (1952, p. 144) states, "Ornamentation of left valve consisting of many closely spaced costae; about 10 primary costae remaining slightly more prominent than secondary and later costae throughout height of valve; later costae added by intercalation so that entire valve appears about evenly costate . . . and all costae appear sharply and finely striated longitudinally." This characteristic ornamentation and general resemblance of other features permits a fairly positive identification of these poorly preserved specimens.

A left valve with a lower umbonal angle and an apparently less-extended posterior auricle is questionably identified with the other forms on the basis of its ornamentation.

Aviculopecten bellatulus Newell, a smaller form described from apparently the same locality and horizon of the Kaibab limestone as *A. kaibabensis*, differs essentially only in size. The two species are most probably synonymous and are in turn closely related to forms such as *A. girtyi*, *A. vanvleeti*, and *A. gryphus*.

OCCURRENCE: *Aviculopecten* cf. *kaibabensis* is rare in the Ervay member at Bull Lake, Wyoming; rare and questionably identified from the upper member of the Shedhorn sandstone at Flat Creek, Wyoming, and from the Tosi member at Hogback, Montana.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. No. 28316, U.S.N.M. No. 140481.

Aviculopecten cf. basilicus Newell

Plate 6, figures 1, 2

Aviculopecten basilicus NEWELL, 1937, p. 52, pl. 6, figs. 13–16b.

DISCUSSION: Some generally poorly preserved and incomplete left valves are referred to the upper Pennsylvanian species *A. basilicus*. The present forms resemble *A. basilicus* in their relatively large size, high convexity, large umbonal angle, and general ornamentation. The spines and imbrications characteristic of the species are absent, and the concentric filose ornamentation is poorly shown except on the auricles. The distal splitting of broad costae, a possibly gerontic character (Newell, 1937, p. 52), is also absent on the specimens at hand.

A fairly well-preserved left valve has the following dimensions: height, 31.5 mm.; length, 29.0 mm.; hinge length, 25 mm.; half convexity, 6 mm.; total shell costae, 39; auricular costae, 11 anteriorly, seven posteriorly; umbonal angle, 85 degrees.

Aviculopecten basilicus is one of four highly similar Upper Carboniferous species described from the southern mid-continent area of the United States. The other species are *A. arctisulcatus* Newell, *A. exemplarius* Newell, and *A. occidentalis* (Shumard). These forms are separated by details of ornamentation and slight differences in configuration. The Wyoming Permian forms show characters common to all these species, but derivation from any one stock is difficult to establish. It seems highly probable that the four Upper Carboniferous forms may represent a single species. The present forms fall within the limits of variation of the Upper Carboniferous forms, which indicates that aviculopectinids of this type ranged well into the Permian.

OCCURRENCE: *Aviculopecten* cf. *basilicus* is common to abundant in the Ervay member at Bargee, Wyoming; common in the Franson member at Washakie Reservoir and rare in the Franson at South Fork of Gypsum Creek, Wyoming; and rare in the Retort member at Deadline Ridge, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. No. 28315, U.S.N.M. No. 140482.

Aviculopecten sp.

Plate 7, figures 12, 13

Deltopecten occidentalis, C. C. BRANSON, 1930, p. 50, pl. 11, fig. 21.

DISCUSSION: Poorly preserved, incomplete internal molds of a moderately large *Aviculopecten* are common in the Franson member at Tosi Creek, Wyoming. One badly worn, but nearly complete, left valve and a deformed specimen showing the nature of shell ornamentation are illustrated. Ornamentation consists of closely spaced radiating costae, in four ranks, crossed by numerous fine concentric fila, about three per millimeter at the ventral margin, which produce slight imbrications on the surface of the costae. The nearly complete left valve is slightly prosocline, nearly circular in outline, and moderately convex and has a height of 59 mm., length of 60 mm., and an umbonal angle of about 105 degrees.

The large size of these forms is suggestive of *A. kaibabensis* or the large forms described above as *A.* cf. *vanvleeti*. The ornamentation, however, is unlike that of any of these forms in that there is no evidence of development of large spines on the primary radial costae, and the present forms show closely spaced concentric fila. The available material cannot be assigned to any known species but is insufficiently known for designation as a new species.

The hypotype of the form identified by Branson as *Deltopecten occidentalis* is too poorly preserved for positive identification with the Pennsylvanian species, which is characterized by slender body costae, numerous auricular costae, and other features not shown on the Wyoming specimen. The ornamentation, though poorly shown, and configuration are somewhat similar to those of the forms discussed above. They are thus tentatively grouped with the Tosi Creek forms as *A*. sp.

OCCURRENCE: These forms are common in the Franson member at Tosi Creek, Wyoming. Branson's specimens are from the Grandeur member at Bull Lake, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28320:1, 28320:2.

FAMILY **MONOTIDAE**

MONOTIS BRONN, 1830

Monotis? landerensis (C. C. Branson)

Plate 6, figure 8

Aviculopecten landerensis C. C. BRANSON, 1930, p. 48, pl. 12, figs. 2, 3.

DISCUSSION: This species is characterized by its relatively small size and the relatively small, subequal auricles which are essentially continuous with the shell body. The equilateral nature of the valves and non-distinct auricles make separation of right and left valves very difficult.

This species closely resembles the Lower Triassic species *Monotis? thaynesiana*, from the Woodside and Thaynes formations of southern Idaho (p. 80; pl. 15, fig. 16). The generic affinities of the two species and related forms are poorly known (see discussion of *Monotis?*, p. 80).

The greatest significance of the present species is that it represents the only Permian bivalve species in the extensive collections from the Middle Rockies that can be closely compared with forms in the overlying Lower Triassic sequence. The Triassic form *Monotis? thaynesiana* differs from *M.? landerensis* in having slightly more numerous radial costae and more prominent concentric ornamentation. They are most probably congeneric and are apparently closely related specifically. The Permian species is the earliest known occurrence of this equilateral, nearly equivalved, type of pectinoid and may thus be indicative of the ancestral stock of the group.

OCCURRENCE: The holotype of *M.? landerensis* is from the Ervay member at Bull Lake, Wyoming, and Branson reports the species from that horizon throughout the Wind River Mountains, Wyoming. Additional specimens in the present collection are common in the Tosi member at Bull Lake and Spring Creek, Wyoming.

CATALOGUED SPECIMEN: Holotype, U.M. No. 5305.

LIMIPECTEN GIRTY, 1904

Limipecten? sp.

Plate 7, figure 14

DISCUSSION: A few relatively large, poorly preserved left valves and a single, incomplete silicified left valve show ornamentation characteristic of *Limipecten*. The ornamentation consists of intercalate radiating costae, about 2.5 mm. at the ventral margin, in three or four ranks, crossed by finely spaced concentric, imbricating lamellae (about three per millimeter near the ventral margin). The ornamentation of the left anterior auricle is essentially continuous with the shell body, although the auricle is separated by a distinct umbonal fold and sulcus.

MEASUREMENTS (IN MM.): Two left valves, respectively: height, 65, 24.5; length, 51+, 21; hinge length, 47, —; umbonal angle, 85 degrees to 90 degrees, ?80 degrees to 90 degrees.

The ornamentation of this species is similar to that of *L. wewokanus* Newell from the Pennsylvanian of Oklahoma, but the present forms have less-extended anterior auricles, a more clearly defined auricular sulcus, and a greater relative height.

This is probably a new species of *Limipecten* or one of *Aviculopecten* that has developed ornamentation similar to that of *Limipecten*. The generic identity cannot be definitely established because right valves, which show intercalated radial ornamentation in *Limipecten* and a bifurcated pattern in *Aviculopecten*, have not been found.

OCCURRENCE: Large specimens are common in the Ervay member at Bargee, Wyoming. The single silicified valve is from the Franson member at Washakie Reservoir, Wyoming.

Limipecten is known only from the Carboniferous. This occurrence of the genus, if valid, would extend the known range to the Upper Permian.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.M. No. 28321.

ACANTHOPECTEN GIRTY, 1903

Acanthopecten coloradoensis (Newberry)

Plate 7, figures 8–11

Pecten (Monotis?) coloradoensis NEWBERRY, 1861, p. 129, pl. 1, figs. 6, 6a.

Acanthopecten coloradensis, NEWELL, 1937, p. 75, pl. 12, figs. 7a, b, 13–15b.

DISCUSSION: The present collection contains a number of fairly large left valves and a few small silicified forms, probably juveniles. Included in this group are a number of specimens from a single locality that differ from other specimens in the present collection but appear to fall within the general limits of the species. A representative left valve is relatively higher, has a lower umbonal angle (90° as contrasted to an average of about 115° for the species), and has narrower, more closely spaced, radial costae. In addition, the concentric lamellae appear to be more prominent, but this may be a result of preservation. (There is apparently considerable variation in the prominence of the ornamentation among all the specimens included in this group, but much of this may be attributed to differences in the method of preservation, including silicification, internal molds, casts, and partially preserved original material.)

TABLE 16

MEASUREMENTS (IN MILLIMETERS) OF *Acanthopecten coloradoensis* (NEWBERRY)

	H	L	HGL	SC	UA
Lt	66+	72+	—	16	115°
Lt	51	53	—	25	120°
Lt	45	47+	—	20+	—
Lt	36	—	20+	25	90°
Lt	29	30	—	24+	110°

The present forms generally differ from previously described forms of *A. coloradoensis* in having a greater length than height, and in showing greater variation in shell ornamentation and umbonal angle. Quantitative measurements have a restricted value because of the small numbers of well-preserved specimens both in the present collection and in the Kaibab and Word formation occurrences previously described. Several varieties or perhaps several species may be represented in the present collection, but it seems most desirable to group the forms tentatively under *A. coloradoensis*.

OCCURRENCE: *Acanthopecten coloradoensis* has been identified from the Grandeur member at Bull Lake, Wyoming; the Franson member at Tosi Creek, Sheep Ridge, Red Basin, and Washakie Reservoir, Wyoming, and Brazer Canyon, Utah; the Tosi member at Hogback and West Fork of Blacktail Creek, Montana; the Ervay member at Bargee, South Fork Canyon, and Dinwoody Canyon, Wyoming; and the upper member of the Shedhorn sandstone at Sawtooth Peak, Montana. It is generally common in occurrence but may be locally abundant.

Occurrences of *A. coloradoensis* in the Kaibab formation of Arizona and the Word formation of West Texas indicate that the species may be a useful guide in the correlation of the Permian of the Middle Rockies with that of the southwestern United States.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28319:1–28319:4.

Acanthopecten cf. delawarensis (Girty)

Plate 7, figure 7

Aviculopecten delawarensis GIRTY, 1908, p. 437, pl. 23, figs. 2, 2a.

Acanthopecten delawarensis, NEWELL, 1937, p. 75, pl. 12, fig. 12.

DISCUSSION: A few poorly preserved left valves are referred to Girty's West Texas species. The number of costae, 16 or 17, is the same as on the holotype. Other general characters such as shape, size, and auricular proportions are sufficiently similar for these forms to be considered conspecific or closely related to those of the Delaware Mountain formation of West Texas.

OCCURRENCE: *Acanthopecten* cf. *delawarensis* is common in the Grandeur member at Wheat Creek, Wyoming, and is questionably identified from the same horizon at Cumberland, Wyoming.

CATALOGUED SPECIMEN: Hypotype, U.S.-N.M. No. 140483.

ANNULICONCHA Newell, 1937

Annuliconcha? sp.

Discussion: A single poorly preserved specimen, having eight raised concentric fila but with no indication of less prominent fila or radial costae, is questionably designated as *Annuliconcha*. The general configuration and size are also suggestive of the genus.

Occurrence: The single specimen is from the Grandeur? member (possibly older, upper Pennsylvanian) at Hidden Pastures, Montana.

Beautifully preserved silicified specimens are common in the Word formation of the Glass Mountains of West Texas.

GIRTYPECTEN Newell, 1937

Girtypecten sublaqueatus (Girty)

Plate 8, figure 4

Aviculopecten sublaqueatus Girty, 1908, p. 440, pl. 9, fig. 12.

Girtypecten sublaqueatus, Newell, 1937, p. 78, pl. 13, figs. 11–14b.

Discussion: A few silicified left valves from a single locality are confidently identified as *G. sublaqueatus*.

Left valves of the species are characterized by prominent, widely spaced, radial ribs and equally prominent concentric fila. Larger specimens show the development of faint second-order costae, generally about three or four between primary ribs. Also characteristic are the highly extended auricles which, especially in juveniles, cause the hinge line to be the greatest linear dimension.

Right valves of the species are not known.

A closely related, possibly conspecific form, *G. chitralensis* (Reed), occurs in the Lower Productus limestone of the Salt Range of Pakistan (see Reed, 1944, pl. 312, p. 55, fig. 2).

TABLE 17

Measurements (in Millimeters) of *Girtypecten sublaqueatus* (Girty)

	H	L	HGL	PR	PCF
Lt	—	32.0	—	?8	7+
Lt	12	12.5	—	8	6+
Lt	7	8.0	7.5+	7	5
Lt	7	7.0	10.0	8	6

Occurrence: Silicified juveniles and fragments of larger specimens are common in the Franson member at Washakie Reservoir, Wyoming.

Girtypecten sublaqueatus is known from the Delaware Mountain and Word formations of Lower Guadalupian age, and from the Upper Guadalupian Capitan formation, in the southwestern United States.

Catalogued Specimen: Hypotype, A.M.-N.H. No. 28323.

STREBLOCHONDRIA Newell, 1937

Streblochondria? guadalupensis (Girty)

Plate 8, figure 8

Aviculopecten guadalupensis Girty, 1908, p. 436, pl. 16, figs. 20, 20a.

Aviculopecten sp. *a* Girty, 1908, p. 436, pl. 16, fig. 21.

Streblochondria? guadalupensis, Newell, 1937, p. 86, pl. 15, figs. 6, 7.

Discussion: Two incomplete right valves from a single locality are identified with Girty's West Texas Capitanian species. The general configuration, pattern of ornamentation, and characteristically depressed right posterior auricle suggest that the Wyoming forms are conspecific with those of West Texas. The right anterior auricle is lost on the available specimens.

The more complete specimen is 34 mm. high, 28 mm. long, and has a half convexity of about 7 mm.

The preservation of a small section of shell material shows the development of closely spaced small nodes on the radial costae (formed by intersection of the concentric fila with the costae). This suggests a possible relationship with *S. condrai* Newell, from the Upper Pennsylvanian of Oklahoma.

Later costae are added by bifurcation in this species, making generic placement of this species and closely related forms (*S.? tubicostata* Ciriacks, new species, and *S.? maynci* Newell) very difficult. In his discussion of the latter species, Newell (1955, p. 20) states that individuals of this type have the form of *Streblochondria* and the ornamentation of *Aviculopecten* and cannot be definitely referred to either.

As in the earlier collections, the material is unsuitably preserved and limited in quantity, so that the diagnosis of a new genus is not desirable at the present time.

OCCURRENCE: The two right valves of *S.? guadalupensis* are from the Ervay member at Bull Lake, Wyoming.

Streblochondria? guadalupensis is known only from the Capitan formation of West Texas and may be useful in correlating the Ervay member with the Permian of the southwestern United States.

CATALOGUED SPECIMENS: Hypotype, U.S.N.M. No. 140484.

Streblochondria? tubicostata Ciriacks, new species

Plate 8, figures 16–21

DESCRIPTION: Shell suborbicular, acline to opisthocline, slightly higher than long; posterior auricles depressed, considerably smaller than anterior auricles; shell ornamentation consisting of radial ribs, which become rounded and distinctly raised ventrally on mature specimens, and concentric fila, which are very prominent in juvenile and young stages, forming short imbrications at intersections with ribs; fila more widely spaced and less common on ventral regions of mature shells.

Left valves slightly more acline, showing irregular intercalation of second-order ribs; left anterior auricle set off from shell body by a fairly deep sulcus, but ornamented essentially continuously with shell, containing up to 10 costae (in two ranks) and prominent concentric fila; left posterior auricle greatly reduced, showing faint radiating costae, generally three or less, and well-developed concentric fila.

Right valve more opisthocline; second-order ribs originating (in some specimens in pairs or bundles) by bifurcation of primary ribs; second-order ribs often best developed on anterior half of shell body and probably initially added in that region; right posterior auricle similar to that of left valve; right anterior auricle unknown.

The hinge characters and internal features are unknown.

DISCUSSION: The species is described on the basis of about 25 silicified specimens from a single locality. There is no single complete specimen, as the beaks and cardinal plates are invariably broken away.

The present species is closely related to both *S.? guadalupensis* from the Capitanian of West Texas, and *S.? maynci* from the Upper Permian of Greenland. *Streblochondria? tubicostata* has an umbonal angle which varies between 90 degrees and 95 degrees, intermediate between the wider Greenland forms (about 100°) and the slightly narrower West Texas forms (about 85°). The left anterior auricles are relatively larger and more prominent, and the valves are more finely ornamented than in the other two species.

The widespread occurrence of these forms suggests close age relationships between rocks containing these highly similar species. They are probably members of a new genus (bifurcation of the costae on the right valves is unknown in true representatives of *Streblochondria*), but the internal features are not known, so that the diagnosis of a new genus is not desirable.

OCCURRENCE: About 25 silicified specimens were obtained in the etching of about 500 pounds of limestone from the Franson member at Washakie Reservoir, Wyoming.

CATALOGUED SPECIMENS: Holotype, A.M.-N.H. No. 28327; topoparatypes, A.M.N.H. Nos. 28328:1–28328:5.

TABLE 18

MEASUREMENTS (IN MILLIMETERS) OF *Streblochondria? tubicostata* CIRIACKS, NEW SPECIES

	H	L	SC	PAC	AAC	UA
Lt	28.0	25.0	43	2	10	—
Lt	28.0	—	—	—	?9	—
Lt	21.0	17.5	31	2	—	95°
Lt, holotype	18.0	16+	31	?3	6+	90°
Lt	11.0	9.5	27+	—	7	—
Rt	22.0	22.0	46+	—	3	90+°
Rt	11.5	11.5	31	—	—	—
Rt	10.0	9+	30	—	3	92°

TABLE 19

MEASUREMENTS (IN MILLIMETERS) OF *Streblochondria? montpelierensis* (GIRTY)

	H	L	H/L	HGL
Lt	32.0	26+	1.23−	15.5
Lt	29.5	26.0	1.13	15.0
Lt	16.5	16.0	1.03	—
Lt	14.0	12.5	1.12	—
Lt	13.0	13.0	1.00	7.0
Rt	19.5	19.0	1.03	13.0
Rt	18.5	16.0	1.16	8.0
Rt	13.0	13.0	1.00	8.0
Rt	10.5	10.5	1.00	5.5
Rt	8.5	9.0	0.94	4.0

Streblochondria? montpelierensis (Girty)

Plate 8, figures 9–15

Aviculopecten? montpelierensis GIRTY, 1910, p. 42, pl. 4, figs. 9, 10.

Streblochondria? montpelierensis, NEWELL, 1937, p. 83, pl. 14, figs. 6, 7.

DISCUSSION: The species is characterized by its subcircular configuration, nearly smooth valves, and distinctive, elongate, and lobate right anterior auricle, which is bounded by a deep byssal notch. Right valves are less convex and generally more nearly equidimensional than corresponding left valves. Well-preserved left valves show a faint but distinctive development of fine radiating costellae on the shell body. A few left valves have regularly developed concentric fila which become progressively less distinguishable toward the ventral margins.

There is apparently an ontogenetic increase in height/length ratio. Some variation in relative dimensions is undoubtedly due to distortion of the specimens that occur in structurally deformed calcareous mudstones.

Hinge and internal characters are not known so that a generic placement of the species is questionable. The present species is quite unlike the other two species here dubiously referred to *Streblochondria* (*S.? guadalupensis and S.? tubicostata.*) The latter two are generally larger, possess prominent shell ornamentation, and occur in apparently shallow-water limestone facies.

Streblochondria? montpelierensis is most similar to *S.? tenuilineata* (Meek and Worthen) from the Pennsylvanian of the midcontinent of the United States. The present species differs in having a more circular configuration and a more elongate, sharply defined, right anterior auricle which lacks auricular costae.

OCCURRENCE: *Streblochondria? montpelierensis* is probably the most widespread bivalve in the Meade Peak member. It is common to locally abundant in fossiliferous beds of this horizon throughout southeastern Idaho, western Wyoming, and southwestern Montana.

CATALOGUED SPECIMENS: Lectotype, U.S.N.M. No 1713; paratype, U.S.N.M. No. 1714; topotype?, A.M.N.H. No. 28326; hypotypes, U.S.N.M. Nos. 140485–140488.

OBLIQUIPECTEN HIND, 1903

Obliquipecten sp.

Plate 8, figures 1–3

Monopteria sp., C. C. BRANSON, 1930, p. 44, pl. 10, fig. 24.

DISCUSSION: Four right valves and a small left valve are confidently referred to *Obliquipecten*, previously reported only from the Lower Carboniferous of England. The flattened, opisthocline right valves, with faintly developed radiating costae near the anterior margin, and subcircular to subquadrate right anterior auricles are highly similar to those of *O. laevis* Hind, the genotype and only known species. The small left valve is more convex, less opisthocline, and has less well-defined auricles than the right valves. The left valve is very similar to that of *O. laevis* illustrated by Newell (the lectotype), and right valves show similar variation in configuration and ornamentation (Newell, 1937, pl. 8, figs. 3–5b).

The present forms differ from *O. laevis* primarily in the fact that right auricles are considerably smaller relative to body size and are prominently ornamentated by strong radiating costae or strong concentric fila and weak costae. The forms from Wyoming are also smaller than the species from England.

MEASUREMENTS (IN MM.):

	H	L	HGL
Lt	12.5	10.0	7.0
Rt	24.0	22.0	9.0
Rt	21.0	18.0	10.5
Rt	18.0	13.0	7.0
Rt	17.0	15.5	7.0

The hypotype of Branson's *Monopteria* sp., represented by only a single specimen in the present collection, is included with *Obliquipecten* sp. because of similarity in configuration to the small left valve discussed above.

The new occurrence of the genus in the Permian and in North America, plus morphological differences from the other known species, suggests that the present forms represent a new species. Critical characters such as the nature of the hinge and details of surface ornamentation are inadequately shown on the five available specimens, so that the introduction of a new name at the present time is undesirable.

OCCURRENCE: These forms are rare in the Ervay member at Dinwoody Canyon, and rare to common in float from the Ervay (Franson?) member at South Fork Canyon, Wyoming. Branson's hypotype of *Monopteria* sp., here referred to *Obliquipecten* sp., is from the Ervay member at Bull Lake, Wyoming, and he reports these forms from this horizon throughout the Wind River Mountains, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.-N.H. Nos. 28322/1:1, 28322/1:2, 28322/2.

CAMPTONECTES AGASSIZ, 1864

Camptonectes? sculptilis Girty

Plate 8, figures 6, 7

Camptonectes? sculptilis GIRTY, 1908, p. 434, pl. 9, figs. 4, 4a.

Camptonectes? sculptilis, NEWELL, 1937, p. 91, pl. 14, fig. 1.

DISCUSSION: Two incomplete valves of this characteristically ornamented species are confidently identified as *C.? sculptilis*. The shell surface is ornamented by two sets of curved lirae diverging pinnately from a midumbonal line, the two sets in some specimens overlapping on the dorsal umbonal region to form a papillate pattern. Characters other than the surface sculpture and general configuration are not shown on the available specimens.

One of the two valves can be definitely identified as a right valve. The smaller, less well-preserved valve has a more pronounced area of intersecting lirae and is relatively more convex than the known right valve, which indicates that it is probably a left valve.

MEASUREMENTS (IN MM.):

	H	L
Lt	13	10+
Rt	19	20

Camptonectes? sculptilis differs from similar forms, such as *C.? asperatus* Girty and *C.? papillatus* Girty, all of which are associated in the West Texas Capitan formation, in having more prominent radial ornamentation which diverges from a midumbonal line.

The species is questionably referred to *Camptonectes* because of similarity of surface ornamentation. The absence of pinnately diverging lirae in the other associated species questionably referred to the genus suggests, as stated by Girty, that these forms may represent a new genus too poorly known for proper diagnosis.

OCCURRENCE: The two valves are from the Franson member at South Fork Canyon, Wyoming.

The species is known definitely from the middle Capitan limestone and questionably from the Word formation of West Texas. The restricted range of these forms indicates that the species may be useful as a guide in a correlation of the Wyoming Permian with that of the southwestern United States.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28325:1, 28325:2.

CYRTOROSTRA C. C. BRANSON, 1930, EMENDED CIRIACKS

Cyrtorostra C. C. BRANSON, 1930, p. 44.

GENOTYPE: *Cyrtorostra varicostata* C. C. Branson, 1930.

SUBJECTIVE SYNONOMY; *Oxytoma* Meek, 1864 (in part); *Blandfordina* Reed, 1944.

DIAGNOSIS: Branson's original description is: "Shell short, convex, sub-conical; beak pointed, situated anterior of middle, extended beyond hinge, twisted posteriorly; posterior ear larger than anterior ear, margin of ear slightly concave, turned over at edge; margin of shell with long spines; surface ribbed; area below beaks concave; hinge-plate short, flat, with alternating teeth and sockets."

This description was apparently based on small or juvenile specimens, probably only left valves, and is revised on the basis of subsequently collected, more representative material.

Shell suborbicular, inequivalved, moderately convex, with right valve flatter than left, acline to markedly opisthocline; beaks narrow, prosogyre, extending beyond hinge line; posterior auricles nearly continuous with shell body, anterior auricles set off by byssal sinus and deep auricular sulcus on left valves, and by prominent byssal notch on right valves; shell ornamentation characterized by slender ribs, extended distally beyond shell body to form long spines; ribs separated by broad, rounded ribs or interspaces which may insert higher-order costae near ventral margin of mature specimens; cardinal area with deep, broadly subtrigonal, forwardly directed resilifer; lateral teeth poorly developed or absent behind the ligament.

DISCUSSION: The general configuration, inequivalved nature of the valves (with flatter right valves containing a prominent byssal notch), and the general pattern of ornamentation indicate that the genus is properly a member of the Aviculopectinidae.

Cyrtorostra is characterized by its surface ornamentation, the heavily folded and irregularly shaped right anterior auricle, and the broad, subtrigonal resilifer. It cannot be closely compared with other genera, and its phylogenetic relationships are thus poorly known.

C. C. Branson (1948, pp. 600–601) has placed Permian species of the genus *Oxytoma* [originally described as a subgenus of *Pteria* by Meek (1864; p. 79), with a Jurassic form, *Pteria munsteri*, as the type species] in *Cyrtorostra*. These include species from the Permian of India, Russia, Timor, and Italy. These forms resemble *Cyrtorostra* in configuration and surface ornamentation and bear little resemblance to the Jurassic species of *Oxytoma*. The reference of Permian species to *Oxytoma* thus appears unjustified.

The Permian genus *Blandfordina*, from the Middle and Upper Productus limestones of the Salt Range, bears great resemblance to *Cyrtorostra* of Wyoming and to Permian species that have been referred to *Oxytoma* (Reed, 1944, p. 312). Several species of *Blandfordina* have been described by Reed. The genus is apparently more variable than known forms of *Cyrtorostra*. It is, however, highly probable that the two forms are congeneric and can be confidently placed into synonymy bearing the older name, *Cyrtorostra*.

Undescribed forms of *Cyrtorostra* from the Canadian Arctic and West Texas are presently being studied by N. D. Newell and the writer and will further document the New World occurrence of this cosmopolitan genus.

KNOWN RANGE OF THE GENUS: Permian; Leonardian-Guadalupian (upper Artinskian-Kazanian).

Cyrtorostra varicostata C. C. Branson

Plate 9, figures 1–14

Cyrtorostra varicostata C. C. BRANSON, 1930, p. 44, pl. 11, figs. 16–19.

Aviculopecten alternatus C. C. BRANSON, 1930, p. 49, pl. 11, figs. 4–8.

Aviculopecten alatus C. C. BRANSON, 1930, p. 47, pl. 11, figs. 9–10.

Cyrtorostra? alternata, C. C. BRANSON, 1948, p. 600.

DESCRIPTION: An accumulation of a number of silicified specimens and other larger specimens indicates that Branson's description was based on juveniles and immature specimens. The orignal description is here supplemented and revised on the basis of subsequently collected, well-preserved material.

Valves suborbicular, slightly higher than long, acline to strongly opisthocline in mature specimens; beaks subcentrally placed, prosogyre, slightly extended beyond hinge line; hinge line short, gently curved in a broadly sigmoidal pattern; large, subtrigonal, anteriorly directed resilifer directly below beaks, with surface marked by closely spaced horizontal and radially disposed, vertical striations; hinge teeth absent or very poorly developed.

Left valves relatively convex; auricles subequal, anterior auricle with concentric growth lines, set off by byssal sinus; posterior auricle only slightly separated from shell body by shallow sulcus.

Right valves slightly convex to nearly flat, maybe slightly smaller than opposite left valves; right anterior auricle longer than posterior auricle, containing three or four prominent folds, extending to margin forming an irregular anterior lobe, separated from shell body by deep byssal notch; posterior auricle like that of left valve.

Ornamentation of both valves consisting of 11 or, more commonly, 12 slender radiating ribs which extend distally beyond the shell margin as sharp, pointed spines; ribs separated by broad, rounded interspaces which possess closely spaced, dorsally arched, concentric lines which are especially prominent near ventral margin, forming a scalloped distal edge on interspaces; faintly developed higher-order costae irregularly added by intercalation at lateral edges of interspaces.

DISCUSSION: There is considerable variation in the relative flatness of the right valves. Some are nearly equidimensional; others, considerably higher than long. This may be a reflection of variations in growth resulting from different growth positions of individual right valves which may have been attached during much of their ontogeny. There appears to be a general ontogenetic increase in length relative to height. There is also a pronounced ontogenetic change in obliquity, especially in right valves. Small valves are slightly prosocline or acline; large forms, distinctly opisthocline.

TABLE 20

MEASUREMENTS (IN MILLIMETERS) OF *Cyrtorostra varicostata* BRANSON

	H	L	H/L	HGL	PR
Lt	20.5	19.5	1.05	11.5	12
Lt	17.0	13.6	1.25	—	12
Lt	14.6	12.0	1.22	—	12
Lt	14.4	12.4	1.20	—	12
Lt	7.4	6.4	1.16	—	12
Lt	6.2	5.4	1.15	—	12
Lt	5.4	4.6	1.17	3.8+	12
Lt	5.2	4.2	1.24	3.4+	12
Lt	5.2	4.2	1.24	—	12
Lt	4.8	4.0	1.20	2.8	11
Rt	33.6	28.2	1.19	—	12
Rt	26.4	25.0	1.06	13.2	12
Rt	21.0	18.0	1.17	11.0	12
Rt	20.0	20.0	1.00	13.0	12
Rt	14.8	12.8	1.16	6.4+	12
Rt	13.6	10.8	1.26	6.4	12
Rt	11.0	8.8	1.25	—	12
Rt, holotype	11.0	8.5	1.29	—	11
Rt	10.4	9.0	1.16	4.4+	12
Rt	6.4	5.6	1.14	—	12
Rt	4.8	3.8	1.26	3.0	12
Rt	3.8	3.2	1.19	2.2	12

The species is characterized by its regular surface ornamentation of 11 or 12 primary ribs, its nearly equidimensional configuration, and its fairly regular ontogenetic change in obliquity. *Cyrtorostra varicostata* is most closely related to undescribed forms, almost certainly conspecific, from the upper Leonard to Word Number 4 limestones of West Texas. The silicified forms at hand most closely resemble forms of the Word Number 3 limestone and are literally indistinguishable from these forms.

Branson's *Aviculopecten alternatus* (also referred by him to *Cyrtorostra? alternata*) and *A. alatus* are here placed in synonymy with *C. varicostata*. The types of these species are merely larger, more mature specimens than the types of *C. varicostata*, which are in some cases distorted to an apparently different configuration. The surface ornamentation is identical, and hinge characters, as far as discernible, are also similar. The types of *C. varicostata* and "*A. alternatus*" are from the same horizon and locality, and those of "*A. alatus*" from the underlying horizon at the same locality. Thus the stratigraphic occurrence also supports their being grouped into one species.

OCCURRENCE: *Cyrtorostra varicostata* is widespread in the Franson and Ervay members in Wyoming. The largest single collection, about 30 silicified valves, is from the Franson at Washakie Reservoir, Wyoming, where it is associated with abundant *?Streblochondria tubicostata*. Other common to locally abundant occurrences are in the Franson at Dinwoody Canyon and Basin Creek; the Ervay member at Dinwoody Canyon, Bargee, Bull Lake, and Red Creek, Wyoming; and the Tosi member at Bull Lake, Wyoming. *Cyrtorostra varicostata* is rare in the Franson at Sheep Ridge and Middle Fork of Pine Creek, Wyoming; rare in the Ervay at Burroughs Creek and Tosi Creek, Wyoming; rare in the upper member of the Shedhorn sandstone at Sheep Creek, Montana; and rare in a limestone lens of the Rex member at the divide between Trial and Wood Canyon, Idaho. It is questionably identified from the Franson at Hoback, Wyoming, and Wadham Spring, Montana, and from the Retort member at West Fork of Blacktail Creek, Montana.

The species generally occurs in brachiopod- and bryozoan-rich calcarenites and fine limestones but is also found in a relatively coarse quartz arenite and questionably identified from a black mudstone.

The close similarity of the species with undescribed forms from the Word Number 3 limestone of West Texas suggests that the upper members of the Permian in the Middle Rockies are correlative in age with the Word Number 3 limestone of West Texas.

CATALOGUED SPECIMENS: Holotype, U.M. No. 5300; hypotypes, A.M.N.H. Nos. 28329/1, 28329/2:1–28329/2:4, U.S.N.M. No. 140489, U.M. No. 5293, 5295.

FAMILY **PSEUDOMONOTIDAE**

PSEUDOMONOTIS BEYRICH, 1862

Pseudomonotis sp.

Plate 8, figure 5

DISCUSSION: Poorly preserved specimens and fragments displaying surface ornamentation characteristic of Permian pseudomonotids are widespread in limestones of the Park City formation. Large forms, exceeding 85 mm. in height, were among the largest bivalves which lived in Permian seas of this region. Many of the specimens bear resemblance to *P. hawni* (Meek and Hayden), a Lower Permian form common in the midcontinent and southwestern United States.

OCCURRENCE: *Pseudomonotis* sp. is always rare locally. It has been identified from the Franson member at Basin Creek, Dinwoody Canyon, and Washakie Reservoir, Wyoming, and Hidden Pastures, Montana; from the Ervay member at South Fork Canyon, Dinwoody Canyon, Bargee, and Bartlett Creek, Wyoming; from the Meade Peak member at Cokeville, Wyoming, and Waterloo, Idaho; and from the Retort member at Deadline Ridge, Wyoming.

CATALOGUED SPECIMEN: Hypotype, A.M.N.H. No. 28324.

FAMILY **MYOPHORIIDAE**

SCHIZODUS KING, 1844

Schizodus bifidus Ciriacks, new species

Plate 10, figures 13–15

DESCRIPTION: Shell ovate-elongate, height/length ratio about 3/4, convexity about two-thirds of shell height; anterior margin high, broadly rounded, curving uniformly into long, convex-down ventral margin; posterior margin relatively low, tapering, slightly truncated; dorsal margin slightly concave-up from posterodorsal angle to a point below beaks, then convex rounding into anterior margin; beaks prominent, distinctly opisthogyre, situated between one-third and one-half of shell length behind anterior extremity; ornamentation consisting of a rounded to subangular postumbonal (siphonal) ridge extending to posteroventral angle, bounded ventrally by a shallow depression which terminates as a slight indentation of ventral margin; shell surface containing fairly coarse, rounded, concentric fila, numbering about one per millimeter, best displayed on anterior umbonal slope and becoming imperceptible posteriorly.

Dentition,

$$\frac{3a\ ,\ 3b}{4a\ ,\ 2\ ,\ (4b)},$$

with anteriormost cardinal tooth on left valve; 3a subtrigonal and heavy, 4a and 3b slender and elongate, inclined nearly parallel to hinge, 2 broadly triangular, distinctly bifid, the two lobes diverging at an angle of slightly more than 90 degrees from a sharp groove on the under side of the tooth, 4b indistinct, maybe absent as there is apparently no opposing socket on right valve; ligament opisthodetic, ligament grooves not well shown; adductor muscle impressions moderately deep, subovate, tapering dorsally, anterior scar extending longitudinally under beak; several longitudinal pedal muscle impressions on umbone extending up under beak.

MEASUREMENTS (IN MM.):

	H	L	½C
Rt, holotype	42.0	?56.0	14
Rt, paratype	25.5	36.0	—
Lt, paratype	22.5	31.5	7

DISCUSSION: The species is internally characterized by the distinctly bifid cardinal tooth, number 2, of the left valve. The homologous tooth is generally undivided or only slight bilobed in other species that are externally similar to *S. bifidus*.

Externally the species is characterized by the relatively strongly opisthogyre beaks, the broad siphonal ridge and depression inclined at a relatively low angle to the hinge, and the strong development of concentric fila on the anterior umbonal slope.

Schizodus canalis bears a similar but more angular siphonal ridge and is distinctly less elongate than the present species. *Schizodus* sp. a has a more subquadrate outline and orthogyre or prosogyre beaks. Some forms of *S. texanus* show similar concentric ornamentation but lack the radial ornamentation of the posterodorsal region, have orthogyre or prosogyre beaks, and a less prominent siphonal ridge and depression.

Newell (1940, p. 293), in discussing relationships of *Schizodus* and *Myophoria*, indicates that the bifid tooth, number 2, of the left valve, and opisthogyre beaks are features of specialization in *Schizodus*, beyond that of the stratigraphically younger genus *Myophoria*, and in these respects *Schizodus* is more like *Trigonia* and may be directly ancestral to it. *Schizodus bifidus* may thus be specialized and phylogenetically more advanced than other known forms of the Permian of North America.

OCCURRENCE: *Schizodus bifidus* is common in the Franson member at Hidden Pastures, Montana; rare in the Franson at Spring Creek, Wyoming; rare in the Ervay member at Burroughs Creek and Red Creek, Wyoming; and rare in the upper member of the Shedhorn sandstone at Flat Creek, Wyoming, and Big Timber, Montana. The species is questionably identified from rare occurrences in the lower chert member at Wheat Creek, Wyoming, the Retort member at Deadline Ridge, Wyoming, and the Grandeur member at Horseshoe Canyon, Utah.

Despite the fairly widespread occurrence, well-preserved specimens are extremely rare, and certain features such as surface ornamentation and variations in configuration are poorly known.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 140490; topoparatype, U.S.N.M. No. 140491; paratype, U.S.N.M. No. 140492.

Schizodus canalis C. C. Branson

Plate 10, figures 7, 8

Schizodus canalis C. C. BRANSON, 1930, p. 46 'pl. 13, fig. 1.

DISCUSSION: This relatively small schizodid is characterized by its relatively great height, short and very steeply inclined anterior umbonal slope, slightly opisthogyre beaks, and a sharp, angular siphonal ridge and bounding depression. The dentition of the species is unknown.

Two relatively large specimens, an incomplete specimen from float at the holotype locality and an internal mold from a nearby locality, suggest that Branson's holotype may be an immature specimen. The internal mold shows evidence of a very prominent, ovate, anterior adductor muscle impression. The posterior adductor impression is barely recognizable, but preservation of this portion of the specimen may be incomplete.

This species closely resembles undescribed forms of Lower Wordian age of the southwestern United States. The latter are probably conspecific with *S. canalis*. *Schizodus emarginatus* Reed, from the Upper Productus limestone of the Salt Range, is also very similar to the North American forms.

MEASUREMENTS (IN MM.):

	H	L	½C
Rt	20+	24	7
Rt, holotype	14	16	5
Lt	21+	23+	7

OCCURRENCE: The holotype is from the Grandeur member at Bull Lake, Wyoming. The two additional specimens in the present collection are from float of questionable Grandeur age at Bull Lake, and from the Meade Peak member at Mexican Creek, Wyoming. Branson reports the species from the Grandeur member of the Wind River Mountains, Wyoming.

CATALOGUED SPECIMENS: Holotype, U.M. No. 5312; hypotype, A.M.N.H. No. 28332.

Schizodus subovatus Ciriacks, new species

Plate 10, figures 1–6

DESCRIPTION: Shell subquadrate to ovate, prosocline, height/length ratio about 4/5, convexity a little less than shell height; anterior margin indistinct, rounded acutely and uniformly into dorsal and ventral margins; ventral margin broadly rounded, convex-down, turning abruptly at greater than 90 degrees into a nearly straight, relatively short posterior margin; posterodorsal angle obtuse, dorsal margin gently arched, highest point beneath the beaks; beaks prosogyre, located slightly anteriorly, extending beyond hinge line; ornamentation consisting of gently rounded, subdued, postumbonal ridge extending to the posteroventral angle, and very fine, faintly developed, concentric fila.

Dentition,

$$\frac{3a \ , \ 3b}{4a \ , \ 2 \ , \ (4b)},$$

with anteriormost cardinal tooth on the left valve; 2 and 3a large, subtrigonal, 2 not distinctly bilobed or bifid, but undivided, 3b heavy, elongate, inclined nearly parallel to hinge, 4a short and slender, 4b indistinct, or may be the edge of ligament nymph; ligament opisthodetic; adductor muscle impressions shallow, subcircular, located high under hinge.

TABLE 21

MEASUREMENTS (IN MILLIMETERS) OF *Schizodus subovatus* CIRIACKS, NEW SPECIES

	H	L	½C	PDA
Lt	13.0	15+	3.5	145°
Lt, holotype	7.5	9	2.5	140°
Rt	12.0	15	4.0	135°
Rt	8.0	10	3.0	130°

DISCUSSION: This relatively small myophoriid is described on the basis of seven silicified specimens, three of which are fragmentary, from a single locality. The species is characterized by the relatively extended, uniformly rounded, anterior shell region, the strong forward obliquity, and the only slightly tapering posterior margin with a distinct, obtuse posteroventral angle. The umbonal ridge is broadly rounded and relatively obscure. The dentition differs from more typical forms in that the bilobation of cardinal tooth number 2 is nearly imperceptible in the specimens at hand.

The relatively high posterior margin and rounded postumbonal ridge are suggestive of *S. ferrieri*, a slightly younger form common in the Meade Peak member of Idaho. *Schizodus ferrieri* is less extended anteriorly, has a lower posterodorsal angle, and has a more steeply inclined postumbonal ridge than *S. subovatus*.

The relatively small size of the available specimens indicates that they may be juveniles. They are, however, morphologically distinct from other larger forms known to the writer. Although the limited quantity of specimens is not sufficient for a complete characterization, the available specimens show diagnostic external and internal characters that make the designation of a new species justifiable.

OCCURRENCE: *Schizodus subovatus* is known only from the Grandeur member at Cephalopod Gulch, Utah, where it is associated with a single specimen of *Eoastarte subcircularis* and abundant *Orthonema* gastropods.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 140493; topoparatype, U.S.N.M. No. 140494.

Schizodus ferrieri Girty

Plate 10, figures 11, 12

Schizodus ferrieri GIRTY, 1910, p. 41, pl. 4, figs. 12, 13.

DISCUSSION: *Schizodus ferrieri* is characterized by its nearly square configuration, high convexity, prosogyre beaks, and rounded postumbonal ridge developed at a relatively high angle (about 55° in the holotype) to the hinge line. The left valve included in Girty's types is relatively longer (having a height/length ratio of 0.8 as opposed to 1.0 for the holotype right valve) which indicates either a wide variation in configuration of the species, as suggested by Girty, or that the left is not conspecific with the right valves of *S. ferrieri*.

There is some doubt as to the generic placement of the species because the dentition is unknown. Girty placed the species with *Schizodus* because of its shape and general expression, realizing that strong development of a posterior region which tapers only slightly and with a posterior margin nearly at right angles to the hinge is unlike most other species of *Schizodus*.

MEASUREMENTS (IN MM.):

	H	L
Rt, holotype	22.5	24
Lt, paratype	23.0	30

OCCURRENCE: Girty reports the species from the Meade Peak member in the Crawford Mountains (station 969) and Coal Canyon, Wyoming; and Bear Lake and Montpelier Canyon, Idaho. The present collections show additional rare occurrences in the Meade Peak at Hot Springs, Waterloo, and North Rasmussen Valley, Idaho, and Layland Canyon, Wyoming. *Schizodus ferrieri* is questionably identified from the Meade Peak at Paris Canyon, Lone Pine Spring, and North Wooley Range, Idaho.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 1712; paratype, U.S.N.M. No. 1711.

Schizodus sp. **a**

Plate 10, figures 18, 20

DISCUSSION: A single well-preserved internal mold is referred to *Schizodus* sp. a. It is similar to an undescribed form from the upper Kaibab formation of northern Arizona. The subquadrate lateral profile, prosogyre beaks, fairly angular postumbonal ridge defining a relatively large posteroventral region, and relatively high umbonal angle suggest close relationship with the Arizona forms.

The internal mold is 23 mm. high, 28 mm. long, and has a convexity of about 15 mm.

OCCURRENCE: The single specimen is from the Ervay member at Mexican Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, A.M.N.H. No. 28334.

Schizodus cf. **oklahomensis** Beede

Plate 10, figures 16, 17, 19

Schizodus? oklahomensis BEEDE, 1907, p. 157, pl. 7, fig. 6.

Schizodus ovatus, BEEDE, 1907, p. 157, pl. 7, figs. 7–7b.

Schizodus oklahomensis, NEWELL, 1940, p. 291, pl. 1, figs. 1–6.

DISCUSSION: A number of small, generally incompletely preserved, silicified specimens have the same general configuration and concentric ornamentation as *S. oklahomensis*. The dentition is difficult to compare because of poor preservation of the marginal cardinal teeth. In the Whitehorse forms described by Newell the anterior cardinal tooth, 4a, is highly developed, and the posterior cardinal tooth, 4b, becomes obsolete in mature individuals. The present forms show a fairly well-developed 4b, but the valves are relatively small in comparison to the Whitehorse specimens and may be juveniles. Cardinal tooth 2 is slightly bilobed in both the Whitehorse forms and the specimens at hand.

Some of the present forms are more equidimensional than typical *S. oklahomensis*, and all the available specimens fail to show radial costae on the posterodorsal region. A highly similar form, *Myophoria praecox* Waagen, from the Upper Productus limestone of the Salt Range, also lacks the radial costae and may be more closely related to the present forms.

MEASUREMENTS (IN MM.):

	H	L
Lt	12.5	15.0
Lt	9.5	11+
Rt	10.0	11.5+
Rt	9.0	11+

OCCURRENCE: *Schizodus* cf. *oklahomensis* is abundant in the upper member of the Shedhorn sandstone at Alpine Creek, Montana, and rare in the same horizon at Forellan Peak, Wyoming; questionably identified from common occurrences in the Franson member at Crystal Creek, Wyoming, the Meade Peak member at Cokeville, Wyoming, and the Grandeur member at Wheat Creek, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140495–140497.

Schizodus sp. **b**

Plate 10, figures 9, 10

DISCUSSION: Some small internal molds and silicified specimens from different horizons at three localities are grouped under *Schizodus* sp. b. All are relatively flat and nearly equidimensional, have orthogyre to slightly opisthogyre beaks, and possess a subangular postumbonal ridge. The dentition,

$$\frac{3a \quad , \quad 3b}{4a \quad , \quad 2 \quad , \quad (4b)},$$

is typically schizodid.

These specimens are probably closely related to *S. supaiensis* Winters, from the Supai formation of Arizona. The small size suggests they might, however, be juveniles of forms like *S. oklahomensis* or *S. canalis*.

MEASUREMENTS (IN MM.):

	H	L
Lt	10.0	12.0
Lt	7.5	9.5
Rt	6.0	8.0

OCCURRENCE: Silicified specimens referred to *Schizodus* sp. b are rare in the Grandeur member at Willow Creek, Wyoming, and in the Ervay member at Mexican Creek, Wyoming. Internal molds are common in the Franson member at Fontenelle Creek, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. No. 28333.

COSTATORIA WAAGEN, 1907

Costatoria sexradiata (C. C. Branson)

Plate 11, figures 3, 4

Deltopecten sexradiata C. C. BRANSON, 1930, p. 50, pl. 11, figs. 11–12.

DESCRIPTION: Shell subtrigonal, prosocline, inequilateral, posteriorly extended, height/length ratio about 4/5; beaks prominent, located slightly anteriorly, slightly prosogyre; hinge line straight, about two-thirds as long as shell; shell body ornamented by from five to seven or more coarse, radiating plicae, separated by broad interspaces; posterior plica sharply angular and raised, and diverging slightly posteriorly to form posteroventral angle; a broad, steeply sloping, apparently smooth shelf separating terminal plica and posterior margin; fine, closely spaced, dorsally arched concentric fila prominently displayed on interspaces; adductor muscle impressions circular, subequal, located just below hinge line; pallial line deeply impressed, simple, located about 5 mm. from shell margin on lectotype; dentition unknown.

The lectotype, an internal mold of a left valve, is 28 mm. high, 35 mm. long, and has a half convexity of about 7 mm.

DISCUSSION: Although Branson's syntypes of the species are poorly preserved internal molds, the general configuration and ornamentation indicate that these forms bear the generic characters of the cosmopolitan Triassic genus *Costatoria*. Comparison with similar, undescribed, silicified material from the Permian of West Texas confirms this view.

The specific name is somewhat misleading in that only five plicae can be recognized on the lectotype, and additional material identified as *C. sexradiata* may have as many as seven or more plicae per valve. Because of the small number of specimens and poor preservation, the species is relatively poorly known. The species is characterized by its subtrigonal configuration, variable but relatively few radial plicae, and the angular siphonal ridge. Similar, but specifically distinct, undescribed forms from the Word formation of the southwestern United States differ in configuration and ornamentation. The forms described below as *C. sexradiata?* may be conspecific with the present forms but are treated separately because of slight differences in morphology and stratigraphic occurrence.

OCCURRENCE: The lectotype is from the Ervay member at Big Horn Canyon, Wyoming; the paratype, from the Ervay at Bull Lake, Wyoming. Additional rare occurrences are in the Ervay at Bargee and Burroughs Creek, Wyoming, and a questionably identified fragment is from the upper member of the Shedhorn sandstone at Cinnabar Mountain, Montana.

This occurrence of *Costatoria*, its presence in the Permian of the southwestern United States, and an occurrence in the questionably late Permian of Japan (Nakazawa, 1960, p. 54) indicate that the known geologic range of the genus can be extended back into the Permian, probably as far as the base of the Wordian in North America.

CATALOGUED SPECIMENS: Lectotype, U.M. No. 5297; paratype, U.M. No. 5296.

Costatoria sexradiata? (C. C. Branson)

Plate 11, figures 1, 2

Deltopecten sexradiata C. C. BRANSON, 1930, p. 50, pl. 11, figs. 11–12.

DISCUSSION: The internal molds of two right valves are generally similar to *C. sexradiata* but differ from Branson's types in that they are smaller, appear to be more finely ornate (containing seven and about 10 plicae per valve), and have an even more prominent and angular, sharply diverging, posterior plica. The slope posterior to the siphonal ridge is inclined at nearly right angles to the shell body and is smooth except for the faint development of two ridges near the beak and concentric fila.

A nearly complete mold is 18.5 mm. high, 23.5 mm. long, and has a half convexity of about 6 mm.

The limited knowledge of the variation and morphological limits of *C. sexradiata* makes it difficult to decide whether these forms are juveniles or variants of *C. sexradiata*, or if they represent a separate species, possibly ancestral to *C. sexradiata*, as suggested by their slightly older stratigraphic position. The small size and more numerous plicae of these specimens suggest a form somewhat intermediate between undescribed species from the Word Number 3 limestone and those from the Word Number 4 limestone of West Texas.

OCCURRENCE: The two specimens are from the Franson member at Crystal Creek, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140498, 140499.

FAMILY SCAPHELLINIDAE

SCAPHELLINA NEWELL AND CIRIACKS, 1962

Scaphellina phosphoriensis (C. C. Branson)

Plate 11, figures 7–10

Schizodus phosphoriensis C. C. BRANSON, 1930, p. 47, pl. 13, figs. 2–7.

DESCRIPTION: Shell slightly elongate, extended posteriorly, tapering to a truncate, slightly gaping posterior margin; height/length ratio variable from about 4/5 to nearly 1/1, convexity a little less than shell height; beaks slightly opisthogyre, located slightly anteriorly, curved down over hinge; surface of shell smooth except for faintly developed concentric fila; pallial line prominent, with fairly deep, broadly to more sharply curved pallial sinus; adductor muscle impressions subovate to subtrigonal, tapering dorsally, posterior adductor supported by strong myophoric buttress, adductors located relatively high on body under hinge; dentition unknown.

MEASUREMENTS (IN MM.), NEARLY COMPLETE INTERNAL MOLDS:

	H	L
Lt, lectotype	43	44+
Lt, topotype?	34	47
Lt	32	41
Rt	36	44
Rt	29	31+

DISCUSSION: *Scaphellina phosphoriensis* possesses a prominent pallial sinus, strong posterior myophoric buttress, and gaping posterior margin—characters of the genus that distinguish it from *Schizodus*. In size and general configuration the species is very similar to the genotype, *S. bradyi* Newell and Ciriacks, from the lower Kaibab limestone of Arizona. Branson's types, plus additional material presently available, are insufficiently preserved to establish definitely that the two species are conspecific, but a close relationship is certainly indicated. *Scaphellina phosphoriensis* is also closely related to *S. concinnus*, a generally smaller, more elongate form which occurs in the Grandeur member, a stratigraphically lower horizon than that of the known occurrences of *S. phosphoriensis*.

Included in Branson's syntypes is a bivalved internal mold with prosogyre beaks and a size and shape suggestive of those of *Edmondia gibbosa*. Another fragmentary specimen, which has no indication of the posterior myophoric buttress characteristic of *Scaphellina*, is probably a true schizodid.

OCCURRENCE: The species is rare in the Ervay member at Red Creek, Wyoming; abundant in the upper member of the Shedhorn sandstone at Sappington, Montana; rare in the same horizon at Big Timber, Montana; rare in the Franson member at North Wadham Spring, Montana; and abundant in float, Grandeur?, west of Dubois, Wyoming. It is questionably identified in the Franson member at Washakie Reservoir, Wyoming.

CATALOGUED SPECIMENS: Lectotype, U.M. No. 5313; topotype?, A.M.N.H. No. 28335/1; hypotypes, U.S.N.M. No. 140522, A.M.N.H. No. 28335/2.

Scaphellina concinnus (C. C. Branson)

Plate 11, figures 5, 6

Schizodus concinnus C. C. BRANSON, 1930, p. 46, pl. 13, figs. 12–13.

DESCRIPTION: Shell ovate-elongate, extended to form a slightly gaping posterior margin; height/length ratio about 2/3, convexity low; beaks subdued, opisthogyre, nearly centrally located; surface of shell smooth except for faintly developed fine concentric fila; pallial line with prominent sinus, variable from shallow and broadly rounded to deep and acutely angular; adductor muscle impressions subcircular, situated relatively low on the body; dentition unknown.

MEASUREMENTS (IN MM.), INTERNAL MOLDS:

	H	L
Lt, lectotype	21	30
Lt	14	21

DISCUSSION: This species is smaller, relatively longer, and has more centrally located beaks than other known species of *Scaphellina*. It is possible that these forms are immature individuals of *S. phosphoriensis*, since small forms of the latter have not been identified. However, the present forms are distinctly separable from *S. phosphoriensis* and, in the absence of transitional morphological forms, can be considered a valid species.

The generic characters of *Scaphellina* are well displayed on several internal molds. Branson apparently misinterpreted the pallial sinus as a posterior muscle scar. He refers to two posterior adductor scars situated one above the other.

OCCURRENCE: The lectotype and topoparatype, plus three additional molds in the present collection, are from the Grandeur member at Bull Lake, Wyoming. Branson reports the species from the Grandeur in the Wind River and Owl Creek Mountains, Wyoming, but subsequent collecting has yielded only the three specimens from the type locality.

CATALOGUED SPECIMENS: Lectotype, U.M. No. 5316; topoparatype, U.M. No. 5315; hypotype, U.S.N.M. No. 140500.

FAMILY ASTARTIDAE

ASTARTELLA HALL, 1858

Astartella subquadrata Girty

Plate 12, figures 6–9

Astartella subquadrata GIRTY, 1909, p. 94, pl. 10, figs. 10–13.

Astartella subquadrata, CLIFTON, 1942, p. 693.

Astartella subquadrata, H. CHRONIC, 1952, p. 150, pl. 10, figs. 5–15.

DISCUSSION: An incomplete silicified right valve and a single bivalved specimen show close similarity to and are probably conspecific with *A. subquadrata*. The silicified valve possesses the dentition characteristic of the species, and the configuration, surface ornamentation, and measurements of the bivalved specimen are similar to those of larger forms described by Chronic from the upper Kaibab limestone.

The bivalved specimen is 6.4 mm. high, 7.3 mm. long, and has a convexity of 4.8 mm.

Astartella subquadrata is apparently closely related to *A. nasuta* Girty, a species described on the basis of fragmentary material from the Delaware Mountain formation of West Texas.

Astartella nasuta is slightly larger and more anteriorly extended than typical *A. subquadrata*. The dentition of the Texas form is not known, and differences in size and configuration, based on observations of a very few specimens, do not sufficiently distinguish the species from similar forms. The bivalved specimen at hand has an anteriorly extended outline similar to that of the West Texas forms, but its measurements, and the form and dentition of the silicified right valve from the same horizon at another locality, are clearly those of *A. subquadrata*. It seems most probable that all these forms are members of a single widespread species.

OCCURRENCE: The two available specimens are from the Grandeur member at Cephalopod Gulch, Utah, and Grizzly Creek, Idaho.

Astartella subquadrata also occurs in the upper Kaibab formation in Arizona, the San Andres and Yeso formations in New Mexico, and the Word Number 1 limestone and probably other horizons of the Permian of West Texas. Similar forms, such as *A. vallisneriana* (King) from the Upper Permian of Greenland, Zechsteinian of England and Germany, and the Artinskian in Russia, *A. tunstallensis* (King) from the Magnesium limestone of England, and *A. permocarbonica* (Tschernyschew) from the Kanzanian of Russia, indicate a cosmopolitan distribution of closely similar, small representatives of the genus (see Newell, 1955, p. 30).

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 140401, 140402.

Astartella sp.

Plate 12, figure 10

DISCUSSION: A nearly complete right valve, a poorly preserved internal mold, and a fragmentary specimen possess the generic characters of *Astartella* but show insufficient detail for specific designation. The internal mold indicates a dentition similar to that of *A. subquadrata*, although it is incompletely preserved. The present forms differ from *A.*

subquadrata in having a slightly greater height than length, highly prosogyre beaks, and a more circular configuration. Surface ornamentation consists of very prominent, raised concentric lamellae, numbering about 25 on a specimen 7.4 mm. high, spaced progressively farther apart marginally. Very fine, closely spaced, concentric fila occur between the lamellae.

OCCURRENCE: The three specimens are from different horizons at three localities: the Retort member at Cedar Creek, Montana; the Franson member at Middle Fork of Pine Creek, Wyoming; and the Grandeur member at Spring Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, U.S.-N.M. No. 140503.

EOASTARTE CIRIACKS, NEW GENUS

GENOTYPE: *Eoastarte subcircularis* Ciriacks, new species.

DIAGNOSIS: Shell ovate or subcircular, inequilateral, prosocline; beaks prominent, anteriorly placed, prosogyre; shell surface smooth; dentition lucinoid-astartid,

$$\frac{,\ \ 3b\ \ ,\ \ 5b}{2\ \ ,\ \ 4b\ \ ,}\ ,$$

with cardinal teeth of left valve anterior to those of right valve, without lateral teeth; 3b and 4b heavy, subtrigonal, steeply inclined to hinge; 2 short, slender, 5b elongate, slender, both inclined nearly parallel to adjacent shell margins; ligament opisthodetic, ligament nymphs and grooves short and shallow; adductor muscle scars deep, subovate, dorsally extended, located high under hinge; anterior adductor pit bounded above by a strong buttress which is fused with cardinal plate; pedal muscle impressions present on umbones, extending up under beaks; pallial line prominent, simple, subcircular.

DISCUSSION: The new genus is represented by six silicified specimens of the genotype, and two silicified specimens, probably specifically distinct, from the Word Number 1 limestone of West Texas. Thus characterization and diagnosis of normally variable morphological features are difficult.

The dentition is well displayed and is clearly distinct from that of other closely similar genera. The absence of lateral teeth, with a typically astartid cardinal dentition, is unique to this genus and *Kaibabella* H. Chronic, 1952, from the upper Kaibab formation of Arizona. The dental formula of *Kaibabella* is

$$\frac{,\ \ 3b\ \ ,\ \ 5b}{2\ \ ,\ \ 4b\ \ ,\ \ (6b)}\ ,$$

differing from that of *Eoastarte* by the presence of a faintly developed posterior cardinal tooth on the left valve. In addition, the left anterior cardinal tooth, 2, is highly extended laterally in *Kaibabella*, and the other teeth and sockets differ slightly in inclination and relative prominence. Externally, *Kaibabella* is unlike *Eoastarte* in having a more elongate, subquadrate profile, subdued, centrally placed beaks, and prominent concentric ornamentation.

Eoastarte is characterized externally by its subcircular shape, smooth shell surface, and prominent prosogyre beaks. These features are similar in some forms of the younger genus *Astarte* (Jurassic to Recent). *Astarte*, however, is characterized by a well-developed anterior lateral tooth on the right valve, AI, but the remainder of the dentition is similar to that of both *Eoastarte* and *Kaibabella*. The relatively reduced dentition of *Eoastarte* suggests that the genus may have great evolutionary significance in representing an early ancestral form of the Astartidae.

KNOWN RANGE OF GENUS: Permian; Park City formation (Grandeur member), Wyoming and Utah; Word Number 1 limestone, Texas.

Eoastarte subcircularis Ciriacks, new species

Plate 12, figures 11–15

DESCRIPTION: Shell subcircular, gibbose, inequilateral, posteriorly extended, slightly longer than high, convexity about two-thirds of shell height; beaks prominent, prosogyre, extended beyond and curved down over hinge, located about one-fourth of shell length behind anterior extremity; lateral profile broadly, nearly uniformly rounded except for dorsal margin which is straight behind beaks, then slightly concave upward to anterior margin; shell surface apparently smooth, unornamented; dentition and other internal features those of the genus (defined above).

MEASUREMENTS (IN MM.):

	H	L	½C
Lt, holotype	14.0	14.5	4.5
Lt, topoparatype	11.5	12.0	3.5
Lt, topoparatype	10.0	10.5	3.5
Lt, topoparatype	7.5	7+	2.5
Rt, paratype	9.0	10.0	3.0

DISCUSSION: The species is described on the basis of six silicified valves, four left valves, and a fragmentary right valve from one locality, and a single right valve from the same horizon at a second locality. The hinge characters and dentition confirm the generic identity of the single right valve, and the size, shape, smooth surface, and stratigraphic position indicate that it is conspecific with the left valves.

The separation of specific and generic characters is, of course, difficult, because other representatives of *Eoastarte* have not been described. Two small silicified specimens, from the Word Number 1 limestone in West Texas, have similar dentition but differ from *E. subcircularis* in being more equilateral and in having less prominent beaks and a lower convexity.

The diagnostic features of *E. subcircularis* thus appear to be its subcircular configuration, prominent and anteriorly located beaks, and relatively high convexity. The generic identification of specimens not showing internal features is difficult. The external characters are similar to many other genera, often in very distantly related groups, such as the nuculids.

OCCURRENCE: Five specimens are from the Grandeur member at Willow Creek, Wyoming, associated with *Oriocrassatella* sp., *Schizodus* sp. b, *Polidevcia obesa*, and *Nuculopsis poposiensis*. The single complete right valve is from the Grandeur member at Cephalopod Gulch, Utah, associated with *Schizodus subsubovatus*.

CATALOGUED SPECIMENS: Holotype, A.M.N.H. No. 28337; topoparatypes, A.M.N.H. Nos. 28338:1–28338:4; paratype, U.S.N.M. No. 140504.

FAMILY CRASSATELLIDAE

ORIOCRASSATELLA ETHERIDGE, JR., 1907

Oriocrassatella sp.

Plate 12, figures 1–3

DISCUSSION: A single silicified right valve and a dentition fragment of a right valve are assigned to *Oriocrassatella*. Although the hinge plate is somewhat incomplete, owing to breakage and poor preservation, it appears to be that of the genus, with dental formula AI3a-3b-rsl-PIII, as indicated by Newell (1958, p. 6). The lateral teeth are poorly preserved, and 3a is not distinctly separated from the anterior part of the hinge plate. (The latter feature formerly distinguished *Oriocrassatella* from *Procrassatella*, which are now considered congeneric.) The resilifer and dividing septum are clearly shown.

The general elongate configuration, lack of a well-defined lunule and escutcheon, and smooth nature of the shell confirm the generic identity. A new species is not designated, because a single specimen seems insufficient for characterization of a species in this genus.

The right valve is 11 mm. high, 17 mm. long, and has a half convexity of about 3 mm.

The specimen is somewhat similar to but is smaller than *O. plana* (Golowkinsky) from the Kazanian of Russia.

OCCURRENCE: *Oriocrassatella* sp. is rare in the Grandeur member at Willow Creek, Wyoming. The genus is believed to range from Artinskian to Kazanian and has been reported from Greenland, Russia, Australia, Timor, and Kashmir?, but is previously unknown from the continental New World.

CATALOGUED SPECIMEN: Hypotype, A.M.N.H. No. 28336.

FAMILY PERMOPHORIDAE

PERMOPHORUS CHAVAN, 1954

Permophorus albequus (Beede)

Plate 13, figure 15

Pleurophorus? albequus BEEDE, 1907, p. 160, pl. 6, figs. 8–8e.

Pleurophorus? albequus longus BEEDE, 1907, p. 162, pl. 6, fig. 9.

Pleurophorus albequus, NEWELL, 1940, p. 298, pl. 3, figs. 1, 4–8, 14, 16–18.

Pleurophorus albequus longus, NEWELL, 1940, p. 300, pl. 3, figs. 2, 3, 15, 19–23.

DISCUSSION: *Permophorus albequus* is represented in the present collection by an incomplete silicified left valve and a few poorly preserved internal molds. The silicified valve shows the cardinal dentition of one tooth and socket and the vertical buttress behind the anterior muscle pit. The external surface does not display the papillate ornamentation of the species but possesses a few faintly developed costae that extend radially from the beak to the posterior margin.

Internal molds are highly elongate and are probably of the variety *P. albequus longus* of earlier authors. Newell (1940, p. 300) has suggested that the differences in configuration of this variety and more typical forms of the species, which are commonly associated, may be due to dimorphism within a single population. In addition to similar size and shape, the internal molds possess the impression of the vertical buttress and the broad, flattened, umbonal sulcus characteristic of the species.

A typical internal mold is 9.5 mm. high and 20.5 mm. long.

The internal molds are difficult to distinguish from molds of *P. pricei*, a species similar in size and shape but having prominent radial surface ornamentation. *Permophorus pricei* occurs higher in the stratigraphic sequence in the Wind River Mountains, Wyoming.

OCCURRENCE: *Permophorus albequus* is rare in the Grandeur member at Cephalopod Gulch, Utah, and Wheat Creek, Fontenelle Creek, and La Barge Creek, Wyoming. The species is questionably identified from the Grandeur at Cumberland, Wyoming, where it is abundant, and from rare occurrences in the Franson member at Blind Stream and Coulter Ranger Station, Utah, and Fontenelle Creek, Wyoming.

CATALOGUED SPECIMEN: Hypotype, U.S.N.M. No. 140505.

Permophorus pricei (C. C. Branson)

Plate 13, figures 1, 2

Pleurophorus pricei C. C. BRANSON, 1930, p. 52, pl. 12, figs. 8, 9; pl. 13, figs. 11, 12.

DISCUSSION: The species is characterized by its anteriorly extended beaks, strong forward obliquity, subrectangular lateral profile, and prominent radial ornamentation. The dentition is unknown and internal features are poorly known, based on an internal mold which shows the vertical buttress impression characteristic of the genus.

Only two left valves and an internal mold (Branson's syntypes) are presently available. Intraspecific variation and morphological limits of the species are essentially unknown, but the specimens are distinctive and can be readily recognized on the basis of external features. *Permophorus pricei* cannot be closely compared to other species of *Permophorus* known to the writer.

MEASUREMENTS (IN MM.) OF TYPES:

	H	L	½C
Lt, lectotype	7.0	16.5	2.5
Lt, topoparatype	9.5	21+	3.5

OCCURRENCE: The types are from the Ervay member at Bull Lake, Wyoming. Branson reports the species as fairly abundant in the Ervay of the Wind River Mountains, Wyoming, but subsequent collecting has revealed no additional specimens.

CATALOGUED SPECIMENS: Lectotype, U.M. No. 5318; topoparatype, U.M. No. 5317.

Permophorus? sp.

DISCUSSION: Internal molds of an elongate, subovate, concentrically ornamented form are questionably referred to the common Permian genus *Permophorus*. Internal characters are not shown, but the general configuration, with subdued, anteriorly placed beaks, is suggestive of the genus.

An external mold shows beaks that may have extended well over the hinge line and were located about one-quarter of the shell length behind the anterior margin. This configuration is more suggestive of forms such as *Edmondia* or *Wilkingia*.

A compressed, but essentially complete, left internal mold is 14.5 mm. high and 25 mm. long.

OCCURRENCE: These forms are rare in the Tosi member at Hogback, Montana, and are questionably identified from rare occurrences in the Ervay member at Dinwoody Canyon and Burroughs Creek, Wyoming.

PSEUDOPERMOPHORUS CIRIACKS, NEW GENUS

GENOTYPE: *Pseudopermophorus annettae* Ciriacks, new species.

DIAGNOSIS: Shell heavy, slightly inequivalved, elongate, subquadrate, tapering slightly posteriorly; beaks subdued, placed slightly behind anterior extremity; dorsal margin broadly convex, ventral margin sinuous, gently indented medially at terminus of a broad, shallow, umbonal sulcus; posterior and anterior margins broadly rounded, latter slightly shorter, with a small circular gape just below beak; escutcheon deep, long, more prominent on right valve, gaping depression in front of beak occupying position of lunule; ligament opisthodetic, parivincular, nymphs well defined; shell surface ornamented with course, rounded, concentric fila.

Dentition heterodont, dental formula

$$\frac{,\ 3b\ ,\ 5b\ ,\ (PIII)}{2\ ,\ 4b\ ,\ PII\ \ ,},$$

cardinal teeth of left valve anterior to those of right; 2 and 3b elongate, subtrigonal, and heavy, 4b and 5b slender and elongate, PII very long, well developed, PIII difficult to distinguish from cardinal margin, but opposed by deep socket on left valve; anterior adductor impression deep, subcircular, supported by a strong, nearly vertical buttress; a deep, rounded-subtrigonal depression located at anterior end of cardinal plate, depression larger on left valves, bounded by cardinal tooth 2 and a rim on left valve, which fit closely into corresponding socket and shelf of right valve, probably isolating chamber from interior of shell.

DISCUSSION: The external configuration and internal characters of the genus are closely similar to those of *Permophorus*. Characteristic differences are found in the dentition and anterior region of the cardinal plate. *Pseudopermophorus* possesses a slender, but well-defined, second cardinal tooth, 5b, on the right valve which is posterior to 4b of the left valve. The anterior cardinal tooth, 2, of the left valve is smaller than the homologous tooth in *Permophorus*, probably owing to the presence of the very striking and unusual depression situated in front of the cardinal dentition and above the anterior adductor in *Pseudopermophorus*.

This depression is larger on left valves than opposing right valves and is apparently isolated from the interior of the shell by a compact closure of the bounding tooth and rim of the left valve into a corresponding socket and shelf on the right valve. The location of the depression, anterior to the beaks, and the presence of well-defined, characteristically permophorid, ligament grooves and nymphs posterior to the cardinal dentition strongly suggest that the depression is not a resilifer. A split ligament or a ligament located below the beaks is unknown in permophorids or other closely related forms.

The depression may be considered an invaginated lunule because of its homologous position, but this fails to explain the functional significance of this chamber. *Coelopsis* (*Cryptocoelopsis*) *locularis* Bittner, from the Karnian of the Alps, has a somewhat similar chamber anterior to the cardinal dentition and in front of the lunule. Bittner (1895, p. 34) suggests that this may be a brood chamber and questionably designates forms possessing this feature as females of a closely similar form, *C.* (*C.*) *affinis* (males), which lack the invaginated chamber. The present forms, however, show no evidence of dimorphism.

The circular external opening of this chamber is somewhat reminiscent of the pedicle opening in some forms of brachiopods, and possibly the chamber in the present forms housed a mechanism for temporary attachment of the anterior end of these apparently burrowing bivalves. Speculation of this type is, however, unsupported by evidence in fossil or living forms. The function of this depression cannot be determined without reference to analogous living forms or additional evidence in fossil material.

The genus *Protrete*, described by Girty (1908, p. 448) from the Delaware Mountain formation of West Texas, is a very small permophorid type of bivalve (about 8 mm. long) which also possesses a tubular perforation below the beaks. Girty states: "The dentition is not known with certainty, but there appear to be neither cardinal nor anterior teeth. In the left valve the long hinge line is thickened and longitudinally indented by a median groove. This may be the position of a resilium. At the same time there is an obscure escutcheon on the outside of the cardinal line, as if for an external ligament." The median groove mentioned by Girty may be homologous to the prominent lateral socket above PII, and opposing PIII, on the left valve.

Similarities in configuration, the lateral dentition of the left valve, and the presence of the unique circular, gaping depression below the beak indicate a close relationship between *Protrete* and the larger present forms. This is strengthened by their occurrence in rocks of similar, probably Guadalupian, age. However, the critical cardinal dentition is either absent or not preserved in *Protrete*, and Girty's generic description is based on a few very small, probably juvenile specimens. Extensive collections of Guadalupian bivalves from West Texas have not revealed forms like *Protrete*, and the forms at hand cannot be referred to this apparently similar but poorly known genus. This uncertainty regarding the dentition indicates that *Protrete* is probably unrecognizable, and it is here suggested that the West Texas forms be tentatively placed into synonymy with *Pseudopermophorus*.

KNOWN RANGE OF GENUS: Upper Permian; Park City formation (Franson member) and Phosphoria formation (Retort member), Montana; questionably present in the Delaware Mountain formation, Texas.

Pseudopermophorus annettae Ciriacks, new species

Plate 13, figures 6–14

DESCRIPTION: Shell elongate, height/length ratio about 1/3, convexity about one-quarter of shell length; beaks very subdued, almost indistinct, located just behind anterior extremity and above anterior gape; shell ornamented by a broad, shallow, umbonal sulcus, a posterior umbonal ridge defining a narrow, triangular, posterodorsal region, and fairly coarse, irregularly thickened, concentric lamellae, numbering 30 to 40 on mature specimens, which are highly imbricated near margins; escutcheon deep, elongate, nearly restricted to right valve, lunule apparently invaginated; ligament opisthodetic, nymphs well defined, extending back about one-quarter of shell length; dentition that of genus, dental plate anteriorly characterized by opposed depressions, a large, inflated, subtrigonal depression on left valve and a distinctly smaller, subcircular depression on right valve, forming a chamber with a circular, external opening.

DISCUSSION: Characterization of the species is difficult because it is the only known form of the genus. Size, relative dimensions, configuration, and surface ornamentation are commonly used to distinguish species in permophorid bivalves. *Pseudopermophorus annettae* may thereby be characterized by its relatively large size, low height/length ratio, gently sinuous ventral margin, and the presence of strongly imbricating concentric lamellae. Characters such as the subdued nature of the beaks, the restriction of the escutcheon to the right valve, and the inequality of the opposed depressions on the anterior cardinal plate cannot be assessed as specific or generic until other representatives of the genus are found.

TABLE 22

MEASUREMENTS (IN MILLIMETERS) OF *Pseudopermophorus annettae* CIRIACKS, NEW SPECIES

	H	L	C
B	25.0	63.5	15+
B, holotype	23.5	68.0	16.0
B	23+	75.0	19.5
B	19.5	56.5	17.0
Lt	22.5	64.5	—
Lt	21.0	68.5	—
Lt	21.0	61.0	18.0
Rt	26.0	75.0	—
Rt	25.5	66.0	—
Rt	23.0	63.5	—
Rt	17.5	53.0	—
Rt	13.0	41.5	—

A possibly closely related form is *Protrete texana* from the Delaware Mountain formation of West Texas (see discussion of genus above). If Girty's specimens are not juveniles, that species is considerably smaller, less densely ornate, and has a less tapering posterior margin than *P. annettae*.

Specimens not displaying the internal features or circular anterior gape of the species and genus are nearly inseparable from certain forms of the genus *Permophorus*.

OCCURRENCE: Abundant silicified specimens were obtained from the Franson member at Hidden Pastures, Montana, associated with rare *Schizodus bifidus* and *Polidevcia obesa*. The species is also common in a limestone tongue of the Retort member at Cedar Creek, Montana, and rare in the Franson at Sheep Creek, Montana.

CATALOGUED SPECIMENS: Holotype, U.S.N.M. No. 140506; topoparatypes, U.S.N.M. Nos. 140507–140510; paratypes, U.S.N.M. Nos. 140511, 140512.

CELTOIDES Newell, 1957

Celtoides unioniformis Newell

Plate 12, figures 4, 5

Celtoides unioniformis Newell, 1947, p. 12, figs. 3B, C, 4.

Discussion: A few additional specimens of this large, thick-shelled permophorid are recorded from the Franson member in western Wyoming. A poorly preserved internal mold shows that the surface is ornamented by fairly prominent, apparently irregular, concentric growth lines. The enormous size (the holotype is 125 mm. long) and thickness of the shell (up to 12 mm.) make identification, even of fragmentary material, quite reliable.

As indicated by Newell, this genus and species are closely related to *Permophorus*, differing primarily in details of the dentition.

Occurrence: The types are from the Franson member at Torrey Lake, near Dubois, Wyoming. Present collections show rare occurrences in the Franson at Tosi Creek and Crystal Creek, Wyoming; a rare occurrence in float of questionable Franson age at South Fork Canyon, Wyoming; and a common occurrence in the Rex member (probably a limestone lens of the Franson) at Deadline Ridge, Wyoming.

Catalogued Specimens: Holotype, A.M.-N.H. No. 28046; paratypes, A.M.N.H. Nos. 28046:1, 28046:2; hypotype, A.M.N.H. No. 28339.

STUTCHBURIA Etheridge, Jr., 1900

Stutchburia sp.

Plate 13, figures 3–5

Pleurophorus pinnaformis C. C. Branson, 1930, p. 52, pl. 12, figs. 5–7; pl. 13, fig. 13.

Discussion: Some highly variable, generally poorly preserved internal molds, with a configuration suggestive of that of *Stutchburia* and *Myoconcha*, are collectively referred to *Stutchburia* sp. The forms included vary in size and shape but have in common the general modioloid, posteriorly expanding shape and a slightly oblique buttress posterior to the anterior adductor. Some forms possess a distinct lunule and escutcheon, characteristic of *Stutchburia*.

The critical characters of the dentition are not known so that generic assignment is uncertain. Specific designation is undesirable because external features are poorly shown on the available specimens. The species *Pleurophorus pinnaformis* is considered essentially unrecognizable.

The specimens assigned to *Stutchburia* sp. generally are of two broad types: relatively large, elongate forms, including the types of Branson's *P. pinnaformis*, which show a rapid expansion posteriorly (attaining the greatest height near the posterior margin) and show faintly developed, closely spaced concentric lines; and smaller forms, generally resembling the subgenus *Netschajewia* Jakolew, 1925, which are smooth-shelled. Several species and perhaps several genera may be represented by the specimens at hand, but collective assignment to a single taxon seems least confusing at the present time.

Some of the forms resemble more elongate specimens of *S.? modioliformis* (King), which is widespread in the Upper Permian of Europe and Greenland.

Occurrence: The larger forms, including Branson's types of *P. pinnaformis*, are from the Grandeur member at Bull Lake, Wyoming; he reports these forms from the Grandeur member of the Wind River Mountains, Wyoming. The smaller forms here included in *Stutchburia* sp. are rare in the Ervay member at Dinwoody Canyon, Wyoming; in the Franson member at Gros Ventre Canyon, Flat Creek, and Hoback, Wyoming; and in the Meade Peak member at Cokeville, Wyoming. They are common in the lower member of the Shedhorn sandstone at Hoback, Wyoming, and abundant in the Franson at North Wadham Spring, Montana.

Catalogued Specimens: Hypotypes, U.M. Nos. 5307, 5319, U.S.N.M. No. 140515.

Family PHOLADOMYIDAE

WILKINGIA Wilson, 1959 (ALLORISMA King, 1850)

Wilkingia wyomingensis (C. C. Branson)

Plate 14, figures 11, 14

Allerisma wyomingensis C. C. Branson, 1930, p. 50, pl. 14, figs. 1–3.

Discussion: This large, robust species is characterized by the highly anterior position of the beaks, a fairly prominent posterodorsal gape, a shallow, ventrally flaring, midumbonal sulcus, and its surface ornamentation of irregularly thickened concentric fila intersected by fine, wavy, radial costellae. Branson observed that these forms can be readily recognized in dorsal view by their "axe-head" type of profile.

MEASUREMENTS (IN MM.), BIVALVED SPECIMENS:

	H	L	C
	60	115	40+
	60	105+	45+
	57+	120	45
	50	105	43
Holotype	46	93	38

Similar forms that occur in the lower Kaibab formation (Gamma member) of Arizona are generally called *Allorisma capax* Newberry. Newberry's species is, however, unrecognizable (C. C. Branson, 1948, p. 561) as it was based on a single poorly preserved internal mold. The Kaibab forms observed by the writer are essentially indistinguishable from the present forms and are quite certainly conspecific with *W. wyomingensis*. *Allorisma waageni* Reed, from the Lower Productus limestone of the Salt Range, is very similar to the North American forms.

OCCURRENCE: *Wilkingia wyomingensis* is rare in the Franson member at Bull Lake and South Fork Canyon, Wyoming, and in float of questionable Franson age at an unspecified locality in the Wind River Mountains, Wyoming.

CATALOGUED SPECIMEN: Holotype, U.M. No. 5321.

Wilkingia? sp.

Plate 14, figure 15

DISCUSSION: A few incomplete internal molds of an elongate, concentrically ornamented bivalve are questionably referred to the genus *Wilkingia*. There is no posterior umbonal ridge as in *Sanguinolites*, and the margins are unlike those of *Parallelodon*. A compressed bivalved specimen possesses a lunule and escutcheon, which indicate that it is not an *Edmondia*.

The present forms show slight resemblance to *Allorisma komiansis* Moslennikow, from the Permian of Russia (Licheraw and others, 1939, p. 133, pl. 32, figs. 3, 4), which possesses coarse concentric ornamentation, but is distinctly less elongate than the forms at hand.

OCCURRENCE: Forms assigned to *Wilkingia?* sp. are rare to common in the Ervay member at Dinwoody Canyon, Wyoming.

CATALOGUED SPECIMEN: Hypotype, U.S.N.M. No. 140516.

FAMILY SOLENOMORPHIDAE

SANGUINOLITES McCOY, 1844

Sanguinolites? elongatus Ciriacks, new species

Plate 14, figures 6–10

DESCRIPTION: Shell equivalved, inequilateral, posteriorly extended, height/length about 2/5, convexity about two-thirds of shell height; beaks small, prosogyre, located about one-third of shell length behind anterior extremity; dorsal margin straight in front of beaks, then concave upward posteriorly; anterior margin rounded, curving uniformly into ventral margin which is nearly parallel to dorsal margin, slightly sinuous, gently indented at terminus of a broad, shallow, midumbonal sulcus; ventral margin curving abruptly into relatively high, truncate, slightly gaping, posterior margin which meets dorsal margin at a slightly obtuse angle; a slight, but distinct postumbonal ridge defining a narrow, subtriangular, posterodorsal region which may display a slight ridge and depression near the dorsal margin; lunule and escutcheon present, poorly known owing to distortion of specimens; shell thin, ornamented by irregularly thickened concentric folds and very fine concentric fila; ligament, dentition, and other internal characters unknown.

DISCUSSION: The species is highly similar to forms described as *Sanguinolites?* sp., from the upper Kaibab formation of Arizona (H. Chronic, 1952, p. 152, pl. 10, figs. 16, 17). The present forms differ in having a less well-defined postumbonal ridge and a more sinuate ventral margin, but the two forms are probably conspecific. Forms described below as *S.?* sp., from slightly higher in the sequence, have a similar configuration but possess distinctive fine radial costae.

MEASUREMENTS (IN MM.), BIVALVED SPECIMENS:

	H	L	C
	11.0	25.5	6.5
Holotype	10.5	25.0	7.0
	9.5	24.0	7.5
	8.5	18.5	5.5
	8.0	19.5+	6.0

Sanguinolites? elongatus possesses the external features characteristic of the genus, but internal characters are not displayed in the available specimens. Chronic states that the dentition is not preserved in her silicified specimens, but this may be a reflection of the edentulous hinge of the genus.

These forms cannot be closely compared with older, generally less elongate, forms of the genus.

OCCURRENCE: The species is represented by nine specimens from the Grandeur member at a single locality, Horseshoe Canyon, Utah.

CATALOGUED SPECIMENS: Holotype, U.S.-N.M. No. 140517; topoparatypes, U.S.N.M. Nos. 140518, 140519.

Sanguinolites? sp.

Plate 14, figures 12, 13

DISCUSSION: A few poorly preserved specimens are similar to *S.? elongatus* in configuration and size but differ in possessing closely spaced, radiating costellae which are faintly developed on the shell body, becoming imperceptible toward the dorsal margin. The postumbonal ridge is slightly more prominent than that of *S.? elongatus*, and the ventral margin is apparently not sinuous.

A nearly complete left valve is 12 mm. high and 28 mm. long.

These forms bear generic characters of *Sanguinolites* but are unlike known species in possessing radial costellate ornamentation. The designation of a new species is not desirable with the poorly preserved available material.

OCCURRENCE: These forms are rare in the Ervay member at Red Creek and Burroughs Creek and questionably identified in the Ervay at Dinwoody Canyon, Wyoming; rare in the Franson member at Canyon Creek, Montana.

CATALOGUED SPECIMENS: Hypotypes, A.M.-N.H. No. 28331, U.S.N.M. No. 140522.

Sanguinolites carbonaria (Girty)

Plate 14, figures 1–5

Grammysia? carbonaria GIRTY, 1910, p. 36, pl. 6, figs. 11–13.

DESCRIPTION: Shell slightly longer than high, moderately convex, posteriorly expanded, with greatest height near posterior margin; beaks subdued, prosogyre; ventral margin straight, nearly parallel to dorsal margin, rounding abruptly into anterior and posterior margins; posterodorsal angle slightly obtuse; ornamentation consisting of broad, rounded, concentric lamellae, numbering 25 to 30 on valves 20 mm. high, which are interrupted by a sharp, narrow, umbonal depression, roughly perpendicular to dorsal and ventral margins, located one-fourth to one-third of shell length behind anterior extremity; lamellae offset on opposite sides of depression; lamellae abruptly flexed into V shape (opening dorsally) along a line running roughly along posterior edge of umbone, terminating near beaks; flexing less pronounced ventrally, becoming imperceptible near posteroventral angle; internal features unknown.

MEASUREMENTS (IN MM.):

	H	L
Lt	29	44.5
Rt	20	28.0

DISCUSSION: Five specimens, four right valves and one left valve, of a form described by Girty as *Grammysia? carbonaria*, resemble *S. v-scriptus* Hind from the Carboniferous of England. The configuration and the highly characteristic surface ornamentation are nearly identical. The present forms are slightly larger than the British forms.

The Russian form *Goniomya artiensis* Krotow (see Licheraw and others, 1939, p. 134, pl. 32, fig. 12) is an apparently closely related Permian species which is probably congeneric with the Idaho and British forms.

OCCURRENCE: *Sanguinolites carbonaria* is represented by only five specimens in the present collections: three right valves (Girty's syntypes) and one left valve from the Meade Peak member at Montpelier Canyon, Idaho, and a single right valve from the Meade Peak at Lone Pine Spring, Idaho.

The British occurrences of *S. v-scriptus* are in the Millstone Grit (Lower Pennsylvanian) and Upper Limestone series (Upper Mississippian) and are thus distinctly older than the Permian occurrence of the present Idaho forms.

CATALOGUED SPECIMENS: Hypotypes, U.S.N.M. Nos. 1708, 1709, 1710, A.M.N.H. No. 28330.

EDMONDIA DE KONINCK, 1844

Edmondia gibbosa Swallow

Plate 11, figure 16

Edmondia gibbosa SWALLOW, *in* Swallow and Hawn, 1858, p. 189.

Edmondia gibbosa, C. C. BRANSON, 1930, p. 41, pl. 10, figs. 28–30.

DISCUSSION: Branson's hypotype of this relatively large, gibbose species is here refigured. The pustulose surface ornamentation and the fine radiating costellae and concentric folds on the internal molds appear to be characteristic of the species.

OCCURRENCE: The hypotypes, a right and left valve, are from the Grandeur member at Bull Lake, Wyoming. Although Branson reports the species from the Grandeur of the Wind River Mountains, Wyoming, additional specimens have not been found.

Edmondia gibbosa is reported from Pennsylvanian and Lower Permian strata in the southwestern United States and in Russia.

CATALOGUED SPECIMENS: Hypotypes, U.M. Nos. 5289, 5290.

Edmondia phosphatica Girty

Plate 11, figures 12–15

Edmondia? phosphatica GIRTY, 1910, p. 36, pl. 6, fig. 9.

DESCRIPTION: Shell inequilateral, prosocline, subquadrate-elongate, height/length ratio variable from 1/2 to 2/3, convexity about two-thirds of shell height; beaks prominent, prosogyre, located about one-quarter of shell length behind anterior extremity; anterior region extended, margin acutely curved, passing uniformly into slightly convex or slightly sinuate ventral margin; posterior margin higher than anterior, truncate, meeting dorsal margin at a generally distinct, obtuse angle; dorsal margin straight behind beaks, slightly concave up in front of beaks; a rounded postumbonal ridge extends to posteroventral angle, defining a triangular, gently sloping, posterodorsal shell area; shell thin, ornamented with fine, closely spaced, concentric fila, some of which are irregularly raised; internal characters unknown.

TABLE 23

MEASUREMENTS (IN MILLIMETERS) OF *Edmondia phosphatica* GIRTY

	H	L	H/L	C	PDA
B, lectotype	12.0	19.5	0.62	10.5	?135°
B	11.0	17.0	0.65	7.5	115°
B	10.5	17.0	0.62	7.5	125°
B	9.0	14.0	0.64	7.0	—
B	8.5	13.0	0.65	6.0	112°

DISCUSSION: Girty's original description is slightly modified to include forms that are apparently more variable than indicated. Girty failed to designate a holotype, or the holotype has been lost, and the single internal mold in his type collection, the specimen he illustrated, is here designated the lectotype. Subsequently collected forms, from the same member and general geographic area, differ slightly from the type specimen but are confidently placed in this species. Many forms show a distinct, obtuse, posterodorsal angle, which in the type is indistinct and rounded. Girty indicated that the straight or sinuate profile of the ventral margin is a diagnostic specific character, but many specimens show a broadly convex ventral margin.

The species is characterized by its relatively prominent postumbonal ridge, relatively extensive posterodorsal region (often with a distinct, obtuse, posterodorsal angle), and its strong forward obliquity. *Edmondia? bellula* Girty, from the Delaware Mountain and Capitan formations of West Texas, is very similar to *E. phosphatica* in size and configuration. The two forms may be conspecific.

The internal characters are unknown, but the species is confidently assigned to *Edmondia* on the basis of general configuration and the lack of a lunule and escutcheon.

OCCURRENCE: *Edmondia phosphatica* is abundant in the Meade Peak member at Hot Springs, Idaho, and Cokeville, Wyoming; rare in the Meade Peak at Trail Canyon, Idaho. Girty reports the species in the Meade Peak at Coal Canyon, Wyoming, and the Pruess Range, Idaho.

CATALOGUED SPECIMENS: Lectotype, U.S.-N.M. No. 1715; hypotype, U.S.N.M. No. 140521.

Edmondia sp.

Plate 11, figure 11

DISCUSSION: A single incomplete internal mold is very similar to abundant undescribed forms of *Edmondia* from the middle Permian of West Texas. J. Chronic (*in* Newell and others, 1953, p. 150, pl. 33, figs. 3a, b) described a similar form, *Edmondia* sp., from the Permian of Peru.

The single right valve is characterized by its subquadrate shape, apparently strongly prosogyre beaks, and its surface ornamentation of widely spaced, sharply crested, concentric ridges.

OCCURRENCE: The single specimen is from the Tosi member at Hogback, Montana.

CATALOGUED SPECIMEN: Hypotype, U.S.-N.M. No. 140513.

EOTRIASSIC BIVALVES

FAMILY MYTILIDAE

MYTILUS LINNÉ, 1758

Mytilus? postcarbonica (Girty)

Plate 16, figure 7

Myalina postcarbonica GIRTY, 1927, p. 442, pl. 30, figs. 34–35.

Mytilus? postcarbonica, NEWELL AND KUMMEL, 1942, p. 957.

DISCUSSION: A single poorly preserved right valve is identified with Girty's species which Newell and Kummel questionably referred to the genus *Mytilus*. The specimen resembles Girty's species in size, narrowly ovate outline, high obliquity, and surface ornamentation.

OCCURRENCE: The right valve is from the *Claraia* zone of the Dinwoody formation at Little Popo Agie Canyon, Wyoming, where it is associated with abundant *Promyalina putiatensis*. The forms described by Girty and the single valve reported by Newell and Kummel are from the *Claraia* zone at Montpelier Canyon, Idaho.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28340.

FAMILY MYALINIDAE

PROMYALINA KITTL, 1904

Promyalina putiatensis (Kiparisova)

Plate 16, figures 1–5

Myalina vetusta, BITTNER, 1889, p. 17, pl. 4, figs. 17–19.

Myalina putiatensis KIPARISOVA, 1938, p. 292, pl. 6, figs. 10–12.

Myalina putiatensis, NEWELL AND KUMMEL, 1942, p. 957, pl. 3, figs. 9–10.

DISCUSSION: Specimens identified as *P. putiatensis* show considerable variation in shape, convexity, and inclination of the hinge. The specimens illustrated by Newell and Kummel resemble Bittner's illustrations quite closely and are somewhat larger and less ovate than those figured by Kiparisova. A new occurrence in the *Claraia* zone has yielded numerous molds of both larger, more oblique, relatively flat forms and smaller, ovate, relatively convex representatives (the latter showing strong resemblance to Kiparisova's forms). These varying forms occur in direct association and cannot be sharply divided into two morphological types. Thus they are quite certainly members of a single, highly variable species.

This species has a greater obliquity than other Eotriassic species, such as *P. spathi*, but is generally more erect than Permian representatives of the genus *Myalina*.

Available left valves of *P. putiatensis* show a characteristically higher angle α, especially in larger specimens, than corresponding right valves. This feature is not apparent in illustrations of Asian representatives of the species.

OCCURRENCE: *Promyalina putiatensis* is

TABLE 24

MEASUREMENTS (IN MILLIMETERS) OF *Promyalina putiatensis* (KIPARISOVA)

	H	L	GD	HGL	Angle α
Lt	32.0	25.0	44.0	19.5	58°
Lt	30.0	23.0	44.0	19.0	52°
Lt	23.5	20.0	33.0	17.0	52°
Lt	21.0	13.5	23.5	10.0	62°
Rt	38.5	20.5	43.0	18.0	70°
Rt	32.0	19.0	34.0	17.0	70°

rare in the *Lingula* zone of the Dinwoody formation at Green River Lakes and Gros Ventre Canyon, Wyoming; abundant in the *Claraia* zone at Little Popo Agie Canyon, Wyoming, rare in the same horizon at Gros Ventre Canyon; and common in the upper Dinwoody (400 feet below the *Meekoceras* zone) at Wood Canyon, Idaho.

The species was originally described from the Lower Triassic of Ussuri (eastern Siberia).

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28348/1–28348/4.

Promyalina spathi (Newell and Kummel)

Plate 16, figure 6

Myalina spathi NEWELL AND KUMMEL, 1942, p. 956, pl. 3, fig. 11.

DISCUSSION: The holotype is refigured for comparison with related forms. This species is distinguished from similar forms by its erect configuration and nearly straight anterior margin. *Myalina platynotus* Girty, from the Thaynes formation, and *P. putiatensis*, discussed above, are closely related and differ primarily in having a more sinuate anterior margin than *P. spathi*. Specific identification of internal molds is very difficult.

The holotype is 33.5 mm. high, 21.5 mm. long, and has a greatest dimension of 35 mm. and a hinge length of 15 mm.

OCCURRENCE: Newell and Kummel report the species as widely distributed in the *Lingula* and *Claraia* zones of western Wyoming, southeastern Idaho, and southwestern Montana, and rare in the upper Dinwoody (immediately below the Thaynes formation) near Henry, Idaho. Additional specimens have not been identified in the present collections.

CATALOGUED SPECIMENS: Holotype, A.M.-N.H. No. 28349.

FAMILY **BAKEVELLIIDAE**

GERVILLEIA ROMINGER, 1846

Gervilleia cf. **ussurica** Kiparisova

Plate 16, figure 16

Gervilleia cf. *exporrecta*, BITTNER, 1899, p. 15, pl. 3, figs. 1–5.

Gervilleia cf. *exporrecta*, SPATH, 1935, p. 69, pl. 22, figs. 9a–c.

Gervilleia ussurica KIPARISOVA, 1938, p. 241, pl. 6, figs. 5–8.

Gervilleia ussurica, NEWELL AND KUMMEL, 1942, p. 959.

DISCUSSION: Specific identification of this small pterioid bivalve is difficult, because critical hinge characters are not preserved in the available specimens. This form is doubtfully referred to Kiparisova's species on the basis of its general configuration and size and because of its stratigraphic occurrence in the *Claraia* zone with other typical Eotriassic species.

OCCURRENCE: The species is locally abundant in the *Claraia* zone of the Dinwoody formation at Gros Ventre Canyon and rare in the same horizon at Little Popo Agie Canyon, Wyoming. Newell and Kummel report it as common in the *Claraia* zone in western Wyoming and southeastern Idaho.

Gervilleia ussurica has a cosmopolitan distribution in the Lower Triassic.

CATALOGUED SPECIMEN: Hypotype, M.C.Z. No. 15676.

FAMILY **AVICULOPECTINIDAE**

EUMORPHOTIS BITTNER, 1900

DISCUSSION: Bittner (1900, p. 566) applied the name *Eumorphotis* to those forms of *Pseudomonotis* characterized by a strong development of the auricles, in which the left valve is often more richly ornamented than the underlying flat right valve which generally remains quite plain. *Pseudomonotis telleri* Bittner, *P. multiformis* Bittner, and numerous other species were assigned to this group (subgenus), *P. telleri* being designated the type.

Newell and Kummel (1942, p. 957) tentatively raised *Eumorphotis* to generic rank in their discussion of *E. multiformis* on the basis of the fact that there is no close relationship between this species and the genotype of *Pseudomonotis*. They furthermore suggested a close relationship between *Eumorphotis* and the upper Paleozoic genus *Limipecten*, but specimens at hand examined by the present writer do not appear to possess the distinctive intercalated costae on both valves which typify *Limipecten*.

Eumorphotis is highly similar to *Aviculopecten*. In fact, it is often very difficult to distinguish isolated left valves of the two genera. *Eumorphotis* differs from *Aviculopec-*

ten in the flatness, obsolescent ornamentation, and sharply defined byssal notch of right valves (a character that distinctly separates it from *Pseudomonotis*), and in the higher convexity of the left valves. An examination of several right valves of *Eumorphotis* from the Thaynes formation of northern Utah and reference to illustrations of published species (Bittner, 1900) fail to show ontogenetic addition of radial costae through bifurcation, a distinguishing characteristic of *Aviculopecten.*

An excellent and thorough study of the taxonomy and phylogeny of *Eumorphotis* was made by Ichikawa (1958). He placed the genus in the subfamily Aviculopectininae Meek and Hayden, 1864, emended Newell, 1937, and indicated a probable derivation of the genus from *Limipecten.*

Eumorphotis is a very important and highly characteristic bivalve of the Eotriassic. It has a cosmopolitan distribution and is known to range from Scythian to Karnian.

Eumorphotis multiformis (Bittner)

Plate 15, figures 13, 15

Pseudomonotis multiformis BITTNER, 1899, p. 10, pl. 2, figs. 15–22.

Pseudomonotis (Eumorphotis) multiformis, BITTNER, 1900, p. 566.

Pseudomonotis (Eumorphotis) multiformis, SPATH, 1935, p. 74, pl. 22, fig. 8.

Pseudomonotis (Eumorphotis) multiformis, KIPARISOVA, 1938, p. 224, pl. 2, figs. 4, 9, 12; pl. 3, figs. 2–4.

Eumorphotis multiformis, NEWELL AND KUMMEL, 1942, p. 957, pl. 2, figs. 10, 11.

DISCUSSION: A few poorly preserved right valves of this species are here recorded in addition to the Dinwoody occurrences of left valves reported by Newell and Kummel. Right valves occur in association and agree in general form with left valves of the species. The flatness and deep byssal notch are well shown, but ornamentation is either obsolescent or poorly preserved on the right valves.

The species is characterized by prominent radial ornamentation of left valves which, although highly variable, consists of prominent first- and second-order costae and generally more numerous, very fine, higher-order costae.

OCCURRENCE: *Eumorphotis multiformis* is common in the *Claraia* zone of the Dinwoody formation at Montpelier Canyon, Dry Ridge, and near Henry, Idaho, and at Melrose, Montana; it is rare in the Thaynes formation at Mahogany Hills and Fort Douglas, Utah.

The species has a cosmopolitan distribution in marine strata of Scythian age.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. No. 28347, M.C.Z. No. 15666.

Eumorphotis multiformis regularaecosta (Kiparisova)

Plate 15, figure 14

Pseudomonotis (Eumorphotis) multiformis regularaecosta KIPARISOVA, 1937, p. 287, pl. 2, figs, 10, 11.

DISCUSSION: A single left valve is confidently assigned to the variety described by Kiparisova from the Lower Triassic of Russki Island in eastern Siberia. This variety is characterized by the regular arrangement of four orders of radial costae which possess serrated surfaces. The costae number three to four per millimeter at the ventral margin and occur generally in a 1-4-3-4-2-4-3-4-1 pattern. Kiparisova reports and illustrates a specimen with ornamentation transitional between this variety and typical *E. multiformis.*

The single left valve is 24 mm. high, about 20 mm. long, and has a hinge length of about 15 mm.

OCCURRENCE: The specimen is from the *Claraia* zone of the Dinwoody formation at Little Water Canyon, Montana.

CATALOGUED SPECIMEN: Hypotype, M.C.Z. No. 15667.

Eumorphotis amplicostata Ciriacks, new species

Plate 15, figures 10–12

DESCRIPTION: Left valve suborbicular, equilateral, strongly convex; auricles well developed, subequal, anterior auricular sulcus fairly deep; hinge line straight, nearly as long as shell; ornamentation consisting of three orders of prominent radial costae, first-order costae characteristically low, broad (up to 1.5 mm. at ventral margin), and flat; costae generally occurring in regular 1-3-2-3-1 pattern at ventral margin, third-order costae inserted at about one-third of shell height above ventral margin of mature specimens becoming faint toward the anterior and pos-

TABLE 25

MEASUREMENTS (IN MILLIMETERS) OF *Eumorphotis amplicostata* CIRIACKS, NEW SPECIES

	H	L	HGL	C	UA
Lt, holotype	22	19	14	6	60°
Lt, paratype	34	32	—	8	75°
Lt, paratype	31	29	?19	5	65°

terior margins; weakly developed concentric fila best displayed on auricles, a few more prominent concentric ridges occurring on shell body of some specimens; left anterior auricle of holotype with about 12 radial costae in two ranks, posterior auricle having eight or nine costae grading transitionally into costae of shell body; large specimens showing simultaneous appearance by splitting of one to four or five costellae on first-order costae near ventral margin, possibly a gerontic trait; right valves and internal characters of the species unknown.

DISCUSSION: The species is characterized by very broad, flat, first-order costae. Transitional forms between this species and other taxa of *Eumorphotis* are not known to the writer, but the size and general configuration are similar to those of *E. multiformis*. *Eumorphotis amplicostata* differs from the latter in being less convex, relatively longer, and especially in having very broad, flat, primary radial costae.

Although right valves of the species are presently unknown, the generally conservative nature of the right valves of the genus permits the designation of a new species based on characters of the left valve alone.

OCCURRENCE: The species is common in the *Claraia* zone of the Dinwoody formation at Frying Pan Gulch, Montana, and locally abundant in the same horizon at West Fork of Blacktail Creek, Montana, where it is associated with abundant examples of *Unionites breviformis* and rare ones of *Lingula*.

CATALOGUED SPECIMENS: Holotype, M.C.Z. No. 15664; paratypes M.C.Z. Nos. 15665/1, 15665/2.

FAMILY **PSEUDOMONOTIDAE**

CLARAIA BITTNER, 1901

DISCUSSION: *Claraia* is probably the most widespread and common Eotriassic bivalve and has been widely used as a guide in the identification of marine strata of Scythian age. Ichikawa (1958), in his excellent study of the genus, reported 15 species, representing four major morphological groups, which he separated on the basis of differences in configuration and ornamentation. Two of these groups, one possessing prominent concentric ornamentation and typified by *C. clarai*, the second possessing prominent radial ornamentation and typified by *C. stachei*, are especially characteristic of the lower Scythian. These two groups are well represented in the Eotriassic of the Middle Rockies.

As Ichikawa pointed out, the ligamental structure of the genus is unknown and other internal characters are only poorly known, based on observations of a few internal molds, owing to generally poor preservation in an apparently cosmopolitan siltstone-shale facies of early Eotriassic age. Consequently, a comparison with similar genera and phylogenetic classification, commonly based on internal structures, is very difficult.

Claraia has frequently been described as a subgenus of *Pseudomonotis*, but it differs in being constantly prosocline throughout ontogeny, less variable in configuration, and in having markedly less well-developed anterior auricles. Ichikawa considered it highly probable that *Claraia* is not a *Pseudomonotis* and did not originate directly from this highly specialized genus but evolved independently, at a later date, from the same ancestral stock (represented by the Paleozoic genus *Limipecten*).

Claraia clarai (Emmrich)

Plate 15, figure 7

Posidonomya clarae EMMRICH, 1844, p. 791.

Claraia clarai, LEONARDI, 1935, p. 58, pl. 2, figs, 21–23; pl. 3, fig. 1.

Claraia clarai occidentalis NEWELL AND KUMMEL, 1942, p. 955, pl. 3, figs. 1, 2.

Claraia clarai, ICHIKAWA, 1958, p. 141, pl. 22, figs. 1–2. (Contains complete synonymy.)

DISCUSSION: The present form was designated as a new variety by Newell and Kummel. However, its sparse occurrence and the limits imposed by poor preservation make assignment to previously described varieties or designation as a new variety undesirable.

Claraia clarai is characterized by the presence of both radial costae and concentric folds. The poor development of the latter, a relatively high forward obliquity, and the presence of a well-defined byssal notch distinguish this species from the closely related form *C. extrema* (Spath), which occurs in the overlying Thaynes formation.

MEASUREMENTS (IN MM.):

	H	L	HGL
Rt	24	28	11
Rt	24	27	11

OCCURRENCE: This species is rare in the *Claraia* zone of the Dinwoody formation at Martin Creek and Meadow Creek, Wyoming, and questionably identified from the Dinwoody at Frying Pan Gulch, Montana.

Claraia clarai is widespread in the Eotriassic of Europe.

CATALOGUED SPECIMEN: Hypotype, A.M.-N.H. No. 28345.

Claraia extrema (Spath)

Plate 15, figures 5, 6

Pseudomonotis (*Claraia*) *extrema* SPATH, 1935, p. 72, pl. 20, fig. 10; pl. 21, fig. 2.

DISCUSSION: This species is characterized by coarse concentric folds which are dominant over the radial costae, the latter being faintly developed or absent in the specimens at hand. The number of major concentric folds is variable, with right valves having about twice as many as associated left valves. Because the associated valves are similar in size and general configuration, the differences in the number of folds is assumed to be a distinction between opposite valves of a single form, not one that defines separate taxa.

MEASUREMENTS (IN MM.):

	Lt	Rt	Rt
H	19	16	13
L	26	20	19
HGL	14	—	12
No. of folds	6	14	13

This species generally resembles *C. clarai* in shape and ornamentation. However, the present forms display a more prominent concentric ornamentation and essentially lack the radial costae of *C. clarai*. The two species are probably very closely related, with the slightly younger *C. extrema* being derived from *C. clarai*.

OCCURRENCE: A single left valve, two right valves, and fragmentary specimens of questionable right valves occur in the Thaynes formation at Hammond Creek, Idaho.

The species was originally described from the Lower Triassic of east Greenland.

CATALOGUED SPECIMENS: Hypotypes, M.C.Z. Nos. 15671, 15672.

Claraia mulleri Newell and Kummel

Plate 15, figure 8

Claraia mulleri NEWELL AND KUMMEL, 1942, p. 956, pl. 3, figs. 3, 4.

DISCUSSION: This species is characterized by somewhat irregular, intercalated, radial costae, numbering about one per millimeter at the ventral margin, by a lack of concentric folds, and by a highly extended, unornamented posterior auricle and posterodorsal area, particularly on the right valve.

The available specimens are larger than representatives of *C. clarai* and *C. stachei* and differ from these forms in details of ornamentation.

The holotype right valve has apparently been lost. The paratype left valve, the only available specimen, is 37 mm. high, 38.5 mm. long, and has a hinge length of about 18 mm.

OCCURRENCE: *Claraia mulleri* is known only from the *Claraia* zone of the Dinwoody formation at Gros Ventre Canyon, Wyoming.

CATALOGUED SPECIMEN: Paratype, A.M.-N.H. No. 28346.

Claraia stachei Bittner

Plate 15, figures 1–3

Claraia stachei BITTNER, 1900, p. 587.

Claraia stachei, SPATH, 1930, p. 46, pl. 9, figs. 1a–d; pl. 10, figs. 5a, b.

Claraia stachei, NEWELL AND KUMMEL, 1942, p. 955, pl. 3, figs. 5–8.

Claraia stachei, TOZER, 1961, p. 97, pl. 28, figs. 1, 2.

DISCUSSION: This widespread Eotriassic species has a more highly developed right anterior auricle, a less extended posterior auricle and posterodorsal area, and slightly coarser, more subdued, radial ornamentation than *C. mulleri*, which is otherwise very similar, especially with regard to the left valves. The size and shape of *C. stachei* appear to be more variable than those of related forms, possibly owing largely to its more common and widespread occurrence.

OCCURRENCE: This is clearly the most widespread species of *Claraia* in the Lower Triassic of the Middle Rockies. The writer has observed specimens in the Dinwoody formation at Little Popo Agie Canyon and Hidden Anticline, in the southern Wind River Mountains, Wyoming; at Martin Creek and Green River Lakes, in western Wyoming; at Paris Canyon and Montpelier Canyon, in southeastern Idaho; and at Frying Pan Gulch, in southwestern Montana. It is known from three horizons in the Thaynes formation at Hammond Creek, in southeastern Idaho.

In addition to specific localities, Newell and Kummel report *C. stachei* as rare in the *Lingula* zone at many localities in southeastern Idaho and western Wyoming, and in the non-red Woodside equivalents near Henry, Idaho. Also, they report the species as abundant in the *Claraia* zone throughout the Middle Rockies.

Claraia stachei ranges from the lowermost Dinwoody beds, of Otoceratan age, into the Thaynes formation, which ranges as high as Prohungaritan age (upper Scythian). The horizons at which *C. stachei* occurs in the Thaynes at the Hammond Creek locality are not dated in terms of ammonite zones but are probably younger than the *Meekoceras* fauna, which suggests that the species ranges at least as high as Owenitan age. Thus, although the exact upper range of the species is not yet known, the species is generally restricted to the lower half of the Scythian and is a good guide fossil in early Eotriassic marine strata.

The species has been reported from the Scythian of the Alps, east Greenland, and the Canadian Arctic.

CATALOGUED SPECIMENS: Hypotypes; A.M.N.H. No. 28344, M.C.Z. Nos. 15669, 15670.

Claraia sp. **a**

Plate 15, figure 4

DISCUSSION: Incomplete preservation of the auricles makes specific identification of this form very difficult. The single questionable left valve differs from that of other forms of *Claraia* in having a greater convexity and a more reduced posterior auricle. This specimen most generally resembles *C. stachei* and may be a variant of that species.

OCCURRENCE: This specimen was found in a fine, black limestone concretion in talus above the *Meekoceras* zone of the Thaynes formation at Hot Springs, Idaho.

CATALOGUED SPECIMEN: Hypotype, M.C.Z. No. 15677.

Claraia sp. **b**

Plate 15, figure 9

DISCUSSION: This form is represented by a single incomplete left valve. The relative flatness, faint concentric and even less distinct radial ornamentation, and the strong inequality of the auricles (very short anterior auricle) indicate generic affinity with *Claraia*. Identification with known species is difficult because this valve possesses a more extended anterior auricle, a sharply angular postero-dorsal margin, and a greater relative height than do other forms known to the writer. The general configuration is similar to that of *C. stachei* and *C. mulleri*, but both these forms display prominent radial ornamentation. This form probably represents a new species but will not be designated as such because of insufficient available material.

The specimen is 24 mm. high, 25 mm. long, and has a hinge length of about 16 mm.

OCCURRENCE: The single left valve is from the Woodside? formation at Gros Ventre Canyon, Wyoming.

CATALOGUED SPECIMEN: Hypotype, M.C.Z. No. 15673.

Claraia? sp.

DISCUSSION: A small, possibly deformed specimen is questionably referred to *Claraia* on the basis of faint but distinct radiating costae, a greater hinge length posterior to the umbone (suggesting a larger posterior auricle), and a remote resemblance to a Lower Triassic Alpine form, *C. aurita gibba*, described by Leonardi (1935, p. 65). Leonardi's variety and the species *aurita*, however, show no radial ornamentation.

OCCURRENCE: The single internal mold is from the *Claraia* zone of the Dinwoody formation at Gros Ventre Canyon, Wyoming.

FAMILY MONOTIDAE

MONOTIS BRONN, 1830

Monotis? thaynesiana (Girty?)

Plate 15, figure 16

Aviculopecten thaynesianus, BOUTWELL, 1912, pl. 7, figs. 13, 13a.

Monotis thaynesiana, GIRTY, 1927, p. 440, pl. 30, figs. 27, 28.

DISCUSSION: A single well-preserved, questionably left valve is confidently identified with Girty's illustrations and description of *M. thaynesiana.* The species is apparently characterized by the equilateral nature of the valves (with auricles essentially continuous with shell body) and by the numerous relatively fine, intercalated, radial costae.

As Girty suggests, affinities with *Aviculopecten occidaneas* Meek and *A. curticardinalis* Hall and Whitfield, from the Thaynes formation in northern Utah, are sufficient for all to be included in one species. Juvenile stages of *M. thaynesiana* are much like those of *M. bregeri* Girty, also known only from the Thaynes. Additional study of the variability and ontogenetic changes of these forms is required for proper classification.

This species and similar apparently equivalved, nearly equilateral pectenoids, seemingly widespread in rocks of later Scythian age but also including the Permian species *Monotis? landerensis* (C. C. Branson), (p. 51, present report), probably represent a new genus. These forms differ from *Monotis* in being more equilateral, less oblique, and in lacking the smooth, well-defined posterior auricle. Right valves have not been recognized in any of these forms, and internal features are unknown. Thus designation of a new genus at this time is undesirable.

The similarity between *M.? thaynesiana* and *M.? landerensis* is highly significant. These are the only closely comparable bivalve species on opposite sides of the Permo-Triassic boundary in the Middle Rockies.

OCCURRENCE: The single specimen and common fragments of the same species were collected in the Woodside formation at Peale Mountain, west of Bear Lake, Idaho. Girty reports the species as abundant in the Thaynes formation at Crow Creek, Idaho.

CATALOGUED SPECIMEN: Hypotype, M.C.Z. No. 15668.

FAMILY PACHYCARDIIDAE

UNIONITES WISSMAN, 1841
(**ANODONTOPHORA** COSSMAN, 1897)

Unionites breviformis (Spath)

Plate 16, figures 14, 15

Anodontophora breviformis SPATH, 1935, p. 75, pl. 22, figs. 3, 4; pl. 23, figs. 2, 3.

DISCUSSION: This relatively large robust species is confidently identified with Spath's forms from the Lower Triassic of east Greenland. The species has a greater relative height than most species of *Unionites,* giving it a more contracted, "breviform" configuration. Poor preservation of both the Greenland forms and the specimens at hand makes characterization of the species very difficult. The species shows some variation in height-length proportions.

MEASUREMENTS (IN MM.), CHARACTERISTIC MOLDS:

	H	L	H/L
Lt	12.5	18.0	0.70
Lt	12.5+	17.5	0.72+
Rt	14.5	21.4	0.68
Rt	13.0	20.0	0.65

OCCURRENCE: *Unionites breviformis* is rare in the *Claraia* zone of the Dinwoody formation at Gros Ventre Canyon, Wyoming, and occurs abundantly in a "*Unionites* bed" in the *Claraia* zone at West Fork of Blacktail Creek, Montana, where it is associated with *Lingula* and *Eumorphotis amplicostata.*

CATALOGUED SPECIMENS: Hypotypes, M.C.Z. No. 15674.

Unionites canalensis (Catullo)

Plate 16, figures 11, 12

Tellina canalensis CATULLO, 1848, p. 56, pl. 4, fig. 4.

Anodontophora canalensis, BITTNER, 1899, p. 23, pl. 3, figs. 34–38.

Homomya canalensis, LEONARDI, 1935, p. 35, pl. 1, figs. 13–15.

Anodontophora canalensis? NEWELL AND KUMMEL, 1942, p. 959.

DISCUSSION: This species occurs as internal molds only and therefore fails to show certain characteristic morphological features such as a well-defined siphonal ridge and an extended posterodorsal area with a marked posterodorsal angle. However, the general shape, relatively medial location of the umbones, and faint concentric fila are specific characters of *U. canalensis*. The forms at hand most resemble the Lower Triassic representatives of the species described by Leonardi as *Homomya canalensis*, from Venezia.

MEASUREMENTS (IN MM.), TYPICAL MOLDS:

	H	L	H/L
Lt	12	19	0.63
Rt	13	20	0.56

OCCURRENCE: The species is generally locally abundant and is recorded from the following localities: *Claraia* zone of the Dinwoody formation at Little Popo Agie Canyon, Dinwoody Canyon, Gros Ventre Canyon, Red Creek, Green River Lakes, and Meadow Creek Canyon, Wyoming; from unspecified horizons in the Dinwoody at West Fork of Blacktail Creek and Daly's Spur, Montana, and at Peale Mountain, west of Bear Lake, Idaho; and from the Thaynes formation at Swift Creek Canyon, Wyoming, and Hogback Mountain, Montana.

The species has a cosmopolitan distribution in the Scythian.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28358:1, 28358:2.

Unionites fassaensis (Wissman)

Plate 16, figure 13

Myacites fassaensis WISSMAN, 1841, p. 9, pl. 16, fig. 2.

Anodontophora fassaensis, BITTNER, 1899, p. 22, pl. 3, figs. 28–33.

Homomya fassaensis, LEONARDI, 1935, p. 33, pl. 1, fig. 6.

Anodontophora fassaensis, NEWELL AND KUMMEL, 1942, p. 958, pl. 2, fig. 13.

DISCUSSION: This species differs from *U. canalensis* primarily in having less centrally placed umbones. The forms at hand are also smaller than *U. canalensis* and appear to have less prominent beaks.

A representative specimen is 11 mm. high and 17 mm. long.

OCCURRENCE: The species has been positively identified from the *Claraia* zone of the Dinwoody formation at Little Popo Agie Canyon, Gros Ventre Canyon, and South Fork Canyon, Wyoming. Newell and Kummel refer to well-preserved specimens and a fairly widespread distribution, but material presently available is generally poorly preserved and unsuitable for positive identification. It is probably more abundant than is indicated above and may have a similar distribution as *U. canalensis*, with which it is commonly associated here, as it is in Greenland, the Alps, and Ussuri.

CATALOGUED SPECIMEN: Hypotype, A.M.N.H. No. 28343.

Unionites? sp.

Plate 16, figures 16, 17

DISCUSSION: A poorly preserved right valve, with fairly coarse, rounded, concentric fila, and an internal mold of nearly identical size and shape, but with no indication of surface ornamentation, are questionably assigned to *Unionites*. The configuration is suggestive of the genus, and the mold is associated with *U. canalensis*. However, coarsely ornamented forms of the genus are not known to the writer. The ornamented specimen occurs at a distinctly younger horizon (Thaynes) than the smooth mold (lower Dinwoody), which suggests that the two specimens may not be conspecific.

MEASUREMENTS (IN MM.):

	H	L	H/L
Rt	16.5	25.5	0.61
Rt	15.0	23.0	0.65

OCCURRENCE: The ornamented specimen is from the Thaynes formation at the Fort Hall Indian Reservation, Idaho. The internal mold is from the *Claraia* zone of the Dinwoody formation at Gros Ventre Canyon, Wyoming.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. No. 28342, M.C.Z. No. 15675.

FAMILY MYOPHORIIDAE

MYOPHORIA BRONN, 1834

Myophoria laevigata (Ziethen)

Plate 16, figures 18, 19

Trigonia laevigata ZIETHEN, 1830, p. 94, pl. 71, figs. 2, 6.

Myophoria laevigata, ALBERTI, 1834, p. 87.

Myophoria cf. *laevigata*, BITTNER, 1899, p. 20, pl. 3, figs. 17?, 18–26.

DISCUSSION: The specimens at hand are slightly larger than average forms of the species, but their general configuration, shell ornamentation, and occurrence with typically associated Eotriassic forms (*Claraia*, *Promyalina*, and *Unionites*) make specific identification reasonably certain.

A representative left valve is 17 mm. high and 24 mm. long.

Similar forms from the Eotriassic of Japan are designated *Neoschizodus* cf. *laevigatus* (Nakazawa, 1960, p. 56).

OCCURRENCE: The species is rare in the *Claraia* zone of the Dinwoody formation at Little Popo Agie Canyon, Gros Ventre Canyon, Martin Creek, and Green River Lakes, Wyoming; questionably identified from the same horizon at West Fork of Blacktail Creek, Montana.

Myophoria laevigata is widespread in the Lower Triassic of Europe and Asia but has not been previously reported from Greenland or North America.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28348/1, 28348/2.

FAMILY PERMOPHORIDAE

PERMOPHORUS CHAVAN, 1954

Permophorus? bregeri (Girty)

Plate 16, figures 8, 9

Pleurophorus bregeri GIRTY, 1927, p. 445, pl. 30, figs. 40, 41.

Pleurophorus similis GIRTY, 1927, p. 446, pl. 30, figs. 38, 39.

Pleurophorus rotundus GIRTY, 1927, p. 446, pl. 30, figs. 42, 43.

Pleurophorus? bregeri, NEWELL AND KUMMEL, 1942, p. 957, pl. 2, fig. 12.

DISCUSSION: The small permophorid illustrated by Newell and Kummel generally resembles Girty's illustrations of *P. bregeri* but also fits very well the description of *P. similis:* "Upper and lower margins nearly straight and parallel or but slightly converging toward the anterior end. . . . The umbonal ridge is pronounced and subangular, and a plication is commonly developed about midway on the postumbonal slope, producing a slight change in direction in the truncated posterior outline."

Girty described three species (*P. bregeri*, *P. similis*, and *P. rotundus*) from two stations in the Woodside shale at Montpelier Canyon, Idaho. The three species are differentiated largely on the basis of configuration. Postumbonal ornamentation, angularity of umbonal ridge, and prominence of the anteriorly located beaks proved unsatisfactory as distinguishing characters. In reference to these criteria Girty states, "These characters also might have been employed in classification, and other more numerous subdivisions recognized, but no matter what line of separation I sought to follow no sharp distinction was found." In addition, Girty states, "Some specimens seemed balanced between two species; others seem out of place in any of the species recognized and apparently might be made starting points for still other species."

Although the writer has not studied Girty's types, it seems apparent from his illustrations and descriptions that these forms can be confidently interpreted as variants of a single species. They occur in direct association. The three species are here placed into synonymy and the name *P. bregeri* is retained because, based on Girty's descriptions, this taxon appears to be the most variable and least specialized of his three original forms.

The internal features of these forms are not known, and the generic affinities are therefore uncertain. There is superficial resemblance to the Permian genus *Permophorus*, and an internal mold shows evidence of a similar myophoric buttress behind the anterior adductor. If the forms are true representatives of *Permophorus*, they differ strongly and cannot be closely compared with Permian species in the underlying sequence.

OCCURRENCE: *Permophorus? bregeri* is known only from the *Claraia* zone of the Dinwoody formation at Montpelier Canyon, Idaho, where it is apparently common to abundant. The writer has collected a single internal mold identified with this species from the Silty limestone unit near the base of the Dinwoody at Sheep Creek, Idaho.

CATALOGUED SPECIMENS: Hypotypes, A.M.N.H. Nos. 28350/1, 28350/2.

APPENDIX

STRATIGRAPHIC SECTIONS OF THE PERMIAN-TRIASSIC CONTACT INTERVAL

SECTION 1. WIND RIVER CANYON, WYOMING

Section measured at north end of Wind River Canyon, about 5 miles south of Thermopolis, Wyoming. Contact exposed about 100 yards to east of road; sect. 20, T. 7 N., R. 6 E., Hot Springs County, Wyoming.

	Thickness in Feet
Triassic System	
Dinwoody formation	
?Gray Shale unit	
6. Shale, calcareous and gypsiferous; light brown, weathers buff; very thin-bedded, soft; contains abundant iron concretions, gypsiferous toward top, capped by 3-foot unit of white, bedded gypsum	33
5. Covered interval	10
4. Shale, calcareous, quartzose; light brown, weathers buff; very thin-bedded, soft; contains abundant iron stain and iron concretions .	4.2
Permian System	
Park City formation	
Ervay member	
3. Limestone, argillaceous, slightly quartzose; very light gray, weathers chalky cream; crystalline; very soft, weathered; argillaceous near top grading into bed 4	0.2
2. Limestone; light brownish gray, weathers light brown; crystalline; thin-bedded; locally banded near top, with white and chocolate bands about 1 mm. thick, darker bands with recrystallized calcite and ?iron mineral; locally prominent mud cracks on bedding surfaces	1.8
1. Limestone; light brownish gray, weathers light brown; crystalline; medium- to thick-bedded, locally massive; probably a recrystallized calcarenite; contains abundant molds of unidentifiable bivalves and *Plagioglypta canna;* lower beds not examined . . .	10
Total measured thickness	59.2

SECTION 2. LITTLE POPO AGIE CANYON, WYOMING

Section measured on south wall of Little Popo Agie Canyon, in the Wind River Mountains, about 13 miles southwest of Lander; SE. $\frac{1}{4}$, NE. $\frac{1}{4}$, sect. 8, T. 31 N., R. 99 W., Fremont County, Wyoming.

	Thickness in Feet
Triassic System	
Dinwoody formation	
Claraia zone	
27. Shale, calcareous; light green, weathers light brownish green; finely laminated, iron-rich and iron-free layers; grades into red (?Chugwater formation) soil . .	5
26. Calcisiltite, quartzose; light brownish gray, weathers mottled medium and dark brown; thin-bedded, capped by 6-inch bed; locally cross-bedded; intercalated are thin, less resistant beds of argillaceous calcilutite	5.5
25. Calcisiltite, quartzose; light brownish gray, weathers buff to medium brown; thin-bedded, capped by 6-inch bed; locally vuggy; intercalated are thin, less resistant beds of argillaceous calcilutite	3.0
24. Calcisiltite, argillaceous, quartzose; light brownish gray, weathers medium to dark brown; thin-bedded; upper 6 to 8 inches very fossiliferous, contains *Claraia, Unionites, Promyalina, ?Mytilus,* and *?Bellerophon;* intercalated are thin, less resistant calcilutites	2.8
23. Calcisiltite, argillaceous; light greenish gray, weathers light brown; very thin-bedded, very soft	0.8
22. Calcisiltite, quartzose, locally argillaceous; light greenish gray, weathers light to medium brown; medium-bedded, soft; basally intercalated thin-bedded calcilutites	5.0
21. Calcisiltite, quartzose; light gray, weathers light to medium brown; thin-bedded; locally laminated .	0.8

20. Covered, trenching revealed following: Unit D: Shale, calcareous; light olive brown; thin-bedded, soft 0.5

PERMIAN SYSTEM

Park City formation

Ervay member

Unit C: Iron band, calcareous, argillaceous; light reddish brown to dark blackish brown; unbedded; probably an iron residue from leaching of calcareous rock; thickness variable 0.2

Unit B: Calcilutite, argillaceous; light gray, weathers chalky white; thin-bedded, hard; contains dark iron oxide minerals . 0.2

Unit A: Shale, highly calcareous; light olive brown, weathers light to buff gray; thin-bedded, fairly hard 0.1

19. Calcarenite, slightly quartzose; light brownish gray, weathers buff to medium brown; thin to medium-bedded; highly recrystallized; more weathered and leached toward top, contains pressure solution features (microstyolites) 3.3

18. Calcarenite; light gray, weathers mottled medium and dark brown; fine- to medium-grained, oolitic; massive, except for lower 2 feet which is thin-bedded; vuggy 5.7

17. Calcarenite; light gray, weathers brownish gray; fine-grained, slightly oolitic; medium- to thick-bedded; abundant calcite geodes and concretions near top . . . 7.5

16. Calcisiltite; light to medium gray, weathers buff to light brown; massive; prominent vertical joints form angular outcrop face 8.5

15. Calcisiltite, argillaceous; very light gray, weathers light reddish brown; poorly, unevenly bedded, softer than adjacent beds . . . 6.0

14. Calcisiltite; light to medium gray, weathers buff to light reddish brown; massive, forms prominent ledge; contains calcite geodes; fossiliferous, contains ramose bryozoans and ostracodes replaced by green mineral, probably glauconite 2.5

13. Calcisiltite, cherty; medium gray, weathers light greenish brown; unevenly bedded; contains light gray chert nodules which preserve abundant ramose bryozoans; bryozoans and ostracodes also occur in matrix. 1.0

Phosphoria formation

Tosi member

12. Calcisiltite, cherty, argillaceous; light olive brown, weathers mottled light to medium brown; thin-bedded; fossiliferous, contains bryozoans, ostracodes, and small gastropods; unit becomes extremely cherty near base; chert is light to dark gray; nodular and tubular, grading into calcisiltite at borders 2.5

11. Chert, calcareous; medium to dark gray, weathers mottled dark gray and reddish brown; medium-bedded, intercalated are thin beds of calcisiltite; contains limonite and calcite concretions; fossiliferous, contains abundant very small gastropods; contains small phosphorite pellets. . . . 14.5

Retort member

10. Phosphorite, argillaceous; greenish gray, weathers darker greenish gray; phosphate pelletal, occurs in light green shaly matrix with a few chert grains; fossiliferous, contains scattered ramose bryozoans replaced by phosphate . 0.5

9. Shale; dark greenish gray, weathers medium gray; thin-bedded, fairly soft; contains a few dispersed phosphorite grains 0.7

8. Shale, phosphatic; dark gray, weathers to a speckled white and medium gray; phosphorite pellets variable in size, hard; fossiliferous, contains ramose bryozoans and small gastropods, the latter replaced by phosphorite . 0.3

7. Chert, calcareous, argillaceous; medium to dark gray, weathers to speckled white and light greenish gray; thin and wavy-bedded; contains large calcite geodes and concretions; varies laterally in thickness and character 3.5–4.0

6. Shale, phosphatic, calcareous; dark gray, weathers to speckled white and medium gray; slightly cherty, appears to grade into overlying chert 0.2

5. Shale, calcareous; dark gray,

weathers light tannish gray; poorly bedded; contains some phosphorite and chert grains . 1.0

4. Phosphorite, argillaceous; dark greenish gray, weathers light greenish brown; phosphorite pellets of variable sand size in shaly matrix; locally cherty; contains abundant calcite stringers causing uneven breakage of rock . . 0.4
3. Chert, calcareous, argillaceous; medium to dark gray, weathers mottled light green and tan; hard, breaks unevenly; thin and wavy-bedded, with layers of shaly, calcareous beds separating chert layers; upper foot contains large calcite geodes and concretions 2.8
2. Phosphorite, argillaceous; dark gray, weathers tannish gray; poorly bedded; phosphate locally concentrated, consists of rounded to subangular pellets and oolites of sand size in a shaly matrix; fossiliferous, contains some bryozoan fragments 0.5
1. Shale, calcareous; dark gray, weathers speckled white and medium gray; thin-bedded; slightly phosphatic. 0.5

Base of Retort member not exposed.
Total measured thickness 86.3

SECTION 3. RED BASIN, WYOMING

Section measured on east wall of a gully about 200 yards north of secondary road at Red Basin, on the Wind River Indian Reservation, approximately 20 miles northwest of Fort Washakie; NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, sect. 21, T. 1 N., R. 3 W., Fremont County, Wyoming.

THICKNESS IN FEET

TRIASSIC SYSTEM
Dinwoody formation
Claraia zone

6. Quartz siltstone, calcareous, interbedded with argillaceous calcisiltites; siltstone light brownish gray, weathers dark greenish brown; medium-bedded, fairly resistant; fossiliferous, contains *Unionites;* calcisiltite light gray, weathers buff and greenish brown; thin-bedded, platy, less resistant, usually covered; sparsely fossiliferous, contains *Claraia* 60
5. Limestone; dirty white, weathers greenish gray; poorly bedded, soft; highly recrystallized, with abundant secondary calcite stringers; highly weathered and apparently leached, making rock porous; has Permian aspect . . 2.0
4. Limestone, slightly quartzose; light gray, weathers light greenish gray; thin- to medium-bedded, locally platy, typically Dinwoody; contains small pebbles of possibly reworked underlying sediment 2.3

PERMIAN SYSTEM
Park City formation
Ervay member

3. Limestone, slightly quartzose; light gray; weathers mottled buff and gray; medium-bedded; recrystallized; locally cherty or dolomitic, hard, breaking unevenly; contains well-rounded, weathered, vertical joints; unit varies laterally in thickness and character . 2.2
2. Limestone; light gray, weathers mottled brown; medium- to thick-bedded; recrystallized; heavily jointed, joints filled with secondary dolomite saddles and locally with fine sand; fossiliferous, contains *Plagioglypta* and unidentifiable shell fragments 13.0
1. Limestone; light brownish gray, weathers mottled brown and gray; thin-bedded; fine, crystalline, dense, probably a calcilutite; fossiliferous, contains brachiopod shell fragments, crinoid columnals, small spines, and questionable bryozoan fragments 1.5

Lower part of Ervay member not measured.
Total measured thickness 81.0

SECTION 4. DINWOODY CANYON, WYOMING

Section measured in northwest-trending draw, several hundred yards north of Upper Dinwoody Lake, in the Wind River Mountains; NW. $\frac{1}{4}$, sect. 6, T. 4 N., R. 5 W., Fremont County, Wyoming.

	Thickness in Feet
TRIASSIC SYSTEM	
Dinwoody formation	
Lingula zone	
30. Calcisiltite, quartzose; brownish gray, weathers greenish and reddish brown; thin- to medium-bedded, fairly hard, caps covered interval of less resistant, thin-bedded siltstones and shales . .	8.0
29. Calcisiltite, hematitic; light reddish brown, weathers to mottled reddish brown; thin-bedded, platy; locally laminated; contains a few fissile greenish calcilutites; fossiliferous, contains distorted *Lingula* and questionable bivalve molds	1.2
28. Limestone, hematitic; light brownish gray, weathers mottled reddish brown; medium-bedded, resistant; finely crystalline; fossiliferous, contains distorted *Lingula* and bivalve molds	1.8
27. Calcisiltite, highly quartzose; light greenish gray, weathers to dirty mottled gray; thin-bedded, platy; contains a few intercalated light green, fissile calcilutites . . .	2.0
26. Quartz arenite, calcareous, locally bituminous; medium gray, weathers to dirty mottled gray; medium-grained, well sorted; locally calcareous cement has been leached, making rock friable, very hard on fresh surface	1.0
25. Quartz arenite, slightly cherty and bituminous; spotted dirty brown and cream, weathers to dirty grayish brown; unbedded, soft, friable, entire unit deeply weathered and leached; contains iron oxide band near top; unit locally thicker, extending into joints and channels of underlying limestone.	1.0
PERMIAN SYSTEM	
Park City formation	
Ervay member	
24. Limestone, slightly quartzose; medium gray, weathers mottled brownish gray; crystalline; questionably cherty; thin- to medium-bedded; weathered near top, base not exposed	2.0
Units below measured about 200 yards to southeast of beds 24 to 30.	
23. Limestone, quartzose; medium gray, weathers mottled brownish gray; thin- to medium-bedded; finely to medium crystalline; locally glauconitic, slightly hematitic; fossiliferous, contains bryozoan fragments; weathered near top, top of unit probably equivalent to bed 24, overlain by cover	5.0
22. Limestone, slightly quartzose; light to medium gray, weathers light brownish gray; thick-bedded, hard; finely crystalline; slightly glauconitic; fossiliferous, contains very prominent large ramose bryozoans near top	6.2
21. Limestone; light gray, weathers light brownish gray; thinly, unevenly bedded; fine to medium crystalline; contains abundant chert nodules; fossiliferous, locally rich in bryozoan fragments.	2.2
20. Limestone; medium gray, weathers light brownish gray; massive; finely crystalline; slightly glauconitic; fossiliferous, contains bryozoan fragments	1.0
19. Limestone; light to medium gray, weathers mottled brownish gray; thinly, irregularly bedded; finely crystalline; slightly glauconitic, locally cherty; fossiliferous, contains *Plicatoderbyia*, bryozoan fragments, crinoid columnals, and worm casts.	3.5
18. Limestone, glauconitic, cherty; light greenish gray, weathers light gray; thinly, unevenly bedded; finely crystalline; contains calcite concretions, chert balls, and abundant glauconite grains; fossiliferous, contains very small trochospiral gastropods and ramose bryozoans	2.7
17. Calcisiltite, glauconitic; light green, weathers greenish gray; thinly, unevenly bedded; fossiliferous, contains very small trochospiral gastropods and shell fragments.	1.0
16. Limestone, glauconitic, cherty; medium gray, weathers to mottled cream and dirty gray; unevenly bedded; fine to medium crystalline; contains sand-sized chert and glauconite grains; resistant, forms ledge; fossiliferous, contains bryozoan fragments . . .	2.0
15. Limestone, glauconitic; light green,	

weathers dark gray and green; thin-bedded, locally fissile; finely crystalline; contains abundant calcite concretions and geodes; richly fossiliferous, contains *Composita, Hustedia*, spirifers, fenestrate and ramose bryozoans, crinoid columnals, and other unidentifiable fragments 2.7

14. Limestone, cherty; dark gray, weathers to dirty brownish gray; unevenly bedded; very finely crystalline, dense, resistant, forms slight ledge; contains a few intercalated soft, fissile calcisiltites 1.8

Phosphoria formation

Tosi member

13. Calcilutite, argillaceous; medium brownish gray, weathers to dirty dull brown; poorly bedded, mostly covered, contains a few sand-sized grains of calcareous, glauconitic, and phosphatic material; fossiliferous, contains a few bryozoans 0.8
12. Chert, calcareous; medium to dark gray, weathers light brownish gray; medium-bedded, locally tubular and nodular; finely crystalline; contains petroliferous calcite geodes; contains some intercalated greenish gray, fissile calcisiltites with chert framents 5.5
11. Shale, phosphatic, cherty; medium brownish gray, weathers to mottled light brownish gray; thin-bedded to fissile; locally contains nodular and tubular chert, and sand-sized phosphorite grains; less resistant than adjacent cherts; fossiliferous, contains rhynchonellid brachiopods and crinoid columnals 1.3
10. Chert and shale; dark gray to black, weathers to light brownish gray; chert medium-bedded, more poorly bedded toward top where it becomes nodular and tubular; shale slightly calcareous, sparsely intercalated as thin, fissile beds; unit contains abundant calcite geodes and iron concretions, and a few unidentifiable fossil molds 31.0
9. Mudstone, cherty, calcareous; dark brownish gray, weathers reddish brown and light gray; thin-bedded; becomes more cherty upward, grading into bed 10 . . . 7.2

Retort member

8. Phosphorite, argillaceous; dark brownish gray, weathers to speckled cream and dirty brown; contains sand-sized oolites of phosphate in shaly matrix; massive 0.3
7. Mudstone, calcareous; chocolate brown, weathers light brownish gray; thin-bedded; intercalated are dark gray, fissile shales; unit becomes more calcareous and cherty upward; locally contains large calcite geodes 20.2
6. Shale, phosphatic, calcareous; dark brownish gray, weathers to speckled cream and dirty brown; thinly, poorly bedded; phosphate occurs as sand-sized pellets, progressively less phosphatic upward 1.2
5. Shale, highly phosphatic, calcareous; medium brownish gray, weathers to speckled cream and dark brown; phosphate occurs as sand-sized grains and larger granules in matrix which is irregularly more calcareous or more argillaceous; contains some fossil spines 0.8
4. Shale; chocolate brown, weathers light brown; very thin-bedded to fissile; contains local concentrations of phosphate grains; contains external molds of brachiopods or bivalves 0.8
3. Phosphorite, calcareous, argillaceous; dark brownish gray, weathers light greenish tan; grain size variable from fine sand grains to large subangular pellets, may contain some chert fragments; abundant secondary calcite stringers; petroliferous odor; contains phosphatized productid brachiopod shells 1.0
2. Calcarenite; medium gray, weathers light brownish gray; poorly bedded, locally nodular and questionably siliceous; contains dark gray, fissile calcisiltites; upper 5 feet richly fossiliferous, contains productid and spiriferid brachiopods, *Aviculopecten*, bryozoans, and other shell fragments . . . 11.2
1. Phosphorite, argillaceous; dark reddish brown, weathers to mottled greenish gray and dark brown; poorly bedded; fine- to medium-

grained phosphate pellets in shaly matrix which also contains some chert fragments; contains a few calcareous fossil fragments; good marker bed	1.2
Franson member not measured.	
Total measured thickness	127.6

SECTION 5. CINNABAR MOUNTAIN, MONTANA

Section measured at east side of Cinnabar Mountain, about ½ mile west of U. S. Highway 89, 3 miles northwest of Gardiner, Montana; sect. 31, T. 8 S., R. 8 E., Park County, Montana.

	Thickness in Feet
TRIASSIC SYSTEM	
Dinwoody formation	
Undifferentiated	
10. Quartz arenite, gypsiferous; light greenish gray, weathers whitish and pale green; poorly bedded, soft, friable; fine-grained, contains abundant shall dark ?chert grains; contains abundant secondary gypsum in veins crosscutting sand; thickness not measured, unit arbitrarily chosen as top of section	—
9. Gypsum; white, weathers light greenish gray; massive, soft, friable; finely crystalline; locally contains limonitic iron stain . .	1.2
8. Quartz arenite, gypsiferous; light greenish gray, weathers light brownish gray; poorly bedded; fine- to medium-grained with calcareous cement, hard; contains dark ?chert fragments and thin bands of secondary gypsum; locally iron stained . . .	2.8
7. Limestone, gypsiferous; medium gray, weathers cream and light gray; thin-bedded, fairly hard; medium crystalline; contains roughly intercalated secondary gypsum	0.5
6. Limestone, quartzose; light gray, weathers medium greenish gray; thin-bedded to fissile; finely crystalline; contains pyrite crystals, quartz silt, and fine sand . . .	1.2
5. Limestone, highly quartzose; medium to dark gray, weathers to dirty brownish gray; thin-bedded, hard, resistant; unit consists of relatively pure limestone with roughly interbedded bands of highly quartzose sediment; unit shows primary intraformational distortions	2.8
PERMIAN SYSTEM	
Shedhorn sandstone	
Upper member	
4. Quartz siltite, calcareous; brownish gray, weathers light greenish brown; thinly, poorly bedded; maybe slightly cherty; contains abundant iron oxide stain near top	1.0
3. Quartz arenite, calcareous, slightly phosphatic; dark grayish brown, weathers dirty medium brown; massive, poorly cemented, almost friable; well-sorted, medium-grained; contains small amount of iron stain	0.8
2. Quartz arenite, calcareous; dark gray to black, weathers light brownish gray; thin- to medium-bedded, highly weathered; well sorted, medium-grained; cement calcareous	6.0
1. Quartz arenite, calcareous; medium brownish gray, weathers light brownish gray; medium- to thick-bedded, hard, forms prominent ledge; fine- to medium-grained; lower beds not measured	10
Total measured thickness	26.3

SECTION 6. GROS VENTRE CANYON, WYOMING

Section measured at steeply inclined slope near north bank of Gros Ventre River, south of the Gros Ventre Slide, in the Gros Ventre Range; SW. ¼, sect. 5, T. 42 N., R. 114 W., Teton County, Wyoming.

	Thickness in Feet
TRIASSIC SYSTEM	
Dinwoody formation	
Lingula zone	
6. Calcilutite, quartzose; light greenish brown, weathers mottled light brown and gray; fine- to medium-bedded, soft; contains abundant iron stain; contains	

some vertical burrow casts; unit contains a few interspersed beds of more resistant, thin-bedded quartz arenites; overlain by covered interval 10.5

5. Quartz arenite, cherty, phosphatic; dark brownish gray, weathers mottled light brown and gray; quartz, chert, and phosphate grains variable in size from fine silt to over 5 mm. in diameter, angular to subrounded, poorly sorted, essentially conglomeratic in a cherty and calcareous matrix; basal surface irregular, contains flattened chert or phosphorite pebbles; contains unidentifiable fossil fragments 0.5

PERMIAN SYSTEM
Phosphoria formation
?Retort member

4. Chert, quartzose, phosphatic; dark gray to black, weathers light brown and greenish gray; thin- to medium-bedded; chert is finely crystalline, contains fine silt grains of quartz and phosphate; unit contains a few shaly partings. 2.2
3. Shale, calcareous; dark gray to black, weathers light brown; thin-bedded to fissile; becomes cherty upward grading into bed 4 1.5

Shedhorn sandstone
Upper member

2. Quartz arenite, calcareous; grayish brown, weathers dirty tan; thick-bedded to massive, hard; medium to coarse-grained, fairly well sorted. 24

Phosphoria formation
Tosi member

1. Chert; dark gray to black, weathers mottled yellowish brown and gray; thin- to medium-bedded, hard; chert composed of fine individual grains in a finely crystalline matrix; unit contains two 1-foot beds of vertical tubular chert, near middle of unit . . . 30

Base of Tosi not exposed.
Total measured thickness 68.7

SECTION 7. HOBACK, WYOMING

Section measured at road cut and natural exposure on north side of U. S. Highways 89 and 26 about 17 miles southwest of Jackson; SW. ¼, NE. ¼, sect. 32, T. 39 N., R. 116 W., Teton County, Wyoming.

THICKNESS IN FEET

TRIASSIC SYSTEM
Dinwoody formation
?Lingula zone

20. Calcisiltite, quartzose, argillaceous; light greenish brown, weathers mottled dark brown; thin-bedded; contains abundant iron stain; top not exposed. 0.5
19. Calcilutite, quartzose; grayish brown, weathers light brown; thin-bedded; contains streaks and patches of argillaceous material 7.5
18. Shale, quartzose, phosphatic; medium brown, weathers light brown; thin-bedded; lower few inches conglomeratic, containing tabular fragments, granules, and fine grains of black phosphate mineral, and a few quartz grains; locally contains very thin band of reddish iron oxide just above base; basal surfaces undulates, with about ½ inch of microrelief 1.0

PERMIAN SYSTEM
Phosphoria formation
Retort member

17. Phosphorite, quartzose; dark gray to black, weathers dark brownish gray; poorly bedded, soft; locally conglomeratic, contains pebbles and granules of black phosphate mineral, and abundant red iron oxide grains; also contains large amount of detrital quartz sand; basal surface undulates, depressed slightly into bed 16 . . . . 1.2
16. Shale, phosphatic, iron-rich; reddish brown, weathers yellowish brown; fissile, soft; contains small phosphate grains; deeply weathered 0.4
15. Phosphorite, quartzose; black, weathers mottled brown and gray; unevenly bedded, hard, resistant; phosphate occurs as pellets, oolites, and large angular grains in a fine matrix which is also phosphatic. 0.6
14. Mudstone; dark brown, weathers medium brown; thin-bedded to fissile, locally contains Liesegang rings cutting across bedding; unit

locally distorted and deformed . 1.3

13. Mudstone, phosphatic, iron-rich; black, weathers yellowish brown; massive, hard, resistant; phosphate occurs as pellets in shaly matrix; contains abundant iron oxide fragments 0.8
12. Mudstone; dark brown, weathers medium brown; thin-bedded to fissile; contains reddish iron oxide stain; locally contains secondarily formed crystals of a soft, black, platy mineral and a soft, colorless, ?zeolite mineral; contains Liesegang rings 3.5
11. Shale, carbonaceous; black, weathers mottled yellowish green and dark gray; fissile, soft; contains small balls of a soft, yellowish green, clay-like mineral and ?zeolite minerals; rock has a nearly iridescent hue on fresh surface . 3.0

Shedhorn sandstone

Upper member

10. Orthoquartzite; brownish gray, weathers dark brownish gray; thick-bedded to massive, hard, resistant, forms ledge; recrystallized; weathered surfaces contain abundant limonitic iron stain; fossiliferous, contains molds of brachiopods and bryozoans 10.5
9. Orthoquartzite, slightly phosphatic; medium gray, weathers reddish brown and gray; thick-bedded to massive; contains phosphate pellets and abundant reddish iron stain; fossiliferous, contains molds and casts of large brachiopods and ramose bryozoans; unit capped by 2 to 3 inches of sandy, phosphatic shale 5.2
8. Quartz siltite, argillaceous, iron-rich; light reddish brown, weathers mottled reddish brown and gray; thin-bedded to fissile, soft, highly weathered; contains bands of dark reddish brown iron stain 0.8
7. ?Graywacke; light to medium gray, weathers light yellowish brown; unbedded, soft, weathered, almost friable; contains fine to coarse, generally subangular fragments of ?clay mineral in shaly matrix 0.8
6. Orthoquartzite and silty shale; orthoquartzite light gray, weathers greenish gray; thin- to medium-bedded, hard; shale light yellowish brown, soft, fissile, contains quartz silt and abundant limonitic iron stain, becoming more iron-rich near top; may be slightly phosphatic in upper few inches 2.2

Phosphoria formation

Tosi member

5. Covered; a 2-foot trench reveals highly weathered calcareous rock, quartzose and argillaceous, with reddish brown iron stain; may represent old erosional surface. 1.8
4. Limestone, cherty; light gray, weathers light greenish gray; massive, hard, resistant; finely crystalline; chert occurs as cement in limestone and as dark cherty patches; highly fractured 1.5
3. Calcisiltite, cherty, argillaceous; chalky gray, weathers cream and pale greenish gray; very thin-bedded, soft; chert occurs as stringers and nodules, is light gray and finely crystalline . . . 2.2
2. Mostly covered, trench reveals rock same as bed 3, but with large (up to 3 inches in diameter), calcareous, chert nodules. 1.8
1. Chert, calcareous; dark gray to black, weathers light gray; thin- to medium-bedded; finely crystalline, locally nodular in matrix of calcisiltite; some of nodules large and irregularly shaped as in bed 2 . . . . 11.0

Carbonates and cherts of Tosi member and ?Franson member (Park City formation), about 70 feet, then Meade Peak member.

Total measured thickness 57.6

SECTION 8. COKEVILLE, WYOMING

Section measured at Cokeville Butte, $\frac{3}{4}$ mile east of U. S. Highway 30, at the former Stauffer Chemical Company phosphate mine; S. $\frac{1}{2}$, sect. 35, T. 25 N., R. 119 W., Lincoln County, Wyoming.

THICKNESS IN FEET

TRIASSIC SYSTEM

Dinwoody formation

Lingula zone

Large interval of well-exposed silty limestones and shales; limestones thin-bedded, more resistant, contain *Lingula* and bivalve molds.

11. Limestone, quartzose, and calcareous shale; medium greenish gray, weathers buff; thin-bedded to fissile, limestone more resistant than shale; limestone contains abundant quartz silt; unit mostly covered 5.0
10. Limestone, argillaceous; greenish gray, weathers light greenish gray; thin-bedded, platy, to medium-bedded, fairly hard and resistant; finely crystalline . . 2.5
9. Limestone, quartzose, and calcareous shale; greenish brown, weathers light greenish brown; limestone thin- to medium-bedded, more resistant, finely crystalline, contains quartz silt; shale fissile, soft, contains abundant reddish brown iron stain; unit mostly covered 2.0
8. Limestone, quartzose, slightly phosphatic; dark grayish brown, weathers light brown; thinly, poorly bedded; soft, highly weathered; finely crystalline, with fine quartz silt; lower 3 to 4 inches finely conglomeratic, contains fine to coarse (more than 5-mm. in diameter) grains of phosphate and quartz which become progressively less abundant upward and disappear near the top of the unit; basally abundant reddish brown iron mineral fragments also disappear higher in the unit 1.5

PERMIAN SYSTEM
Phosphoria formation
Retort member

7. Phosphorite, calcareous, quartzose; dark grayish brown, weathers medium grayish brown; very soft, mostly covered; phosphate occurs as nodules and small grains in sandy and fine calcareous matrix; contains abundant reddish brown iron mineral fragments; closely resembles lower part of bed 8; contains a productid brachiopod 0.6
6. Limestone, phosphatic, quartzose; dark gray to black, weathers mottled greenish brown and dark gray; massive, hard; phosphate occurs as fine pellets to coarse (4 mm. in diameter) rounded to subangular nodules in matrix of finely crystalline limestone . . 0.8
5. Limestone, phosphatic, quartzose; like bed 6 but with coarser phosphate grains (up to 8 mm. in diameter); contains plicated shell fragments 0.5
4. Shale, slightly calcareous; dark chocolate brown, weathers lighter greenish brown; thin-bedded to fissile, soft; probably carbonaceous 1.8

?Cherty shale member

3. Mudstone, highly calcareous; black, weathers light greenish brown; thin-bedded to platy, fairly hard; carbonaceous; outcrops locally in bottom of gully; transitional with bed 2 . . . . 2.8
2. Mudstone, calcareous, ?siliceous; black, weathers medium greenish brown; thinly, unevenly bedded, hard, resistant, outcrops fairly persistently; heavily fractured, contains abundant secondary calcite veins. 2.2
1. Mudstone, calcareous, ?siliceous; dark brown, weathers light brown; thin- to medium-bedded, fairly hard on fresh surface, but generally soft and weathered, mostly covered 2.5

Large covered interval, about 100 feet, revealing black calcareous mudstone in float, then ridge-forming Rex chert member. —
Total measured thickness 22.2

SECTION 9. HOT SPRINGS, IDAHO

Section measured at overturned exposure on east slope of East Bear Mountain, across gully and 100 yards to west of "jeep" trail; E. ½, sect. 13. T. 15 S., R. 44 E., Bear Lake County, Idaho.

THICKNESS IN FEET

TRIASSIC SYSTEM
Dinwoody formation
Lingula zone
Covered interval of about 10 feet, overlain by about 25 feet similar to bed 3.

3. Limestone, quartzose; olive brown, weathers medium greenish brown;

thin-bedded, platy; contains black, ?iron-stained patches; contains a few shell fragments, *?Lingula*, and burrow casts . . 3.0

PERMIAN SYSTEM

Phosphoria formation

Retort member

2. Phosphorite, quartzose, calcareous; dark gray, weathers mottled greenish brown and dark gray; massive, hard, heavily fractured; phosphate occurs as fine grains and pellets to coarse nodules in very finely crystalline calcareous and ?siliceous matrix; contains small amount of silt-sized detrital quartz; fossiliferous, contains *Orbiculoidea* and unidentifiable fragments; (lithologic break between beds 2 and 3 very sharp) 0.7

?Cherty shale member

1. Mudstone, calcareous; dark gray to black, weathers light greenish brown; thin-bedded, platy, brittle; contains some reddish brown iron concretions; carbonaceous 10

Poorly exposed interval, about 40 feet, with lithology similar to bed 1, underlain by ridge-forming Rex chert member.

Total measured thickness 13.7

SECTION 10. PARIS CANYON, IDAHO

Section measured at overturned exposure 50 yards north of Paris Canyon secondary road, about 2 miles west of U. S. Highway 89, in the town of Paris; SE. ¼, sect. 8, T. 14 S., R. 43 E., Bear Lake County, Idaho.

THICKNESS IN FEET

TRIASSIC SYSTEM

Dinwoody formation

?Lingula member

Covered interval, overlies about 10 feet of faulted Dinwoody lithologically similar to bed 8, containing *Claraia;* separated from bed 8 by fault of unknown magnitude, probably only a few feet.

8. Limestone, quartzose, slightly phosphatic; light grayish brown, weathers mottled buff and brownish gray; thin-bedded to fissile; fine-grained, basally contains fine to coarse phosphate grains, apparently reworked from underlying beds, becoming less abundant and disappearing upward in unit; locally heavily iron stained; top of unit (base of overturned section) not exposed 1.7

PERMIAN SYSTEM

Phosphoria formation

Retort member

7. Phosphorite, quartzose, calcareous; dark grayish brown, weathers mottled yellowish brown and gray; massive, hard; phosphate occurs as small grains and oolites and as large subangular fragments in a finely crystalline, highly calcareous matrix; unit appears to be transitional with bed 8 with regard to the phosphate abundance which becomes progressively less over a 6-inch zone grading into bed 8 . . . . 0.7

Cherty shale member

6. Chert and calcareous mudstone; chert is dark gray, weathers dirty brownish gray; medium-bedded, highly fractured; very finely crystalline; contains abundant pyrite cubes; mudstone is dark grayish brown, weathers light reddish brown; thin-bedded, interbedded with chert, becoming progressively less common upward; unit forms ledge over Phosphoria-Dinwoody contact . 9.2

5. Mudstone, calcareous; dark gray to black; weathers buff to light gray; alternately medium-bedded and thin-bedded to fissile, thicker beds highly calcareous; carbonaceous 18.8

4. Limestone, highly argillaceous; black, weathers dark brownish gray; thick-bedded to massive; finely crystalline; very hard, forms ledge 1.3

3. Mudstone; chocolate, weathers buff to medium brown; thin-bedded to fissile, relatively soft, weathered; contains thin shaly partings 5.5

Rex chert member

2. Chert, slightly calcareous; grayish brown, weathers light reddish brown and light gray; thinly, unevenly bedded, heavily fractured; very finely crystalline . . 10.0

1. Chert, calcareous; light reddish brown, thin-bedded, heavily

fractured, locally iron stained; forms prominent outcrops; thickness not measured, probably 75 to 100 feet . . . . —

Total measured thickness 47.2

SECTION 11. MONTPELIER CANYON, IDAHO

Section measured on north wall of canyon, several hundred feet to north of and above U. S. Highway 89, 3 miles east of Montpelier; SW. $\frac{1}{4}$, sect. 31, R. 45 E., T. 12 S., Bear Lake County, Idaho.

	THICKNESS IN FEET
TRIASSIC SYSTEM	
Dinwoody formation	
?Lingula zone	
8. Limestone, slightly quartzose; medium gray, weathers light greenish gray; thin- to medium-bedded, sometimes fissile or platy and brittle; finely crystalline; contains burrow casts and molds of *?Claraia;* upper part of unit not measured	25
7. Limestone, quartzose; medium brownish gray, weathers light greenish brown; very thin-bedded, platy, with shaly partings; finely crystalline	4.0
6. Limestone, brownish gray, weathers light greenish gray; massive; finely crystalline, dense, clean; contains ?styolites or shaly veins	0.8
5. Covered interval; trenched at following intervals:	29
H: 25.5 feet above bed 4: Limestone, highly argillaceous; chocolate, weathers greenish brown; thin-bedded to fissile; finely crystalline; contains a few shell fragments and burrow casts	
G: 20.5 feet above bed 4: Calcilutite; light green, weathers mottled dark brown and green; massive; very fine grained, dense, resembles lithographic limestone; contains some burrow casts.	
F: 17.7 feet above bed 4: Limestone, quartzose; dark greenish gray, weathers to mottled cream and light greenish gray; finely laminated, with silty quartz layers alternating with limestone layers which are finely crystalline.	
PERMIAN SYSTEM	
Phosphoria formation	
?Cherty shale member	
E: 14.1 feet above bed 4: Mudstone, calcareous; black, weathers mottled cream and light gray; thin-bedded, very brittle; contains a few phosphate or chert nodules.	
D: 10.6 feet above bed 4: Similar to E.	
C: 7.8 feet above bed 4: Mudstone, siliceous, calcareous; black, weathers mottled light brown and dark gray; no bedding observed, very hard, brittle; maybe cherty.	
B: 6.4 feet above bed 4. Mudstone, calcareous; dark brown, weathers dirty whitish gray; thin- to medium-bedded, soft, highly weathered.	
A: Immediately above bed 4. Mudstone, phosphatic, ?cherty; black, weathers dirty medium brown; no bedding observed; contains coarse grains of phosphate or ?chert.	
Retort member	
4. Phosphorite, quartzose, calcareous; dark gray to black, weathers mottled dark brownish gray and cream; poorly bedded; phosphate occurs as fine grains and pellets, and as large nodules (1 cm. in diameter) in a finely crystalline calcareous and ?siliceous matrix; contains abundant iron stain . .	0.8
3. Mudstone, calcareous; black, weathers mottled cream and dark grayish brown; thin-bedded, platy; mostly covered. . .	4.5
2. Chert, calcareous, ?phosphatic; dark gray to black, weathers mottled light brownish gray and dark gray; medium-bedded; chert occurs bedded and as large nodules and fragments in a calcareous matrix; chert is finely crystalline and includes small ?phosphate grains and ?sponge spicule casts	4.5

Rex member

1. Chert, calcareous, and cherty, crystalline limestone; dark gray to black; thick-bedded to massive; ledge-forming; fossiliferous, contains large productid brachiopods; unit about 70 feet thick, overlies Meade Peak member .

Total measured thickness 68.6

SECTION 12. BALLARD MINE, IDAHO

Section measured at artificial cut just east of old mine entrance road, off Blackfoot River Road, about 18 miles northeast of Soda Springs, Idaho, via State Highway 34 and the Blackfoot River Road; SE. ¼, sect. 12, T. 7 S., R. 42 E., Caribou County, Idaho.

	Thickness in Feet
Triassic System	
Dinwoody formation	
Undifferentiated	
6. Limestone, quartzose; medium gray, weathers dirty brownish gray; thin-bedded; fine to medium crystalline, contains small amount of detrital quartz silt; unit occurs as channel filling apparently cut into bed 5; top of unit removed either artifically or by erosion	3.0
Permian System	
Phosphoria formation	
Retort member	
5. Mudstone, highly calcareous, phosphatic; medium to dark brown, weathers streaked cream and light brown; thin-bedded, soft, highly weathered; contains abundant iron oxide mineral; top of unit not exposed	2.5
4. Phosphorite, cherty, calcareous; dark gray to black, weathers dirty brown and gray; massive, hard, heavily fractured, phosphate occurs as fine grains and pellets and in coarse, ?cherty fragments in a finely crystalline cherty matrix, small amount of angular quartz silt	0.7
3. Shale; dark grayish brown to black, weathers yellowish brown and chocolate; thin-bedded to fissile; locally contains fine grains of phosphate	2.8
2. Mudstone, phosphatic, quartzose; dark grayish brown, weathers streaked yellowish brown; massive; contains fine to coarse phosphate fragments, some detrital quartz silt; contains Liesegang rings	0.5
1. Shale; black, weathers light brown; thin-bedded to fissile, locally nodular; maybe slightly phosphatic; base not exposed	3.5
Total measured thickness	13.0

LOCALITY INDEX

PERMIAN FOSSIL LOCALITIES

Wyoming

Bargee: T. 7 N., R. 1 W., Owl Creek Mountains, Fremont County

Bartlett Creek: Sect. 23, T. 38 N., R. 111 W., Sublette County

Basin Creek: Sects. 12, 13, T. 26 N., R. 117½ W., Lincoln County

Blue Holes Canyon: Sect. 18, T. 40 N., R. 105 W., Fremont County

Bull Lake: Sect. 6, T. 2 N., R. 3 W., Fremont County

Burroughs Creek: NE. ¼, sect. 14, T. 43 N., R. 107 W., Fremont County

Coal Canyon: Sect. 7, T. 26 N., R. 119 W., Lincoln County

Cokeville: NE. ¼, NW. ¼, sect. 4, T. 24 N., R. 119 W., Lincoln County

Crystal Creek: S. ½, NW. ¼, sect. 34, T. 42 N., R. 113 W., Teton County

Cumberland: SW. ¼, NE. ¼, sect. 19, T. 19 N., R. 117 W., Lincoln County

Deadline Ridge: Sect. 7, T. 27 N., R. 114 W., Lincoln County

Dinwoody Canyon: SW. ¼, SW. ¼, sect. 6, T. 4 N., R. 5 W., Fremont County

Flat Creek: Sect. 1, T. 41 N., 115 W., Teton County

Fontenelle Creek: Sect. 35, T. 27 N., R. 116 W., Lincoln County

Forellan Peak: South slope of Forellan Peak in northern part of Grand Teton National Park

Gros Ventre Canyon: SE. $\frac{1}{4}$, sect. 5, T. 42 N., R. 114 W., Teton County
Hoback: SW. $\frac{1}{4}$, NE $\frac{1}{4}$, sect. 33, T. 39 N., R. 117 W., Teton County
Layland Canyon: Sect. 30, T. 27 N., R. 119 W., Lincoln County
Little Dry Creek: Sects. 7, 18, T. 4 N., R. 5 W., Fremont County
Mexican Creek: Center, NE. $\frac{1}{4}$, sect. 11, T. 33 N., R. 101 W., Fremont County
Middle Fork of Pine Creek: Sect. 35, T. 25 N., R. 118 W., Lincoln County
Red Basin: NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, sect. 21, T. 1 N., R. 3 W., Fremont County
Red Creek: T. 5 N., R. 6 W., Fremont County
South Fork Canyon: T. 1 S., R. 2 W., Fremont County
South Fork of Gypsum Creek: NW. $\frac{1}{4}$, sect. 22, T. 38 N., R. 109 W., Sublette County
Spring Creek: T. 1 S., R. 2 W., Fremont County
Steer Creek: Sect. 9, T. 36 N., R. 116 W., Lincoln County
Torrey Lake: Road cut, 8 miles southeast of Dubois, Fremont County
Tosi Creek: Sect. ?24, T. 39 N., R. 111 W., Sublette County
Washakie Reservoir: NW. $\frac{1}{4}$, sect. 16, T. 1 S., R. 2 W., Fremont County
Wheat Creek: Sect. 4, T. 23 N., R. 116 W., Lincoln County
Willow Creek: Center, N. $\frac{1}{2}$, sect. 10, T. 31 N., R. 100 W., Fremont County

Montana

Alpine Creek: N. $\frac{1}{2}$, sect. 26, T. 10 S., R. 2 W., Madison County
Big Timber: Sect. 23, T. 5 S., R. 12 E., Snodgrass County
Canyon Creek: NW. $\frac{1}{4}$, sect. 13, T. 2 S., R. 10 W., Beaverhead County
Cedar Creek: Sect. 26, T. 9 S., R. 11 W., Beaverhead County
Cinnabar Mountain: Sect. 31, T. 8 S., R. 8 E., Park County
Hidden Pastures: Sects. 26, 35, 11, T. 14 S., R. 10 W., Beaverhead County
Hogback Mountain: S. $\frac{1}{2}$, NW. $\frac{1}{4}$, sect. 8, T. 11 S., R. 4 W., Madison County
Little Water Canyon: SE. $\frac{1}{4}$, sect. 4, T. 13 S., R. 10 W., Beaverhead County
Sappington Canyon: Sect. 25, T. 1 N., R. 2 W., Gallatin County
Sawtooth Peak: NE. $\frac{1}{4}$, SW. $\frac{1}{4}$, sect, 10, T. 12 S., R. 5 W., Beaverhead County
Sheep Creek: NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, sect, 23, T. 9 S., R. 9 W., Beaverhead County
Wadhams Spring: Sects. 22, 28, T. 13 S., R. 7 W., Beaverhead County
West Fork of Blacktail Creek: SE. $\frac{1}{2}$, sect. 26, T. 12 S., R. 6 W., Beaverhead County

Idaho

Bear Creek: NE. $\frac{1}{4}$, sect. 31, T. 1 S., R. 45 E., Bonneville County
Divide between Trail and Wood Canyon: Sect. ?26, T. 8 S., R. 45 E., Caribou County
East Georgetown Canyon: NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, sect. 30, T. 10 S., R. 45 E., Bear Lake County
Grizzly Creek: Sect. 30, T. 5 S., R. 40 E., Caribou County
Hot Springs: Sect. 13, T. 15 S., R. 44 E., Bear Lake County
Kendall Canyon: Sect. 28, T. 7 S., R. 44 E., Caribou County
Lone Pine Springs: NE. $\frac{1}{4}$, sect. 4, T. 9 S., R. 45 E., Caribou County
Mabie Canyon: NW. $\frac{1}{4}$, NE. $\frac{1}{4}$, sect. 10, T. 8 S., R. 44 E., Caribou County
Montpelier Canyon: Sect. 31, T. 12 S., R. 45 E., Bear Lake County
Mud Springs: Sec. 7, T. 12 S., R. 29 E., Cassia County
North Rasmussen Valley: Sect. 6, T. 7 S., R. 44 E., Caribou County
North Wooley Range: Sect. 24, T. 6 S., R. 42 E., Caribou County
Paris Canyon: Sect. 8, T. 14 S., R. 43 E., Bear Lake County
Snowdrift Mountain: NW. $\frac{1}{4}$, NW. $\frac{1}{4}$, sect. 8, T. 10 S., R. 45 E., Caribou County
Swan Lake Gulch: NE. $\frac{1}{4}$, SW. $\frac{1}{4}$, sect. 29, T. 9 S., R. 43 E., Caribou County
Trail Canyon: SW. $\frac{1}{4}$, NW. $\frac{1}{4}$, NW. $\frac{1}{4}$, sect. 39, T. 8 S., R. 43 E., Caribou County
Waterloo: SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, sect. 6, T. 13 S., R. 45 E., Bear Lake County
West Dairy: NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, sect. 19, T. 9 S., R. 44 E., Caribou County
Woodall Creek: NW. $\frac{1}{4}$, sect. 26, T. 7 S., R. 42 E., Caribou County

Utah

Blind Stream: SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, sect. 14, T. 1 N., R. 8 W., Duschene County
Brazer Canyon: NW. $\frac{1}{4}$, sect. 9, T. 11 N., R. 8 E., Rich County
Cephalopod Gulch: NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, sect. 27, T. 1 N., R. 1 E., Salt Lake County
Coulter Ranger Station: W. $\frac{1}{2}$, sect. 12, T. 2 S., R. 21 E., Uintah County
Horseshoe Canyon: Sect. 36, T. 3 N., R. 20 E., Daggett County
Strawberry Valley: NW. $\frac{1}{4}$, sect. 14, T. 2 S., R. 12 W., Wasatch County

TRIASSIC FOSSIL LOCALITIES

Wyoming

Dinwoody Canyon: S. ½, sect. 31, T. 5 N., R. 5 W., Fremont County
Green River Lakes: SW. ¼, sect. 36, T. 39 N., R. 109 W., Fremont County
Gros Ventre Canyon: NW. ¼, SE. ¼, sect. 10, T. 42 N., R. 114 W., Teton County
Hidden Anticline: Red Canyon, Wind River Mountains, 12 miles southeast of Lander, Fremont County
Little Popo Agie Canyon: SE. ¼, NE. ¼, sect. 8, T. 31 N., R. 99 W., Fremont County
Martin Creek: NW. ¼, sect. 16, T. 38 N., R. 116 W., Lincoln County
Meadow Creek Canyon: Sect. 2, T. 3 N., R. 5 W., Teton County
Red Creek: SW. ¼, sect. 24, T. 7 N., R. 4 W., Fremont County
South Fork Canyon: T. 1 S., R. 2 W., Fremont County
Swift Creek Canyon: SE. ¼, sect. 19, T. 32 N., R. 118 W., Lincoln County

Montana

Daly's Spur: North of corner of sects. 35, 36, T. 8 S., R. 10 W., Beaverhead County
Frying Pan Gulch: NE. ¼, sect. 35, T. 6 S., R. 10 W., Beaverhead County
Hogback Mountain: NW. ¼, sect. 28, T. 11 S., R. 4 W., Madison County
Little Water Canyon: Center, sect. 2, T. 13, R. 31 E., Beaverhead County
Melrose: Sect. 22, T. 2 S., R. 10 W., Beaverhead County
West Fork of Blacktail Creek: Sects. 35, 36 T., 12 S., R. 35 E., Beaverhead County

Idaho

Dry Ridge: First canyon south of Stewart Canyon, T. 8 S., R. 45 E., Caribou County
Hammond Creek: Center of boundary between sects. 27, 28, T. 13 S., R. 43 E., Bear Lake County
Henry: Sect. 7, T. 6 S., R. 41 E., Caribou County
Montpelier Canyon: W. ½, sect. 31, T. 27 N., R. 45 E., Bear Lake County
Paris Canyon: SE. ¼, sect. 8, T. 14 S., R. 43 E., Bear Lake County
Peale Mountain: West of Bear Lake, Bear Lake County
Sheep Creek: Sect. 23. T. 6 S., R. 43 E., Caribou County
South of Paris Canyon: Float from south side of Paris Canyon road, Bear Lake County
Wood Canyon: SE. ¼, SW. quadrant, T. 8 S., R. 43 E., Caribou County

Utah

Duchesne River: North of Hanna, T. 1 N., R. 8 W., Duchense County
Fort Douglas: On crest of ridge at east edge of Fort Douglas
Mahogany Hills: North of Weber River, T. 1 S., R. 6 E., Summit County
Thistle: Road cut, east side of Highway 6, near Thistle, Utah, and at junction of Diamond and Spanish Fork rivers

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PLATES 1–16

PLATE 1

PERMIAN-TRIASSIC CONTACT

1. Contact at exposure on south wall, Little Popo Agie Canyon, southern Wind River Mountains, Wyoming (section 2, text fig. 4; units 19–21 in stratigraphic description, p. 85). The contact is placed at top of highly weathered erosional profile in oolitic calcarenites of the Ervay member, and at the base of silty limestones of the Dinwoody (pl. 3, figs. 3, 5, and 7 show petrography of units).

2. Contact exposure at Dinwoody Canyon, Wind River Mountains, Wyoming (section 4, text fig. 4; units 24 and 25 in stratigraphic description, p. 87). Joint filling of basal Dinwoody quartz arenite, between blocks of recrystallized calcarenite of the Ervay member (pl. 3, figs. 6 and 8 show petrography of units).

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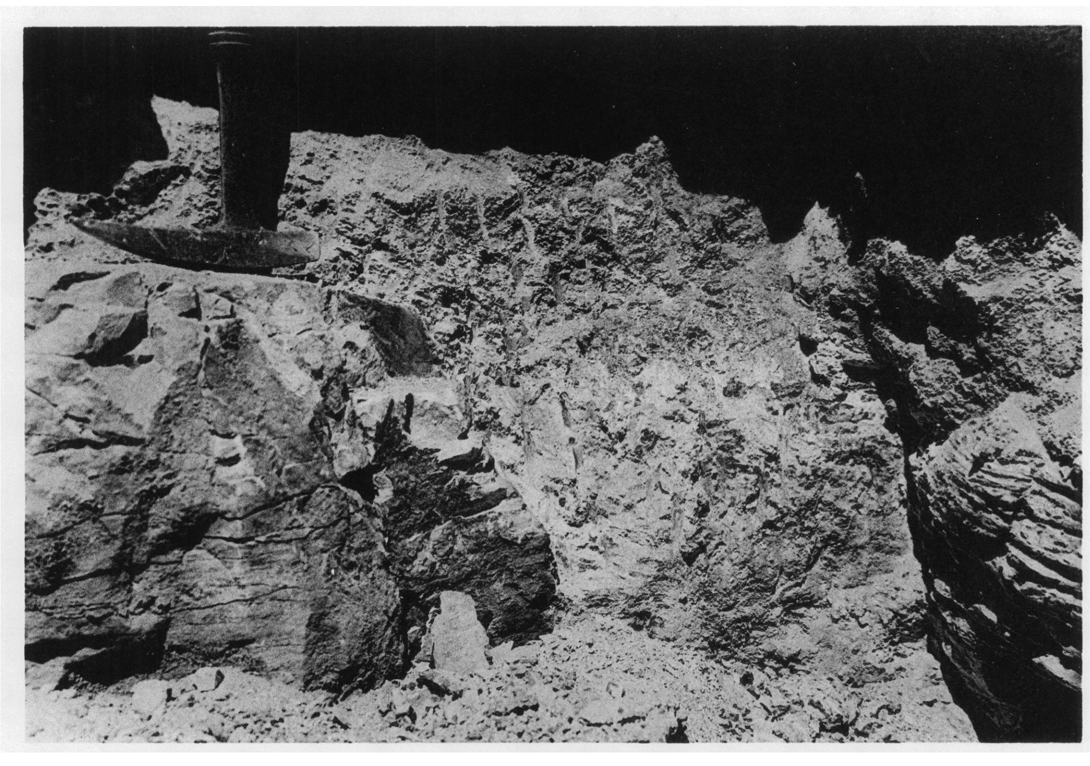

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PLATE 2

Permian-Triassic Contact

1. Artificial exposure of contact at mine pit, Ballard Mine, in the Fox Hills Range, 18 miles northeast of Soda Springs, Idaho (section 12, text fig. 4; units 1–6 in stratigraphic description, p. 95). Dashed line shows channel containing gray, relatively pure Dinwoody limestones cut into dark carbonaceous and phosphatic beds of Retort member.

2. Natural exposure of contact at Red Basin, on the east flank of the Wind River Mountains, Wyoming (section 3, text fig. 4; units 2–5 in stratigraphic description, p. 86). The contact is placed at top of medium-bedded Ervay limestone, containing rounded, weathered joints, and at base of platy, silty limestone of the Dinwoody.

PLATE 3

Thin Sections

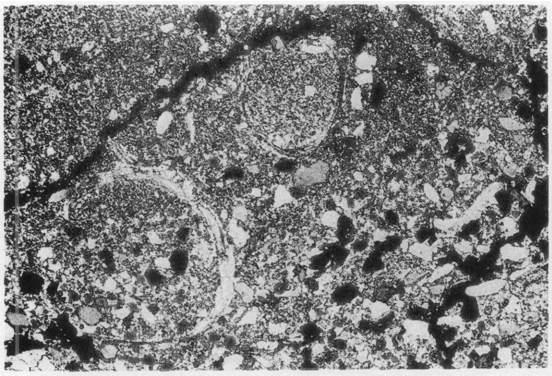
1. Silty limestone, typical of lower Dinwoody; contains up to 50 per cent of subangular detrital quartz, poorly sorted and irregularly distributed in fine calcareous matrix; fossil in cross section is small trochospiral gastropod; Red Basin, Wind River Mountains, Wyoming (unit 6, section 3, p. 86).

2, 4. Rocks immediately above and below Permian-Triassic contact, Hot Springs, Idaho (units 3 and 2, section 9, p. 93). 2. Very fine silty limestone; contains 15 per cent to 20 per cent of very fine detrital quartz silt and a few larger dark phosphorite grains in a non-distinct calcareous matrix. 4. Phosphorite bed, typical of that capping Retort member (thus Permian sequence) over wide area in southeast Idaho; contains large, irregular, phosphorite grains, smaller phosphorite pellets, and subangular detrital quartz in a cherty, calcareous matrix.

3, 5, 7. Rocks above and below Permian-Triassic contact, Little Popo Agie Canyon, Wind River Mountains, Wyoming (units 21, 19, and 18, section 2, p. 85). 3. Fine (top) and coarser (bottom) silty limestone of basal Dinwoody; contains 30 per cent to 40 per cent of subangular to rounded detrital quartz, and minor amounts of detrital calcite, in a fine calcareous matrix. 5. Weathered, partially recrystallized limestone near top of Ervay member; contains microstyolites which show concentration of pyrite and fine detritus on irregular ?corrosion surface (may be a pressure-solution phenomenon). 7. Relatively pure oolitic calcarenite, less than 1 foot below rock in figure 5; contains well-rounded, partially recrystallized oolites, the centers of which are commonly replaced by quartz, in a calcareous matrix; suggestive of shallow-water, relatively turbulent environment.

6, 8. Rocks above and below Permian-Triassic contact at Dinwoody Canyon, Wind River Mountains, Wyoming (units 26 and 24, section 4, p. 87). 6. Quartz arenite of basal Dinwoody, similar to unit in joint filling of upper Permian limestones (pl. 1, fig. 2); contains about 60 per cent of angular to subrounded, poorly sorted, detrital quartz and minor amounts of detrital calcite and phosphorite, in a fine calcareous matrix. 8. Limestone, near top of Ervay member; appears to be more highly recrystallized equivalent of rock shown in figure 7, which occupies similar stratigraphic position.

All figures crossed-Nicols. ×20.



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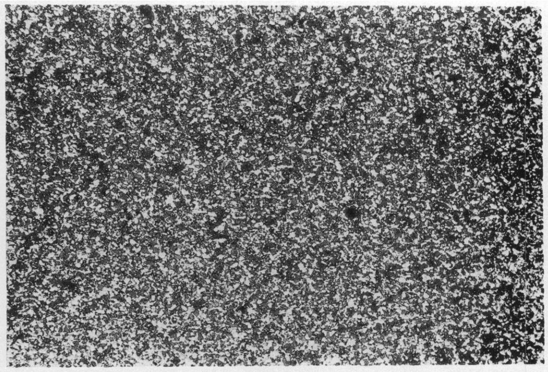

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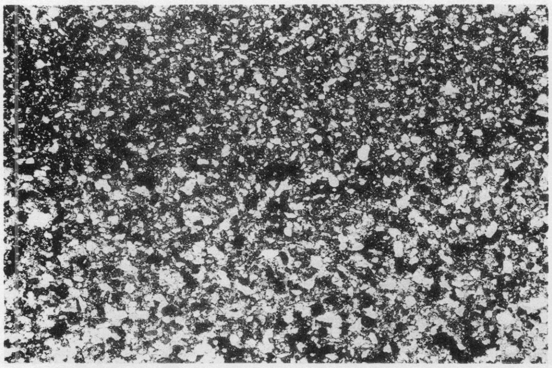

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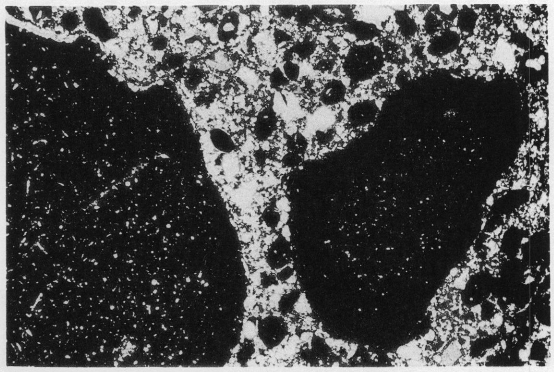

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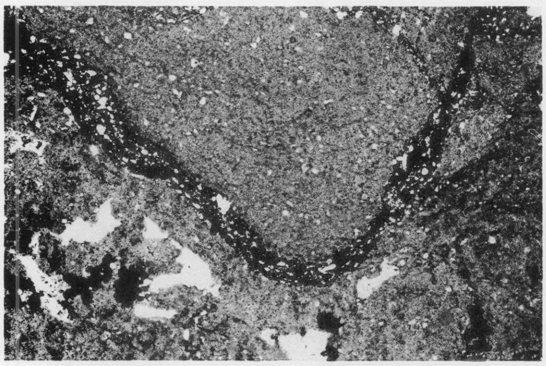

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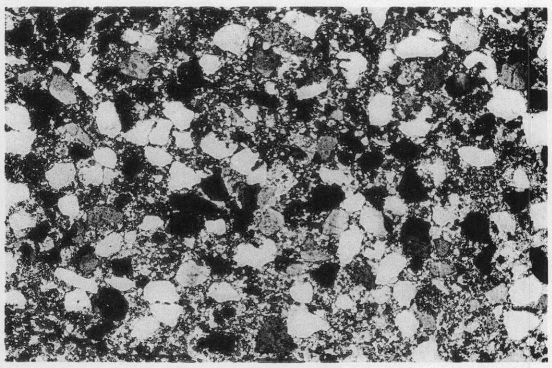

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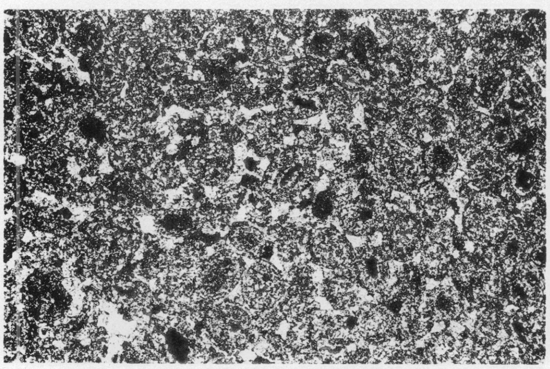

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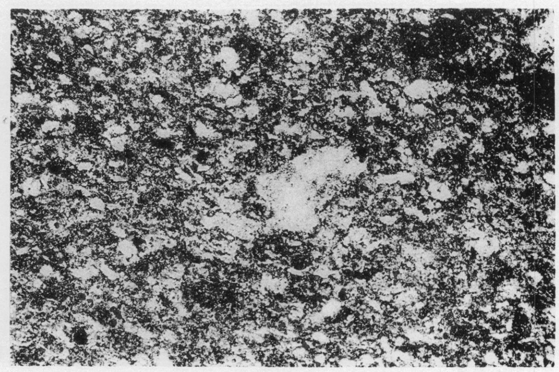

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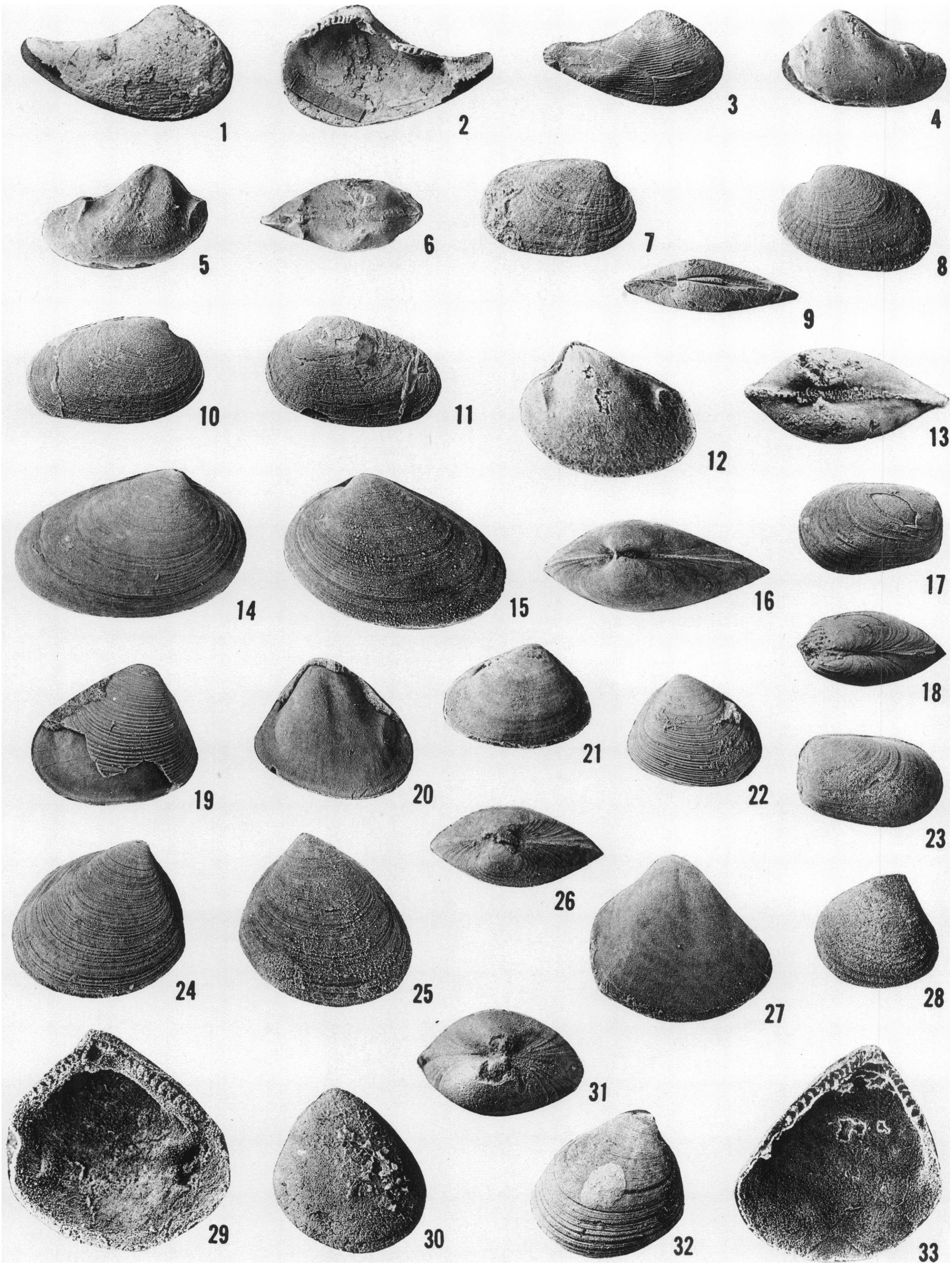
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PLATE 4

Permian Bivalves

1–3. *Polidevcia obesa* (White); see page 42. 1, 2. External and internal views, respectively, of right valve, Franson member, Hidden Pastures, Montana, U.S.N.M. No. 140468. 3. Right valve, showing midumbonal depression, Meade Peak member, South Stewart Canyon, Idaho, U.S.N.M. No. 140469.

4–6. *Polidevcia bellistriata* (?Stevens); see page 41. Left, right, and dorsal views, respectively, of internal mold, float, ?Franson member, Blue Holes Canyon, Wyoming, A.M.N.H. No. 28306.

7–11. *Paleoneilo? parviradiatus* Ciriacks, new species; see page 37. 7, 8. Right and left valves, respectively, of bivalved specimen, holotype, U.S.N.M. No. 140458. 9–11. Dorsal view, showing ligament and right and left valves, respectively, of a smaller bivalved specimen, topoparatype, U.S.N.M. No. 140459. Both specimens from Franson member, Coulter Ranger Station, Utah.

12–16. *Paleoneilo mcchesneyana* (Girty); see page 37. 12. Left internal mold, Grandeur member, Mud Spring, Idaho, U.S.N.M. No. 140457. 13. Same specimen, dorsal view, indicating continuous dentition. 14–16. Right valve, left valve, and dorsal view, respectively, of bivalved specimen, holotype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1705.

17, 18, 23. *Nuculopsis* sp. a; see page 38. Left valve, dorsal view, and right valve, respectively, of this robust, subrectangular form, Meade Peak member, Waterloo, Idaho, U.S.N.M. No. 140460.

19–22. *Nuculopsis* sp. c; see page 39. 19, 20. Broken left valve and right internal surface, respectively, of a large bivalved specimen, U.S.N.M. No. 140461. 21. A more elongate left internal mold, U.S.N.M. No. 140462. Both specimens from Meade Peak member, Trail Canyon, Idaho. 22. Well-preserved right valve, Meade Peak member, Hot Springs, Idaho, U.S.N.M. No. 140463.

24–27. *Nuculopsis montpelierensis* (Girty); see page 39. 24–26. Left valve, right valve, and dorsal view, respectively, of a bivalved specimen, holotype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1700. 27. Right internal mold, Meade Peak member, Hot Springs, Idaho, U.S.N.M. No. 140464.

28, 29. *Nuculopsis montpelierensis?* (Girty); see page 40. 28. Small left valve, U.S.N.M. No. 140465. 29. Internal view and dentition of large left valve, U.S.N.M. No. 140466. Both specimens from Grandeur member, Mud Spring, Idaho.

30–33. *Nuculopsis poposiensis* (Branson); see page 40. 30. Right valve, upper member, Shedhorn sandstone, Alpine Creek, Montana, U.S.N.M. No. 140467. 31, 32. Dorsal view and left valve, respectively, of a bivalved specimen, lectotype, Retort member, Big Popo Agie Canyon, Wyoming, U.M. No. 5277. 33. Internal view and dentition of right valve, Grandeur member, Willow Creek, Wyoming, A.M.N.H. No. 28307.

Magnifications: 1–3, ×1; 4–6, ×3; 7, 8, ×2; 9–11, ×3; 12, ×8; 13, ×10; 14–16, ×5; 17–23, ×2; 24–27, ×4; 28, ×3; 29, ×4; 30–32, ×3; 33, ×4.

PLATE 5

Permian Bivalves

1, 2. *Aviculopinna* sp. a; see page 45. 1. Right internal mold, showing peculiar corrugation of surface, A.M.N.H. No. 28308:1. 2. Posterior view, A.M.N.H. No. 28308:2. Both specimens from Tosi member, Bull Lake, Wyoming.

3, 4. *Aviculopinna* sp. b; see page 46. 3. Right external mold, showing only slight concentric ornamentation, A.M.N.H. No. 28309:1. 4. Fragment of right internal mold, A.M.N.H. No. 28309:2. Both specimens from Tosi member, Bull Lake, Wyoming.

5–7. *Cassianella sexradiata* (Branson); see page 45. 5. Left valve, showing nature of ornamentation, holotype, U.M. No. 5299. 6. Left valve, showing the pronounced left anterior auricle, topoparatype, U.M. No. 5299:1. 7. Same specimen, dorsal view. Both specimens from Ervay member, Bull Lake, Wyoming.

8. *Goniophora?* sp.; see page 43. Left valve, Ervay member, Tosi Creek, Wyoming, A.M.N.H. No. 28310.

9. *Parallelodon?* sp.; see page 43. Left internal mold, Grandeur member, Bull Lake, Wyoming, U.M. No. 5322.

10. *Bakevellia?* sp.; see page 44. Left internal mold, Franson member, Fontenelle Creek, Wyoming, U.S.N.M. No. 140471.

11. *Parallelodon* cf. *multistriatus* Girty; see page 42. Left valve, Ervay member, Dinwoody Canyon, Wyoming, A.M.N.H. No. 28311.

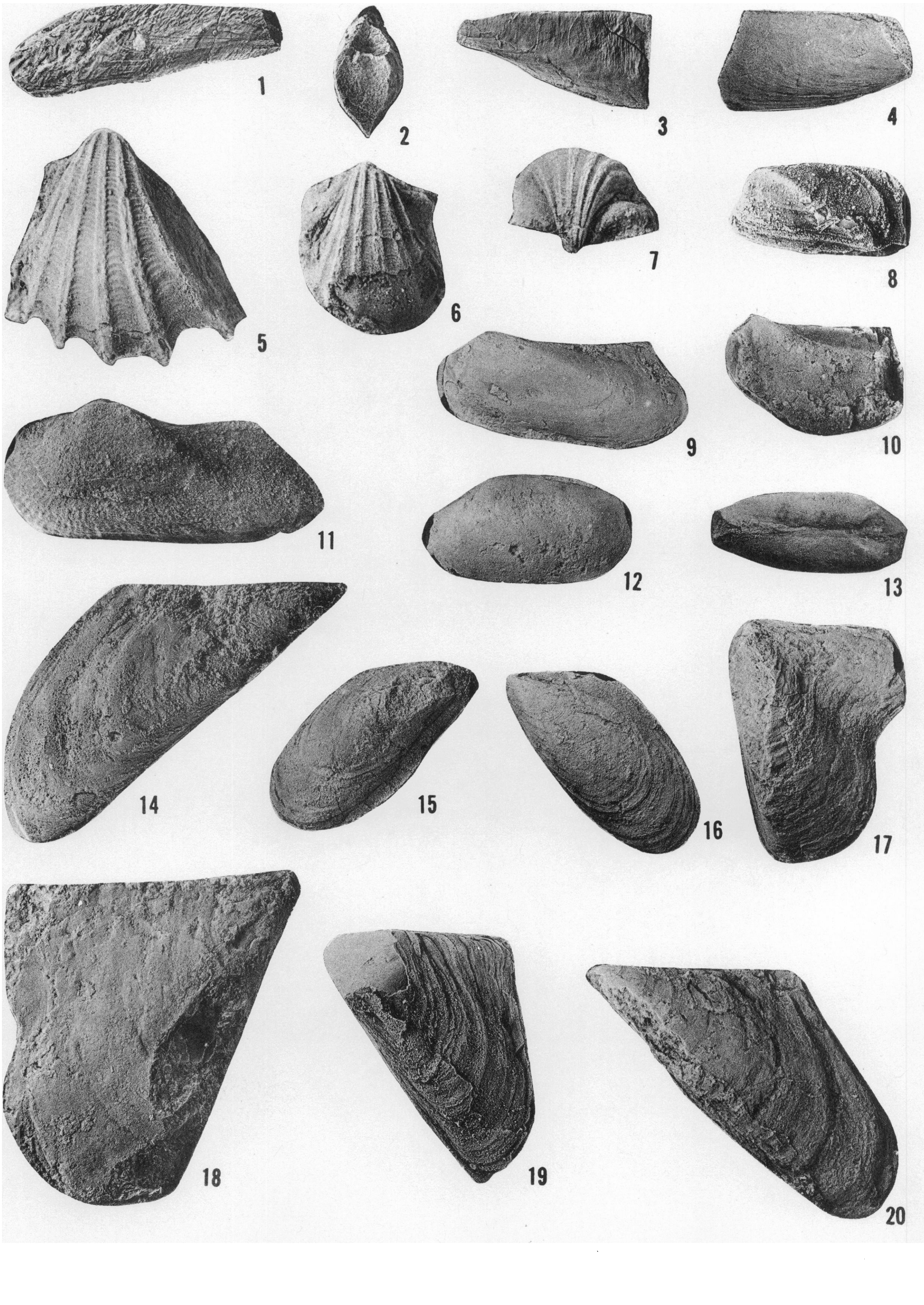
12, 13. *Solemya* sp.; see page 42. Left view and dorsal view, respectively, of bivalved internal mold, Ervay member, Cody, Wyoming, U.M. No. 5275.

14, 19, 20. *Myalina* (*Myalina*) *wyomingensis thomasi* Newell; see page 44. 14. Right internal mold, Ervay member, Little Dry Creek, Wyoming, A.M.N.H. No. 28314/1:1. 19. Incomplete left valve, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28314/2. 20. Left internal mold, Ervay member, Little Dry Creek, Wyoming, A.M.N.H. No. 28314/1:2.

15, 16. *Myalina* (*Myalinella*) *meeki* Dunbar; see page 44. Right and left valves, respectively, of bivalved specimen; left valve appears slightly larger and extends beyond anterior margin of right valve, Tosi member, Hogback, Montana, U.S.N.M. No. 140470.

17, 18. *Myalina* (*Myalina*) *sinuata* Branson; see page 43. 17. Large left internal mold, designated the neotype, A.M.N.H. No. 28312. 18. Right internal mold, A.M.N.H. No. 28313. Both specimens from Ervay member, Little Dry Creek, Wyoming.

Magnifications: 1–4, ×1; 5, ×5; 6–8, ×3; 9, ×1; 10, ×2; 11, ×3; 12–16, ×1; 17, ×0.5; 18–20, ×1.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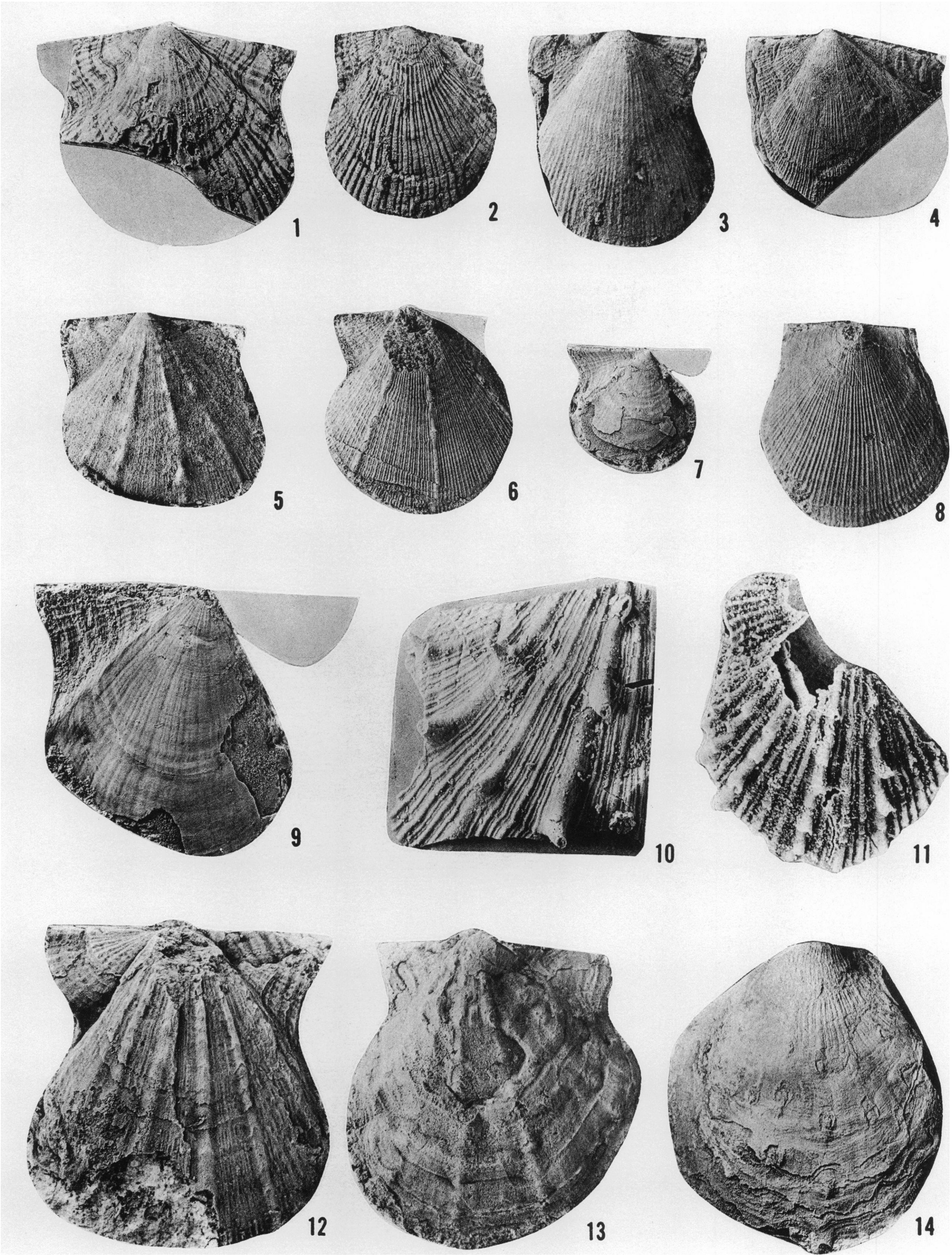


PLATE 6

Permian Bivalves

1, 2. *Aviculopecten* cf. *basilicus* Newell; see page 50. 1. Large incomplete left valve, Retort member, Deadline Ridge, Wyoming, U.S.N.M. No. 140482. 2. A nearly complete left internal mold, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28315.

3, 4. *Aviculopecten* cf. *kaibabensis* Newell; see page 49. 3. Left valve with incomplete auricles, upper member, Shedhorn sandstone, Flat Creek, Wyoming, A.M.N.H. No. 28316. 4. A large left valve, Ervay member, Bull Lake, Wyoming, U.S.N.M. No. 140481.

5–7, 9. *Aviculopecten girtyi* Newell; see page 47. 5. Left valve, U.S.N.M. No. 140477. 6. Left valve with fewer primary costae, U.S.N.M. No. 140478. 7. Associated right valve referred to the species, U.S.N.M. No. 140479. 9. Right valve, showing bifurcation of costae, U.S.N.M. No. 140480. All specimens from Grandeur member, Horseshoe Canyon, Utah.

8. *Monotis? landerensis* (Branson); see page 51. A ?left valve, holotype, Ervay member, Bull Lake, Wyoming, U.M. No. 5305.

10, 11, 13, 14. *Aviculopecten* cf. *vanvleeti* Beede; see page 49. 10. Fragment of large specimen, showing two ranks of spine-bearing costae, and total of five to six ranks of costae, Franson member, Burroughs Creek, Wyoming, U.S.N.M. No. 140514. 11. Juvenile, showing similar ornamentation, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28317/1. 13. Left internal mold, Ervay member, Blue Holes Canyon, Wyoming, A.M.N.H. No. 28317/2. 14. Incomplete specimen (Branson's *Deltopecten occidentalis*) here referred to this group, Ervay member, Bull Lake, Wyoming, U.M. No. 5292.

12. *Aviculopecten gryphus* Newell; see page 48. Left valve, showing numerous primary ribs, float, ?Franson member, South Fork Canyon, Wyoming, A.M.N.H. No. 28318.

Magnifications: 1, 2, ×1; 3, ×2; 4–7, ×1; 8, ×3; 9, ×2; 10, ×1; 11, ×3; 12, ×2; 13, 14, ×1.

PLATE 7

Permian Bivalves

1–6. *Aviculopecten phosphaticus* Girty; see page 46. 1. Large prosocline left valve, U.S.N.M. No. 140472. 2. A nearly orthocline left valve, U.S.N.M. No. 140473. 3. Squeeze of small holotype left valve, Meade Peak member, Coal Canyon, Wyoming, U.S.N.M. No. 1737. 4. Specimen showing rotated opposite valves in occlusion at the hinge, U.S.N.M No. 140474. 5. A large right valve, U.S.N.M. No. 140475. 6. A small right valve with very long hinge spines, U.S.N.M. No. 140476. All specimens except that shown in figure 3 from Meade Peak member, Cokeville, Wyoming.

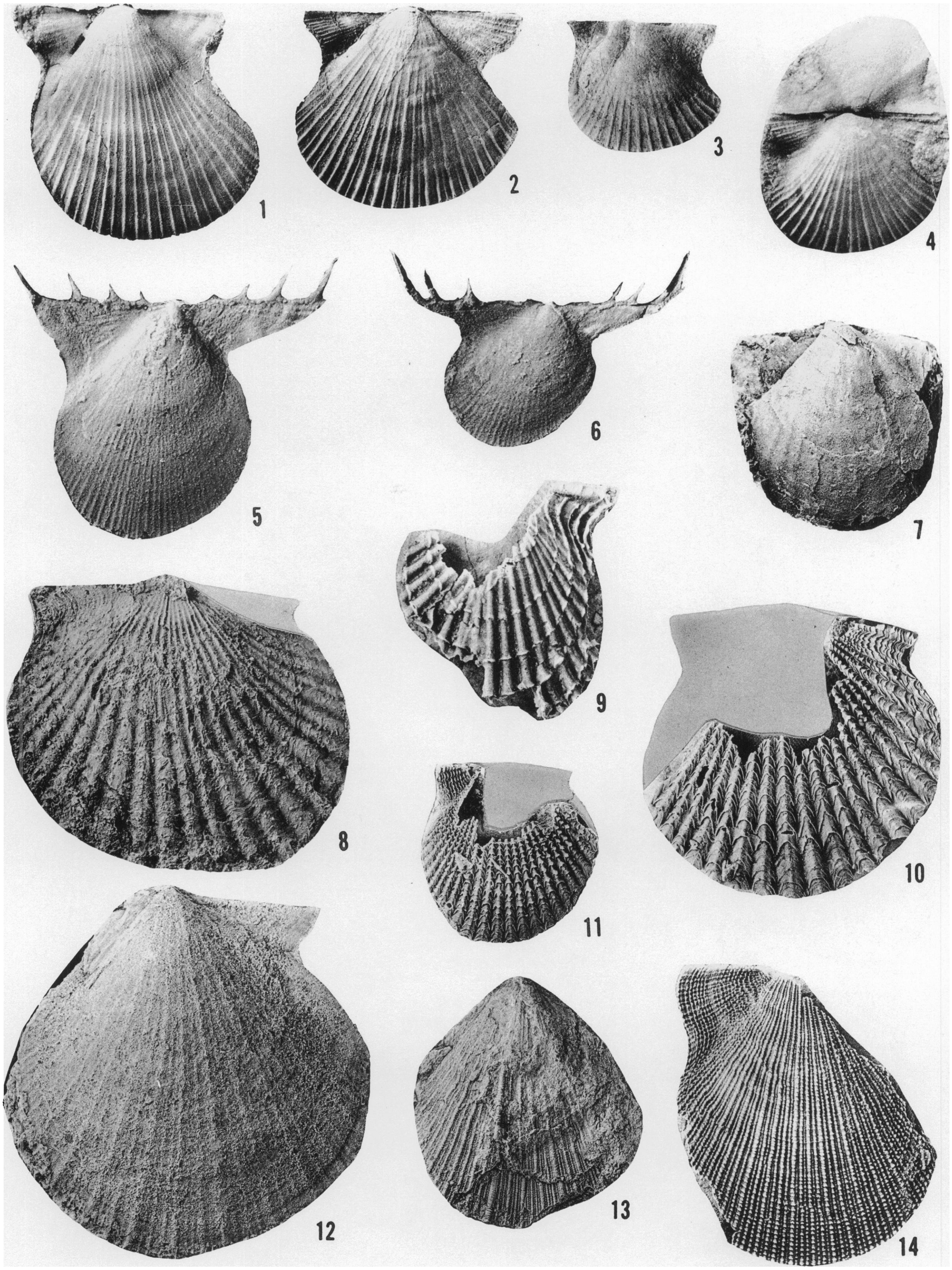
7. *Acanthopecten* cf. *delawarensis* (Girty); see page 52. A poorly preserved left internal mold, Grandeur member, Wheat Creek, Wyoming, U.S.N.M. No. 140483.

8–11. *Acanthopecten coloradoensis* (Newberry); see page 52. 8. Latex cast of a large, nearly complete, left valve, A.M.N.H. No. 28319:1. 9. Fragment of juvenile left valve, showing early ornamentation, A.M.N.H. No. 28319:2. 10. Incomplete, relatively narrow, left valve, A.M.N.H. No. 28319:3. 11. Fragment of left valve, showing adult ornamentation, A.M.N.H. No. 28319:4. All specimens from Franson member, Washakie Reservoir, Wyoming.

12, 13. *Aviculopecten* sp.; see page 50. 12. A large left internal mold, A.M.N.H. No. 28320:1. 13. An associated fragmentary specimen showing nature of ornamentation, A.M.N.H. No. 28320:2. Both specimens from Franson member, Tosi Creek, Wyoming.

14. *Limipecten?* sp.; see page 51. Incomplete left valve, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28321.

Magnifications: 1, 2, ×2; 3–6, ×3; 7, ×2; 8, ×1; 9, ×3; 10–13, ×1; 14, ×2.



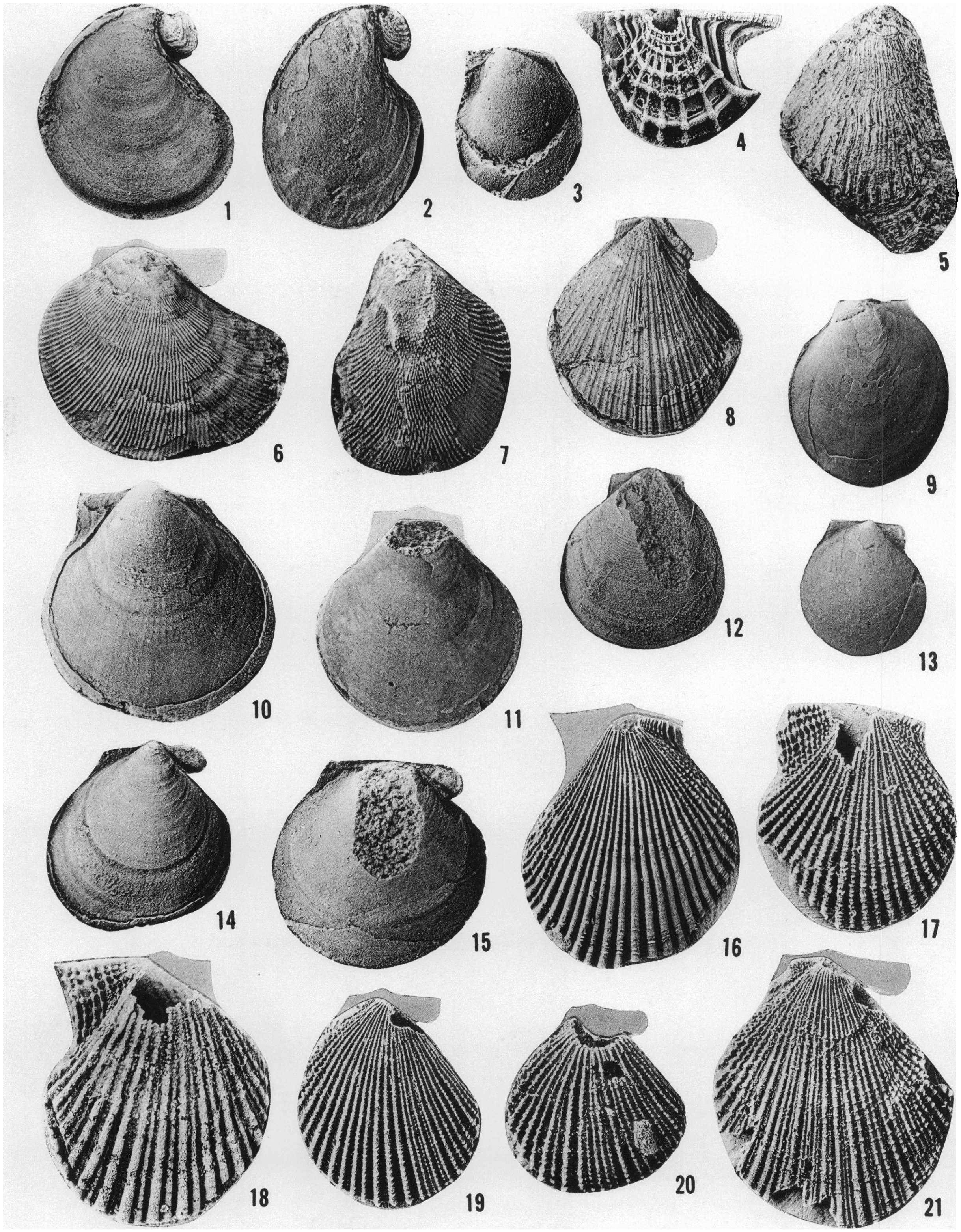

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PLATE 8

Permian Bivalves

1–3. *Obliquipecten* sp.; see page 55. 1. A relatively equidimensional right valve, A.M.N.H. No. 28322/1:1. 2. An associated narrower right valve, A.M.N.H. No. 28322/1:2. Both specimens from Ervay member, Dinwoody Canyon, Wyoming. 3. A small left valve, float, ?Ervay member, South Fork Canyon, Wyoming, A.M.N.H. No. 28322/2.

4. *Girtypecten sublaqueatus* (Girty); see page 53. A small left valve, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28323.

5. *Pseudomonotis* sp.; see page 59. A large incomplete specimen showing ornamentation characteristic of Permian species, Ervay member, Bargee, Wyoming, A.M.N.H. No. 28324.

6–7. *Camptonectes? sculptilis* Girty; see page 56. 6. A broad right valve showing distinctive ornamentation of the species, A.M.N.H. No. 28325:1. 7. An incomplete ?left valve, A.M.N.H. No. 28325:2. Both specimens from Franson member, South Fork Canyon, Wyoming.

8. *Streblochondria? guadalupensis* (Girty); see page 53. A nearly complete right valve, Ervay member, Bull Lake, Wyoming, U.S.N.M. No. 140484.

9–15. *Streblochondria? montpelierensis* (Girty); see page 55. 9. A large, smooth left valve, ?topotype, Meade Peak member, Montpelier Canyon, Idaho, A.M.N.H. No. 28326. 10. Left valve showing trace of radial ornamentation, Meade Peak member, Waterloo, Idaho, U.S.N.M. No. 140485. 11. An incomplete left valve, lectotype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1713. 12. A left valve showing trace of concentric ornamentation, Meade Peak member, Cokeville, Wyoming, U.S.N.M. No. 140486. 13. A juvenile right valve, paratype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1714. 14. Latex cast of well-preserved right valve, Meade Peak member, Cokeville, Wyoming, U.S.N.M. No. 140487. 15. Small right valve, Meade Peak member, Waterloo, Idaho, U.S.N.M. No. 140488.

16–21. *Streblochondria? tubicostata* Ciriacks, new species; see page 54. 16. A relatively large left valve, topoparatype, A.M.N.H. No. 28328:1. 17. Left valve, holotype, A.M.N.H. No. 28327. 18. A juvenile left valve, topoparatype, A.M.N.H. No. 28328:2. 19. A small right valve, topoparatype, A.M.N.H. No. 28328:3. 20. A juvenile right valve, topoparatype, A.M.N.H. No. 28328:4. 21. A large right valve, topoparatype, A.M.N.H. No. 28328:5. All specimens from Franson member, Washakie Reservoir, Wyoming.

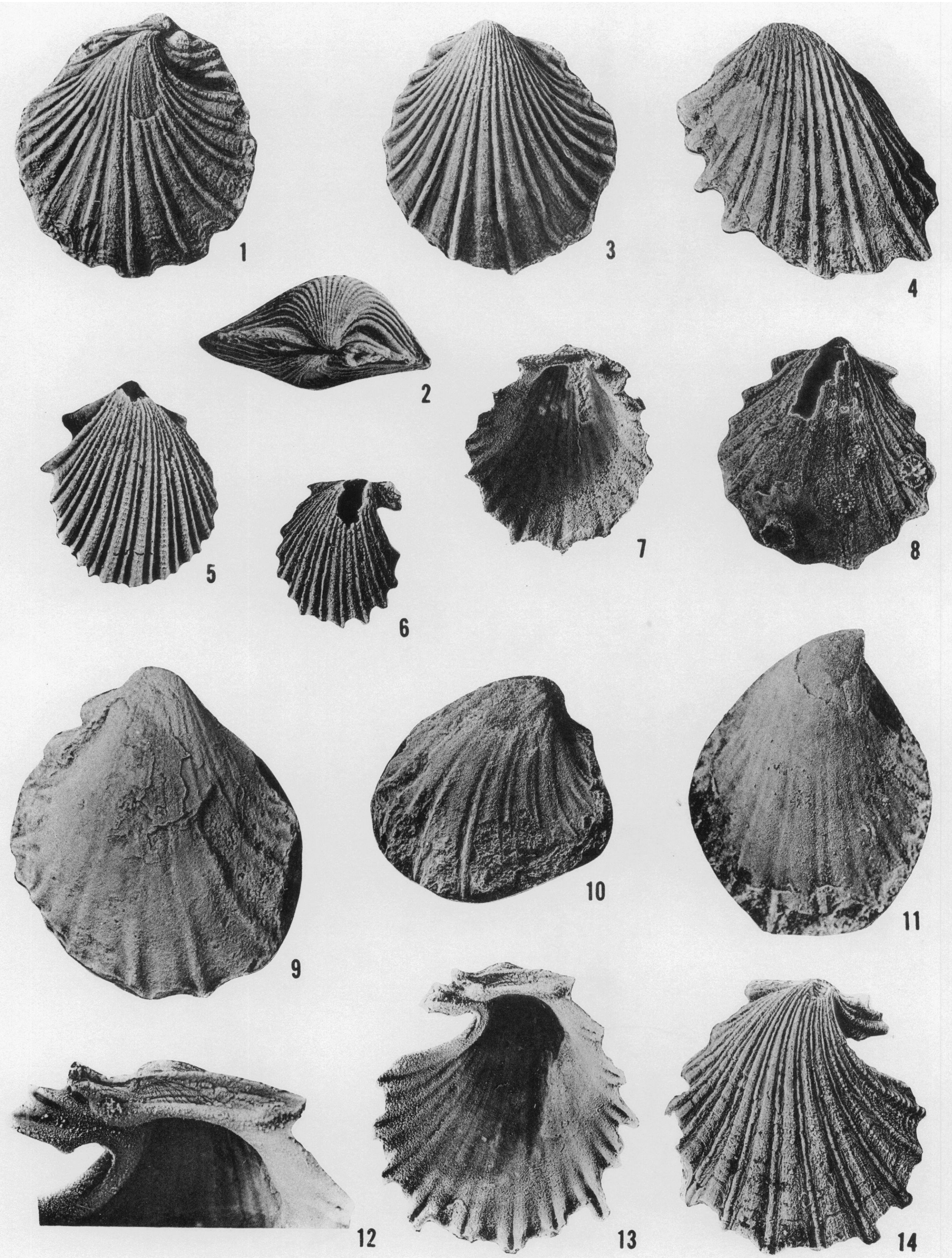
Magnifications: 1–3, ×2; 4, ×3; 5, ×0.5; 6, ×2; 7, ×3; 8, 9, ×1; 10, ×3; 11–14, ×2; 15, ×4; 16, 17, ×2; 18, 19, ×4; 20, ×6; 21, ×2.

PLATE 9

Permian Bivalves

1–14. *Cyrtorostra varicostata* Branson, emended Ciriacks; see page 57. 1–3. Right, dorsal, and left views, respectively, of a bivalved specimen, Ervay member, Dinwoody Canyon, Wyoming, A.M.N.H. No. 28329/1. 4. A deformed left valve (Branson's *Aviculopecten alatus*), Tosi member, Bull Lake, Wyoming, U.M. No. 5295. 5. A juvenile left valve, A.M.N.H. No. 28329/2:1. 6. A juvenile right valve, A.M.N.H. No. 28329/2:2. 7, 8. Internal and external views, respectively, left valve, A.M.N.H. No. 28329/2:3. Specimens 5–8 from Franson member, Washakie Reservoir, Wyoming. 9. A large left valve (Branson's *Aviculopecten alternatus*), Ervay member, Bull Lake, Wyoming, U.M. No. 5293. 10. A large, incomplete, right, internal mold, Rex member, divide between Trail and Wood Canyon, Idaho, U.S.N.M. No. 140489. 11. An incomplete small right valve, holotype, Ervay member, Bull Lake, Wyoming, U.M. No. 5300. 12–14. Dentition, internal view, and external view, respectively, of beautifully preserved right valve, Franson member, Washakie Reservoir, Wyoming, A.M.N.H. No. 28329/2:4.

Magnifications: 1–3, ×2; 4, ×3; 5, 6, ×5; 7–9, ×2; 10, ×1; 11, ×4; 12, ×6; 13, 14, ×3.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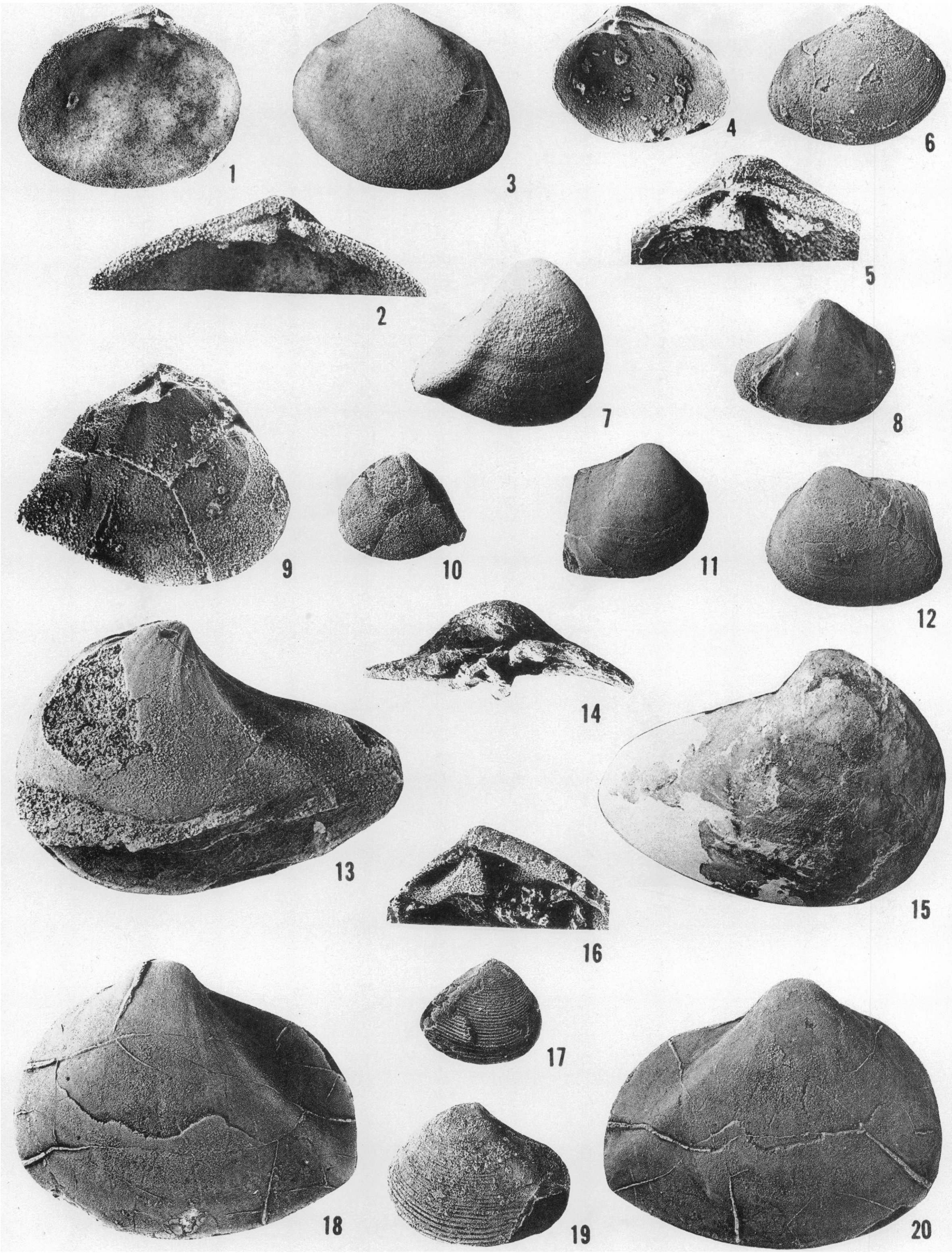
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PLATE 10

Permian Bivalves

1–6. *Schizodus subovatus* Ciriacks, new species; see page 60. 1–3. Internal view, dentition, and external view, respectively, of left valve, holotype, U.S.N.M. No. 140493. 4–6. Internal view, dentition, and external view, respectively, of right valve, topoparatype, U.S.N.M. No. 140494. Both specimens from Grandeur member, Cephalopod Gulch, Utah.

7, 8. *Schizodus canalis* Branson; see page 60. 7. Right valve, holotype, Grandeur member, Bull Lake, Wyoming, U.M. No. 5312. 8. A larger internal mold referred to the species, Meade Peak member, Mexican Creek, Wyoming, A.M.N.H. No. 28332.

9, 10. *Schizodus* sp. b; see page 62. 9. Internal view of right valve, Grandeur member, Willow Creek, Wyoming, A.M.N.H. No. 28333. 10. Same specimen, external view.

11, 12. *Schizodus ferrieri* Girty; see page 61. 11. Right valve, holotype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1712. 12. A more elongate left valve, paratype, Meade Peak member, Montpelier Canyon, Idaho, U.S.N.M. No. 1711.

13–15. *Schizodus bifidus* Ciriacks, new species; see page 59. 13. Left internal mold, paratype, upper member, Shedhorn sandstone, Big Timber, Montana, U.S.N.M. No. 140492. 14. Dorsal view of cardinal area of left valve, showing protruding bifid tooth, topoparatype, U.S.N.M. No. 140491. 15. Partially reconstructed right valve, holotype, U.S.N.M. No. 140490. 14 and 15 from Franson member, Hidden Pastures, Montana.

16, 17, 19. *Schizodus* cf. *oklahomensis* Beede; see page 62. 16. Left dentition, U.S.N.M. No. 140495. 17. Right valve, U.S.N.M. No. 140496. 19. Left valve, U.S.N.M. No. 140497. All specimens from upper member, Shedhorn sandstone, Alpine Creek, Montana.

18, 20. *Schizodus* sp. a; see page 62. Left and right internal molds, respectively, of a bivalved specimen, Ervay member, Mexican Creek, Wyoming, A.M.N.H. No. 28334.

Magnifications: 1, ×4; 2, ×8; 3, ×4; 4, ×2; 5, ×5; 6, 7, ×2; 8, ×1; 9, ×4; 10, ×2; 11, 12, ×1; 13, ×2; 14, ×4; 15, ×1; 16, ×5; 17–20, ×2.

PLATE 11

Permian Bivalves

1, 2. *Costatoria sexradiata?* (Branson); see page 63. 1. Incomplete right internal mold, U.S.N.M. No. 140498. 2. A well-preserved right internal mold, U.S.N.M. No. 140499. Both specimens from Franson member, Crystal Creek, Wyoming.

3, 4. *Costatoria sexradiata* (Branson); see page 63. 3. Left internal mold, lectotype, Ervay member, Big Horn Canyon, Wyoming, U.M. No. 5297. 4. Incomplete right internal mold, paratype, Ervay member, Bull Lake, Wyoming, U.M. No. 5296.

5, 6. *Scaphellina concinnus* (Branson); see page 64. 5. A small internal mold, topotype, U.S.N.M. No. 140500. 6. Left internal mold, lectotype, U.M. No. 5316. Both specimens from Grandeur member, Bull Lake, Wyoming.

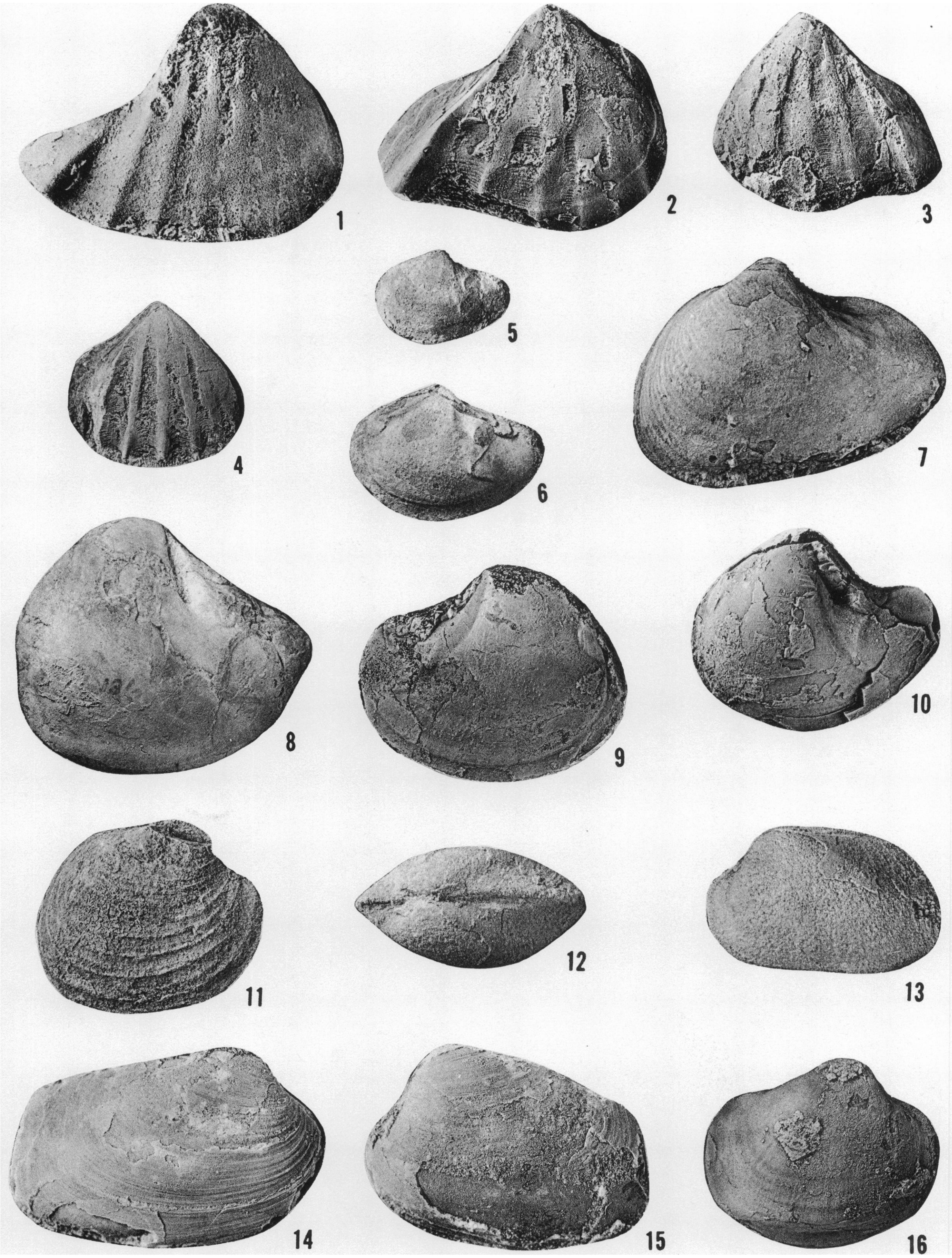
7–10. *Scaphellina phosphoriensis* (Branson); see page 64. 7. Left valve, referred to this species on basis of configuration, ?topotype, Ervay member, Red Creek, Wyoming, A.M.N.H. No. 28335/1. 8. Incomplete left internal mold, lectotype, Ervay member, Red Creek, Wyoming, U.M. No. 5313. 9. Right internal mold, upper member, Shedhorn sandstone, Sappington Canyon, Montana, U.S.N.M. No. 140522. 10. Left internal mold, with some of shell preserved, float, ?Grandeur member, unspecified locality, west of Dubois, Wyoming, A.M.N.H. No. 28335/2.

11. *Edmondia* sp.; see page 75. An incomplete right internal mold, Tosi member, Hogback, Montana, U.S.N.M. No. 140513. ×2.

12–15. *Edmondia phosphatica* Girty; see page 74. 12, 13. Dorsal and left internal view, respectively, of bivalved specimen, lectotype, Meade Peak member, Preuss Range, Idaho, U.S.N.M. No. 1715. 14, 15. Right and left valves, respectively, of bivalved specimen, Meade Peak member, Cokeville, Wyoming, U.S.N.M. No. 140521.

16. *Edmondia gibbosa* Swallow; see page 74. Right internal mold, Grandeur member, Bull Lake, Wyoming, U.M. No. 5289.

Magnifications: 1, 2, ×2; 3–10, ×1; 11–13, ×2; 14, 15, ×3; 16, ×1.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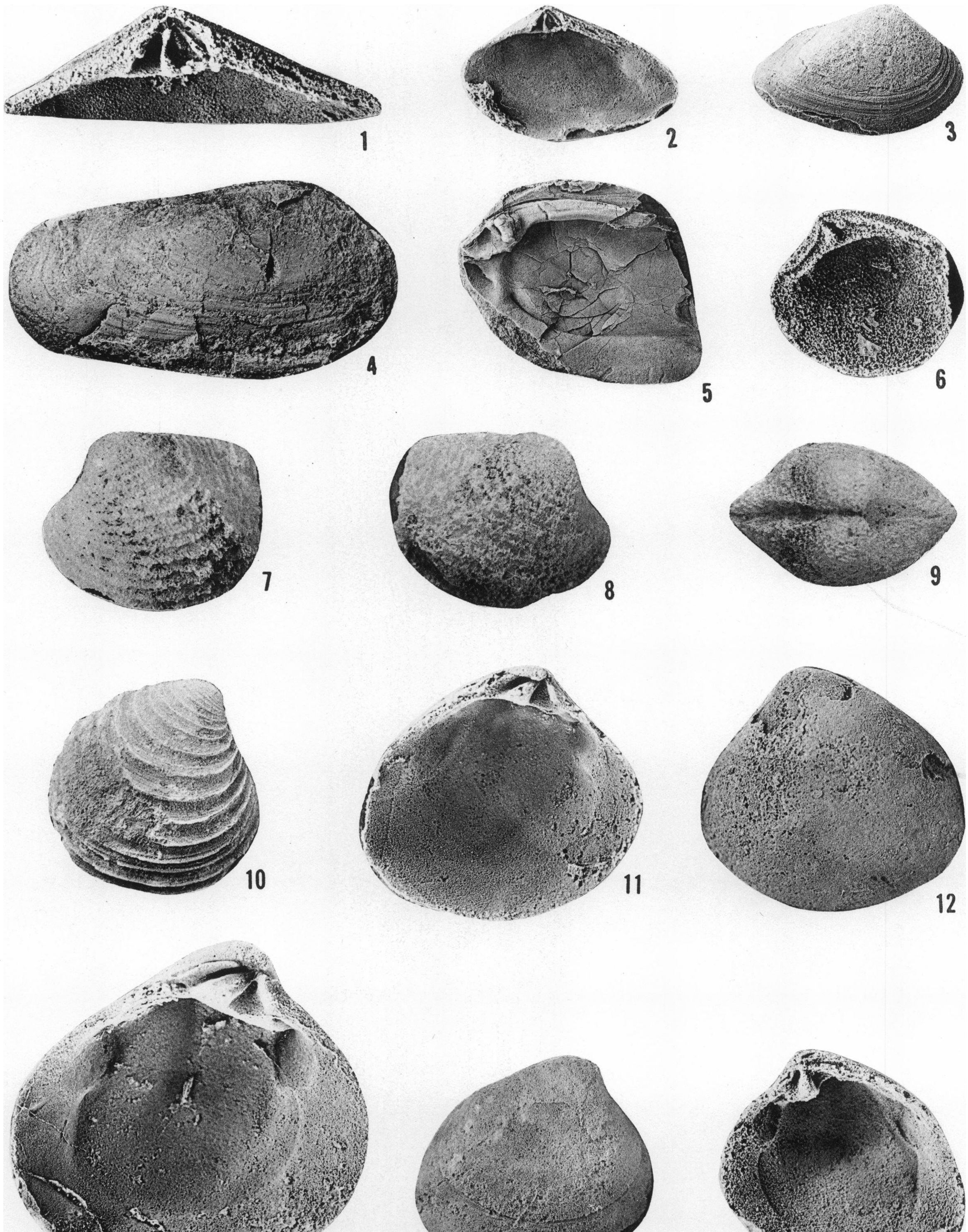
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PLATE 12

Permian Bivalves

1–3. *Oriocrassatella* sp.; see page 67. Dentition, internal view, and external view, respectively, of a right valve, Grandeur member, Willow Creek, Wyoming, A.M.N.H. No. 28336.

4, 5. *Celtoides unioniformis* Newell; see page 71. 4. Right valve, Franson member, Tosi Creek, Wyoming, A.M.N.H. No. 28339. 5. Right dentition, paratype, Franson member, Torrey Lake, Wyoming, A.M.N.H. No. 28046:1.

6–9. *Astartella subquadrata* Girty; see page 65. 6. Right valve, internal view, Grandeur member, Cephalopod Gulch, Utah, U.S.N.M. No. 140401. 7–9. Left, right, and dorsal views, respectively, of bivalved specimen, Grandeur member, Grizzly Creek, Idaho, U.S.N.M. No. 140502.

10. *Astartella* sp.; see page 65. Right valve, Retort member, Cedar Creek, Montana, U.S.N.M. No. 140503.

11–15. *Eoastarte subcircularis* Ciriacks, new genus and species; see page 66. 11, 12. Internal and external views, respectively, of left valve, topoparatype, A.M.N.H. No. 28338. 13. Internal view and dentition of a large left valve, holotype, A.M.N.H. No. 28337. 11–13 from Grandeur member, Willow Creek, Wyoming. 14–15. External and internal views, respectively, of right valve, paratype, Grandeur member, Cephalopod Gulch, Utah, U.S.N.M. No. 140504.

Magnifications: 1, ×5; 2, 3, ×2; 4, 5, ×0.5; 6–10, ×5; 11–15, ×4.

PLATE 13

Permian Bivalves

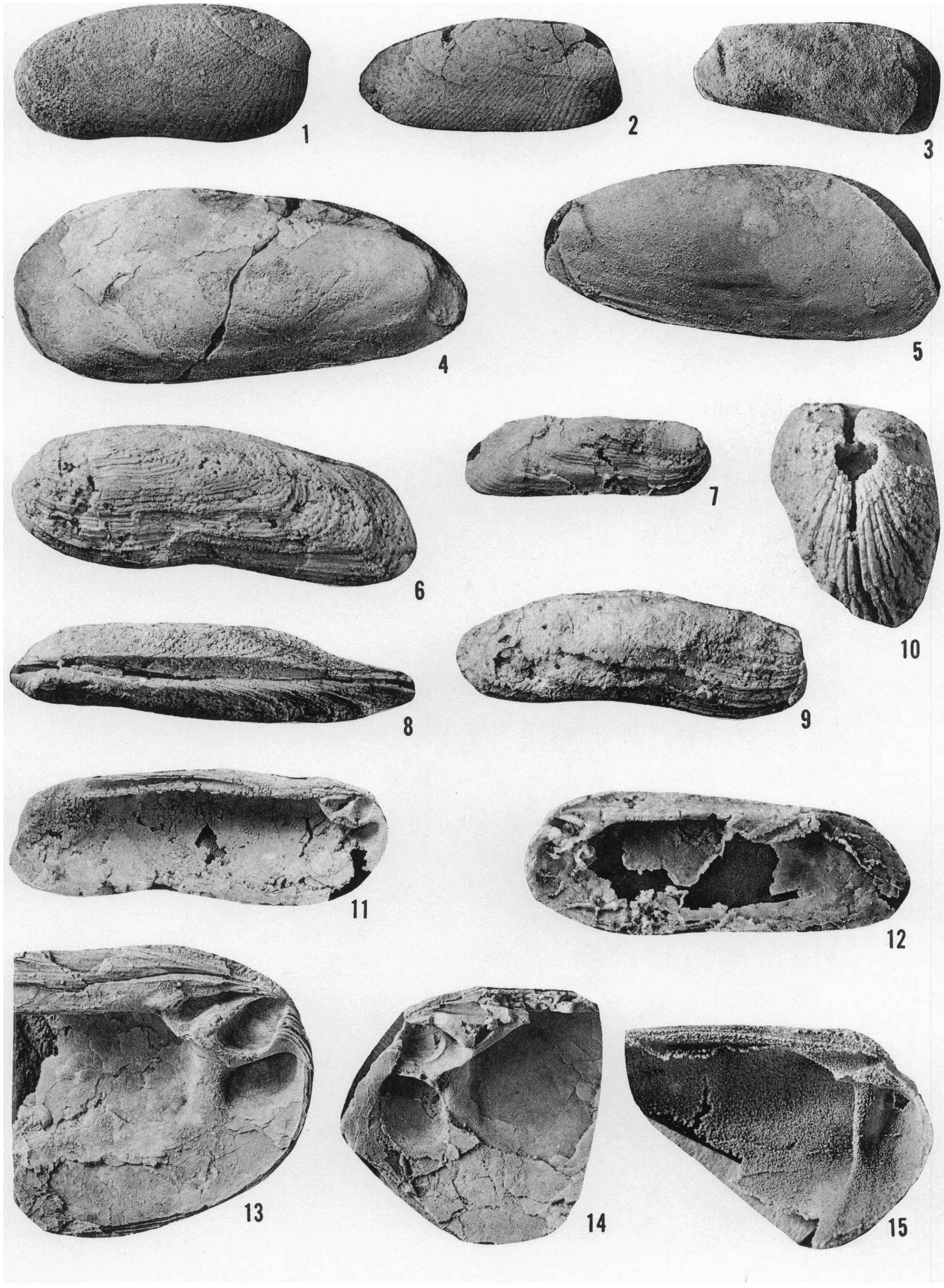
1, 2. *Permophorus pricei* (Branson); see page 68. 1. Right valve, lectotype, U.M. No. 5318. 2. Right valve, topoparatype, U.M. No. 5317. Both specimens from Ervay member, Bull Lake, Wyoming.

3–5. *Stutchburia* sp.; see page 71. 3. Small left internal mold, lower member, Shedhorn sandstone, Hoback, Wyoming, U.S.N.M. No. 140515. 4. Right internal mold, Grandeur member, Bull Lake, Wyoming, U.M. No. 5319. 5. Left internal mold, Ervay member, Bull Lake, Wyoming, U.M. No. 5307. (4 and 5 are types of Branson's *Pleurophorus pinnaformis*, here declared unrecognizable.)

6–14. *Pseudopermophorus annettae* Ciriacks, new genus and species; see page 70. 6. Left valve of bivalved specimen, holotype, U.S.N.M. No. 140506. 7. A small right valve, smallest in collection, topoparatype, U.S.N.M. No. 140507. 8. Dorsal view showing broad development of escutcheon on right valve, holotype, U.S.N.M. No. 140506. 9. Right valve, topoparatype, U.S.N.M. No. 140508. 10. Same specimen, anterior view showing peculiar circular opening at normal position of lunule. 11. Left valve, internal view, topoparatype, U.S.N.M. No. 140509. 12. Right valve, internal view (small white lump below large cardinal socket is matrix, not an anterior cardinal tooth), topoparatype, U.S.N.M. No. 140510. Specimens 6–12 from Franson member, Hidden Pastures, Montana. 13. Left dentition, posterior cardinal tooth, 4b, partly broken away, paratype, U.S.N.M. No. 140511. 14. Right dentition, posterior cardinal tooth, 5b, partly broken away, paratype, U.S.N.M. No. 140512. 13 and 14 from Retort member, Cedar Creek, Montana.

15. *Permophorus albequus* (Beede); see page 67. A left dentition, Grandeur member, Cephalopod Gulch, Utah, U.S.N.M. No. 140505.

Magnifications: 1, ×3; 2, 3, ×2; 4, ×1; 5, ×2; 6–9, ×1; 10, ×2; 11, 12, ×1; 13, 14, ×2; 15, ×4.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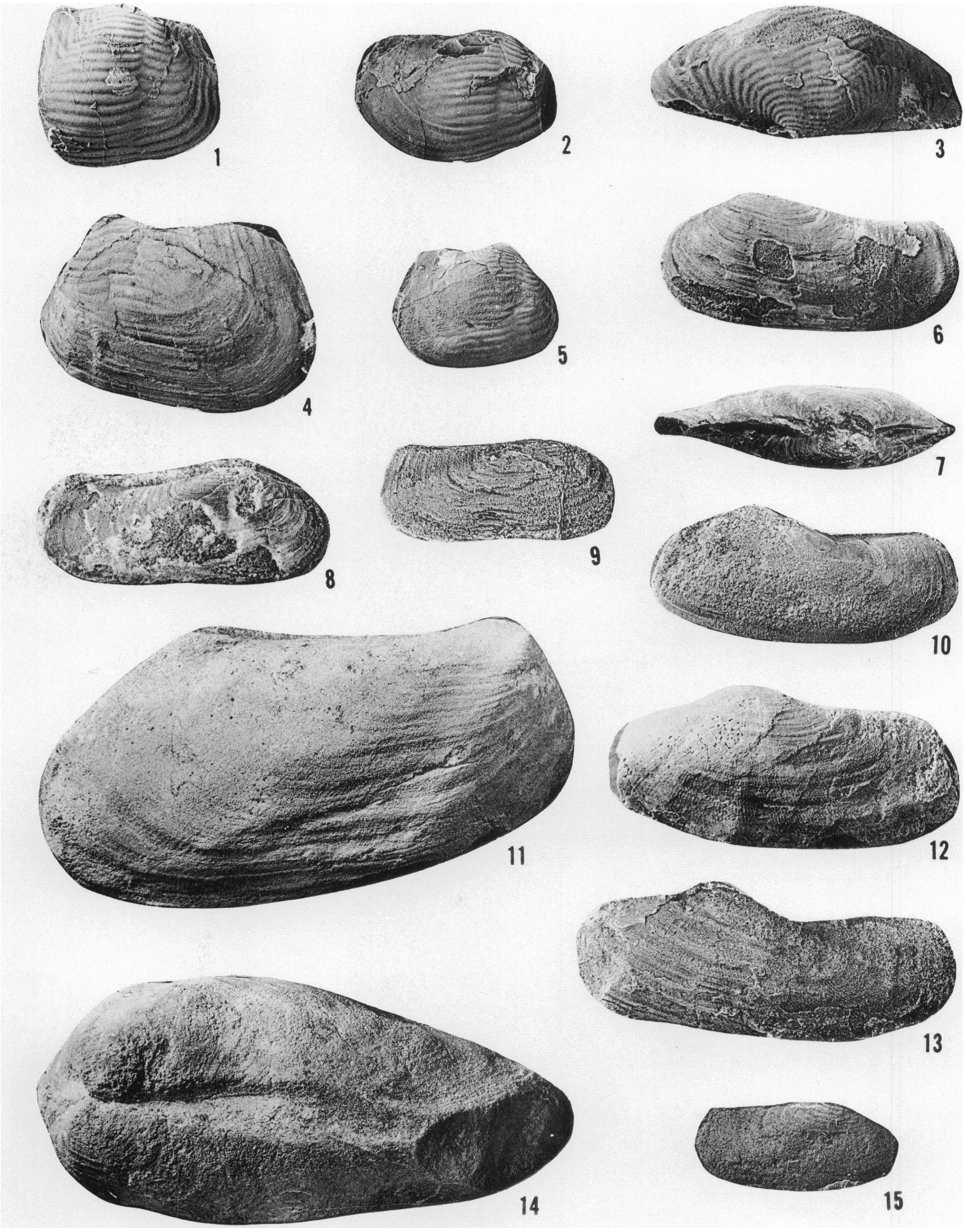
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PLATE 14

1–5. *Sanguinolites carbonaria* (Girty); see page 73. 1. Incomplete right valve, showing V bend in fila, and vertical furrow cutting fila, U.S.N.M. No. 1709. 2. An elongate right valve, U.S.N.M. No. 1708. 3. Same specimen, dorsal view. 4. A large left valve, A.M.N.H. No. 28330. 5. A complete right valve, U.S.N.M. No. 1710. All specimens from Meade Peak member, Montpelier Canyon, Idaho.

6–10. *Sanguinolites? elongatus* Ciriacks, new species; see page 72. 6–8. Left valve, dorsal view, and right valve, respectively, of bivalved specimen, holotype, U.S.N.M. No. 140517. 9. A smaller right valve, topoparatype, U.S.N.M. No. 140518. 10. Left valve, topoparatype, U.S.N.M. No. 140519. All specimens from Grandeur member, Horseshoe Canyon, Utah.

11, 14. *Wilkingia wyomingensis* (Branson); see page 71. Right view and dorsal view, respectively, of right valve, holotype, Franson member, Bull Lake, Wyoming, U.M. No. 5321.

12, 13. *Sanguinolites?* sp.; see page 73. 12. Incomplete left valve, Franson member, Canyon Creek, Montana, U.S.N.M. No. 140520. 13. An elongate left valve, Ervay member, Red Creek, Wyoming, A.M.N.H. No. 28331.

15. *Wilkingia?* sp.; see page 72. Right valve, Ervay member, Dinwoody Canyon, Wyoming, U.S.N.M. No. 140516.

MAGNIFICATIONS: 1, ×2; 2, ×1; 3, ×2; 4, 5, ×1; 6–10, ×2; 11, ×1; 12, 13, ×2; 14, 15, ×1.

PLATE 15

EOTRIASSIC BIVALVES

1–3. *Claraia stachei* Bittner; see page 79. 1. Rubber cast of large left valve, *Claraia* zone, Dinwoody formation, Martin Creek, Wyoming, A.M.N.H. No. 28344. 2. Right valve, M.C.Z. No. 15669. 3. Left valve, M.C.Z. No. 15670. Specimens 2 and 3 from *Claraia* zone, Dinwoody formation, Frying Pan Gulch, Montana.

4. *Claraia* sp. a; see page 80. ?Left valve, talus above *Meekoceras* limestone, Thaynes formation, Hot Springs, Idaho, M.C.Z. No. 15677.

5, 6. *Claraia extrema* (Spath); see page 79. 5. Left valve, M.C.Z. No. 15671. 6. Right valve, showing finer rugose ornamentation, M.C.Z. No. 15672. Both specimens from Thaynes formation, Hammond Creek, Idaho.

7. *Claraia clarai* (Emmrich); see page 78. Right valve, *Claraia* zone, Dinwoody formation, Meadow Creek Canyon, Wyoming, A.M.N.H. No. 28345.

8. *Claraia mulleri* Newell and Kummel; see page 79. Left valve, paratype, *Claraia* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, A.M.N.H. No. 28346.

9. *Claraia* sp. b; see page 80. An essentially smooth left valve, ?Woodside formation, Gros Ventre Canyon, Wyoming, M.C.Z. No. 15673.

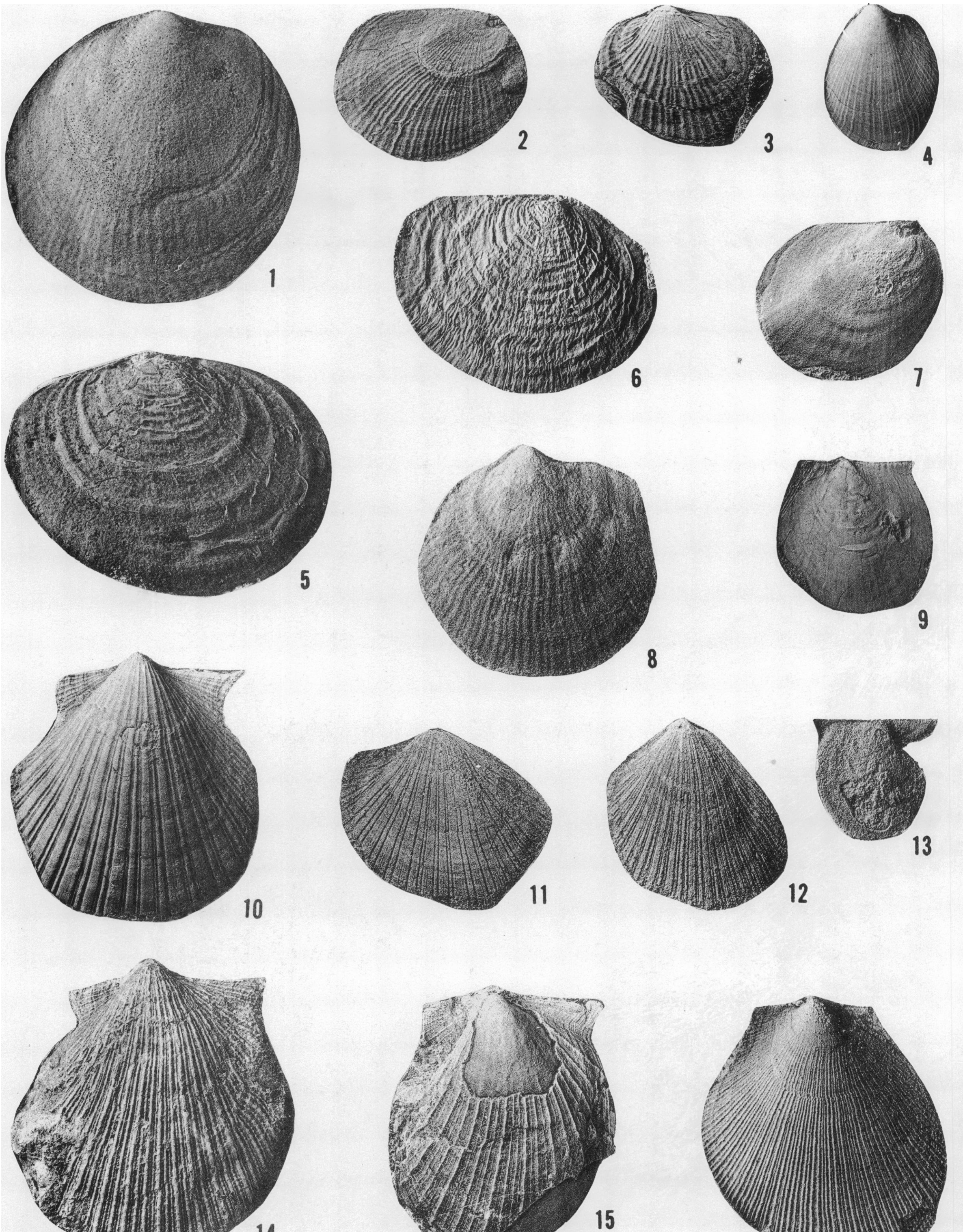
10–12. *Eumorphotis amplicostata* Ciriacks, new species; see page 77. 10. Left valve, holotype, *Claraia* zone, Dinwoody formation, Frying Pan Gulch, Montana, M.C.Z. No. 15664. 11. Left internal mold, paratype, M.C.Z. No. 15665/1. 12. Left internal mold, paratype, M.C.Z. No. 15665/2. Specimens 11 and 12 from *Claraia* zone, Dinwoody formation, West Fork of Blacktail Creek, Montana.

13, 15. *Eumorphotis multiformis* (Bittner); see page 77. 13. A small right valve, *Claraia* zone, Dinwoody formation, Dry Ridge, Idaho, M.C.Z. No. 15666. 15. Left valve, *Claraia* zone, Dinwoody formation, Melrose, Montana, A.M.N.H. No. 28347.

14. *Eumorphotis multiformis regularaecosta* (Kiparisova); see page 77. Left valve, *Claraia* zone, Dinwoody formation, Little Water Canyon, Montana, M.C.Z. No. 15667.

16. *Monotis? thaynesiana* (Girty); see page 81. A ?left valve, Woodside formation, Peale Mountain, Idaho, M.C.Z. No. 15668.

MAGNIFICATIONS: 1–4, ×1; 5, 6, ×2; 7–9, ×1; 10, ×2; 11–13, ×1; 14, ×2; 15, ×1; 16, ×5.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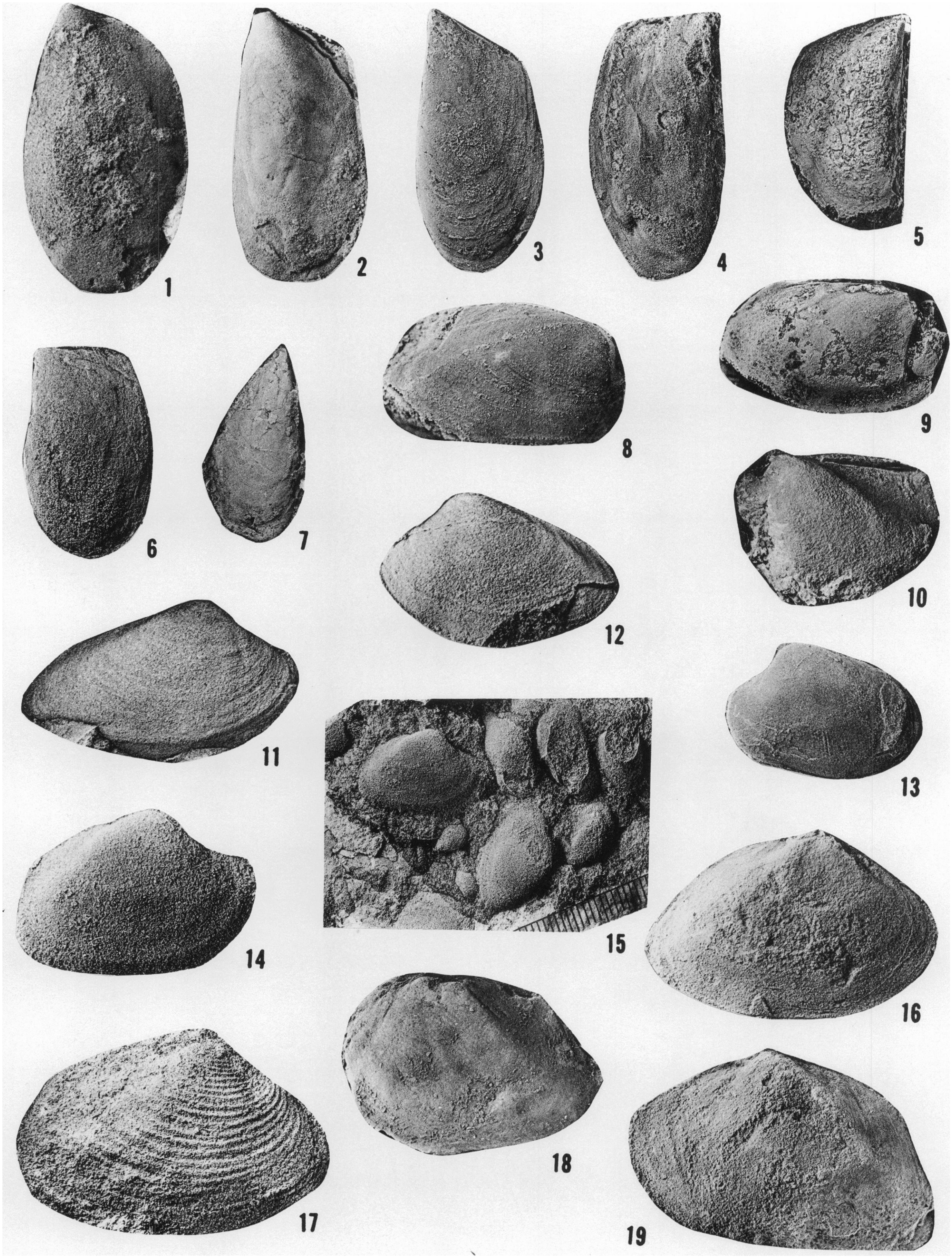

PLATE 16

Eotriassic Bivalves

1–5. *Promyalina putiatensis* (Kiparisova); see page 75. 1. A subovate left internal mold, *Claraia* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, A.M.N.H. No. 28348/1. 2. An elongate, flat, left internal mold, *Claraia* zone, Dinwoody formation, Little Popo Agie Canyon, Wyoming, A.M.N.H. No. 28348/3:1. 3. A well-preserved, relatively oblique, left valve displaying postumbonal furrow, *Lingula* zone, Dinwoody formation, Green River Lakes, Wyoming, A.M.N.H. No. 28348/4. 4. A more erect right valve, *Lingula* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, A.M.N.H. No. 28348/2. 5. Right internal mold showing postumbonal furrow, *Claraia* zone, Dinwoody formation, Little Popo Agie Canyon, Wyoming, A.M.N.H. No. 28348/3:2.

6. *Promyalina spathi* (Newell and Kummel); see page 76. Left valve, holotype, *Claraia* zone, Dinwoody formation, Melrose, Montana, A.M.N.H. No. 28349.

7. *Mytilus? postcarbonica* (Girty); see page 75. A highly oblique right internal mold, *Claraia* zone, Dinwoody formation, Little Popo Agie Canyon, Wyoming, A.M.N.H. No. 28340.

8, 9. *Permophorus? bregeri* (Girty); see page 83. 8. Right valve, ?topotype, *Claraia* zone, Dinwoody formation, Montpelier Canyon, Idaho, A.M.N.H. No. 28350/1. 9. Right internal mold, showing permophorid myophoric buttress impression, lower Dinwoody formation, Sheep Creek, Idaho, A.M.N.H. No. 28350/2.

10. *Gervilleia* cf. *ussurica* Kiparisova; see page 76. Left internal mold, *Claraia* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, M.C.Z. No. 15676.

11, 12. *Unionites canalensis* (Catullo); see page 81. 11. A right internal mold, A.M.N.H. No. 28351:1. 12. A left internal mold, A.M.N.H. No. 28351:2. Both specimens from *Claraia* zone, Gros Ventre Canyon, Wyoming.

13. *Unionites fassaensis* (Wissman); see page 82. A left internal mold, *Claraia* zone, Dinwoody formation, South Fork Canyon, Wyoming, A.M.N.H. No. 28343.

14, 15. *Unionites breviformis* (Spath); see page 81. 14. A robust right internal mold, *Claraia* zone, Dinwoody formation, West Fork of Blacktail Creek, Montana, M.C.Z. No. 15674. 15. Same specimen showing occurrence in "*Unionites* bed."

16, 17. *Unionites?* sp.; see page 82. 16. A flattened right internal mold, *Claraia* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, A.M.N.H. No. 28342. 17. A coarsely ornamented right valve with a configuration similar to that shown in figure 16, Thaynes formation, Fort Hall Indian Reservation, Idaho, M.C.Z. No .15675.

18, 19. *Myophoria laevigata* (Ziethen); see page 82. 18. An incomplete left internal mold, *Claraia* zone, Dinwoody formation, Little Popo Agie Canyon, Wyoming, A.M.N.H No. 28341/1. 19. A left valve showing prominent postumbonal ridge, *Claraia* zone, Dinwoody formation, Gros Ventre Canyon, Wyoming, A.M.N.H. No. 28341/2.

Magnifications: 1, ×2; 2–7, ×1; 8, ×3; 9–14, ×2; 15, ×1; 16–19, ×2.