Ordovician Fossils From Wells in the Williston Basin Eastern Montana

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ORDOVICIAN FOSSILS FROM WELLS IN THE WILLISTON BASIN, EASTERN MONTANA

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ABSTRACT

This paper deals primarily with the stratigraphic significance of Late Ordovician brachiopods and corals and Early Ordovician trilobites from cores of five wells in eastern Montana.

As much as 350 feet of the uppermost limestones and shales of the Deadwood formation of Cambrian and Ordovician age contain trilobites ranging in age from very Early Ordovician (*Bellefontia* zone) to approximately middle Early Ordovician. In one well (from which samples were not available for the present study), 390 feet of Cambrian strata is authentically reported to occur beneath similar rocks of Ordovician age without apparent break.

Varied and abundant conodonts, not yet studied, are in the overlying quartzose sands and shales of the Winnipeg formation. Ostracoderms of types previously recorded from the Harding sandstone of Colorado are also abundant. Similar fish are now known to range into the Late Ordovician. Analysis of the faunal evidence for the Middle Ordovician age of the Winnipeg and its presumed correlatives indicates the age is tenuous.

Most of the species found in the upper 300 feet of the Red River formation occur also in the overlying Stony Mountain formation, indicating no major faunal break; a similar fauna was found in the base of the questionable Leigh dolomite member of the Bighorn dolomite. Probable equivalence of the lower Red River with the lower massive member of the Bighorn is suggested by only scanty faunal evidence.

The fauna and lithologic character of the calcareous lower shale member of the Stony Mountain formation are strikingly similar to those of shaly beds in the uppermost Bighorn, and both are of Late Ordovician age. The few species identified from the upper dolomitic member of the Stony Mountain show affinities with the Late Ordovician of Maritime Canada. The Red River and Stony Mountain formations in the subsurface are designated the Bighorn group. The term Bighorn dolomite is retained for undivided surface occurrences.

INTRODUCTION

This paper summarizes the probable stratigraphic distribution of Ordovician fossils in the Williston basin. It is based on a study of cores from five deep wells located on the Cedar Creek anticline and northwestward of it in eastern Montana, along the western margin of the basin (fig. 67). The limitations of a study based on so few wells are obvious, but the probable value to current exploration activity of a list of the fossils identified to date (1954) determined the release

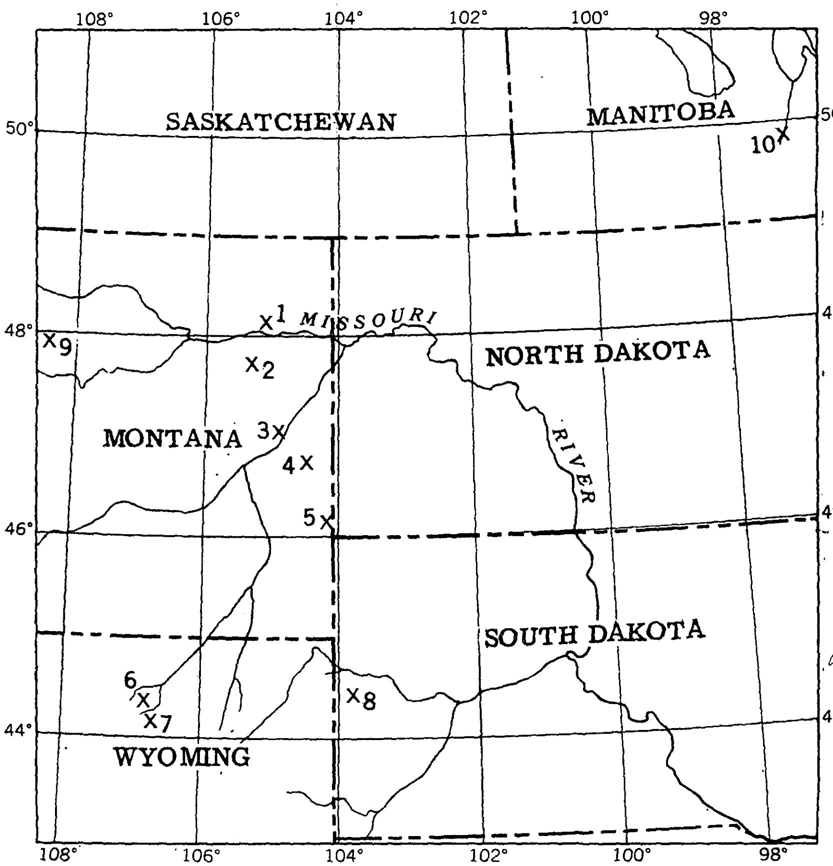

FIGURE 67.—Index map showing location of wells and other localities discussed. Localities 1–5 are listed on page 441; 6, Bighorn dolomite locality, South Fork of Rock Creek; 7, Bighorn dolomite locality, North Fork of Crazy Woman Creek; 8, Deodwood, S. Dak. (type area for Deadwood and Whitewood formations); 9, Little Rocky Mountains; 10, Winnipeg, Manitoba.

of this report. Illustrations and descriptions of some characteristic fossils are also presented as an aid in subsurface zonation.

SCOPE AND EXTENT OF INVESTIGATION

In the summer of 1952, cores from several deep wells in the Williston basin were made available at Billings, Mont., for paleontologic sampling and study. About 1 year later R. P. Kunkel and C. L. Nieschmidt prepared a geological age log for each of the wells, utilizing the results of the preliminary faunal reports. These were made available in open files of the Geological Survey. A reconnaissance of the surface exposures of supposedly correlative formations was then undertaken during the summer of 1953 in the northern Black Hills of South Dakota, along the east flank of the Bighorn Mountains in Wyoming, and in the Little Rocky Mountains. The hope of obtaining adequate collections with which to determine exact correlation between formations in the subsurface and those cropping out to the south and west was only partly fulfilled, however.

The cores studied were taken from wells located roughly along a line running north-northwesterly from the intersection of the boundaries of North and South Dakota and Montana (fig. 67). These wells are:

1. C. H. Murphy Corp., East Poplar Unit No. 1, Center, SW¼NE¼, sec. 2, T. 28 N., R. 51 E., Roosevelt County, Mont.
2. Shell Oil Co., Richey area, Northern Pacific R. R. No. 1, SE¼NW¼NW¼, sec. 19, T. 23 N., R. 50 E., Dawson County, Mont.
3. Empire State Oil Co., Hathaway No. 1, Center, SE¼NE¼, sec. 6, T. 14 N., R. 55 E., Dawson County, Mont.
4. Shell Oil Co., Pine Unit No. 1, SW¼SW¼NE¼, sec. 30, T. 12 N., R. 57 E., Wibaux County, Mont.
5. Shell Oil Co., Little Beaver No. 1, NE¼SW¼, sec. 13, T. 4 N., R. 61 E., Fallon County, Mont.

Although samples of other cores have been made available or furnished by other companies they are not reported here either because they include only post-Ordovician fossils, or because there has not been enough time to study them.

It must be emphasized that within a given formation or zone the entire fossil assemblage may not be listed. In some places, particularly in the dolomitic portions of the cores, preservation is too poor to warrant even the best intelligent guess as to identity. In others new species are present but not well-enough represented to permit proper description. Although bryozoans and conodonts are abundant in some strata, for the most part they have been left out of consideration until they can be studied in detail.

The work of Miss Helen Duncan (1956) on Ordovician and Silurian corals has obviated the necessity for discussing them in detail in this report.

ACKNOWLEDGMENTS

Much of the sampling and collecting from the cores was undertaken by R. P. Kunkel, who with P. W. Richards aided in obtaining information as need arose. During the 1953 field season T. H. Rogers assisted the author in reconnoitering lower Paleozoic surface exposures and subsequent technical assistance was rendered by F. B. Rowell. Without the cooperation and interest of numerous members of the geologic and paleontologic staffs of oil companies the project would not have been possible.

Most of the fossils collected were identified by Helen Duncan and Jean M. Berdan, particularly the corals and ostracodes. Much of the preparation and preliminary identification of the brachiopods was done by Josiah Bridge. Specimens of fish have been identified by D. H. Dunkle, and G. A. Cooper has given much valuable time in consultation.

Dr. Hans Frebold, chief, Division of Stratigraphic Paleontology, Canadian Geological Survey, furnished casts of type specimens of Okulitch's (1943) Stony Mountain species. Professor J. P. Gries made available for examination the core of the Carter Oil Co., Northern Pacific No. 1 well, stored at the South Dakota School of Mines.

METHOD OF PRESENTATION

Although stratigraphic information is usually presented in sequence from oldest to youngest, during drilling operations strata are encountered in the reverse order. As it is intended that this report be of interest to petroleum geologists in the Williston basin in particular, the younger formations are discussed first.

The paper is divided into three main parts: (1) a discussion of the formations involved, (2) listings of the faunal evidence obtained from each well, including the basis for placement of the Silurian and Ordovician boundary, and (3) brief illustrated descriptions of or notes on genera and species involved.

ORDOVICIAN STRATIGRAPHIC UNITS OF THE WESTERN WILLISTON BASIN

DERIVATION OF STRATIGRAPHIC TERMINOLOGY

The pre-Silurian strata encountered in the five cores are all of Ordovician age. The formations recognized since 1951 in the subsurface of the Williston basin have been traced southward from Manitoba by petroleum geologists using lithologic similarity, evidence from faunal studies, and data obtained by various geophysical methods with varying success. As a result, the terminology in use has been essentially that of the surface exposures of southern Manitoba, where the formations in descending order are the Stonewall, the Stony Mountain, the Red River, and the Winnipeg. Because of distinctive lithologic features within these formations or marked changes between them, they can be recognized without much difficulty in most of the cores examined. The most troublesome exception is the recognition of the boundary between the Stonewall and (or) Stony Mountain formations and the overlying Silurian deposits, which are so similar in lithologic character that in at least one core differentiation has been based almost entirely on fossil evidence.

Despite proximity of many of the wells to the Black Hills of South Dakota the use of Whitewood dolomite has not generally been adopted and is not recommended here for two reasons.

First, the Whitewood limestone as defined by Darton and Paige (1925, p. 5–7, 24–25) is certainly equivalent to no more than the Red River formation of the subsurface and probably not to all of that; no demonstrable Stony Mountain equivalent has yet been found in the Black Hills.

Second, the Whitewood formation as redefined by Furnish, Barragy, and Miller (1936, p. 1330–1332) includes underlying siltstones and shales of probable Middle Ordovician age as well as the "limestone" of Darton. Much of this lower clastic material is lithologically similar to and holds the same stratigraphic position as the Winnipeg formation. Until 1952 (McCoy) no formal designation had been offered for these clastic beds, and it was only natural that the Manitoban terms be used in the subsurface.

The Whitewood limestone of Darton is here designated the Whitewood dolomite. Its lithologic character is closely similar to that of the lower part of the Bighorn dolomite. The Whitewood dolomite is restricted to the dolomite and sandy dolomite of Ordovician age in the Black Hills, and the term is used in the same sense as that of Darton and Paige (1925). The underlying shales, siltstones, and sandstones are purposely excluded.

In 1952 McCoy (p. 44–47) proposed names for the siltstones, shales, and sandstones which lie beneath the true dolomites of the Whitewood and above the Deadwood formation in the northern Black Hills. These in descending order are the Roughlock siltstone, the Ice Box shale, and the Aladdin sandstone—the last being the Scolithus sandstone of authors. Unfortunately McCoy's account was written for a guidebook and is necessarily abbreviated. Until a more complete treatment of these units is published, it will not be possible to determine their utility. McCoy has noted that his units change facies within short distances; some of these lithic changes have been verified and others found during the present reconnaissance. It is evident that more work needs to be done before his nomenclature can be evaluated or consistently applied even in the Black Hills.

Obviously a large portion, if not all, of the interval between the Whitewood and Deadwood strata is equivalent to the Winnipeg formation in position, in lithologic character, and probably in faunal content, but published and otherwise available information is far too sketchy to permit interchangeability of terminology at this juncture. As an example, several geologists feel that the so-called Scolithus (or

Aladdin of McCoy, 1952) sandstone is the same as the basal sandstone of the Winnipeg formation; actually we know only that earliest Early Ordovician fossils have been obtained just below this sandstone in the uppermost Deadwood strata (Lochman and Duncan, 1950, p. 351; McCoy, 1952, p. 47) and that Middle Ordovician(?) shale overlies it in the northern Black Hills. In the Carter Oil Co. Northern Pacific No. 1 well to the north, shales and siltstones apparently equivalent to the Winnipeg formation occur at a depth of 8,845–8,930 feet (core is missing from 8,858–8,900 feet). These are underlain by limestone containing abundant brachiopod shells, none accurately identifiable, but suggesting Lower Ordovician genera. Below this limestone lies clean quartoze sandstone at a depth of 9,040–9,130 feet. The question then arises as to whether this sandstone is the extension of the so-called Scolithus (Aladdin of McCoy, 1952) or represents another similar body within the Deadwood formation; if it is the former, it cannot be considered the basal part of the Winnipeg beds or their equivalents. If it is not the so-called Scolithus sandstone, it is equally apparent from the core examined that the sandstone is not present at the base of the apparent Winnipeg at about 8,930 feet. It may later prove possible to trace the Roughlock, Ice Box, and Aladdin formations as proposed by McCoy beneath the surface in wells located close to the flanks of the Black Hills, but it would be inadvisable to use his terminology in the area of this report.

To the west and southwest of the Williston basin, Ordovician strata crop out in the Bighorn and Little Rocky Mountains. From these areas the Bighorn dolomite might have been followed in the subsurface and used as a basis for terminology in eastern Montana. As in formations in the Black Hills, however, several facts discourage any such usage. In the first place exploration within the Williston basin has spread westward from North Dakota, not eastward from the Rocky Mountains. Second, although the Bighorn dolomite can be divided into three members (in descending order the Leigh member of Blackwelder (1918), an unnamed member, and the Lander sandstone member of Miller (1930), it is not certain to which, if any, of these members the Stony Mountain, Red River, and Winnipeg formations exactly correspond.

According to paleontologic evidence presently available the Bighorn dolomite, including the Lander sandstone member (Miller, 1930, p. 196) but excluding the "Harding" sandstone equivalent (Kirk, 1930, p. 460–461), corresponds to all of the Red River and much of the Stony Mountain formations as they are developed in the subsurface of the Williston basin; it is therefore proposed that the term

Bighorn group be applied to include these two formations in eastern Montana. It may eventually prove feasible to include the Winnipeg formation in this group, depending on future studies of its conodonts and fish. The term Bighorn dolomite of formational rank is retained for undivided surface occurrences in Montana and Wyoming.

Beneath the Winnipeg formation as indicated in two of the cores studied lie limestones which are glauconitic, pyritiferous and in part composed of intraformational conglomerates. Thin partings of black or very dark green shaly material are interspersed throughout these limestone beds, which are so similar to the upper strata of the Deadwood formation of the Black Hills and of the Bighorn Mountains (in the latter case the Gallatin limestone of recent authors) that they were originally logged as Upper Cambrian. Despite the fact that only Early Ordovician fossils have been found in these limestones in the two cores studies, the name Deadwood formation is here applied to them. Since 1950 (Lochman and Duncan, p. 351) it has been known that the topmost Deadwood beds in the Black Hills contain Lower Ordovician fossils. In addition, James L. Wilson, of the Shell Oil Co. (personal communication, oral and written), states that in the core of Shell's Southwest Richey No. 32–33B well there are 740 feet of Deadwood strata in the upper 350 feet of which Lower Ordovician trilobites are present.

The stratigraphic terminology used in this report is summarized in text figure 68.

THE FORMATIONS

The Ordovician formations of southern Manitoba have been discussed by Baillie (1952). His report includes descriptions of the Stony Mountain, Red River, and Winnipeg formations. More recently Stearn (1953, p. 1477–1478) has concluded that the overlying Stonewall formation should be included in the Ordovician rather than in the Silurian system, where it has traditionally been placed. Stearn's conclusions are based on faunal evidence, and they confirm the earlier suggestion of Baillie (1952, p. 42) that the Stonewall formation, as restricted by him (1951, p. 6–9), might be more closely allied to the underlying than to the overlying rocks. In the present report, dealing primarily with paleontology, no effort has been made to differentiate between the dolomitic strata designated by others as the Stonewall formation and the upper Stony Mountain formation. In any event, as long as the so-called Stonewall strata seem to be assignable to the Upper Ordovician it would seem best to regard them as a member of the Stony Mountain formation if they were to be separately designated.

	Dowling, 1900	Foerste, 1929, p. 35		Okulitch, 1943		Baillie, 1951, 1952 Stearn, 1953		This report		
UPPER ORDOVICIAN						Stonewall formation		BIGHORN GROUP	Stony Mountain formation	Dolomitic member
	Stony Mountain formation	Stony Mountain formation		Stony Mountain formation	Birse member	Stony Mountain formation	Gunton member			
					Gunton member					
					Penitentiary member		Penitentiary member			
					Stony Mountain shale member		Stony Mountain shale member			Lower shale member
	Upper Mottled limestone	Red River formation	Selkirk member			Red River formation	Selkirk member		Red River formation	
	Cat Head limestone		Cat Head member				Cat Head member			
	Lower Mottled limestone		Dog Head member				Dog Head member			
MIDDLE ORDOVICIAN	Winnipeg sandstone					Winnipeg formation		Winnipeg formation		
LOWER ORDOVICIAN								Deadwood formation		
CAMBRIAN										

FIGURE 68.—Terminology of Ordovician units of the Williston basin and their derivation.

BIGHORN GROUP

STONY MOUNTAIN FORMATION

The Stony Mountain formation was named and defined by Dowling (1900, p. 46–53F, 88–83F) from exposures in the vicinity of Winnipeg; the orginal description included extensive faunal lists, including those published previously by Whiteaves (1895, p. 111–128). In 1943 Okulitch (p. 59–74) presented the results of a more detailed study in which he subdivided the upper, dolomitic portion of the formation into three members—in descending order named Birse, Gunton, and Penitentiary. The lower, shaly portion he named the Stony Mountain shale member.

Baillie (1952, p. 8) disregarded the Birse member, because in the field he was unable to differentiate it from the Gunton. Similarly because of the limitations placed on the present study by the wide spacing of wells and the discontinuous nature of the samples obtained from most of them, no attempt is made here to distinguish between the dolomitic units. These, and the Stonewall formation of Stearn's (1953), are all grouped in an upper dolomitic member for purposes of this report.

In sharp contrast to the yellowish dolomitic rocks of the upper member, the Stony Mountain shale, of Okulitch, here designated simply the lower shale member, is composed of argillaceous limestone and fossiliferous shale of a predominantly reddish-gray color (Baillie, 1952, p. 19) in its type area. Because of this contrast with units above and below, this member is an extremely useful marker in the subsurface. In the core of the Shell Pine Unit No. 1 well the same rock is present, but the color is dark green. In the Empire State Hathaway No. 1 core there are two intervals of green and greenish-black calcareous shale and siltstone below the upper dolomitic member; these are at depths of 8,718–8,728 and 8,830–8,853 feet. Between them, two small samples indicate the presence of lithology apparently identical to that of the underlying Red River formation. Faunally the deeper of these two is most like the lower shale member; the upper is more silty than shaly and may represent the Penitentiary member of the Manitoban section.

The lower shale member is represented southward by red calcareous shales in the Carter Oil Co.'s Northern Pacific No. 1 well at depths of 8,230–8,300 feet. An important occurrence of similar beds bearing an almost identical fauna has been overlooked by many recent workers; this lies in the uppermost few feet of the Bighorn dolomite on the South Fork of Rock Creek, Johnson County, Wyo. (Center, N½NE¼SW¼SW¼, sec. 25, T. 52 N., R. 84 W.). From the red shaly beds at this locality (D1 (CO)) came the extensive fauna of Richmond age listed by Darton in 1906 (p. 4).

The prolific fauna of the lower shale member is correlative with deposits of Richmond age elsewhere, particularly with the Maquoketa shale of Iowa. The few species obtained from the upper dolomitic member seem to indicate close correspondence with the Upper Ordovician deposits of Anticosti Island and Quebec.

RED RIVER FORMATION

In his report of 1900 Dowling (p. 40–46F, 63–88F) recognized beneath the Stony Mountain formation three stratigraphic units which he named the Upper Mottled, Cat Head, and Lower Mottled limestones. Foerste (1929a, p. 35) proposed the term Red River formation to include all three of these; Dowling's formations were reduced to the rank of members. Foerste further changed the name of the Upper Mottled to the Selkirk limestone and the Lower Mottled to the Dog Head limestone. No attempt has been made here to differentiate the three members of the formation.

In the core samples studied the Red River is principally limestone and dolomitic limestone; almost all samples have a brown or tan color. The limestone and dolomitic limestone are more coarsely crystalline than are the dolomites of the upper Stony Mountain formation and their brown color usually contrasts with the yellowish to creamy tinge of the younger dolomites. On this basis the upper limit of the Red River formation is thought to lie between 8,407 and 8,602 feet in the Murphy Corp. East Poplar Unit No. 1 well; almost no reliable fossil evidence is present.

Fortunately dolomitization in many samples has affected the matrix more than the enclosed fossils, and removal of the shells with formic acid has disclosed the internal structures as dolomitic casts.

Although two members of the Red River formation have a mottled appearance in their type areas, this characteristic must be used with care in the subsurface. Samples from two of the cores studied show pronounced cream and light-gray mottling in the fine-grained dolomite of the Stony Mountain formation.

Foerste's paper (1929b) is especially important in assembling the faunal evidence for the Late Ordovician dating of the Red River formation, which had been considered Trentonian by Dowling.

WINNIPEG FORMATION

Although the Winnipeg sandstone was first described by Dowling in 1896, his more detailed account of the Winnipeg formation in 1900 (p. 39–40F, 54–63F) has served as the standard reference to its typical exposure. The description of Baillie (1952, p. 10–14, 25–27) is a more concise, yet thorough work; it furnishes the most complete modern synthesis of what is known concerning the Winnipeg lithologically and faunally. In its type area the formation consists of poorly bedded basal quartzose sandstones overlain by interbedded bluish-green shales, sandstones, and arenaceous shales (Baillie, 1952, p. 11).

The most northerly well studied bottomed in the Winnipeg formation at a depth of 9,163 feet after passing through 118 feet of white quartzite; interspersed with the quartzites are beds of carbonaceous black shale. Most of these are thin and concentrated near the top of the unit. The thickest shale zone was from depths of 9,064–9,102 feet. The deepest 10 feet of the core contains black and white quartzites separated by black shale partings. In the Shell Pine Unit No. 1 core Winnipeg-type rock lies between depths of 9,518 and 9,652 feet. Although two short sections of core—9,619–9,647 feet and 9,519–9,525 feet—were not available for examination, the formation in this well is composed predominantly of green and greenish-black shales, interbedded with numerous thin layers of quartzitic sandstone. The deepest 6 feet consists of red and green mottled siltstone and shale.

The stratigraphic distribution of sandstone and shale within the Winnipeg formation is probably highly variable; a persistent basal sandstone cannot be expected.

In the cores of two wells the formation rests upon glauconitic limestone of the Deadwood formation.

ORDOVICIAN AND CAMBRIAN: DEADWOOD FORMATION

Although the Deadwood formation of the Black Hills was named by Darton in 1901 (p. 505–508) this early discussion is of little use in establishing clear-cut boundaries. In 1904 (p. 382) he defined the formation as though it included all beds between the pre-Cambrian crystalline rocks and the Whitewood limestone, including as much as 45 feet of shale and siltstone at the top. Later (1909, p. 14, 19) he seems to have assigned 24 feet of "white siliceous limestone" (the upper calcareous siltstones of Middle Ordovician(?) age according to more recent interpretation) to the Whitewood beds and to have left the green shales (now recognized as Ordovician) in the Deadwood.

Darton and Paige (1925, p. 6) later established the lower boundary of the Whitewood at its present position below the true dolomite beds, thereby allocating all older units to the Deadwood formation. The discovery of Middle Ordovician(?) fossils in the siltstones and green shales beneath the Whitewood limestone by Furnish, Barragy, and Miller (1936) resulted in reassignment of the siltstones and shales to the Whitewood and lowering of the upper boundary of the Deadwood formation to the top of the so-called Scolithus sandstone. In 1952 McCoy (p. 47) proposed the name Aladdin sandstone to supplant Scolithus beds and removed it from the Deadwood formation.

The formation as represented in the cores studied is composed predominantly of glauconitic, pyritiferous limestones containing much intraformational conglomerate with minor partings and thin layers of black silty shale. Neither glauconite nor pyrite is uniformly abundant.

In lithologic features these rocks so closely resemble the upper Deadwood strata in the northern Black Hills and in the Bighorn Mountains (there used in the sense of Darton, 1904, p. 434) that they are assigned to this formation without hesitation.

Only Lower Ordovician fossils have been obtained from this unit in the cores of the Shell Pine Unit No. 1 and Shell, Richey area, Northern Pacific No. 1 wells. Information furnished by James L. Wilson, of the Shell Oil Co., for the Shell Southwest Richey No. 32–33B well indicates the presence of about 350 feet of Lower Ordovician and 390 feet of Cambrian strata between the base of the Winnipeg formation and the basement rocks. The lower 207 feet of Early Ordovician and upper 158 feet of Cambrian strata are composed of green shale, becoming slightly calcareous and micaceous upward; the intersystemic boundary has been located on faunal evidence only.

These facts are not wholly unexpected. In 1950 Lochman and Duncan (p. 351) reported that the topmost few feet were of Early Ordovician age in the Black Hills. In 1953 Palmer and I collected a fauna from the upper 10–15 feet of the Deadwood along South Piney Creek on the east flank of the Bighorn Mountains, which may be of the same age.

LATE ORDOVICIAN FAUNA

Following a brief summary of the evidence for placement of the Silurian-Ordovician boundary in each of the five cores studied, the fossils so far identified are listed by well and depth within each well. For purposes of comparison, collections made from two localities in the Bighorn dolomite along the east flank of the Bighorn Mountains are also listed. The faunal distribution in all of these is summarized on plate 44 and in the insert facing page 458.

Where formations have been designated in the faunal lists the designations have been made with considerable confidence. On plate 44, however, the placement of many of the formation boundaries are compromises between my own observations of lithologic characteristics in complete cores or random samples, correlation charts published in the Billings Geological Society's Guidebook for 1952, and information obtained from other geologists.

SILURIAN AND ORDOVICIAN BOUNDARY

The upper dolomites of the Stony Mountain formation are overlain by Silurian dolomites so similar in lithologic character that they can be distinguished only with difficulty and seldom with certainty. Fortunately a few fossils—mostly corals of Silurian age—have been obtained; in no core has it been possible to pinpoint the Silurian and Ordovician boundary, but its position can be bracketed between the lowest Silurian and highest Ordovician specimens.

Such faunal evidence as is available for bracketing the boundary is given below by well and depth; obviously faunal evidence is better in some wells than in others. Because the fossils are in dolomites, they are not very well preserved.

1. C. H. Murphy Corp., East Poplar Unit No. 1 well

Very scant poor faunal evidence is available from this core. A Silurian *Halysites* is present at 8,345 feet. Lower in the core there are numerous relicts of fossils, but none certainly identifiable until a depth of 8,975–8,989 feet is reached. There a large specimen of *Receptaculites* similar to those in the lower beds of the Bighorn dolomite is present.

2. Shell Oil Co., Richey area, Northern Pacific R. R. No. 1 well

Depth (feet)	
9,516	*Greenfieldia?* sp. (brachiopod)
	Whitfieldella? sp. (brachiopod)
9,571	*Favosites* sp.
9,656	*Pycnactis?* sp. (horn coral)
9,680	*Favosites* sp.
9,710	Pentamerid brachiopod, similar to *Virginia.*

Except for *Favosites* the forms listed above are exclusively Silurian, and *Favosites* is a common Silurian coral.

At a depth of about 9,784 feet, there is a change in rock type from the creamy dolomites above to brownish dolomites below. From the samples studied it seems certain that at least the interval 9,974–10,169 feet is a single lithologic unit.

In this unit very poorly preserved brachiopods at 9,974 feet suggest the genus *Fardenia* to G. A. Cooper; in my opinion these may belong rather to *Holtedahlina. Fardenia* is a common form in Silurian rocks, but it has been reported from Upper Ordovician strata in the Gaspé (Cooper and Kindle, 1936, p. 357, pl. 51, fig. 39). *Holtedahlina* is an Ordovician genus, and the specimens here are similar in general appearance to those in the Shell Pine Unit No. 1 core at 9,103 feet.

The fact that these specimens are from a single stratigraphic unit in which other Ordovician brachiopods are present at a depth of 9,980–9,989 feet also favors an Ordovician dating.

The Silurian and Ordovician boundary should therefore lie between 9,710 feet and 9,974 feet, in a 260-foot thickness. For lack of better evidence I suggest it be placed tentatively at 9,784 feet to coincide with the lithologic change mentioned above.

3. Empire State Oil Co., Hathaway No. 1 well

At depths of 8,492–8,493 feet two species of *Favosites* and a poorly preserved specimen of *Heliolites?* sp. have been identified by Jean

Berdan, who states that the specimens are more likely to be Silurian than Ordovician.

At a depth of 8,556 feet are found *Strophomena* cf. *S. hecuba* Billings, *Protozeuga* cf. *P. anticostiana* Twenhofel, and *Rhynchotrema?* cf. *R. plicata* Cooper and Kindle. These are Late Ordovician species.

The Silurian and Ordovician boundary probably lies between these two collections.

4. Shell Oil Co., Pine Unit No. 1 well

No core is available for study from a depth of 8,544–8,941 feet. The dolomites between 8,941–8,968 feet have yielded no identifiable fossils. The Silurian and Ordovician boundary should lie within one of these two intervals.

5. Shell Oil Co., Little Beaver No. 1 well

Faunal evidence for placement of the Silurian and Ordovician boundary is very poor. At a depth of 8,112 feet a horn coral with dissepiments is present, though otherwise not identifiable. Jean Berdan (written communication, 1952) notes that dissepiments are not known in such corals in strata older than Silurian.

The highest identifiable Ordovician fossils are *Catazyga?* cf. *C. anticostiensis* (Billings) and *Zygospira?* cf. *Z. aequivalvis* (Twenhofel) from a depth of 8,335 feet.

There are two lithologic changes between these two depths; based on lithologic comparison with other cores I suggest that the Silurian and Ordovician boundary may lie between depths of 8,112 and 8,153 feet in this well.

FAUNAL LISTS

Fossils identified to date (1954) from the five well cores studied are listed below by well and depth. In addition, the fauna of the red shaly beds in the uppermost Bighorn dolomite exposed on the South Fork of Rock Creek in Johnson County, Wyo., and fossils obtained from the base of the upper (Leigh?) member of the Bighorn on the North Fork of Crazy Woman Creek in the same county are listed. Descriptions and notes on most of the species are given on pages 473–503. (See fig. 67 for locations.)

1. C. H. Murphy Corp., East Poplar Unit No. 1 Well (Locality D88 (CO))

Bighorn group:

Fossils from this core are so poorly preserved that even generic determinations have not been attempted. Shadowy dolomitized relicts of brachiopods are abundant in some zones. The little evidence obtained from these and a comparison of rock types suggest correlation between the 8,602–8,670-foot interval in this well and the 9,974–9,984-foot interval in the Shell Richey area, Northern Pacific No. 1 well.

The only identified fossils in the strata presumed to belong in the Bighorn group is a large specimen of *Receptaculites* from 8,975–8,989 feet and very poor molds which probably belong to *Holtedahlina?* at 8,602 feet.

2. *Shell Oil Co., Richey area, Northern Pacific R. R., No. 1 Well, (Locality D89 (CO))*

Bighorn group:

Stony Mountain formation:

Although no diagnostic fossils have so far been obtained, it is probable that the approximate interval 9,784–9,970 feet represents the Stony Mountain formation. This opinion is based entirely on the lithologic character of the strata.

Red River formation:

9,974 feet (loc. D89c (CO)).

Holtedahlina? sp. (ornamentation similar to specimens illustrated by Wang, 1949, pl. 7F).

9,980–9,989 feet. (loc. D89b (CO)).

Megamyonia cf. *M. ceres* (Billings).

10,123–10,135 feet. (loc. D89a (CO)).

Cyclocrinites? sp. (very small)

Numerous brachiopod and coral relicts were found in the dolomite between 9,974 and 10,170 feet, but none, other than those listed above, can be identified with confidence.

3. *Empire State Oil Co., Hathaway No. 1 Well (Locality D90 (CO))*

Bighorn group:

Stony Mountain formation:

Dolomitic member:

8,556–8,664 feet. (loc. D90e (CO)). Same fossils throughout.

Strophomena cf. *S. hecuba* Billings

Rhynchotrema? cf. *R. plicata* Cooper and Kindle

Protozeuga cf. *P. anticostiana* Twenhofel

Numerous unidentifiable, fragmentary relicts of *Rafinesquina*-like shells.

Leperditiid Ostracoda, not generically identifiable.

8,814 feet. (loc. D90d (CO)).

"*Holophragma*" sp.—a horn coral distinctive of the Bighorn dolomite.

Lower shale member:

8,830–8,853 feet.

Fauna more fragmentary but clearly corresponds to that of Shell Pine Unit No. 1 well at depth of 8,986–9,010 feet.

Red River formation:

8,857 feet. (loc. D90c (CO)).

Dinorthis? sp. (relict of shell; appears same as large species from Rock Creek locality of Bighorn dolomite).

9,097 feet (loc. D90b (CO)).

Strophomena cf. *S. rugulifera* Wang

Thaerodonta? sp. or *Sowerbyella?* sp.

9,274 feet (loc. D90a (CO)).

Streptelasma (*Grewingkia*) *robustum* (Whiteaves)

This core is especially valuable in giving some idea of the faunas to be found in the upper dolomite of the Stony Mountain formation. The three brachiopod species identified are known from Upper Ordovician strata of Anticosti Island, Quebec, and the Nicolet River area.

The same problem of identification regarding *Sowerbyella* and *Thaerodonta* is met here at 9,097 feet as in the Shell Pine Unit No. 1 well at 9,023–9,043 feet and 9,286–9,294 feet and in the Shell Little Beaver No. 1 well at 8,526 feet and 8,550 feet.

There is no evidence to suggest that any of the samples from the Red River formation are older than Late Ordovician in age.

4. *Shell Oil Co., Pine Unit 1 Well (Locality D91 (CO))*

The faunas of the shale member of the Stony Mountain formation and Red River formation are better preserved in this core than in the other submitted for study; however, a few genera have been found only in other cores. The fauna of the shale member of the Stony Mountain formation is abundant and many of its elements are very similar to, if not identical with, those found on the surface at the Rock Creek locality of the Bighorn dolomite in Wyoming. In general this assemblage is also similar to those of the Maquoketa shale, of the so-called Stonington beds of northern Michigan (Hussey, 1926), and of the Upper Ordovician of Anticosti Island.

Although their preservation in dolomitic rocks is generally poor, the fossils found in the upper 100–150 feet of the Red River formation are essentially the same as those from the overlying shale. A thin interval between 9,103 and 9,116 feet has yielded poorly silicified brachiopods. At 9,286–9,292 feet two species of brachiopods are recognized, *Megamyonia* cf. *M. unicostata* (Meek and Worthen) and a species which may belong either to *Sowerbyella* or *Thaerodonta*; this same faunal zone may be present in the Shell Little Beaver well at 8,531–8,540 feet.

Fossils identified in the Shell Pine Unit No. 1 well are listed by depth:

Bighorn group:
- Stony Mountain formation:
  - Lower shale member:
    - 8,986–9,010 feet (loc. D91f (CO)).
      - *Batostoma* n. sp.
      - *Trematis?* sp.
      - *Dinorthis* (*Plaesiomys*) cf. *P. proavita* Winchell and Schuchert sp. (large)
      - *Platystrophia* cf. *P. equiconvexa* Wang
      - *Lepidocyclus perlamellosus* (Whitfield)
        - *gigas* Wang
      - *Hypsiptycha hybrida* Wang
      - *Strophomena* cf. *S. vetusta* James
        - *hecuba* (Billings)
      - *Megamyonia* cf. *M. ceres* (Billings)
        - cf. *M. unicostata* (Meek and Worthen)
        - cf. *M. nitens* (Billings)
      - *Megamyonia* sp. (equals Wang, 1949, pl. 9C)
      - *Öpikina?* aff. *Ö. limbrata* Wang
      - *Diceromyonia* cf. *D. ignota* (Sardeson)
        - *storeya* Okulitch
      - *Modiolopsis?* aff. *M. concentrica* Hall and Whitfield
      - *Pterinea?* sp.
      - *Conularia?* sp.
      - *Isotelus?* sp.

Bighorn group—Continued

Red River formation:

9,023–9,043 feet (loc. D91e (CO)).

Strophomena cf. *S. rugulifera* Wang
Megamyonia cf. *M. nitens* (Billings)
cf. *M. ceres* (Billings)
Sowerbyella or *Thaerodonta* sp. (not identifiable as to genus)
Zygospira cf. *Z. resupinata* Wang
Dalmanellid species, not identified
High-spired gastropod, not identifiable generically

9,103–9,116 feet (loc. D91d (CO)). Poorly silicified fossils.

Hesperorthis cf. *H. laurentina* (Billings)
Megamyonia cf. *M. nitens* (Billings)
Strophomena sp.
Holtedahlina aff. *H. moniguensis* Foerste
Catazyga sp.

9,122–9,128 feet (loc. D91c (CO)).

Lepidocyclus cf. *L. perlamellosus* (Whitfield)
Hypsiptycha sp.
Zygospira cf. *Z. aequivalvis* Twenhofel

9,286–9,294 feet (loc. D91b (CO)).

Megamyonia cf. *M. unicostata* (Meek and Worthen)
Thaerodonta? sp. or *Sowerbyella?* sp.
Calapoecia sp.

9,474 feet (loc. D91a (CO)).

Halysites (*Catenipora*) *gracilis* (Hall)

The collections listed above for the Red River formation through a depth of 9,128 feet are so similar to the fauna of the overlying shale of the Stony Mountain formation that they should be included in the Upper Ordovician.

There is some doubt about the small collection from 9,286–9,294 feet; the specimen designated *Megamyonia* cf. *M. unicostata* (Meek and Worthen) in its dolomitized state lacks the characteristically prominent median costella on the pedicle valve. Most of the specimens from the Maquoketa shale of the Patterson Springs locality (Ulrich and Bassler loc. 207g) from which Wang's figured pedicle valve was obtained (1949, p. 33, pl. 9A, fig. 5) have also lost the prominent costella, undoubtedly from abrasion of the shells. On the basis of outline, convexity, and spacing of pseudopunctae the single specimen from the core cannot be differentiated from this species. Associated are numerous small specimens which belong either to *Sowerbyella* or *Thaerodonta* and fragmentary specimens of *Lepidocyclus?*. This thin zone very probably is lithologically and faunally the same as that in the Shell Little Beaver well at a depth of 8,531–8,540 feet.

The presence of *Halysites* (*Catenipora*) *gracilis* (Hall) at 9,474 feet is here interpreted as indicating a Late Ordovician age, although some stratigraphers maintain that its range includes the Middle Ordovician.

5. *Shell Oil Co., Little Beaver No. 1 Well (Locality D92 (CO))*

Bighorn group:

Stony Mountain formation:

No identifiable fossils obtained from this part of core.

Red River formation:

8,330–8,335 feet (loc. D92g (CO)).

Catazyga anticostiensis (Billings)

Zygospira cf. *Z. aequivalvis* Twenhofel

8,362 feet (loc. D92g (CO)).

Paleofavosites? sp.

8,378 feet (loc. D92f (CO)).

Fossils very poorly silicified.

Abundant pelmatozoan columnal plates, circular, pentagonal, and asteriform. Small gastropods. A few fragments of brachiopods, none identifiable.

8,387 feet (loc. D92f (CO)).

Very poor preservation; identifications doubtfully referred.

Holtedahlina? cf. *H. sulcata* Foerste

Megamyonia sp.

8,470 feet (loc. D92e (CO)).

Calyptalaux? sp. (a single pygidium)

8,515 feet (loc. D92e (CO)).

Megamyonia sp.

8,524 feet (loc. D92d (CO)).

Rafinesquina? sp. (Suggestive of *R. alternata* as figured by Foerste, 1924, pl. XIII, figs. 6a, c).

8,526 feet (loc. D92c (CO)).

Rafinesquina sp. (similar in outline to *R. winchesterensis* Foerste, 1910, p. 42, pl. V, figs. 13c, 14).

Megamyonia n. sp. (?)

Thaerodonta sp. or *Sowerbyella* sp.

8,531–8,540 feet (loc. D92b (CO)).

Megamyonia cf. *M. unicostata* (Meek and Worthen)

Thaerodonta cf. *T. recedens* (Sardeson)

Zygospira cf. Z. aequivalvis Twenhofel

Bumastus? sp.

8,550 feet (loc. D92a (CO)).

Holtedahlina? sp.

Thaerodonta? sp. or *Sowerbyella*? sp.

6. *Locality D1 (CO)—Bighorn dolomite; red fossiliferous shaly beds at top. South Fork of Rock Creek, Center, N½NE¼SW¼SW¼, sec. 25, T. 52 N., R. 84 W., Johnson County Wyo.*

This locality, first described by Darton (1906, p. 4) is an extremely important one in correlation of the lower shaly member of the Stony Mountain formation with surface exposures. The fauna obtained from the red shaly and silty beds in the top few feet of the Bighorn dolomite is very similar to that of shale of the Stony Mountain formation and bears a striking similarity to that of the Maquoketa shale of Iowa. Fossils identified are:

Streptelasma trilobatum Whiteaves

cf. *S. latusculum* Billings

"*Holophragma*" sp.

Favosites (*Paleofavosites*) cf. *F. prolificus* Billings

Batostoma sp.
Sceptropora cf S. facula Ulrich
Dinorthis? *sp.* (two new species)
Plaesiomys? *sp.* (one new species)
Pionorthis aff. *P. occidentalis* Okulitch
Lepidocyclus capax (Conrad)
  gigas Wang
  perlamellosa (Whitfield)
Hypsiptycha cf. *H. hybrida* Wang
  anticostiensis (Billings)
Rhynchotrema iowense Wang
Zygospira sp. (n. sp.?)
Thaerodonta sp.
Strophomena hecuba Billings
Megamyonia n. sp. (aff. *M. nitens* (Billings))
Öpikina aff. *Ö. limbrata* Wang
Diceromyonia n. sp. aff. *D. tersa* (Sardeson)
  cf. *D. ignota* (Sardeson)
  storeya Okulitch
Onniella sp.
Astraspis desiderata Walcott
Eriptychius americanus Walcott

7. *Locality D35 (CO)—Bighorn dolomite, 15 feet above the base of the upper (Leigh?) member, North Fork of Crazy Woman Creek, Center NE¼SW¼, sec. 28, T. 49 N., R. 83 W., Johnson Co., Wyo.*
Hypsiptycha cf. *H. hybrida* Wang
Zygospira cf. *Z. resupinata* Wang
Thaerodonta cf. *T. dignata* Wang
Megamyonia cf. *M. unicostata* (Meek and Worthen)
  cf. *M. ceres* (Billings)
Öpikina? *aff. Ö. limbrata* Wang
Isotelus? sp.
Cyclocrinites cf. *C. intermedius* (Billings)

Compared with most collections from the Bighorn dolomite the specimens obtained from this locality by A. R. Palmer and me are fairly good casts and molds. Features such as the denticulation of hinge lines in *Thaerodonta* are unusually well preserved. The one specimen referred to *Zygospira resupinata* Wang is better preserved than that taken from a depth of 9,023–9,043 feet in the Shell Pine Unit No. 1 core.

LATE ORDOVICIAN CORRELATION

At the outset of the present study, I hoped that it might be possible to discover some zonal distribution of the fauna by which each of the Upper Ordovician formations encountered could be subdivided. Although much more work could be done on the cores, the results to date (1954) have been to the contrary; in the two cores with the best lithologic control (Shell Pine Unit No. 1 and Empire State Hathaway No. 1) there seems to be no significant difference between the faunas of the lower shale member of the Stony Mountain formation and most, if not all, of the Red River formation. This fact is immediately evident from examination of plate 44 and the insert facing this page.

Although I have been unable to pick out any distinct zonal arrangement there are a few assemblages which suggest possible close correlation from core to core. These are given alphabetic designations in the insert and their positions are indicated by capital letters (*A*, *B*, *C*) on the right side of columnar sections on plate 44. In suggesting these possibly equivalent zones, I have relied on the general aspect of both the fossils and rocks, for many of the specimens are too poorly preserved for exact identification. As an example, G_2 is indicated for the Murphy East Poplar, Shell Richey, and Shell Pine Unit wells; its placement in the first two is tentative, being based primarily on the occurrence of poor dolomitized specimens of *Holtedahlina*(?), which seem to be the same as those in the Pine Unit well.

On the other hand, the G_3 zone is indicated in the Pine Unit core and in the surface exposure of the Bighorn dolomite with confidence.

The occurrence of most elements of the lower Stony Mountain and Red River faunas in two different rock types is noteworthy. Had it not been for the presence of the abundant G_3 fauna in the red shaly and silty beds of the Bighorn dolomite at locality D1 (CO), I would have proposed a tentative correlation between the lower shale member of the Stony Mountain formation in the Shell Pine Unit well and the lowest beds of the Leigh(?) member of the Bighorn dolomite at locality D35 (CO). It is my present impression that the apparent difference between the faunas of the lower Stony Mountain strata and the upper Red River formation is one of numbers, and that this is only an illusion owing to difficulty in working specimens out of the dolomitized Red River formation. The distribution of the significant fossils is given in the insert.

INTERREGIONAL CORRELATION

For many years there has been uncertainty as to the correct correlation of the Red River, Bighorn, and Whitewood formations. Should their age be considered Late Ordovician, Middle Ordovician, or partly both? Historically Dowling (1900) considered the Stony Mountain strata to be of Richmond age and the Red River formation to be of Trenton age. Similarly Darton (1906, p. 4) thought the upper (Leigh?) member of the Bighorn dolomite to be of Richmond age and the lower massive member to be Trenton in age. Mainly through the work of Foerste (1929) and Miller (1930) all of these formations came to be correlated with Upper Ordovician strata elsewhere. Diversity of opinion still exists and has been thoroughly summarized by Baillie (1952, p. 37–38) and Dunbar (in Twenhofel and others, 1954, p. 257–258). There is no need to review in detail both sides of the controversy here.

Distribution of Late Ordovician fossils in Williston basin and Bighorn Mountains

[Arranged by zones, in large part arbitrary; for use in conjunction with plate 44]

Genus and species / Well and zone																				Summary of fauna reported here by zones (G, apparently good index species; U, of uncertain index value; index to 2 or more zones; P, of dubious index value in delimiting zones here.)						Remarks
Well	Empire State Hathaway No. 1	Empire State Hathaway No. 1	Empire State Hathaway No. 1	Shell Pine Unit No. 1	Bighorn Mts. east flank	Empire State Hathaway No. 1	Shell Pine Unit No. 1	Bighorn Mts. east flank	Murphy E. Poplar Unit No. 1	Shell Richey Northern Pacific No. 1	Shell Pine Unit No. 1	Shell Little Beaver No. 1	Shell Little Beaver No. 1	Empire State Hathaway No. 1	Shell Pine Unit No. 1	Shell Little Beaver No. 1	Murphy E. Poplar Unit No. 1	Shell Pine Unit No. 1	Bighorn Mts. east flank							
Depth in each well (feet)	8556–8664	8314	8857	8986–9010	Top of Leigh(?) (dolomite member)	9097	9023–9043	Bottom of Leigh(?) (dolomite member)	8602	9974–9989	9103–9128	8330–8335	8362, 8387, 8470	9274	9286–9294	8515–8550	8975–8989	9474	Bottom of lower member							
Formation	Stony Mountain (dolomite member)	Stony Mountain (dolomite member)	Red River	Stony Mountain (shale member)	Bighorn dolomite	Red River	Red River	Bighorn	Red River	Red River	Red River	Red River	Red River	Red River	Red River	Red River	Red River	Red River	Bighorn							
Arbitrary zone	Zone H	Zone G_3				Intermediate zone G_3–G_2			Zone G_2				G_{2-1}?	G_1?	Zone G_1		Zone F			H	G_3	G_3-G_2	G_2	G_1?, G_1	F	
Receptaculites sp. (cf. *R. oweni*)																	×		×						G	Species presumably ranges no lower but genus does.
Conularia? sp.				×																	P					No zonal value here; genus ranges much lower.
"*Streptelasma*" *trilobatum*					×																G					
Streptelasma cf. *S. latusculum*					×																G					
(*Grewinkia*) *robustum*														×										G		Originally described from Dog Head member of Red River formation in Manitoba.
"*Holophragma*" sp.		×			×																G					
Calapoecia sp.															×									P		No zonal value here.
Favosites (*Paleofavosites*) cf. *F.* (*P.*) *prolificus*					×																P					Dubious zonal value here; has fairly extensive range within Upper Ordorician.
(*Paleofavosites*) sp.													×													
Halysites (*Catenipora*) *gracilis*																		×							G	
Batostoma sp.				×	×																P					Genus ranges much lower; has no zonal value here.
Sceptropora cf *S. fascula*					×																G					
Rhombotrypa sp.					×																					
Trematis sp.				×																	P					No zonal value here.
Hesperorthis cf. *H. laurentina*											×												P			Zonal value very doubtful; based on Anticosti sections it should be in zone H or higher.
Dinorthis? n. sp. A			×	×	×																G					
? n. sp. B					×																G					
(*Plaesiomys*) cf. *D.* (*P.*) *proavita*				×																	G					
n. sp.					×																G					
(*Pionorthis*) cf. *D.* (*P.*) *occidentalis*					×																G					
Platystrophia cf. *P. equiconvexa*				×																	G					Reported here and in Maquoketa so far.
Lepidocyclus capax					×																G					May range lower.
gigas				×	×																G					
perlamellosus				×	×						×										U		U			May range lower but appears to be limited to zone G_3 and G_2.
Hypsiptycha cf. *H. hybrida*				×	×			×													U	U				Apparently good index to zones G_3 and G_{3-2}.
cf. *H. anticostiensis*				×																	G					
sp.											×												P			Specimens not accurately identifiable.
Rhynchotrema iowense					×																G					
cf. *R. plicata*	×																			G						Probably good index to zone H but may range lower.
Catazyga cf. *C. anticostiensis*												×											P			May be expected higher based on Anticosti range.
sp.											×												P			
Zygospira resupinata								×	×													U				Should range higher based on Maquoketa occurrence.
cf. *Z. aequivalvis*											×	×				×							U	U		Though expected in zone G_3 may prove good index to zones G_2 and G_1.
n. sp.					×																G					
Rafinesquina sp. A	×																			P						
sp. B																×								P		
sp. C																×								P		
Strophomena cf. *S. vetusta*					×																G					
cf. *S. ruqulifera*						×	×															U				Zonal value probably not limited to zone G_{3-2}; expected in zone G_3.
cf. *S. hecuba*	×			×	×															U	U					Probably good index to zones H and G_3.
sp.											×												P			
Megamyonia cf. *M. ceres*				×		×				×											U	U	U			
cf. *M. unicostata*				×				×							×	×					P	P		P		
cf. *M. nitens*					×																G					
sp.										×			×			×										Genus reported higher in Maquoketa; not necessarily limited to zones below G_3.
Holtedahlina cf. *H. sulcata*													×													
aff. *H. moniquensis*											×												G			
? sp.									×	×																
Öpikina aff. *Ö. limbrata*				×	×																G					
Thaerodonta cf. *T. dignata*								×														U				May prove a good index from zones G_3 and G_{3-2}; described from Maquoketa.
cf. *T. recedens*																×								P		Not a valid guide to zone G_1; known from the Maquoketa.
sp.					×																P					
Thaerodonta sp. or *Sowerbyella* sp.						×	×								×	×						P		P		
Diceromyonia n. sp. aff. *D. tersa*					×																G					
cf. *D. ignota*				×	×																G					
storeya				×	×																G					
Onniella sp.					×																P					
Protozeuga cf. *P. anticostiensis*	×																			G						
Modiolopsis aff. *M. concentrica*				×																	G					
Pterinea? sp.				×																	P					
Isotelus sp. A				×																	P					
sp. B								×														P				
Bumastus sp.																×								P		
Calyptalaux sp.													×													
Astraspis desiderata					×																P					No zonal value here; originally considered index to Harding sandstone and correlatives.
Eriptychius americanus					×																					Do.
Cyclocrinites cf. *C. intermedius*								×																		This type found in Silurian of Anticosti.

STONY MOUNTAIN CORRELATIVES

Throughout the fifty-odd years since their description, there has never been any serious doubt as to the Richmond age of the Stony Mountain beds. Through the works of Ulrich (*in* Darton, 1906, p. 4–5) and Okulitch (1943) and particularly the present study, it is obvious that the lower shale member contains a fauna virtually identical with that of the uppermost Bighorn dolomite (loc. D1 (CO)); this fauna is comparable to that of the Maquoketa shale of Iowa, described by Wang (1949). The presence of large coarsely ribbed dinorthid brachiopods, *Strophomena hecuba*, and three species of *Megamyonia* (previously referred to *Leptaena?*) suggests equivalence with the Upper Ordovician formations of Anticosti Island, particularly with the English Head and Vaureal.

The small fauna from the upper dolomitic member of the Stony Mountain formation (Empire State Hathaway No. 1 well) also seems to correlate with the Upper Ordovician of Anticosti and Quebec.

A particularly interesting fossil from the red shaly beds of the uppermost Bighorn is the articulated bryozoan *Sceptropora* cf. *S. facula* Ulrich, originally described from the lower shale member of the typical Stony Mountain formation. The individual segments of this species are only a few millimeters in length and are very distinctive (pl. 37, figs. 10, 11). They may prove valuable in the examination of well cuttings.

CORRELATION OF THE RED RIVER FORMATION

As noted, no fossils obtained from the upper 300 feet of the Red River formation in the cores can be considered significantly different from those from the overlying Stony Mountain formation. Unless contradictory evidence based on other or better preserved specimens of the same elements of the fauna is forthcoming, it seems apparent that approximately the upper 300 feet of this formation must be considered of Late Ordovician age.

Few fossils have been found in the lowermost part of the Red River formation in the cores. The only significant species is *Halysites* (*Catenipora*) *gracilis*, a Late Ordovician form, found only in the Shell Pine Unit No. 1 well. Although the large specimen of *Receptaculites* taken from the Murphy East Poplar No. 1 core suggests possible equivalence with the lowest dolomites of the Bighorn dolomite and with the Whitewood dolomite, it has not been identified with certainty as to species.

Considering the evidence at hand the entire Red River formation, and therefore the Bighorn group as a whole, is believed to be of Cincinnatian age. This conclusion is based almost entirely on brachiopods and a few corals. Neither bryozoans nor conodonts, of which many specimens are still to be removed from the cores, have been studied.

However, there are some objections to this conclusion. One of the most recent is presented by Flower (1952, p. 25–26), who clearly implies, but does not definitely state, that the Bighorn and Red River formations are equivalent to the Trenton of eastern North America. Flower claims that a diminishing number of cephalopod genera are known in "indisputable Richmondian faunas" and not in Trenton assemblages. In 1929 Foerste, in reviewing the fauna of the Red River formation, made it clear that many genera, not only of cephalopods but of other invertebrates, range from Trenton into Richmond strata.

No one has yet obtained and synthesized all possible faunal evidence from the lowermost Red River formation of the cores, from the lower dolomite member of the Bighorn formation, and from the Whitewood dolomite. When this is done it may be found that each of these formations is partly of Middle Ordovician age. But by the same token, as is pointed out in the discussion of the Winnipeg and correlative(?) faunas below, the presumed Middle Ordovician dating of the beds which underlie each of these units—the Lander(?) sandstone member of the Bighorn formation, the siltstones and shales just beneath the Whitewood dolomite, and the Winnipeg formation—is far from an established fact. These all in turn may prove to be of post-Trenton age.

MIDDLE(?) ORDOVICIAN FAUNA

Of the formations encountered in the five cores studied, only the Winnipeg contains Middle Ordovician faunal elements. Barnes (1953, p. 343) states that Middle Ordovician conodonts have been identified from the Winnipeg formation in cores of both the Shell Pine Unit No. 1 and Shell, Richey area, Northern Pacific No. 1 wells. However, neither faunal lists nor systematic descriptions of this fauna have been published.

Scales and plates of primitive fish are abundant in the Winnipeg strata of the Shell Pine Unit No. 1 and Shell, Richey area, Northern Pacific No. 1 cores. Several large samples of core from the Shell Pine Unit No. 1 well were submitted to D. H. Dunkle, of the U. S. National Museum, for identification of the fish plates. He commented as follows:

> Occurring at restricted horizontal levels but distributed throughout submitted sections of both cores Nos. 34 and 35 (9,525–9,596 feet), I have detected extremely well-preserved examples of the osseous plates known as *Astraspis desiderata* Walcott and *Eriptychius americanus* Walcott (see pl. 6, figs. 1–4). Published reports on the occurrence of both of these presumed ostracoderm fishes are two: the Harding sandstone of Colorado and a supposed stratigraphic equivalent in Wyoming. (Walcott, 1892; Kirk, 1930).

Both *Astraspis desiderata* Walcott and *Eriptychius americanus* Walcott, which until May of 1954 had been considered Middle Ordovician indices, have now been identified by Dunkle in collections from the red shaly beds of the uppermost Bighorn dolomite (loc. D1 (CO)), associated with an invertebrate fauna unquestionably of Maquoketa age. If the evidence of the conodonts reported by Barnes is correct, these two fossils can no longer serve as guides to Middle Ordovician strata.

The apparent extension of range of these two fish is in itself no reason to question the Middle Ordivician dating of the Winnipeg formation, for the large faunal list compiled by Baillie (1952, p. 25–27) shows Middle Ordovician affinities. Of interest is the conclusion of Macauley and Leith (1951, p. 1461–1462) that the fauna of the Winnipeg is post-Trenton in age.

CORRELATION WITH THE BLACK HILLS AND BIGHORN MOUNTAINS SECTIONS

Any discussion of the dating of the Winnipeg strata, especially in the subsurface, must inevitably include reference to the Black Hills and Bighorn Mountains sections, despite scarcity of concrete faunal evidence on which to base the discussion.

Many geologists are convinced that the Winnipeg formation beneath the surface of the Williston basin is correlative and continuous with the siltstones and shales (Roughlock and Ice Box of McCoy, 1952) beneath the Whitewood dolomite of the Black Hills. On the evidence of conodonts and scolecodonts these have been dated as equivalent to the Decorah, Plattin, and Platteville formations by Furnish, Barragy, and Miller (1936), who noted an especially close tie with the Spechts Ferry shale (1936, p. 1333, 1336). On this basis the Winnipeg formation should be of early Trenton age.

In 1942, Amsden and Miller suggested similar correlation when they published the results of a study of conodonts from the lower sandstones of the Bighorn formation, here designated the Harding sandstone and the Lander (?) sandy member of the Bighorn dolomite. The separation of these two units was earlier emphasized by Kirk (1930, p. 460–463). During the 1953 field season, A. R. Palmer and I observed the distinctness of the two along the east flank of the Bighorn Range at Billy Creek (W½, T. 48 N., R. 83 W.), on the North Fork of Crazy Woman Creek (Center NE¼SW¼, sec. 28, T. 49 N., R. 83 W.), on the South Fork of Rock Creek (SW¼SW¼, sec. 25, T. 52 N., R. 84 W.), and on the south side of South Piney Creek (SE¼SE¼, sec. 14, T. 53 N., R. 84 W.). At each place the Harding equivalent is a white poorly cemented sandstone, composed of well-rounded frosted quartz grains; the amount of interbedded greenish siltstone varies from one locality to the next. Excellent detailed descriptions of two of these localities are given by Amsden and Miller (1942).

Fish plates are especially abundant at the Rock Creek locality, where the relations with the overlying Lander(?) sandstone member of the Bighorn dolomite are well shown. Fish plates are concentrated at the contact between the two formations, as if by winnowing out of the sand before deposition of the yellowish-buff dolomitic Lander(?) sandstone. Some of the plates have been reworked into the bottom few inches of the younger formation.

At these localities the upper of the arenaceous units grades laterally from a sandy dolomite to a dolomitic sandstone. In the top of this dolomitic material and in the base of the true Bighorn dolomite large cephalopods and large specimens of *Receptaculites* are found.

In its type area it is almost impossible to separate the Lander sandstone member from the base of the Bighorn dolomite, except on well-weathered surfaces (Peck, oral communication 1953), for the two meet at a gradational contact virtually imperceptible on a fresh surface. The same is essentially true on the east flank of the Bighorn Mountains, where the yellowish color of the Lander member stands out.

In their report on the conodonts of what are here considered the probable Harding and Lander equivalents on the east flank of the Bighorn Mountains, Amsden and Miller (1942) did not use the term Lander but clearly differentiated between the two arenaceous units. Their "hard medium-grained, red sandstone-3ft." (fig. 67) is the Lander equivalent of the present interpretation; they listed its fauna above the horizontal line in table 1 (p. 303). This fauna they compared with that of the siltstones and shales beneath the Whitewood dolomite proper but not with the Harding sandstone. According to their study, it is the fauna of the lower fish-bearing sandstones which corresponds to that formation. From this we should conclude that the shales, siltstones, and sandstone which lie above the so-called Scolithus sandstone and below the Whitewood dolomite proper in the northern Black Hills are younger than Harding.

The following facts should be considered before reaching any conclusions regarding the age and correlation of the Harding and Lander(?) units along the east flank of the Bighorn Mountains:

1. Amsden and Miller (1942, p. 306) emphasize that ranges of Middle and Late Ordovician conodonts are not yet well known. They point out the "perplexing analogy" with the siltstones and shales of the Black Hills shared by both the Harding and Lander(?) although neither of these two has any conodonts in common.

2. Their fauna from the Harding equivalent contains many more genera and species in common with the Harding sandstone at its type locality and the Platteville formation than with any other formations (Amsden and Miller, 1942, table 1).

3. Their correlation of the Lander(?) sandstone member of the Bighorn dolomite with Middle Ordovician formations is based on five genera and but a single species (1942, table 1). Branson, Mehl, and Branson (1951, p. 4) have subsequently noted that three of these genera (*Belodus*, *Oistodus*, and *Paltodus*) plus the same single species (*O. curvatus*) are known in the Maquoketa or higher strata of the Richmond group and that *Oistodus* and *Paltodus* are actually characteristic of Richmond strata.

4. There is as yet only fair paleontologic but good stratigraphic and lithologic evidence for considering the Lander(?) sandstone member in the Bighorn Mountains equivalent to the typical Lander member of the Bighorn dolomite in the Wind River Mountains; the paleontologic evidence for the Late Ordovician age of the latter (Miller, 1930) is still impressive.

In summarizing the conclusions which can be drawn from these facts plus earlier remarks concerning the presumed Middle Ordovician siltstones and shales of the Black Hills and the Winnipeg formation it seems evident that

1. Much more research needs to be done on the ranges of conodont genera and species before they can be used with certainty to differentiate Middle from Late Ordovician strata.

2. The Harding sandstone of the Bighorn Mountains is very probably correlative with the Harding sandstone at its type locality in Colorado and probably with the Platteville formation.

3. Statements that most or all of the Bighorn and Whitewood dolomites are of Trenton age (Flower, 1952, p. 25–26; McCoy, 1952, p. 46; Kay, *in* Twenhofel and others, 1954, p. 282), largely on the basis of generic occurrences and (or) paleogeographic interpretation, may be premature.

4. If the Lander(?) sandstone member is correlative with any of the fine-grained clastic sediments below the Whitewood dolomite, further detailed study of the conodonts in the Black Hills sections may show that they are arranged zonally and that both Middle and Late Ordovician strata are included in the siltstones and shales. This would also apply to the Winnipeg formation beneath the surface of the Williston basin.

EARLY ORDOVICIAN FAUNA

Although not adequate for detailed correlation the collections from the Shell Pine Unit No. 1 and Shell, Richey area, Northern Pacific No. 1 wells include Early Ordovician trilobites, in addition to poorly preserved graptolites and brachiopods. The identification of the trilobites is seriously hampered by the fortuitous sampling inherent in coring; as there is no possibility of working along any stratum, disarticulated cranidia are common without their original pygidia and vice versa. Because definite identification of many trilobites, especially of the type collected, depends on finding heads and tails in association, it is difficult to assign many of the forms obtained to a particular genus or species.

LOWER ORDOVICIAN CORRELATION

Although cores of only two wells in which Lower Ordovician rocks have been found (Shell Pine Unit No. 1 and Richey area, Northern Pacific No. 1) are immediately available for study, Dr. J. L. Wilson (Shell Oil Co.) has furnished some information on core from the Shell Southwest Richey No. 32–33B well.

This indicates the presence at depths of 10,250–10,450 feet of a *Bellefontia-Xenostegium* fauna beneath the occurrence of *Kainella* at 10,212 feet. This fauna has been reported by Lochman and Duncan (1950, p. 351) from the top of the Deadwood formation in the Black Hills and in the uppermost beds of the Pilgrim limestone in Montana.

SHELL OIL CO., PINE UNIT NO. 1 WELL

Figure 69 shows the vertical distribution of the fauna in the Lower Ordovician of the Shell Pine Unit No. 1 well. Although the apparent faunal breaks at 9,670 and 9,698 feet may not be real but due to discon-

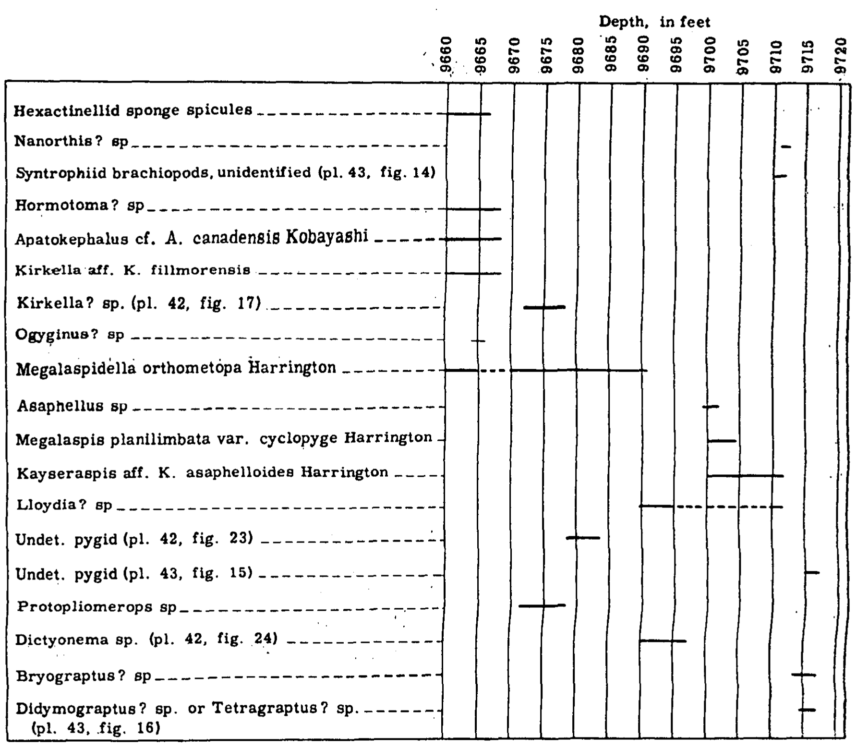

FIGURE 69.—Distribution of the Early Ordovician fauna of the Shell Oil Co., Pine Unit No. 1 well.

tinuous sampling, it is possible to make a preliminary analysis of them.

The species present in the 9,660–9,666-foot interval (pl. 42, figs. 5–16, 19, 20) are *Apatokephalus* cf. *A. canadensis* Kobayashi, *Kirkella* aff. *K. fillmorensis* Hintze, *Megalaspidella* cf. *M. orthometopa* Harrington, and a single pygidium bearing a resemblance to those of some species of *Ogyginus*. Also present are *Hormotoma*-type gastropods and hexactinellid sponge spicules.

Kirkella aff. *K. fillmorensis* indicates correlation with the "G" zone of the Garden City formation in Utah (Hintze, 1952, p. 13–14), or about the middle of the Lower Ordovician sequence as it is developed in the Basin and Range province. The pygidium tentatively referred to *Ogyginus* is similar to one described by Kobayashi (1934b, p. 553, plate IV, fig. 17) from his "*Asaphellus* zone" of Korea. Whittington (written communication, 1953) believes that this pygidium may belong to quite a different genus amongst the Bathyurid trilobites. As a genus *Apatokephalus* probably has less definitive zonal value than has previously been ascribed to it. In Argentina (Harrington, 1938, p. 279) it occurs in the "*Asaphellus*" and "*Triarthrus* faunas," associated with *Shumardia*, *Asaphellus*, *Megalaspis*, *Megalaspidella*, and *Protopliomerops* and well above the *Kainella-Leiostegium* zone. Hintze (1952, p. 189) on the other hand reports *Apatokephalus* associated with these last two genera in Utah. In his report on the pre-Devonian formations of the Canadian Cordillera Walcott (1928, edited by Resser) lists several sections in which *Apatokephalus* is present (p. 284, 390 feet above *Kainella*; p. 359, associated with *Kainella* and *Leiostegium* in what may be a mixed assemblage).

Kobayashi (1953, p. 52) described *Apatokephalus canadensis* from Evan's collections in the Brisco-Dogfoot map area; in his report Evans (1933, p. 129) lists the genus *Apatokephalus* in the *Kainella* zone of the MacKay group.

Megalaspidella cf. *M. orthometopa* Harrington (1938, p. 239–241, plate XII, figs. 1–8, p. 280) belongs to the "*Triarthrus* fauna" of Argentina; its exact position in the Basin and Range sections is not known, but somewhat similar asaphid forms are known in the "G" zone. It occurs also in the next deeper unit of the present core.

Other trilobites are present in the 9,660–9,666-foot interval in the shale beds and partings. These are too badly deformed to identify accurately. Small high-spired snails like, if not actually assignable to, the genus *Hormotoma* are found in the shales (pl. 42, fig. 14); Cloud and Barnes (1946, p. 69) note that this genus is not known below the Gorman formation in central Texas.

Between 9,672 and 9,690 feet (pl. 42, figs. 15–20, 23, 24) occur the species *Protopliomerous* sp., *Megalaspidella* cf. *M. orthometopa*

Harrington, a pygidium questioningly referred to *Kirkella*, an indeterminate species represented by a single pygidium which is very close to that illustrated by Hintze (1952, pl. IX, fig. 9), and the graptolite *Dictyonema* sp. To this list may be added a proparian trilobite so poorly preserved as to be very doubtfully referred to the genus *Pilekia*.

The poor specimen of *Protopliomerops* is probably assignable to *P. superciliosa* Ross, an "F" zone index. The indeterminate pygidium similar to Hintze's suggests a correlation with the lower part of the "G" zone. The significance of *Megalaspidella orthometopa* has been discussed above.

The trilobites in this interval are probably of the same general age as those between 9,660 and 9,666 feet; the differences between the two lists may be the result of sampling.

The interval between 9,698 and 9,715 feet is not a satisfactory one for the student interested in trilobites, for in it we found five different kinds of pygidia but only two types of cranidia. It is difficult to determine to which of the pygidia the two cranidia belong and, until this problem is solved, final identifications cannot be made. However, one of the pygidia can be eliminated from this problem (pl. 43, fig. 15); it is poorly preserved as an impression in a shaly matrix and is clearly not related to the other four.

The tentative identifications are:

Asaphellus? sp.
Megalaspis planilimbata var. *cyclopyge* Harrington
Kayseraspis aff. *K. asaphelloides* Harrington
Lloydia? sp.
Indeterminate pygidium close to that figured by Ross (1951, pl. 19, figs 30, 31).

This association is puzzling. *Kayseraspis* occurs in Argentine sections above *Megalaspis* and *Megalaspidella* and well above *Asaphellus* (Harrington, 1938, p. 280). In this core it is identified with or below all three. *Lloydia* (Bradley, 1925, p. 7) is a Beekmantown form, presumably a contemporary of *Leiostegium*, and its presence is not expected in this young an association within the Lower Ordovician. The undetermined pygidium (pl. 43, fig. 15) is similar to one in the "F" zone of Utah.

Summarizing the trilobite fauna of the Lower Ordovician of the Pine Unit No. 1 core, it is my opinion that it is younger than the trilobite-bearing strata encountered in the Richey area, Northern Pacific No. 1 well at 10,500–509 feet. Several elements of the fauna have closer affinities to South American (Argentine) and Korean assemblages than to any previously described in North America; a marked resemblance is noted to some of the collections designated "*Megalaspis* fauna" in Walcott's (1928) Canadian Cordilleran sections; these collections have never been adequately studied and in some cases are incorrectly designated. For instance, collection 65W (Walcott, 1928, p. 330) actually includes Middle Cambrian as well as "J" zone Lower Ordovician genera.

SHELL OIL CO., RICHEY AREA, NORTHERN PACIFIC NO. 1 WELL

The Early Ordovician trilobite fauna obtained from the Richey area, Northern Pacific No. 1 well is limited to a thin interval between depths of 10,500–10,510 feet. It includes the genera *Leiostegium* and *Kainella* as well as two minute hystricurid species. The assemblage is clearly equivalent to the "D" zone of the Lower Ordovician of Utah and Nevada, the lower part of the Manitou formation of Colorado, part of the Lower Ordovician of the Northeastern States, the lowest division of the Ordovician in Argentina (Harrington, 1938, p. 279–281; Kobayashi, 1935), part of the Lower Ordovician of Korea (Kobayashi, 1953), part of the Mons formation of the Canadian Cordillera (Walcott, 1928, p. 273, 284, 331, 332, 359), and part of the MacKay group of British Columbia (Evans, 1933, p. 126–129). This zone is apparently equivalent to the strata at a depth of 10,212 feet in Shell's Southwest Richey No. 32–33B well.

At a depth of 10,466 feet in the Richey Area, Northern Pacific No. 1 well poorly preserved graptolites are present. These are tentatively assigned to the genus *Bryograptus*. The same graptolite genus, whether it be *Bryograptus* or not, is present at a depth of 9,718 feet at the bottom of the Pine Unit No. 1 well, accompanied by a single minute specimen which may be an immature *Didymograptus* or *Tetragraptus* (pl. 43, fig. 16). The shale partings containing these graptolites in the two wells may not be exactly contemporaneous, but these two occurrences tend to support the belief that the *Kainella-Leiostegium* fauna is older than the lowest fauna reported in this paper from the Pine Unit No. 1 well.

Of more than passing interest is the occurrence of the brachiopod *Imbricatia* at a depth of 10,500–10,509 feet in the Richey Area, Northern Pacific No. 1 well. Although no specimens good enough for illustration were obtained the ornamentation is so distinctive that there can be little doubt as to its identity. This genus has been described by G. A. Cooper (1952 p. 21–23, pl. 3E, figs. 14–19; pl. 4D, figs. 17–22) from the Cool Creek and Manitou formations. Its presence here suggests the possibility of correlating the *Kainella-Leiostegium* trilobite zone with the middle of the Cool Creek formation of Oklahoma.

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SUMMARY

FAUNAL CORRELATION

The study of fossils found in the cores of five wells located along the Cedar Creek anticline and in the Richey and Poplar areas, as well as collections obtained during a reconnaissance of lower Paleozoic rock exposures in the Black Hills and Bighorn Mountains has been limited almost entirely to brachiopods and corals of Late Ordovician and trilobites of Early Ordovician age. Conodonts and bryozoans are probably the two most important groups awaiting investigation by specialists. No cephalopods were recognized in the cores.

The Red River and Stony Mountain formations together seem to include equivalents of the entire Bighorn dolomite and the term Bighorn group is applied to them in the subsurface.

The few species identified from the upper dolomitic member of the Stony Mountain formation show affinities with the Late Ordovician assemblages from Anticosti Island and Quebec. The fauna and lithologic character of the calcareous lower shale member of the Stony Mountain formation, particularly in the core of the Shell Pine Unit No. 1 well, is strikingly similar to the red shaly beds in the uppermost Bighorn dolomite, northwest of Buffalo, Wyo. Both are of Late Ordovician age and correlative with the Maquoketa shale of Iowa.

In the fauna from the cored samples of the Red River formation, which is characterized by brownish limestones and dolomitic limestones, no Middle Ordovician elements have been recognized. Most of the genera and species from the upper 300 feet of the formation are also present in the overlying Stony Mountain strata, indicating no major faunal break. This fauna also resembles a small collection found in the base of the Leigh member of the Bighorn dolomite. Unfortunately the brachiopods of the lower massive member of the Bighorn are virtually unknown and its probable equivalence to the lower Red River strata is only suggested by scanty evidence afforded by large *Receptaculites* and *Halysites* (*Catenipora*) *gracilis*.

The Red River formation is underlain by quartzose sandstones and shales of the Winnipeg formation. In the subsurface, the Winnipeg is presumed to be of Middle Ordovician age and supposedly is correlative with the siltstones and shales beneath the Whitewood dolomite of the Black Hills; published evidence based on a study of conodonts has suggested correlation of these siltstones and shales not only with the Middle Ordovician formations of the Upper Mississippi Valley, but also with the Lander (?) sandstone member of the Bighorn formation along the east flank of the Bighorn Mountains. Analysis of the faunal evidence for this correlation indicates that it its tenuous and requires further study and refinement. All these beds, including the

Winnipeg formation, may eventually prove to be of Late Ordovician age. *Astraspis desiderata* and *Eriptychius americanus*, the presumed ostracoderm fish which are abundantly represented in the Harding sandstone of Colorado, its equivalent in the Bighorn Mountains, and the shales of the Winnipeg formation, are no longer valid Middle Ordovician indices; they have been identified in the fauna of Maquoketa age of the uppermost Bighorn.

As indicated in the cores the Deadwood formation in the western Williston basin is composed of glauconitic limestones, intraformational limestone conglomerates, and shales. As much as 350 feet of the upper part of this formation contain Early Ordovician trilobites, poorly preserved brachiopods, and graptolites. The Lower Ordovician strata are apparently conformable on those of the Upper Cambrian, no evidence of a stratigraphic break between them having been recognized. Trilobites range in age from very Early Ordovician (*Bellefontia* zone) to approximately middle Early Ordovician. The younger forms show affinities with those from the so-called "*Megalaspis*" fauna of British Columbia and from parts of the Lower Ordovician section in Argentina.

Selected fossils of Ordovician faunal zones in the Williston basin and Bighorn Mountains

Upper Ordovician (for complete lists of fossils for zones F–H see insert facing p. 458)
- Zone H
  - *Rhynchotreme* cf. *R. Plicata*
  - *Protozeuga* cf. *P. anticostiensis*
  - *Strophomena* cf. *S. hecuba*
- Zone G (for subdivisions see insert)
  - "*Streptelasma*" *trilobatum*
  - *Dinorthis* (*Plaesiomys*) cf. *D.* (*P.*) *proavita*
    - (*Pionorthis*) cf. *D.* (*P.*) *occidentalis*
  - *Lepidocyclus capax*
    - *gigas*
    - *perlamellosus*
  - *Hypsiptycha hybrida*
    - *anticostiensis*
  - *Megamyonia* cf. *M. ceres*
    - cf. *M nitens*
  - *Diceromyonia storeya*
- Zone F
  - *Receptaculites* cf. *R. oweni*
  - *Halysites* (*Catenipora*) *gracilis*

Middle Ordovician
- Zone E (see pl. 44 for position of Winnipeg formation)
  - *Astraspis desiderata*
  - *Eriptychius americanus*
  - Conodonts as yet unstudied

Lower Ordovician
- Zone D (Shell Pine Unit No. 1 well, 9,660–9,690 feet)
  - *Apatokephalus* cf. *A. canadensis*
  - *Megalaspidella* cf. *M. orthometopa*
  - *Kirkella* aff. *K. fillmorensis*
  - *Ogyginus* sp.
  - *Protopliomerops* sp.
- Zone C (Shell Pine Unit No. 1 well, 9,698–9,715 feet)
  - *Asaphellus* sp.
  - *Megalaspidella* cf. *M. orthometopa*
  - *Kayseraspis* aff. *K. asaphelloides*
  - *Lloydia?* sp.
- Zone B (Shell Pine Unit No. 1 well, 9,718 feet; Shell (Richey) Northern Pacific No. 1 well, 10,466 feet)
  - *Bryograptus?* sp.
- Zone A (Shell (Richey) Northern Pacific No. 1 well, 10,500–10,510 feet)
  - *Imbricatia* sp.
  - *Leiostegium manitouensis*
  - *Kainella* sp.

TENTATIVE PALEOGEOGRAPHIC INTERPRETATIONS

The results of this study as summarized above, and conversations with E. D. McKee, have resulted in an effort to visualize the paleogeography of the Williston basin during Ordovician time. It was not, however, until I had read for a second time Rader's (1952, p. 48–53) paper on the Ordovician carbonates of the basin that I realized that these ideas were foreshadowed by his conclusions. Few conclusions can be drawn from the five cores examined; however, hypotheses can be presented for testing in future research, and these are given in the following paragraphs.

Lochman and Duncan (1950, p. 351) concluded that Early Ordovician sedimentation proceeded in the same manner as that of the Late Cambrian in the Rocky Mountain region because of the occurrence of a *Bellefontia* fauna in the uppermost few feet of the Deadwood formation in the Black Hills and of the Pilgrim limestone in Montana. Brachiopods collected during the 1953 field season in Brown's Canyon in the Northern Little Rocky Mountains substantiate that a very thin interval of Lower Ordovician rock underlies the Bighorn dolomite there. As noted previously, a fauna collected by A. R. Palmer and me from the top 10 or 15 feet of the Deadwood formation west of Storey, Wyo., may prove to be of early Ordovician age.

Although the thickening from a few tens of feet to 350 feet may not be significant when spread over 200–300 miles, the discovery of a younger trilobite fauna in the cored sections than is present in the peripheral surface exposures suggests that downwarping had taken place before the deposition of the Middle(?) and Upper Ordovician units. Too little information is available to be certain of the plan of the downwarped area, nor is it possible to tell whether the downwarping took place throughout Early Ordovician time or abruptly.

Isopach maps by Rader (1952, p. 50, 52) and Barnes (1953, figs. 3, 4, 5) show that in the case of Ordovician, Silurian and Devonian, and Mississippian units each thickens toward the center of the Williston basin. It is conceivable that Lower Ordovician sediments were deposited uniformly over the entire area, downwarped, and then bevelled before Middle and Upper Ordovician strata were laid down and that this process was repeated before Silurian and Devonian, and Mississippian deposition. Broad basinal downwarping of a fairly continuous nature seems a more reasonable explanation, however. This may have been interrupted by stoppages in subsidence which resulted in nondeposition of some units or by local warping and erosion of these units particularly at the periphery. In any case it seems probable that the fundamental and rudimentary structure of the Williston basin had come into existence by the close of Early Ordovician time.

The clastic nature of the Winnipeg formation and its position above an unconformity suggest that its sediments may have resulted from erosion of newly uplifted areas near the periphery of the incipient Williston basin. If basin subsidence had already begun at this time the site of deposition of the clastic sediments should have migrated toward the periphery of the growing basin. If this occurred, the Winnipeg strata in the center of the basin should be older than similar rocks at the borders of the basin. Possibly, therefore, the lowermost carbonate rocks of the Red River formation were being deposited in the center of the basin at the same time that sand, silt, and mud were being deposited at its borders. This interpretation is based wholly on physical evidence and needs faunal verification.

Several blocks of rock from the Whitewood dolomite and from the lower massive member of the Bighorn dolomite have been partly dissolved in formic acid; the dolomite from both contains an unusually large amount of clastic material in the form of very fine sand, silt, and clay.

McKee (1938, p. 47–49, 68–76, text fig. 22) discussed the origin of dolomitic rocks with a high content of detrital clastic material in his study of the Kaibab limestone. He concluded that this facies, exemplified by facies 4 of the Beta member of the Kaibab, is characteristic of both nearshore deposits and residual deposits of retreating seas. In either case, there should be shallow water with poor circulation and consequent concentration of salts.

On examining the samples from the Whitewood and Bighorn dolomites which were being dissolved, McKee expressed the opinion that they probably should be classed with similar nearshore deposits of the Kaibab and that these might be expected around the borders of a basin in the thinner stratigraphic sections.

Perusal of Barnes' (1953, fig. 3) isopach map shows clearly that the sections in which these detrital-rich dolomites occur (the Black Hills and the Bighorn Mountains) are indeed the thinner ones and close to the borders of the basin, although some allowance must be made for post-Ordovician and pre-Mississippian erosion or nondeposition.

In the deeper parts of the Williston basin the Red River formation, apparently holding the same stratigraphic position as the detrital-bearing dolomites in the Black Hills and Bighorn Mountains, is composed of limestone and dolomitic limestone. Samples at hand, perhaps because they were not taken from the deepest part of the basin and probably because they were picked for their fossil content alone, do not check entirely with Rader's (1952) observations and seem to indicate a higher dolomite (and fossil) content near the top of the Red River formation than near the bottom. None of the lower dolomitic rocks sampled are dolomites such as are present in the Whitewood or lower Bighorn.

It is, therefore, suggested that the lower member of the Bighorn dolomite, including the Lander? sandstone member, and the Whitewood limestone, possibly also including much of the underlying calcareous and dolomitic siltstone, may represent a shallow water facies of the Red River formation, particularly of its lower portion. If this is true and if the Whitewood and Bighorn are in any part transgressive, their lower beds should be younger than the lowest beds of the Red River in the subsurface. Currently available paleontologic information neither supports nor disproves this interpretation.

Because the lower member of the Bighorn dolomite is overlain by additional dolomites of the Leigh(?) member and because the Red River is overlain by dolomites of the Stony Mountain formation it is possible that these represent a regressive facies; Rader (1952, p. 51, 53) concluded that the dolomites of the upper Red River and Stony Mountain formations were deposited in restricted waters. The absence of Silurian and Devonian sediments in the Black Hills and of Silurian units in the Bighorn Mountains suggests that the region to the south and west was rising and causing this regression.

This results in a fairly simple hypothetical explanation for the areal and stratigraphic distribution of the Middle(?) and Upper Ordovician rock types of the Williston basin and its borders, calling for Middle(?) or Late Ordovician transgression followed by later Ordovician regression of the sea. However, this hypothesis raises several questions, not the least of which is the necessity for explaining the presence of the lower shale member of the Stony Mountain formation.

Rader (1952, p. 52–53) indicated that the shales of this member thin and disappear in eastern Montana and northeastern Wyoming; however, the presence of the same facies along the South Fork of Rock Creek, near Buffalo, Wyo., suggests either that its distribution is patchy areally and (or) stratigraphically or that the tip of a tongue is exposed, which may extend beneath the surface to the northeastward to join the main deposit. The abundance of fossils and the evidence for abrasion to which many of them have been subjected suggest, as Rader (1952, p. 53) concluded, that the unit was deposited under conditions of well-circulated water where waves were active. Wave action might be expected in a shallowing regressive sea, but further speculation as to the reasons for the brief change from a restricted environment is pointless without additional data on the distribution of the shaly facies.

It may be well to note that there is no intention to imply that any of the subject Ordovician sediments are basinal in a strict sense (formed in a very deep basin of deposition). Rather I visualize an extremely broad area of "shelf-type" sedimentation which stretched southward into the present Southwestern States and perhaps westward into Nevada. Within this area of shoal water and generally restricted circulation the forerunner of Ordovician age of the Williston basin may have been a minor subsiding feature—mainly very shallow at any given time, but undergoing greater subsidence toward its center than at its margins, which resulted in a broad and thinly lenticular body of chiefly dolomitic carbonate rocks.

DESCRIPTIONS OF LATE ORDOVICIAN FOSSILS

The descriptions which follow are presented in abbreviated form in order to point out a few of the diagnostic characteristics of each genus or species. If the specimens are well-enough preserved they are figured on the accompanying plates; if species are represented by poorly preserved specimens reference is made to publications in which adequate illustrations may be found. For the sake of brevity complete synonomies are not necessarily provided for each species.

Two species of *Dinorthis* (?), one of *Megamyonia* and one of *Diceromyonia*, are considered new. They are not described here because there has not been time to study them thoroughly. All four are from the uppermost Bighorn formation; at least two of the four are also present in the Manitoban sections of the lower shale member of the Stony Mountain formation.

Phylum COELENTERATA

CLASS ANTHOZOA

The corals of the Bighorn group and correlative formations and their stratigraphic significance are discussed by Helen Duncan (1956), but several of them have not been portrayed photographically. Four species identified by her are therefore illustrated here without descriptive comment. These are

Streptelasma trilobatum Whiteaves (pl. 37, figs. 1, 2)
Streptelasma cf. *S. latusculum* (Billings) (pl. 37, figs. 4, 8)
"*Holophragma*" sp. (pl. 37, figs. 3, 5, 6, 7)
Paleofavosites prolificus (Billings) (pl. 37, fig. 9)

The first of these occurs in strata of the Stony Mountain formation and uppermost Bighorn dolomite. The second was originally described from the Jupiter formation of Silurian age of Anticosti Island. *P. prolificus* is known from the same units as *S. trilobatum* in addition to the Upper Ordovician rocks of Anticosti.

Phylum BRYOZOA

Order TREPOSTOMATA

Family TREMATOPORIDAE

Genus BATOSTOMA Ulrich, 1882

Batostoma Ulrich; Bassler, 1953, Treatise on invertebrate paleontology, part G, p. G113, fig. 76–1a, b, c, d; 76–2.

Numerous specimens belonging to this genus have been obtained from the lower shale member of the Stony Mountain formation (Shell Pine Unit No. 1 well) and from the red shaly beds of the Bighorn dolomite, locality D1 (CO). R. S. Boardman (written communication, 1953) believes that these represent new species which await detailed study. Therefore no descriptions are submitted here.

Order CRYPTOSTOMATA

Family ARTHROSTYLIDAE

Genus SCEPTROPORA Ulrich, 1888

Sceptropora Ulrich; Bassler, 1953, Treatise on invertebrate paleontology, part G, p. G130, fig. 90–3a, b.

Sceptropora cf. S. facula Ulrich

Plate 37, figures 10, 11

These small club-shaped segments of articulated colonies are extremely distinctive and may prove of considerable use where well cuttings are obtained from drilling operations. A smooth hemispherical condyle caps the smaller end of each segment, the other end of which holds a bowl-shaped socket.

The collections from Rock Creek (loc. D1 (CO)) apparently contain at least two species, one being considerably more slender than

S. facula. Whether either is correctly assignable to this species will not be known until more detailed study is possible.

Figured specimen.—USNM 124805.

Locality.—D1 (CO), red shale beds in top few feet of Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Discussion.—At present this species is known only from Upper Ordovician strata, though the genus ranges into the Silurian. *S. facula* was originally described by Ulrich from the Stony Mountain formation of Manitoba, presumably from the lower shale member.

Phylum BRACHIOPODA

Superfamily ORTHACEA

Genus HESPERORTHIS Schuchert and Cooper 1931

Hesperorthis cf. H. laurentina (Billings)

Plate 37, figures 12–15

Orthis laurentina Billings, 1865, Canada Geol. Survey, Paleozoic Fossils, v. 1, p. 138–139, fig. 115.

Orthis laurentina Billings. Twenhofel, 1928, Canada Geol. Survey Mem. 154, p. 176, pl. XV, figs. 17, 18.

All specimens collected are small. The dorsal valve is gently convex with a distinct but shallow median sulcus.

Figured specimens.—USNM 124806, 124807.

Locality.—D19d (CO), Red River formation, Shell Pine Unit No. 1 well, 9,103–9,116 ft.

Discussions.—The silicified specimens obtained from the core compare so closely in size, outline, and convexity with *H. laurentina* that they are either conspecific or very closely related. The species may be distinguished from Middle Ordovician *H. tricenaria* (Conrad) by the greater convexity of the dorsal valve, fewer number of costae, and lower cardinal area.

Hesperorthis laurentina is described from the Ellis Bay formation of Late Ordovician age on Anticosti Island.

Genus DINORTHIS Hall and Clarke, 1892

Plate 37, figures 16–23
Plate 38, figures 1–8, 11, 15, 17–19

From the red shaly beds of the uppermost Bighorn dolomite along Rock Creek, Wyo. (loc. D1 (CO)), over 50 specimens of large coarse-ribbed dinorthid brachiopods have been assembled from older collections and from those made by me. There has not been time to study these specimens properly, but it seems clear that a minimum of two new species are present.

Numerous specimens closely resemble *Dinorthis* ("*Pionorthis*") *occidentalis* Okulitch, a species of Stony Mountain age, and cannot be distinguished from it on external features; differences in ventral musculature make exact synonomy dubious.

Other specimens are more finely ribbed and probably belong to the subgenus *Plaesiomys* rather than to *Dinorthis* (sensu stricto). The largest specimens of more coarsely ribbed varieties possess gibbous dorsal valves, more strongly convex than in any previously described species of *Dinorthis* or its subgenus *Plaesiomys*. Outlines of some shells are almost rectangular, others almost elliptical, and one other nearly circular.

The abundant wealth of well-preserved material warrants more detailed study than was possible during the preparation of this report.

Similar brachiopods in the cored material cannot be exactly identified but have been listed under the appropriate well. Illustrations of the species of *Plaesiomys* or *Dinorthis* which they most closely resemble are given by Wang (1949, pls. 2 C, D, E and 3C).

Genus PLATYSTROPHIA King, 1850

Platystrophia cf. P. equiconvexa Wang

Platystrophia equiconvexa Wang, 1949, Geol. Soc. America Mem. 42, p. 10–11, pl. 4B.

This species is known in one core from a poorly preserved specimen.

Locality.—D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1, 8,986–9,010 ft.

Superfamily RHYNCHONELLACEA

Genus RHYNCHOTREMA Hall, 1860

Rhynchotrema Hall. Wang, 1949, Geol. Soc. America Mem. 42, p. 11–12.

Many of the species originally assigned to this genus have now been placed in *Lepidocyclus* Wang or in *Hypsiptycha* Wang.

Rhynchotrema iowense Wang

Plate 38, figures 9, 10, 12–14

Rhynchotrema iowense Wang, 1949, Geol. Soc. America Mem. 42, p. 12, pl. 4C

From collections obtained, it is evident that considerable variation exists in this species in the height of fold and sulcus and in their width; though the present collection includes specimens virtually indistinguishable from those illustrated by Wang, comparison with the shell figured here exemplifies this variance.

Figured specimen.—USNM 124813.

Locality.—D1 (CO), red shaly beds in uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Rhynchotrema cf. R. plicata Cooper and Kindle

Rhynchotrema plicata Cooper and Kindle, 1936, Jour. Paleontology, v. 10, no. 5, p. 359, pl. 52, figs. 2, 3, 5, 6.

Although specimens are not well preserved in a dolomitic matrix, the number of costae on fold (5) and in sulcus (4) which distinguish this species is evident as well as a similar outline and convexity of the shells.

Locality.—D90e (CO), dolomitic member, Stony Mountain formation, Empire State Hathaway No. 1 well, 8,556–8,664 ft.

Genus LEPIDOCYCLUS Wang

Lepidocyclus Wang, 1949, Geol. Soc. America Mem. 42, p. 12–13.

Externally shells of this genus are characterized by its strongly globose form and well-developed lamellae forming zigzag lines across the ribbing.

Lepidocyclus perlamellosa (Whitfield)

Plate 39, figures 1–5

Rhynchonella perlamellosa Whitfield, 1882, Paleontology [Wisc. Geol. Survey], Geology of Wisconsin, v. 4, p. 265, pl. 12, figs. 23–25.

Figured specimen.—USNM 124816.

Locality.—D91c (CO), Red River formation, Shell Pine Unit No. 1 well, 9,122–9,128 ft. D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986-9,010 ft. D1 (CO), red shaly beds in uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Lepidocyclus capax (Conrad)

Plate 39, figures 21, 24–27

This species is distinguished from *L. gigas* Wang by its more acutely triangular outline. The two occur together in the uppermost Bighorn dolomite; some of the imperfectly preserved specimens referred to *L. gigas* in the cored material may also belong to this species.

Figured specimen.—USNM 124820.

Locality.—D1 (CO), red shaly beds in uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Lepidocyclus gigas Wang

Plate 38, figures 16, 20–25

Its subelliptical, rather subtriangular, outline characterizes this species. Like specimens of *L. capax* from the same locality, representatives of *L. gigas* from the Rock Creek locality seem to be larger than those reported from other regions.

Figured specimens.—USNM 124814, 124815.

Locality.—D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft. D1 (CO), red shaly beds of the uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Genus Hypsiptycha Wang

Hypsiptycha Wang, 1949, Geol. Soc. America Mem. 42, p. 17.

At present this genus includes three species, *H. hybrida* Wang from the Maquoketa shale, *H. neenah* (Whitfield) from the Maquoketa shale but apparently present in the upper strata of the Montoya formation, and *H. anticostiensis* (Billings), described from the Upper Ordovician of Anticosti Island as well as from Manitoba.

Hypsiptycha cf. H. hydrida Wang

Plate 39, figures 9–11 14, 15, 18–20, 22, 23

Specimens obtained closely resemble Wang's except that the four costae on the fold are of equal strength and height; in his specimens from the Maquoketa the outer two of these four are a little weaker than the middle two.

Although not previously noted, this species is apparently present in the shale of the Stony Mountain.

Figured specimens.—USNM 124818, 124819.

Locality.—D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft. D1 (CO), red shaly beds of the uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo. D35 (CO), Bighorn dolomite, 15 ft above base of upper (Leigh?) member, North Fork of Crazy Woman Creek.

Hypsiptycha cf. H. anticostiensis (Billings)

Plate 39, figures 6–8, 12, 13

Rhynchotrema anticostiensis (Billings). Twenhofel, 1928, Canada Geol. Survey Mem. 154, p. 207, pl. XXI, figs. 4, 5, 6.

The present specimens are considerably smaller than those from Anticosti Island and from beds of the Upper Ordovician in Manitoba (Okulitch, 1943, pl. I, figs. 5, 6). They are readily distinguished from *H. hybrida* Wang by their lower fold and less convex profile.

Figured specimen.—USNM 124817.

Locality.—D1 (CO), red shaly beds of the uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Superfamily SPIRIFERACEA

Genus CATAZYGA Hall and Clark, 1893

Catazyga anticostiensis (Billings)

Catazyga anticostiensis (Billings). Twenhofel, 1928, Canada Geol. Survey Mem. 154, p. 215–216, pl. XX figs. 10–12.

This species is similar to *C. headi* (Billings) but lacks, as far as can be seen from the poor specimens obtained, a vestige of dorsal sinus.

There is, however, a shallow sinus at the front of the ventral valve. Its ribbing is more closely spaced than that of *C. cartieri* Cooper and Kindle; in this respect an obvious misprint should be noted in Twenhofel's description: there are 11 or 12 costellae in 5 mm at the front of the shell, not 8 in 1 mm.

Locality.—D92g (CO), Red River formation, Shell Little Beaver No. 1 well, 8,330–8,335 ft.

Catazyga sp.

Plate 40, figures 1–3

This species differs from *C. headi*, *C. cartieri*, and *C. anticostiensis* in that the dorsal valve is more convex than the ventral. Although the front of the valves is broken in the most complete specimen there seem to have been 12–14 costellae in 5 mm, a number comparable to *C. anticostiensis*. There is no clear evidence for a ventral sulcus, and there certainly is none on the dorsal valve.

Specimens are too poor to warrant full description, but this may be a new species.

Figured specimen.—USNM 124823.

Locality.—D91d (CO), Red River formation, Shell Pine Unit No. 1, well, 9,103–9,116 ft.

Genus ZYGOSPIRA Hall 1862

Zygospira cf. Z. resupinata Wang

Plate 40, figure 5

Zygospira resupinata Wang, 1949 Geol. Soc. America Mem. 42, p. 18, pl. 10A.

This species is known in the cores from a single partly decorticated ventral valve. It is of the size and outline of a typical specimen from the Maquoketa. Possibly because of decortication the ventral fold in which there is a shallow sulcus is not so sharply developed as in the Iowa examples.

Figured specimen.—USNM 124825.

Locality.—D91e (CO), Red River formation, Shell Pine Unit No. 1 well, 9,023–9,043 ft. D35 (CO), Bighorn dolomite, 15 ft above base of upper (Leigh?) member, North Fork of Crazy Woman Creek, Johnson County, Wyo.

Zygospira cf. Z. aequivalvis Twenhofel

Plate 40, figures 6–9, 12

Zygospira recurvirostris aequivalvis Twenhofel, 1928, Canada Geol. Survey Mem. 154, p. 214, pl. XIX, figs. 10–12.

The very small specimens obtained are not well preserved and are difficult to study. The dorsal sulcus is so poorly defined that it is almost impossible to decide how many costae should be included in it. On the entire surface there are 22 in the one complete specimen worked free of the matrix.

Twenhofel states that in general this species has more than 24 costae and notes that 24 is the common number in *Z. recurvirostris* according to Hall's original description. In checking Twenhofel's figures of *Z. acequivalvis* it appears that 18, possibly 20 costae are present, but certainly not more than 24. Furthermore, specimens figured by Hall and Clarke (1894, pl. LIV, figs. 1–6) for *Z. recurvirostris* show a more circular and less convex form than Hall's original illustrations and great variation in the number of costae.

The present specimens are similar to that illustrated by Twenhofel from the English Head formation (of Twenhofel, 1928) and are tentatively considered conspecific.

Figured specimen.—USNM 124826.

Locality.—D91c (CO), Red River formation, Shell Pine Unit No. 1 well, 9,122–9,128 ft. D92b (CO), Red River formation, Shell Little Beaver No. 1 well, 8,531–8,540 ft. D92g (CO), same formation, same well, 8,330–8,335 ft.

Discussion.—It is probable that *Z. recurvirostris* as commonly interpreted is of little use in distinguishing between Middle and Upper Ordovician strata, and that the species needs redefining. Besides there are several specimens from the red shaly beds of the uppermost Bighorn dolomite (loc. D1 (CO)) which could pass for *Z. recurvirostris* (*senso latu*) but which are very probably representative of an undescribed species.

Genus PROTOZEUGA Twenhofel

Protozeuga Twenhofel. Cloud, 1942, Geol. Soc. America Special Paper 38, p. 145–146.

Protozeuga anticostiana Twenhofel

Protozeuga anticostiana Twenhofel, 1928, Canada Geol. Survey Mem. 154, p. 213–214, pl. XXI, figs. 15–17.

Numerous specimens referrable to this species have been obtained from the Stony Mountain formation in the cores. Despite dolomitization a few of these retain coarsely recrystallized spiralia, directed laterally.

Locality.—D90e (CO), dolomitic member, Stony Mountain formation, Empire State Hathaway No. 1 well, 8,556–8,664 ft.

Superfamily STROPHOMENACEA

Genus THAERODONTA Wang, 1949

Thaerodonta Wang, 1949, Geol. Soc. America Mem. 42, p. 19–20.

In his description and discussion of this genus, Wang emphasized four characteristics which differentiate it from *Sowerbyella* Jones. These are a denticulate hinge line and accessory ridges splitting the right and left adductor fields in the dorsal valve, accessory hinge teeth in the ventral valve, and paired conical cavities in the delthyrium. He also implied that this is a genus of Richmond age and that *Sowerbyella* possesses none of these four characteristics.

The present study indicates that one or the other of these two implications is incorrect. Some Trenton species possess denticulate hinge lines and others have paired delthyrial cavities, though in neither case does there seem to be any other of the four characteristics present.

Clearly Wang had no intention of placing ironclad restrictions on *Thaerodonta*, for he included in his generic concept *T. recedens* (Sardeson) in which the accessory hinge teeth are very weak or actually absent, as indicated by his illustrations (Wang, 1949, pl. 11A, fig. 2). Furthermore, in the Maquoketa shale of Iowa a high percentage of the specimens of *T. saxea* (Sardeson) which characteristically has strong accessory hinge teeth may have virtually none.

In the Red River formation in three of the cores studied there is at least one zone in which shells of *Sowerbyella* and (or) *Thaerodonta* are numerous. This same zone appears also to be located at a depth of 8,520–8,570 feet in the Carter Northern Pacific No. 1 well. In the dolomitized matrix, it has been almost impossible to obtain adequate interiors of these shells to tell which of the two genera is present; this distinction may be of importance in substantiating the apparent Late Ordovician age of most, if not all, of the Red River formation.

If *Thaerodonta* is restricted to those species which possess all four critical characteristics given by Wang, it can be considered certainly a Cincinnati index, probably being limited in range to Richmond strata.

If by the same token *Sowerbyella* is restricted to species which possess none of these four features, then there are left numerous intermediate forms, some of Middle and some of Late Ordovician age. To date (1954) too little critical information has been assembled on the number of species which fall in this intermediate category, their character, and their stratigraphic occurrences to permit final classification or their use in dating strata.

Many species previously referred to *Sowerbyella* and *Plectambonites* belong to *Thaerodonta*.

Thaerodonta cf. T. recedens (Sardeson)

Plate 40, figures 26–28

The specimens described are believed to be representative of most, if not all, of the *Sowerbyella*- and *Thaerodonta*-like forms obtained from the Red River formation; at present this cannot be proved, however. Fortunately, the rock matrix in the core from a depth of 8,531–8,540 feet from the Shell Little Beaver No. 1 well is partly dolomitized whereas the specimens are still calcitic. The shells have been removed with formic acid (which acts more selectively than hydrochloric acid) applied very slowly with a medicine-dropper, leaving dolomitic casts of the interiors of a dorsal and ventral valve. From these, rubber molds have been made. Unfortunately some of the dolomitic matrix dissolves in this treatment, and the finest detail is lost.

The ventral valve possesses two conical cavities in the delthyrium separated by a thin septum; the presence of the septum is indicated better on the original cast (pl. 40, fig. 26) than in the rubber mold.

The dorsal hinge line (pl. 40, fig. 27) carries minute denticles for most of its length. The paired median septa are strong and on one side the rudiment of a second pair is present.

The absence of accessory teeth on the ventral hinge is supposedly atypical of the genus. However, *T. recedens* (Sardeson) possesses very weak accessory teeth; in the specimen figured by Wang (1949, pl. 11A, (fig. 2) they are no better developed than those under discussion.

Figured specimens.—USNM 124838, 124839.

Locality.—D92b (CO), Red River formation, Shell Little Beaver No. 1 well, 8,531–8,540 ft. Probably also D90b (CO), same formation, Empire State Hathaway No. 1 well 9,097 ft; D91b (CO) and D91c (CO), same formation, Shell Pine Unit No. 1 well, 9,286–9,294, 9,043 ft; D92a (CO) and D92c (COD), same formation, Shell Little Beaver No. 1 well, 8,550,–8,526 ft.

Genus STROPHOMENA Blainville, 1825

Strophomena cf. S. vetusta James

Plate 40, figure 4

Strophomena vetusta James. Foerste, 1912, Denison Univ. Sci. Lab. Bull., v. 17, p. 98–101, pl. VI, fig. 2E.

Although the imperfect specimen illustrated—the interior of a brachial valve—compares favorably with *S. vetusta*, it may belong properly to *S. neglecta* James. Stratigraphically they are both Late Ordovician species.

Figured specimen.—USNM 124824.

Locality.—D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft.

Strophomena hecuba Billings

Plate 40, figures 10, 11, 13, 16

Strophomena hecuba Billings. Foerste, 1924, Canada Geol. Survey Mem. 138, p. 121, pl. V, fig. 4.

Unless good specimens are obtained *S. hecuba* can be mistaken for *S. fluctuosa*, which Billings stated occurred rarely in Trenton rocks; Foerste (1924, p. 120), however, maintained that both are Late Ordovician species.

Figured specimens.—USNM 124827, 124828.

Localities.—D90e (CO), dolomitic member, Stony Mountain formation, Empire State Hathaway No. 1 well, 8,556–8,664 ft. D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft. D1 (CO), red shaly beds of uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Strophomena cf. S. rugulifera Wang

Plate 40, figure 14

Strophomena rugulifera Wang, 1949, Geol. Soc. America Mem. 42, p. 28, pl. 8B.

It is evident that the specimens studied are much larger than Wang's holotype. They compare closely, however, in outline, degree, and spacing of geniculation and in wrinkled ornamentation.

Figured specimen.—USNM 124829.

Locality.—D90b (CO), Red River formation, Empire State Hathaway No. 1 well, 9,097 ft. D91e (CO), Red River formation, Shell Pine Unit No. 1 well, 9,023–9,043 ft.

Genus MEGAMYONIA Wang, 1949

Megamyonia Wang, 1949, Geol. Soc. America Mem. 42, p. 32.

To the species placed in this genus by Wang should be added *M. ceres* (Billings) and *M. nitens* (Billings).

Megamyonia cf. M. unicostata (Meek and Worthen)

Plate 40, figures 23–25

Megamyonia unicostata (Meek and Worthen). Wang, 1949, Geol. Soc. America Mem. 42, p. 33, pl. 9A.

In this species, topotypic material indicates that near the margins there are about 5 radial rows of pseudopunctae in a transversely measured millimeter and within each row 4 or 5 pseudopunctae per millimeter. No radial row of pseudopunctae can be followed from margin to beak if costellate ornamentation has been removed either artificially or by natural abrasion; 5 to 7 pseudopunctae seem to be the most that can be followed along any radial line. The overall pattern, however, is definitely one of radial lines.

In almost all specimens obtained from the cores, the external costellate ornamentation has been partly removed by natural abrasion from the visceral area of the ventral valve. As a result, there is little or no sign of the strong median costella from which the species takes its name; identifications are, therefore, tentative in most cases and depend on the alate outline which characterizes this species.

Unusually well-preserved casts and molds of this species have been obtained from the Bighorn dolomite.

Figured specimens.—USNM 124835, 124836, 124837.

Locality.—D92b (CO), Red River formation, Shell Little Beaver No. 1 well, 8,531–8,540 ft. D91b (CO), Red River formation, Shell Pine Unit No. 1 well, 9,286–9,294 ft. D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 9,007–9,008 ft. D35 (CO), Bighorn dolomite, 15 ft above base of upper (Leigh?) member, North Fork of Crazy Woman Creek, Johnson County, Wyo.

Megamyonia cf. M. ceres (Billings)

Plate 40, figure 15, 17, 19–21

Leptaena? ceres (Billings). Twenhofel, 1928, Canada Geol. Survey Memo. 154, p. 185, pl. XVIII, figs. 16, 17, 18.

The specimens assigned to this species possess the very strong convexity which differentiates them from all those described and figured by Wang (1949, pl. 9, A, B, C, F). The semicircular outline is closer to *M. knighti* Wang than to any other species. *M. ceres* is more convex and less geniculate than any other species of the genus.

Figured specimens.—USNM 124830, 124831, 124832.

Locality.—D89b (CO), Red River formation, Shell, Richey area, Northern Pacific No. 1 well, 9,980–9,989 ft. D91e (CO), Red River formation, Shell Pine Unit No. 1 well, 9,023–9,043 ft. D91f (CO), lower shale member, Stony Mountain formation, same well, 8,986–9,010 ft. D35 (CO), Bighorn dolomite, 15 ft above base of upper (Leigh?) member, North Fork of Crazy Woman Creek, Johnson County, Wyo.

Megamyonia cf. M. nitens (Billings)

Strophomena nitens Billings, 1865, Canada Geol. Survey, Paleozoic fossils, v. 1, p. 118, fig. 97.

Leptaena? nitens (Billings). Twenhofel, 1928, Canada Geol. Survey Memo. 1954, p. 186, pl. XVII, fig. 19; pl. XVIII, figs. 13, 14.

This species is less convex but more geniculate than *M. ceres* (Billings) and is more convex but less geniculate than *M. unicostata* (Meek and Worthen). Its outline is more alate than *M. ceres* and *M. knighti* but less alate than *M. unicostata.*

Several specimens from the cores and from the red shaly beds of the uppermost part of the Bighorn certainly belong to a new species but are closer in form to *M. nitens* than any other. These like almost all others of the genus found have been so badly abraded that all costellae are removed from the visceral disc of the ventral valve.

Locality.—D91d (CO), Red River formation, Shell Pine Unit No. 1 well, 9,103–9,116 ft. D91e (CO), Red River formation, same well, 9,023–9,043 ft.

Megamyonia aff. M. nitens (Billings)

Plate 41, figures 3, 4, 7

Numerous small specimens that are strongly convex, geniculate, and apparently smooth were found in the red shaly beds of the uppermost part of the Bighorn dolomite on Rock Creek. A few show the faintest suggestions of costellation around the margins, indicating that they may have been similarly ornamented over the entire shell before natural abrasion. These shells unlike typical *Megamyonia* are not all widest at the hinge line. In lateral profile, they are similar to *M. nitens*, but in outline they resemble *M. ceres.*

Figured specimens.—USNM 124842.

Locality.—D1 (CO), red shaly beds in uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo. Probably also amongst specimens from D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft.

Discussion.—In his description of "*Leptaena?*" *nitens*, Twenhofel (1928, p. 186) notes that there are associated in the English Head and Vaureal formations numerous "smaller, nearly smooth, greatly geniculated forms with the part below the geniculation as long as that over the visceral disk." These are probably conspecific or very closely related to the present specimens.

Megamyonia sp.

Plate 40, figure 18

Several shells obtained from the Pine Unit core possess the outline and low convexity of specimens illustrated by Wang (1949, pl. 9, fig. C) from the Maquoketa shale of Iowa. These lack the strong geniculation of *M.* aff. *M. nitens* but are similar in the apparent lack of radial ornamentation, which may be the result of abrasion.

Figured specimen.—USNM 124833.

Locality.—D91f (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft.

Genus ÖPIKINA Salmon, 1942

Öpikina Salmon, 1942, Jour. Paleontology, v. 16, p. 589–591.

Contrary to Salmon's implication (1942, p. 591) this genus (*sensu lato*) is not limited to formations of pre-Cincinnatian age, though it may be necessary eventually to split the post-Trenton forms into more than one genus.

Öpikina? aff. Ö. limbrata Wang

Plate 41, figures 1, 2

Öpikina limbrata Wang, 1949, Geol. Soc. America Mem. 42, p. 22–23, pl. 6B figs. 1–7.

The specimens found are all dorsal valves and lack all but vestiges of the two pairs of lateral septa which characterize the genus.. The septa may have been removed during burial as there is evidence of abrasion of corals and other associated strophomenid shells.

Curiously no associated ventral valve has yet been found with proper type of pseudopunctation to be placed in the genus, though several have the correct general form.

Figured specimens.—USNM 124840, 124841.

Locality.—D91f (CO), lower shale member, Stony Montain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft. D1 (CO), red shaly beds, uppermost part of the Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo. D35 (CO), Bighorn dolomite, 15 ft above base of upper (Leigh?) member, North Fork of Crazy Woman Creek, Johnson County, Wyo.

Discussion.—Not only do these specimens resemble the species from the Maquoketa but also *O. pergibbosa* Foerste from the Stonington beds of Michigan (Hussey, 1926, pl. IV, figs. 7–9).

Genus HOLTEDAHLINA Foerste, 1924

Holtedahlina Foerste. Cooper, 1944, *in* Shimer and Shrock, North American Index Fossils, p. 343, pl. 132, figs. 30–33.

Holtedahlina cf. H. sulcata Foerste

Holtedahlina sulcata Foerste, 1924, Canada Geol. Survey Mem. 138, p. 123–124, pl. XII, figs. 5a, b.

The specimens obtained are poorly preserved in dolomitic limestone but compare closely with Foerste's description and figured specimen. The fold and sulcus are not quite as well defined.

Locality.—D92f (CO), Red River formation, Shell Little Beaver No. 1 well, 8,387 ft. Probably also in D92a (CO), same formation and well, 8,550 ft.

Holtedahlina cf. H. moniquensis Foerste

Plate 41, figures 8, 10, 11

Holtedahlina sulcata moniquensis Foerste, 1924, Canada Geol. Survey Mem. 138, p. 124, pl. XI, fig. 7.

This species differs from *H. sulcata* because it lacks a fold and sulcus at the front and because the hinge line is not the widest part of the shell. The present specimens are poorly silicified and fragmentary, but they show the cardinalia to good advantage (compare pl. 41, fig. 10 with Cooper, 1944, pl. 132, fig. 33).

Figured specimens.—USNM 124844, 124845, 124846.

Locality.—D91d (CO), Red River formation, Shell Pine Unit No. 1 well, 9,103–9,116 ft. Probably D89c (CO), Red River formation, Shell, Richey area, Northern Pacific No. 1 well, 9,974 ft.

PUNCTATE BRACHIOPODA

Genus DICEROMYONIA Wang

Diceromyonia Wang, 1949, Geol. Soc. America Mem. 42, p. 35–36.

Although the three genera *Diceromyonia*, *Resserella*, and *Onniella* are all thought to be represented in the collections from the red shaly beds of the uppermost Bighorn dolomite and although the first two are apparently present in the core samples studied, most attention is given here to *Diceromyonia.* To distinguish positively between the three genera it is necessary to have well-preserved specimens showing the muscle scars of the ventral valves; it is very unlikely that positive generic, let alone specific identifications, can be made in the field where these three are found.

In *Diceromyonia* the diductor scars completely isolate the small oval adductor scars from the front of the entire muscle pattern, being separated from each other by a narrow ridge in most cases (pl. 41, figs. 13, 17; Wang, 1949, pl. 12B, fig. 7; Schuchert and Cooper, 1932, pl. 17, fig. 19). In *Resserella* the diductors are lobate in front but do not meet so that the elongate but shorter adductor tracks have access to the front of the pattern (Schuchert and Cooper, 1932, pl. 17, figs. 4, 22). In *Onniella* both the diductor and adductor scars are of equal length; hence the pattern lacks the bilobed outline found in the other two genera (Schuchert and Cooper, 1932, pl. 17, fig. 33).

Other differences are noted by Wang (1949, p. 35–38). Most of these deal with external form and should be used with care.

Three species of *Diceromyonia* are illustrated here; one is an undescribed species awaiting more thorough study.

Diceromyonia storeya Okulitch

Plate 41, figures 5, 6, 9, 12, 16

Dalmanella storeya Okulitch, 1943, Royal Soc. Canada Trans., 3d ser., sec. 4, v. 37, p. 70–71, pl. I, figs. 1–4.

This species is similar in outline to *D. subrotunda* Wang but is much more convex. Musculature of the ventral valve, not previously known, shows a strong ridge between the diductor scars.

Present specimens have been compared with casts of Okulitch's types as well as with topotypic material.

Figured specimen.—USNM 124843.

Locality.—D91g (CO), lower shale member, Stony Mountain formation, Shell Pine Unit No. 1 well, 8,986–9,010 ft. D1 (CO), red shaly beds of uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

Diceromyonia cf. D. ignota (Sardeson)

Plate 41, figures 13–15, 17–21

Dalmanella ignota (Sardeson). Schuchert and Cooper, 1932, Yale Peabody Mus. Nat. History Mem. v. 4, pt. 1, pl. 17, fig. 19.

In outline this species is less elliptical than *D. tersa* and less circular than either *D. subrotunda* or *D. storeya.* Its convexity is comparable to that of *D. subrotunda.*

Figured specimens.—USNM 124847, 124848, 124849, 124850.

Locality.—D1 (CO), red shaly beds, uppermost Bighorn dolomite, South Fork of Rock Creek, Johnson County, Wyo.

ALGAE

Genus CYCLOCRINITES Eichwald, 1840

Many species belonging to this genus have previously been referred to *Pasceolus* Billings. Of how much use the genus may prove stratigraphically is not yet certain. It is mentioned here because it was found in one of the cores.

The form of a typical specimen is globular and very much resembles a golf ball because of the polygonal depressions on its surface. The specimens from the core (Shell, Richey area, Northern Pacific well 1, 10, 123–10, 135 ft) are about the size of a child's marble, whereas numerous specimens obtained from the base of the Leigh(?) dolomite member of the Bighorn dolomite (North Fork of Crazy Woman Creek, Johnson County, Wyo.) are about 30 mm in diameter.

The genus is known in Middle and Upper Ordovician deposits from Scandinavia across the North American Arctic to the northern United States from Anticosti to the Rocky Mountains.

DESCRIPTIONS OF EARLY ORDOVICIAN TRILOBITES

Special attention is given to two trilobite groups; one of these possesses triangular pygidia with terminal spines. The other is characterized by the "hammer-head" outline of the front of the cranidium. Genera in both groups can be useful guide fossils, but misidentifications within each group can lead to stratigraphic misinterpretation. The importance of securing both cephalic and pygidial parts cannot be overemphasized.

Many trilobites changed shape and ornamentation as they grew. Recent studies on beautifully preserved silicified material by Whittington, Evitt, and Ross have emphasized this. As a result paleontologists are increasingly aware of the necessity for obtaining several specimens of different sizes in order to understand each species. Furthermore, completely articulated exoskeletons are rare. In most places the various parts are found scattered through the enclosing rock, and correct association of heads and tails can be extremely difficult, even for the specialist.

Genus HYSTRICURUS Raymond, 1913

Hystricurus sp.

Plate 43, figures 21, 22, 25, 26

The four small cranidia illustrated may actually belong to two genera but are tentatively considered as representing four different growth stages of the same species. The two smallest specimens have a distinct preglabellar median furrow, the third largest has a very faint suggestion of such a furrow, and the largest has none at all. This change is known in several species of *Hystricurus*.

Except for the lack of pustules, the smallest stage compares favorably with *H. robustus* Ross. The largest is not well enough preserved to be identified specifically.

Figured specimens.—USNM 124891, 124892, 124893, 124894.

Locality.—D70 (CO), Shell, Richey area, Northern Pacific No. 1 well, 10,500–10,509 ft.

Discussion.—The stratigraphic value of these specimens is merely to indicate that the enclosing strata are probably of early Early Ordovician age.

Genus LEIOSTEGIUM Raymond, 1913

Leiostegium manitouensis Walcott

Plate 43, figures 18–20

Leiostegium manitouensis Walcott, 1925, Smithsonian Misc. Coll., 75, no. 3, p. 104, pl. 23, figs. 12–14.

Only cranidia and one hypostome have been obtained. The former compare so closely with Walcott's figured specimen from Colorado that the lack of pygidia does not deter assignment to his species.

The hypostome, although the single specimen is incomplete, is very similar to that of *L. douglasi* Harrington (1938, pl. 6, fig. 4). The subrectangular middle body is deeply creased at the sides by the middle furrow which is carried only faintly across the midline. No true maculae are present.

Figured specimens.—USNM 124888, 124889, 124890.

Locality.—D70 (CO), Shell, Richey area, Northern Pacific No. 1 well, 10,500–10,509 ft.

Discussion.—This species differs from *L. quadratus* (Billings) in the greater relative length of the glabella and in the slight forward taper of the glabella. On the other hand, *L. douglasi* Harrington has a more pronounced forward taper than this species. The hypostome of the Argentinean species seems to be more narrowly elliptical in outline.

Genus LLOYDIA Vodges

Lloydia? cf. saffordi (Billings)

Plate 43, figures 11, 17

Bathyurus saffordi Billings, 1860, Canadian Field Naturalist, v. 5, p. 321, fig. 24.

Bathyurus saffordi Billings, 1865, Geol. Survey Canada, Paleozoic fossils, v. 1, p. 259, 411, figures 241 a, b.

Llloydia saffordi (Billings). Raymond, 1913, Canada Geol. Survey, Victoria Memorial Mus. Bull. 1, VIII, p. 67, pl. VII, fig. 16.

Lloydia saffordi (Billings). Bradley, 1925, Canadian Field Naturalist, v. 39, no. 1, p. 7.

The pygidia illustrated are very similar to *L. saffordi* (Billings), though they may not be properly assignable to that species or even to the genus *Lloydia*. Despite a concerted search no *Lloydia*-type cephalic parts have been found in the cores. Without these parts there can be no certainty that the pygidia do not belong to one of the other asaphid-type genera in the same stratum.

Figured specimens.—USNM 124883, 124884.

Locality.—D66b (CO), Shell Pine Unit No. 1 well, 9,690–9,709 ft.

Discussion.—*Lloydia saffordi* (Billings) has been reported from Division P of the Ordovician strata at Cow Head, Newfoundland, from Point Levis, Phillipsburgh, and Stanbridge, Quebec. In all of these places it is in boulders in conglomerates. Although this species is considered a Beekmantown form, its exact stratigraphic position within the Lower Ordovician is not certain.

Genus MEGALASPIS Angelin, 1851

Megalaspis planilimbata var. cyclopyge Harrington

Plate 43, figures 5, 12, 13

Megalaspis planilimbata var. *cyclopyge* Harrington 1938, La Plata, Univ. Nac., Inst. Mus. Rev., nueva ser., tomo 1, Sec. Paleontologia no. 4, p. 238–239, pl. X, figs. 11, 12, 16, 17.

The present specimens, particularly the pygidia, compare favorably with those described and figured by Harrington. Unfortunately only a part of the front of the cranidium is known from the Argentinean material, and it lacks the palpebral lobes (Harrington, 1938, pl. X, fig. 11). The single cranidium obtained from the cores differs from the South American specimen in the possession of a low, narrow, but distinct preglabellar median ridge. Much of the preglabellar field has been broken off. Comparisons between the two cranidia are almost impossible.

The present specimen has prominent subcircular palpebral lobes located forward of the glabellar midpoint. A median glabellar node is present well to the rear. The posterolateral limbs are stout. The pygidia are of the general construction typical of megalaspid trilobites. Ten distinct rings make up the axis; on each of the pleural platforms are five pleural (or interpleural?) ridges, between each pair of which is a much fainter raised line. The rim is wide, smooth, and gently concave; it is separated from the pleural platforms by a distinct but shallow marginal furrow.

Figured specimens.—USNM 124877, 124878, 124879.

Locality.—D66b (CO), Shell Pine Unit No. 1 well, 9,701–9,705 ft.

Discussion.—The cranidium illustrated is of particular interest for the distinct pattern of muscle scars on its right side. In addition, it is clear from the peculiar scar on the left side of the glabella that this individual was either injured or pathologic.

The significance of the preglabellar ridge may be greater than previous studies would indicate. Such ridges of course can result from deformation of the carapace after moulting (compare Ross, 1951, pl. 28, fig. 5 with 1953, pl. 64, fig. 1). However, if the ridge is a natural morphologic feature we find similar features in *Basiliella carinata* Harrington and *Basilicus marginalis* (Hall), both Middle Ordovician species.

Although the purpose of this ridge is not known, it certainly is as prominent as many of the other criteria used in trilobite taxonomy. It seems peculiar that it should have received no consideration in Kobayashi's revision (1934a, p. 463–465) of the genus *Basilicus*, *B. tyrannus*, the genotype of *Basilicus*, possesses no such ridge, but with it Kobayshi groups *B. marginalis* Hall which does. For the genotype of *Basiliella* Kobayaski chose *B. barrandei* (Hall); this species and *B. romingera* are reported to be synonymous by Harrington (1938 p. 248–249). Some specimens referred to the latter have the preglabellar ridge (Raymond and Narraway, 1910, pl. XVI, fig. 4). On this basis Harrington assigned his species *carinata* to *Basiliella* (1938, p. 247–249, pl. 13, figs. 12, 14, 15, 18).

If additional specimens were available, it might be found that those studied belong to *Basiliella* rather than *Megalaspis*.

Regardless of taxonomic assignment these specimens indicate high rather than low Lower Ordovician stratigraphic position.

A species assigned tentatively to *Basilicus* by Ross (1951, p. 106, pl. 27, figs. 2–5) possesses a similar ridge; it is found in the "G" zone of the Garden City formation. It will be noted that the Utah *Basilicus*? sp., *Basiliella carinata*, and *Basilicus marginalis* have a subtubular rim around the front of the cephalon into which the median ridge runs; unfortunately the specimen illustrated here lacks the frontal portion of the preglabellar field so that the presence or absence of this rim cannot be determined.

Genus MEGALASPIDELLA Kobayasi, 1937

Megalaspidella Kobayashi, 1937a, Imp. Acad. Japan Proc., v. 13, no. 1, p. 15, Tokyo.

Megalaspidella Kobayashi, 1937b Fac. Sci. Jour., Tokyo, Imp. Univ. Jour., Sec. II, v. 4, pt. 4, p. 499.

Megalaspidella Kobayashi; Harrington, 1938, La Plata, Univ. Nac., Inst. Mus. Rev. nueva ser., tomo 1, Sec. Paleontologia no. 4, p. 239–241.

Unfortunately Kobayashi's original generic description was based on inadequate genotypic material, if we are to judge from his figured specimens. Supposedly the glabella is conical, that is, the dorsal furrows converge anteriorly. The figured genoholotype (Kobayashi, 1937b, pl. V, fig. 7) lacks the front end of the glabella, and, although the dorsal furrows do converge between the back of the cranidium and the palpebral lobes, their behaviour in front of the lobes is not certain. Harrington (1938, pl. XII, p. 241, figs. 4, 8) illustrates two immature cranidia of *M. orthometopa* in which the furrows do not converge but are nearly parallel, which difference he mentions in his text. In the present collections specimens tentatively assigned to Harrington's species show parallel dorsal furrows in immature stages, but the glabella expands slightly in front of the palpebral lobes in the larger specimens. The restriction to a "conical" glabella is, therefore, questioned.

Similarly Kobayashi's description calls for a concave border around the pygidium. Both of his figured specimens from the type lot have been deformed. Harrington's specimens (1938, pl. XII, fig. 3) show that the concave border is evident only in those which have been decorticated.

Megalaspidella cf. M. orthometopa Harrington

Plate 42, figures 15, 16, 19, 20

Megalaspidella orthometopa Harrington, 1938, La Plata, Univ. Nac. Inst. Mus. Rev., nueva ser., tomo 1, Sec. Paleontologia no. 4, p. 239–241.

The cranidia in the present collection may differ from the type material as noted above. In those with a length of 7.0 mm the glabella expands very slightly in front of the palpebral lobes; this expansion is distinct in cranidia 8.0 mm long. The pygidia are almost identical to those from the Argentine, although the strong ribbing of decorticated specimens has not been verified.

Figured specimens—USNM 124862, 124863, 124864.
Locality—D66d (CO), Shell, Pine Unit No. 1 well, 9,672–9,690 ft.

Discussion.—In Argentina (Harrington, 1938, p. 280) this species occurs fairly high in the Lower Ordovician strata in the upper part of the range of *Megalaspis planilimbata* var. *cyclopyge*, a form which is present in the Pine Unit No. 1 core at a depth of 9,701–9,705 feet.

Genus KIRKELLA Kobayashi, 1942

Kirkella Kobayashi, 1942, Geol. Soc. Japan Jour., v. 49, p. 118–121.
Ptyocephalus Whittington, 1948, Jour. Paleontology, v. 22, p. 567,572.
Kirkella Kobayashi. Ross, 1951, Yale Peabody Mus. Nat. History, bull. 6, p. 91–94.
Kirkella Kobayashi. Hintze, 1952, Utah Geol. and Minerolog. Survey Bull. 48, p. 181–182.

Because of their distinctive form the species of *Kirkella* are unusually useful index fossils. In the past, listed under such names as

"*Asaphus curiosus*" and "*Billingsura*," the genus has served to mark high Lower Ordovician strata.

The species have special interest because they fall into one of the few trilobite evolutionary sequences which appear to corroborate the theory that "ontogeny recapitulates phylogeny." As shown by Ross (1951, p. 92) the pygidia change with growth from an evenly curved to an angular pentagonal outline in *K. declevita.* Hintze (1952, p. 181–182) has shown that this same change takes place stratigraphically; in other words, the adults of *K. fillmorensis* Hintze, from the "G" zone of Utah and Nevada, of *K. accliva* Hintze from the "H" zone, of *K. yersini* Hintze from the "I" zone, and of *K. vigilans* Whittington from the lower "J" zone represent stages in the same change of shape that we find taking place within the ontogeny of *K. declevita* Ross of the high "J" zone.

At a depth of 9,660–9,666 feet in the Pine Unit No. 1 core, *Kirkella* is represented by a species very similar to *K. fillmorensis* Hintze. It is characteristic of the genus even in immature stages that the marginal furrows of the pygidium be straight or almost straight from the anterior corners to the tip of the axis. In adults of more advanced species with pentagonal pygidia this results in a rim (or border) on each side of the triangular outline; in primitive forms and immature stages the rim on each side has the outline of the segment of a circle. In the species here noted, the marginal furrow is not straight in immature specimens, though it is in the single large adult pygidium found in the core. Two other immature pygidia from a depth of 9,672–9,678 feet are virtually identical.

Kirkella aff. K. fillmorensis Hintze

Plate 42, figures 5, 6, 8–12

Kirkella fillmorensis Hintze, 1952, Utah Geol. and Mineralog. Survey Bull. 48, p. 186, pl. XIV, figs. 1–5.

Except for the course of the marginal furrows on the pygidium of the immature stages, this species is identical in all features to Hintze's from the "G" zone of Utah. The marginal furrows are evenly curved as in unspecialized asaphids; these furrows in *K. fillmorensis* are almost straight or very slightly curved.

Figured specimens.—USNM 124852–124858.

Locality.—D66d–e (CO), Shell Pine Unit No. 1 well, 9,660–9,666, 9,672–9,678 ft.

Discussion.—The two pygidia from the 9,672–9,678-foot depth are clearly immature and are probably from the same species as the higher specimens. One of these is illustrated in figure 17, plate 42. Special attention is called to the upper left corner of figure 6, plate 42, in which the ventral side of the posterior portion of a small fragmentary free cheek is shown; this possesses the distinctive ridge and panderian opening always found in the genus *Kirkella.*

Genus OGYGINUS Raymond, 1912

Ogyginus? sp.

Plate 42, figure 7.

The pygidium illustrated in this report is very tentatively assigned to *Ogyginus.* No cephalic parts were found in association with it, and Whittington (written communication, 1953) believes that some similar pygidia in collections from northeastern North America may belong to quite different bathyurid-type genera. In 1934 Kobayashi (1934b, p. 553, pl. IV, fig. 17) described a pygidium almost identical to the present specimen, assigning it to *Ogyginus,* but it also lacked the corroborating cephalic parts. To this genus he (1937b, p. 495, pl. V, fig. 9) assigned a quite different Bolivian specimen which almost certainly is a bathyurid.

Figured Specimen.—USNM 124859.
Locality.—D66e (CO), Shell Pine Unit No. 1 well, 9,666 ft.

Discussion.—*Ogyginus* typically is from the Llandeilan of the British section. In Korea, Kobayashi (1934b) considers it a contemporary of *Asaphellus,* antedating *Protopliomerops.* As these last two were apparently coexistent in North America, there is some doubt about the Korean relationship. However, neither the present specimen nor Kobayashi's can definitely be assigned to *Ogyginus.*

Genus ASAPHELLUS Callaway, 1877

Asaphellus? sp.

Plate 42, figures 21, 22.

The cranidia and pygidia illustrated furnish one of the few natural associations in the cores in which I have reasonable confidence. Unfortunately the free cheeks are even more fragmentary than the other parts; so far it has not been possible to establish whether or not genal spines are present.

This species possesses a much longer (sagittally) preglabellar field than *A. catamarcensis* Kobayashi (Harrington, 1938, pl. XIII, fig. 8) but is similar in other details of the cranidium and pygidium. From *A. gyracanthus* Raymond it is readily differentiated by the stronger definition of the pygidial axis. Comparisons with *A. tomkolensis* Kobayashi are hampered by the poorness of the material with which Kobayashi (1934b, pl. IV, figs. 1–7) had to work. Actually this species is fairly close to *A. homfrayi* Salter, the genotype; its pygidial axis tapers a little more than the British species and the front of the glabella is a little more distinctly defined.

Figured specimens.—USNM 124867, 124868.
Locality.—D66b (CO), Shell Pine Unit No. 1 well, 9,698 ft.

Discussion.—Assignment of this species to one of the asaphid-type genera like *Ptychopyge* might have been considered if the remotest suggestion of a forked hypostome had been found in association with the cranidia and pygidia. The outline of the glabella is a little more pyriform than is common in *Asaphellus.*

Asaphid trilobites with triangular pygidia

Identification of trilobites with triangular pygidia, possessing a median spine, poses a particularly knotty problem. The following discussion should serve as a warning against attempts to use these pygidia without associated cephalic parts for purposes of correlation.

There are at least seven genera of asaphid type trilobites in which one or more species possesses a triangular pygidium. These are *Megalaspis* Angelin, *Xenostegium* Walcott, *Thysanopyge* Kayser, *Kobayashia* Harrington, *Kayseraspis* Harrington, *Trigonocerca* Ross, *Trigonocercella* Hintze.

The genotype of *Megalaspis* is *M. limbata* Boeck (see Schmidt, 1905, p. 17–20; Taf. I, figs. 9–11), a species with an almost semicircular pygidium; however, *M. acuticauda* Angelin and *M. heros* Dalman have pronouncedly triangular, pointed pygidia. *Megalaspis* possesses an unforked hypostome.

The hypodigm of *Xenostegium* Walcott (1925, p. 124) has been considerably modified from the original. In the past the distinction of this genus has been based in large part upon the triangular form of the pygidium. As a result, several species incompatible because of cranidial form, were included in the genus by Walcott; Ross (1951, p. 100–102) discussed their separation but unfortunately overlooked the earlier treatment of this problem by Harrington (1938, p. 222–228). The latter's discussion had resulted in the erection of the genera *Kobayashia* and *Kayseraspis.* Previously Kobayashi (1934b, p. 557–558) also had noted that Walcott's generic concept included more than one type of pygidium. Harrington's discussion was based largely on this notation.

Xenostegium, as restricted by Ross (1951, p. 100–102), includes species with triangular, spined pygidia and *Bellefontia*-like cranidia and hypostomes. Jaanusson (written communications, 1954–55) has questioned this restriction because of confusion concerning the type species of *Xenostegium.* Ross (in Ms) is attempting to rectify this confusion elsewhere.

Kobayashia Harrington (1938, p. 224) was based on the species *K. taurus* (Walcott), the genotype, and *K. eudocia* (Walcott) (Walcott, 1925, p. 126–127, 128–129, pl. 24, figs. 1, 2, 12), but it is probable that these two do not rightly belong to the same genus (Ross, 1951, p. 100–104, 107; Hintze, 1952, p. 135). There is no known evidence for a triangular-spined pygidium for *K. eudocia* (Walcott) which differs in cranidial features from *K. taurus* (Walcott). Following Hintze (1952, p. 135), *Kobayashia* must be considered a monotypic genus for the present.

Thysanopyge Kayser (Harrington, 1938, p. 225–227, 231, 234, pl. XI, figs. 6, 8–10, 13) possesses a triangular pygidium very similar to some species of *Megalaspis* but differs in that its margin is ornamented with many small sharp spines and in the narrowness of its axis. Three pairs of distinct but shallow furrows are present on the glabella, the posterior pair probably being analogous to the occipital furrow. The form of the hypostome is not known.

Trigonocerca Ross (1951, p. 104–105, pl. 26, figs. 5–13) is distinguished from other genera with triangular pygidia by the outline of the cranidium which is somewhat similar to that of *Isotelus*. The segmentation of the pygidium can only be distinguished in decorticated specimens if at all. The hypostome, although "winged," is intermediate in form between the strongly forked and unforked asaphid types.

Trigonocercella Hintze (1952, p. 239–240, pl. XI, figs. 1–5), at present monotypic, differs from *Trigonocerca* in its strongly forked hypostome and in the acuminate outline of its cephalon.

Finally, *Kayseraspis* Harrington (1938, p. 228–231, pl. X, figs. 1, 2, 6, 7, 10, 14, 15, 18; pl. XI, figs. 1, 3) possesses a less triangular pygidium than the other genera; its terminal spine originates in the margin as does that of *Trigonocerca* and in a manner not unlike that of *Bellefontia? acuminiferentis* Ross (1951, p. 99–100, pl. 25, figs. 7–9; Hintze, 1952, p. 241). The axial and pleural segmentation of the pygidium is very faint. There are no glabellar furrows; the glabella is better defined than in *Trigonocerca* but not so well defined as in *Xenostegium* (as restricted by Ross, 1951). The hypostome has an evenly rounded posterior end. As noted by Harrington (1938, p. 229) the glabella is similar to that of certain species of *Asaphellus* except that it expands slightly anterior to the palpebral lobes.

Although all seven of these genera have not been found within the same stratigraphic section, several have; it is known that *Xenostegium* (as restricted by Ross, 1951) and *Trigoncerca* hold to different zones in the Lower Ordovician strata of Utah and Nevada and are, therefore, very useful indices. Hintze (1952, p. 135) is of the opinion that *Kobayashia* is virtually a contemporary of *Xenostegium* (as restricted by Ross, 1951) but this needs verification; Walcott's faunal lists on one of which the opinion is based are not completely reliable (see pp. 465, 467). Exactly where the other genera, two of them Argentinean, fit into the scheme of North American zonation is not certain.

The above problem has been stated here because at least two of the above genera have been recognized in the Williston basin cores. Several specimens, none well preserved, have been located in the Shell Pine Unit No. 1 core at 9,701–9,708 feet; these are questionably referred to *Kayseraspis*. In Shell's Southwest Richey No. 32–33B well *Xenostegium* is found at depths below 10,250 feet.

Genus KAYSERASPIS Harrington, 1938

Kayseraspis aff. K. asaphelloides Harrington

Plate 43, figures 1–4, 6, 7

Kayseraspis asaphelloides Harrington, 1938, La Plata, Univ. Nac., Inst., Mus. Rev. nueva ser., tomo, Sec. Paleontologia, No. 4, pp. 228–230, pl. 10, figs. 1, 2, 6, 7, 10, 14, 15, 18.

The specimens included here are probably not conspecific with the species *K. asaphelloides* Harrington and, because the cranidial association is uncertain, may not even belong to the same genus. The pygidia clearly do not belong to *Thysanopyge* because they lack spines around the border and their interpleural grooves are faint. The termination of the axis and its relation to the marginal furrow distinguish these pygidia from those of *Xenostegium* (as restricted by Ross, 1951). The distinctness of segmentation and definition of the axis especially in immature stages (compare pl. 43, figs. 6, 7, with Ross, 1951, pl. 26, figs 5–9, and with Hintze, 1952, pl. XI, figs. 6, 9, 10, 14) differentiate them from *Trigonocerca* and *Trigonocercella*. Except for *Kayseraspis*, the form of the two incomplete associated cranidia preclude assignment to any of the seven genera discussed above. As far as can be told from the fragmentary material, the present cranidia differ only slightly from those of *K. asaphelloides* (Harrington, 1938, pl. X, fig. 6). The pygidia may be a little more triangular in outline than those of the Argentinean species.

Figured specimens.—USNM 124871–124876.
Locality.—D66b (CO), Shell, Pine Unit No. 1 well, 9,701–9,708 ft.

Trilobites with "hammer-head" cranidia

There are several useful index fossils amongst the trilobites with "hammer-head" cranidia. This hammer-head appearance results from the strongly divergent course of each facial suture in front of the eyes. Such forms are found in both Cambrian and Lower Ordovician strata; distinguishing them can be important in subdividing these strata.

The present state of classification of these particular trilobites is unsatisfactory. For stratigraphic purposes a clarification of the classification is not necessary and a few rules of thumb will aid in distinguishing between the various genera.

In common these trilobites have the hammer-headed frontal area of the cranidium, many small pits in the marginal furrow, and prominent raised crescentic palpebral rims above the eyes; the pygidia of all but two genera are digitate—the pleura are tipped by sharp spines. In almost all species, at least one pair of glabellar furrows is present; these are usually sigmoid in shape.

At risk of oversimplification these trilobites can be placed in three groups. In the first (pl. 7, figs. 23, 24, 27–30) the glabella is almost rectangular, the sides being straight. A small, almost semicircular, fixed cheek lies inside the crescentic thickened palpebral rims. This group includes the Cambrian genera *Richardsonella*, *Levisella*, and *Loganellus*, and the Lower Ordovician genera *Kainella* and *Pseudokainella*. Most of the species of these genera have a wide (sagittally) preglabellar field on which are radiating ridges. The genal spines are based at the rear "corners" of the cephalon in a manner "normal" for trilobites.

The second group is differentiated from the first on one important feature in particular. There are no fixed cheeks. The glabella is laterally swollen between the eyes in such a way as to fill all the space between the crescentic palpebral lobes (pl. 42, fig. 13). The preglabellar field in this group is usually narrow (sagitally). Another important distinction is the point of origin of the genal spine on the free cheeks; it invariably stems from a point well forward in the rim, not from the posterolateral "corner" of the cephalon as in the first group. This group includes *Apatokephalus* and *Scinocephalus*.

Only one genus, *Menoparia*, is known in the third group which is almost identical with the second. The chief difference is in the fixed cheeks. Here the glabella is swollen between the eyes; but it does not extend all the way to the palpebral rims, nor is it straight sided like the first group.

To date (1954) *Kainella* of the first group and *Apatokephalus* of the second have been found in the cores under study.

In the first group *Kainella* is a very valuable index genus; it is known from both North and South America and Korea very close to the bottom of the Ordovician system. It clearly is not at the very base of the Lower Ordovician, for it occurs in the "D" zone of the Garden City formation in Utah and of the Pogonip group in Nevada (Hintze, 1952, p. 189). *Pseudokainella* is reported from slightly higher strata in Argentina (Harrington, 1938) but not in North America; Hintze's *Pseudokainella? armatus* (1952) from Nevada and Utah clearly belongs to a more primitive genus, as yet unnamed, and probably related to the second group. *Richardsonella* is strikingly similar to *Kainella*.

With the possible exception of *R. granulata* (Raymond) the angle at which projections of the diverging anterior facial sutures meet is under 120° in *Richardsonella.* In the known species of *Kainella* this angle exceeds 150°. In addition, the pygidia of *Richardsonella* are relatively wider than those of *Kainella* and have spinose tips on all the pleura; the pleura themselves are not of the elongate graceful form found in *Kainella.*

Distinction between these two genera is important, for *Richardsonella* has so far been reported only from Upper Cambrian rocks. *Levisella* and *Loganellus* are very similar to *Richardsonella* but do not have spinose pygidia; they are both of Late Cambrian age.

For our present purposes we need only list *Apatokephalus* and *Scinocephalus* in the second group. The first of these apparently ranges through almost the entire Lower Ordovician sequence, whereas the latter has only been reported from about the middle third of it. The two are readily distinguished on the basis of their pygidia and on the inflation of the glabella of *Scinocephalus.*

The third group includes only *Menoparia* which has been reported from the Lower Ordovician strata of Utah and Nevada. Because its known range is more definitive than that of *Apatokephalus* it is to be hoped that *Menoparia* will eventually be found in some of the Williston basin cores.

As noted in the discussion of trilobites with triangular pygidia, it is extremely important that identifications of the hammer-head genera (and resulting stratigraphic correlations) should not be based on either cranidia or pygidia alone. This is made increasingly clear in the discussion under *Kainella* (pp. 501–502).

Genus APATOKEPHALUS Brögger 1897

Apatokephalus aff. A. canadensis Kobayashi

Plate 42, figure 13

Apatokephalus Canadensis Kobayashi, 1953, Japanese Jour. Geology and Geography, v. 23, p. 52, pl. III, fig. 1.

In general form the cranidium at hand is very similar to that of *Apatokephalus canadensis* Kobayashi but does not possess a pustulose surface. The anterior pair of glabellar furrows is more nearly obsolete. Across the front of the glabella close to the marginal furrow is a transverse crease which apparently represents the preglabellar portion of the dorsal furrow. The infinitesimal space between the crease and the pitted marginal furrow proper would represent the preglabellar field. A similar crease is incipient in the holotype of *Scinocephalus solitecti* Ross (1951, pl. 20, fig. 32).

Figured specimen.—USNM 124860.

Locality.—D66e (CO), Shell Pine Unit No. 1 well, 9,660–9,666 ft.

Discussion.—Although Brögger's sketches of *Apatokephalus serratus*, the genotype, indicate an extensive preglabellar field, photographs of topotype material furnished by Whittington (written communication, 1950) show that this is exaggerated, as do Harrington's illustrations (1938, pl. V, figs. 1, 2) of material from the Argentine. Nonetheless the space between the front of the glabella and the marginal rim is wider (sagittally) than in the present specimen of *A. canadensis.*

The stratigraphic significance of this specimen is very indefinite and is covered above (p. 465).

Genus KAINELLA Walcott, 1924

Kainella sp.

Plate 43, figures 23, 24, 27–30

This species is represented by three fragmentary preglabellar fields, two cranidia from which preglabellar fields have been broken, three complete cranidia (all very small and immature), one free cheek, one fair-sized but damaged pygidium, and two very poor small pygidia.

The glabella is subrectangular and low. Two distinct pairs of glabellar furrows are present. The palpebral lobes bear strong rims and the outline of each is gently curved. Sagittally the preglabellar field is one-fifth as long as the glabella. On the field are two sets of bifurcating ridges. Many pits are closely spaced in the marginal furrow behind the wide (sagittally) rim.

The free cheek possesses a gently convex ocular platform, like the glabella granulose but not pustulose on its surface, and limited distally by a distinct but shallow marginal furrow. This furrow fades out a very short way distad on the long, slender genal spine after being joined in an acute angle by the lateral extension of the occipital furrow.

The largest and best preserved pygidium unfortunately lacks the critical posterior portion of the axis; it shows that at least five rings were present. The obverse of this specimen strongly suggests, but does not prove, that there were only five rings ahead of a bluntly rounded terminus, which reached almost to the rear of the pygidium. Three pairs of pleura are present, the first two bearing slender spinose tips. The third pair ends bluntly as part of the confluent posterior apron around the terminus of the axis in the manner of *K. billingsi* Walcott and *K. orientalis* Rasetti.

Figured specimens.—USNM 124895–124900.

Locality.—D70 (CO), Shell Oil Co., Richey area, Northern Pacific No. 1 well, 10,500–10,509 ft.

Discussion.—It is of particular importance to note that the number of paired pleura on the pygidium changes with growth. A pygidium only 5.25 mm in length possess but two pairs, both spinose. There is the merest suggestion that the third pair is about to be developed at this stage. Another specimen 5.8 mm in length has the third pair well developed and forming the circumterminal apron.

Intermediate problems in identification result from this discovery, particularly because so much weight is placed on the number of axial and pleural segments in determining species of this genus.

If this species with continued growth adds one more axial ring, if the axis shortens relative to the overall midlength of the pygidium, and if the pygidium eventually attains a length over 25 mm, it is almost certainly assignable to *K. billingsi* Walcott. The apparent difference in the palpebral lobes may not be a real one. First, it can be demonstrated that in many trilobites during growth, the length (exsagittal) of the palpebral lobes does not increase proportionately with the increase in overall length of the cranidium, as a result young individuals seem to have larger eyes than adults. Second, the palpebral rims of the holotype of *K. billingsi* Walcott (1925, pl. 22, fig. 1) have been broken off, and there is no certainty that their size is correctly portrayed in the retouched photograph.

If, on the other hand, the present specimens represent essentially the adult condition, confident assignment to any one of the other described species is virtually impossible.

Kainella orientalis Rasetti clearly possesses a more rotund glabella with very faint glabellar furrows and a relatively wider pygidium, though agreeing well in other details. This and *K. billingsi* are the only two species which can be considered certainly adult in proportions as described and figured.

Kainella meridionalis Kobayashi is the only other species for which both cranidium and pygidium are known. Descriptions and illustrations of this species present much conflicting evidence.

Kobayashi's figure of *Kainella meridionalis* (1935, pl. XI, fig. 10) has been retouched to show seven rings in front of the axial terminus and four pairs of spinose pleura, none without spines. In 1937 Kobayashi (1937b, pl. VI, fig. 8) published a photograph of a pygidium belonging to the same species. This specimen is not well preserved and appears asymmetric in the photograph. The front pleuron is missing on the right side, but the second and third are clearly spinose. Whether or not the fourth bears a spine, it is impossible to tell. Four axial rings are present, but it appears extremely unlikely that there were originally more than five in front of the axial terminus. The previously described specimen is 15 mm long, whereas the later one is 9.3 mm in length. Harrington (1938, pl. IV, figs. 10, 23) illustrated two pygidia which he assigned to *K. meridionalis;* one of these is too poor to be of critical value (fig. 10). The other (fig. 23) is about 8 mm long. Its axis is composed of five, possibly six, rings plus the terminus; there appears to be three pairs of spinose pleura and one pair without spines. This last agrees better with Kobayashi's second than with his first specimen.

The fact remains that none of the specimens so far described is well enough preserved to be certain of the specific characteristics. Comparisons with other material are extremely unsatisfactory, if not impossible.

Compared to the species under study, *Kainella colombiana* Harrington and Kay possesses relatively larger, semicircular palpebral lobes and a longer (sagittally) preglabellar field. No pygidium is known. The glabellar outline in *K. conica* Kobayashi contracts anteriorly and its preglabellar field is only one-tenth as long (sagittally) as the glabella. No pygidium is known.

According to Kobayashi (1953, p. 45, pl. III, fig. 9), *Kainella euryrachis* has six axial rings plus terminus on the pygidium, although his photograph shows clearly that there are only five; he has counted the articulating half ring. Apparently all three pleural pairs are spinose. Despite his remarks this specimen could not possibly be mistaken for *K. billingsi* Walcott because its axis takes up almost all of the pygidial midlength and consists of one less ring. If the third pair of pleura are actually not spinose, *K. euryrachis* may be synonymous with *K. rugosa* Harrington; the axial terminus is too short for the species under study here.

Kainella flagricauda (White), known only from a very small pygidium, possesses only four axial rings. *K. inexpectans* (Walcott) is based on an immature cranidium and is of little value for purposes of comparison.

In *Kainella primigena* Kobayashi the anterior courses of the facial sutures diverge at a much smaller angle than is common in *Kainella* and the glabella is creased by three rather than two pairs of furrows; this species is almost certainly assignable to *Richardsonella*. *K. stenorachis* Kobayashi differs from all other species in the possession of seven axial rings in the pygidium.

Except for *Kainella billingsi* and *K. orientalis* these species are based on small specimens. How many, if any, will eventually be placed into synonymy, if and when larger more mature specimens are found, cannot be foretold. Other synonyms may result when cranidia and pygidia are discovered for all the species so far described.

Genus PROTOPLIOMEROPS Kobayashi

Protopliomerops cf. P. superciliosa Ross

Plate 42, figure 18

The single small poorly preserved specimen obtained indicates that the shapes of the glabella and of the remaining palpebro-ocular ridge closely resemble those of *P. superciliosa* Ross.

Figured specimen.—USNM 124866.
Locality.—D66d (CO), Shell, Pine Unit No. 1 well, 9,672–9,678 ft.

Discussion.—In Utah this species is an index to the "F" zone of the Garden City formation (Ross, 1951, p. 28–29). It is clearly younger than the *Kainella-Leiostegium* zone and indicates approximate correlation with the bottom of the middle third of the Lower Ordovician strata as developed in the Basin and Range province.

Undetermined species

Undetermined pygidium 1

Plate 42, figure 23

Although not identical, the small pygidium illustrated here is very similar to that figured by Hintze (1952, pl. IX, fig. 9) from the lower part of the "G" zone of Utah and Nevada. Hintze's specimen is more nearly pentagonal. The two are enough alike to suggest possible correlation.

Figured specimen.—USNM 124869.
Locality.—D66d (CO), Shell, Pine Unit No. 1 well, 9,679–9,684 ft.

Undetermined pygidium 2

Plate 43, figure 15

The illustrated specimen is poorly preserved as a flattened imprint in black shaly sediment. It bears a striking resemblance to a pygidium figured by Ross (1951, pl. 19, figs. 30, 31) from the "F" zone of the Garden City formation, likewise unidentified.

Figured specimen.—USNM 124886.
Locality.—D66a (CO), Shell, Pine Unit No. 1 well, 9,715 ft.

Discussion.—This specimen suggests a correlation with the "F" zone of the Lower Ordovician strata of Utah and Nevada, well above the *Leiostegium-Kainella* zone ("D" zone of Utah and Nevada) of the Shell Richey area, Northern Pacific No. 1 well.

SELECTED BIBLIOGRAPHY

Amsden, T. W., and Miller, A. K., 1942, Ordovician conodonts from the Bighorn Mountains of Wyoming: Jour. Paleontology, v. 16, p. 301–306, pl. 41.

Baillie, A. D., 1951, Silurian geology of the Interlake area, Manitoba: Manitoba Dept. Mines and Nat. Res., Pub. 50–1, 81 p., 1 pl.

——— 1952, Ordovician geology of Lake Winnipeg and adjacent areas, Manitoba: Manitoba Dept. Mines and Nat. Res., Pub. 51–6, p. 1–64.

Barnes, T. R., 1953, Williston basin—New province for oil exploration: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 340–354, 12 figs.

Bassler, R. G., 1953, Bryozoa—Treatise on invertebrate Paleontology, part G. p. G1–G253, 175 figs.

Bishop, D., and others, 1952, Radioactivity log correlation section: Billings Geol. Soc. Guidebook, 3d Ann. Field Conf., in pocket.

Blackwelder, E., 1918, New geological formations in western Wyoming: Wash. Acad. Sci. Jour., v. 8, p. 417–426.

Bradley, J. H., Jr., 1925, Trilobites of the Beekmantown in the Phillipsburg region of Quebec: Canadian Field Naturalist, v. 39, p. 5–9, pl. 1.

Branson, E. B., Mehl, M. G., and Branson, C. C., 1951, Richmond conodonts of Kentucky and Indiana: Jour. Paleontology, v. 25, p. 1–17, pls. 1–4.

Cloud, P. E., 1942, Terebratuloid Brachiopoda of the Silurian and Devonian: Geol. Soc. America Special Paper 38, 150 p., 26 pls.

Cloud, P. E., Jr., and Barnes, V. E., 1946, The Ellenburger group of central Texas: Tex. Univ. Pub. 4621, 405 p., 44 pls.

Cooper, G. A., 1944, Phylum Brachiopoda, *in* Shimer, H. W., and Shrock, R. R., North American index fossils, New York, John Wiley & Sons, Inc., p. 227–365, pls. 105–143.

——— 1952, New and unusual species of brachiopods from the Arbuckle group in Oklahoma: Smithsonian Misc. Coll., v. 117, no. 14, p. 1–28, 4 pls.

Cooper, G. A., and Kindle, C. H., 1936, New brachiopods and trilobites from the Upper Ordovician of Percé, Quebec: Jour. Paleontology, v. 10, p. 348–372, pls. 51–53.

Darton, N. H., 1901, Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Ann. Rept. 21, pt. 4, p. 497–607.

——— 1904, Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain front range: Geol. Soc. America Bull., v. 15, p. 379–448.

——— 1906, Description of Cloud Peak and Fort McKinney quadrangles, Wyoming: U. S. Geol. Survey Geol. Atlas, folio 142.

——— 1909, Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Prof. Paper 65.

Darton, N. H., and Paige, S., 1925, Description of the central Black Hills: U. S. Geol. Survey Geol. Atlas, folio 219.

Dowling, D. B., 1895, Notes on the stratigraphy of the Cambro-Silurian rocks of eastern Manitoba: Ottawa Field Naturalists' Club Trans., v. 9, p. 67–68.

——— 1900, Report on the geology of the west shore and islands of Lake Winnipeg: Canada Geol. Survey Ann. Rept. 11, F, 100 p., map.

Duncan, H. M., 1956, Ordovician and Silurian coral faunas of western United States: U. S. Geol. Survey Bull. 1021–F, p. 167–193.

Evans, C. S., 1933, Bristo-Dogtooth map area, British Columbia: Canada Dept. Mines, Geol. Survey Summary Rept. 1932, part A II, p. 106–176.

Flower, R. H., 1952, New Ordovician cephalopods from eastern North America: Jour. Paleontology, v. 26, p. 24–59, pls. 5–10.

Foerste, A. F., 1910, Preliminary notes on Cincinnatian and Lexington fossils of Ohio, Indiana, Kentucky, and Tennessee: Denison Univ. Sci. Lab. Bull., v. 16, p. 15–100, pls. 1–6.

——— 1912, *Strophomena* and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana, and Kentucky: Denison Univ. Sci. Lab. Bull., v. 17,–139, pls. I–XVIII.

——— 1914, Notes on the Lorraine faunas of New York and the Province of Quebec: Denison Univ. Sci. Lab. Bull. v. 17, p. 247–328, pls. I–V.

——— 1924, Upper Ordovician faunas of Ontario and Quebec: Canada Geol. Survey Mem. 138, 255 p., 46 pls.

——— 1929a, Upper Ordovician and Silurian of American Arctic and sub-Arctic regions: Denison Univ. Sci. Lab. Jour., v. 24, p. 27–79, 3 pls.

——— 1929b, The cephalopods of the Red River formation of southern Manitoba: Denison Univ. Sci. Lab. Jour., v. 24, p. 129–235, 39 pls.

Furnish, W. M., Barragy, E. J., and Miller A. K., 1936, Ordovician fossils from upper part of type section of Deadwood formation, South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 20, p. 1329–1341, pls. 1, 2.

Harrington, H. J., 1938, Sobre las faunas del ordoviciano inferior del norte Argentino: La Plata, Univ. Nac., Inst. Mus. nueva ser, tomo 1, Sec. Paleontologia, no. 4, p. 109–289, pls. I–XIV.

Hintze, L. F., 1952, Lower Ordovician trilobites from western Utah and eastern Nevada: Utah Geol. and Mineralog. Survey Bull. 48, p. 1–249, pls. I–XXVIII.

Hussey, R. C., 1926, The Richmond formation of Michigan: Mich. Univ., Mus. Geology Contr., v. 2, no. 8, p. 113–187, 11 pls.

Kirk, Edwin, 1930, The Harding sandstone of Colorado; Am. Jour. Sci., 5th ser., v. 20, p. 456–466.

Kobayashi, Teiichi, 1934a, The Cambro-Ordovician formations and faunas of South Chosen, part I, Middle Ordovician faunas: Jour. Fac. Sci., Tokyo Imp. Univ., v. 3, pt. 8, p. 329–519, pls. I–XLIV.

——— 1934b, The Cambro-Ordovician formations and faunas of South Chosen, part II, Lower Ordovician faunas: Jour. Fac. Sci., Tokyo, Imp. Univ., v. 3, pt. 9, p. 521–585, pls. I–VIII.

——— 1935, On the *Kainella* fauna of the basal Ordovician age found in Argentina: Japanese Jour. Geology and Geography, v. 12, p. 59–67, pl. XI.

——— 1937a, A brief summary of the Cambro-Ordovician shelly faunas of South America, part 2, the list of nongraptolite faunas with descriptions of three new genera and one new subgenus of trilobites: Imp. Acad. Japan Proc., v. 13, no. 1, p. 12–15, 4 figs., Tokyo.

——— 1937b, The Cambro-Ordovician shelly faunas of South America: Fac. Sci. Jour. Tokyo, Imp. Univ., Sec. II, v. 4 pt. 4, p. 369–522, pls. I–VIII.

——— 1953, On the Kainellidae: Japanese Jour. Geology and Geography, v. 23, p. 37–61, pls. III–IV.

Lochman, Christina, and Duncan, D. C., 1950, The Lower Ordovician *Bellefontia* fauna in central Montana: Jour. Paleontology, v. 24, p. 350–353, pl. 52.

Macauley, George, and Leith, E. I., 1951, Winnipeg formation of Manitoba [abs.]: Geol. Soc. America Bull., v. 62, p. 1461–1462.

McCoy, M. R., 1952, Ordovician sediments in the northern Black Hills: Billings Geol. Soc., Guidebook, 3d Ann. Field Conf., p. 44–48.

McKee, E. D., 1938, The environment and history of the Toroweap and Kaibab formations of northern Arizona and southern Utah: Carnegie Inst. Washington Pub. 492, 268 p., 48 pls.

Miller, A. K., 1930, The age and correlation of the Bighorn formation of northwestern United States: Am. Jour. Sci., 5th ser., v. 20, p. 195–213.

Okulitch, V. J., 1943, The Stony Mountain formation of Manitoba: Royal Soc. Canada Trans., 3d ser., v. 37, sec. 4, p. 59–74, 2 pls.

Rader, M. T., Jr., 1952, Ordovician and Silurian carbonates of the central Williston basin: Billings Geol. Soc. Guidebook, 3d Ann. Field Conf., p. 48–55.

Raymond, J. E., and Narraway, J. E., 1910, Notes on Ordovician trilobites, III, Asaphidae from the Lowville and Black River: Carnegie Mus. Annals, v. 7, p. 46–59, pls. XV–XVI.

Raymond, P. E., 1913, A revision of the species which have been referred to the genus *Bathyurus:* Canada Geol. Survey, Victoria Memorial Mus., Bull. 1, p. 51–80, pl. VII.

Ross, R. J., Jr., 1951, Stratigraphy of the Garden City formation in northeastern, Utah, and its trilobite faunas: [Yale Univ.] Peabody Mus. Nat. Hist. Bull. 6, p. 1–155, pls. 1–36.

——— 1953, Additional Garden City (Early Ordovician) trilobites: Jour. Paleontology, v. 27, p. 633–646, pls. 62–64.

Salmon, E. S., 1942, Mohawkian *Rafinesquinae:* Jour. Paleontology, v. 16, p. 564–603, pls. 85–87.

Schmidt, F. von, 1905, Revision der ostbaltischen silurischen Trilobiten, Abt. V Asaphiden, *Lief. 3:* Mém. Acad. Imp. Sci. St. Pétersbourg, v. 19, no. 10 p. 1–62, pls. I–VIII.

Schuchert, Charles, and Cooper, G. A., 1932, Brachiopod genera of the suborders Orthoidea and Pentameroidea: [Yale Univ.] Peabody Mus. Nat. History Mem., v. 4, pt. 1, 190 p., 29 pls.

Stearn, C. W., 1953, Ordovician-Silurian boundary in Manitoba: Geol. Soc. America Bull., v. 64, p. 1477–1478.

Twenhofel, W. H., 1928, Geology of Anticosti Island: Canada Geol. Survey Mem. 154, 351, p., 60 pls.

Twenhofel, W. H., and others, 1954, Correlation of the Ordovician formations of North America, v. 65, p. 247–298, 2 charts.

Walcott, C. D., 1892, Preliminary notes on the discovery of a vertebrate fauna in Silurian (Ordovician) strata, Colorado: Geol. Soc. America Bull. 3, p. 153–172.

——— 1925, Cambrian Geology and paleontology, V., No. 3, Cambrian and Ozarkian trilobites: Smithsonian Misc. Coll., v. 75, no. 3, p. 61–173, pls. 15–24.

——— 1928, edited by C. E. Resser, Cambrian geology and paleontology, V; No. 5, Pre-Devonian Paleozoic formations of the Cordilleran provinces of Canada: Smithsonian Misc. Coll., v. 75, no. 5, p. 174–377, pls. 25–108.

Wang, Y., 1949, Maquoketa Brachiopoda of Iowa; Geol. Soc. America Mem. 42, 39 p., 12 pls.

Whiteaves, J. F., 1895, Systematic list, with references, of the fossils of the Hudson River or Cincinnati formation at Stony Mountain, Manitoba: Geol. Survey Canada, Paleozoic fossils, v. 3, pt. 2, p. 111–128.

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[Italic numbers indicate descriptions]

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PLATE 37

[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Streptelasma trilobatum* Whiteaves (p. 474).

1. Calyx; 2, left alar side, USNM 124800. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

3, 5–7. "*Holophragma*" sp. (p. 474).

3. View of the cardinal side, ×2; 7, calyx, ×2, USNM 124801.

5. Alar side; 6, same view, ×2, USNM 124801. From Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

4, 8. *Streptelasma* cf. *S. latusculum* (Billings) (p. 474).

4. View of counter side; 8, calyx, USNM 124803. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

9. *Favosites* (*Paleofavosites*) cf. *F. prolificus* (Billings) (p. 474).

Fragment of corallum, USNM 124804. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

10, 11. *Sceptropora* cf. *S. facula* Ulrich (p. 474).

10, 11. Oblique and lateral views of one of the articulating segments, ×20, USNM 124805. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

12–15. *Hesperorthis* cf. *H. laurentina* (Billings) (p. 475).

12, 13. Dorsal valve, external and internal views, ×3, USNM 124806. (Right side of valve broken after photographing interior.)

14. Interior of ventral valve, ×4, USNM 124807.

15. Interior of dorsal valve, showing bladelike brachiophore, ×3. All from Upper Ordovician, Red River formation, loc. D91d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,103–9,116 ft.

16, 19, 20, 23. *Dinorthis* (*Plaesiomys* (?)) cf. *D.* (*P.*) *occidentalis* Ladd (p. 475).

16. Lateral view; 19, posterior view; 20, 23, dorsal and ventral views, USNM 124808. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

17, 18, 21, 22. *Dinorthis* (*Pionorthis* (?)) cf. *D.* (*P.*) *occidentalis* Okulitch (p. 475).

17, 18. Lateral and posterior views; 21, 22, dorsal and ventral views, USNM 124809. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek. Johnson County, Wyo.

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[Figures natural size unless otherwise indicated]

FIGURES 1, 2, 5, 6. *Dinorthis (Pionorthis(?)) n. sp. (p. 475).*

1, 2. Ventral and dorsal views; 5, 6, lateral and posterior views, USNM 124810. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

3, 4, 7, 8, 11. *Dinorthis*(?) sp. (p. 475).

3, 7, 11. Lateral, posterior, and anterior views; 4, 8, Dorsal and ventral views, USNM 124811. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo. (The ventral valve of Okulitch's two cotypes for *Pionorthis occidentalis* may belong to this species.)

9, 10, 12–14. *Rhynchotrema iowense* Wang (p. 476).

9, 13. Dorsal and ventral views, × 2; 10, 12, 14, Anterior, posterior, and lateral yiews, × 2. USNM 124813. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

15, 17–19. *Dinorthis*(?) (*Pionorthis*(?)) n. sp. (p. 475).

15, 19. Dorsal and ventral views; 17, 18, posterior and lateral views, USNM 124812. Upper Ordovician, red shaly beds in the uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

16, 20–25. *Lepidocyclus gigas* Wang (p. 477).

16, 20, 23, Lateral, anterior, and posterior views; 21, 24, dorsal and ventral views (specimen slightly distorted), USNM 124814. 22, 25, dorsal and ventral views of undistorted specimen, USNM 124815, All from Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

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FIGURES 1–5. *Lepidocyclus perlamellosa* (Whitfield) (p. 477).

1, 2. Dorsal and ventral views, × 1; 3, 4, 5, posterior, lateral, and anterior views, × 1. USNM 124816. Upper Ordovician, red shaly beds of uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

6–8, 12, 13. *Hypsiptycha* cf. *H. anticostiensis* (Billings) (p. 478).

6, 7, 12. Posterior, anterior, and lateral views, × 2; 8, 13, ventral and dorsal views, × 2, USNM 124817. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

9–11, 14, 15. *Hypsiptycha* cf. *H. hybrida* Wang (p. 478).

9, 14. Dorsal and ventral views, × 2; 10, 11, 15, posterior, lateral, and anterior views, × 2, USNM 124818. Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986–9,010 ft.

16, 17. *Isotelus?* sp.

16, Cranidium, damaged, × 2, USNM 124821.

17. Pygidium × 2, USNM 124822. Upper Ordovician, lower shale member, Stony Mountain formation loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986–9,010 ft.

18–20, 22, 23. *Hypsiptycha* cf. *H. hybrida* Wang (p. 478).

18, 22, 23. Posterior, anterior, and lateral views, × 2; 19, 20, ventral and dorsal views, × 2, USNM 124819. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

21, 24, 25–27. *Lepidocyclus capax* (Conrad) (p. 477).

21, 24, 27. Lateral, posterior, and anterior views, × 1; 25, 26, dorsal and ventral views, × 1, USNM 124820. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

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[Figures natural size unless otherwise indicated]

FIGURES 1-3. *Catazyga* sp. (p. 479).

1, 2, 3. Dorsal, ventral and lateral views of a fragmentary silicified specimen, × 3, USNM 124823. Upper Ordovician, Red River formation, loc. D91d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,103-9,116 ft.

4. *Strophomena* cf. *S. vetusta* James (p. 482).

Interior of dorsal valve, cut by coring bit, USNM 124824. Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986-9,010 ft.

5. *Zygospira* cf. *Z. resupinata* Wang (p. 479).

Ventral view of ventral valve, × 3, USNM 124825. Upper Ordovician, Red River formation, loc. D91e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,023-9,043 ft.

6-9, 12. *Zygospira* cf. *Z. aequivalvis* Twenhofel (p. 479).

6, 8. Ventral and dorsal views, × 3.

7, 9, 12. Anterior, lateral, and posterior views, × 3, USNM 124826. Upper Ordovician, Red River formation, loc. D91c (CO), Shell Oil Co., Pine Unit No. 1 well, 9,122-9,128 ft.

10, 11, 13, 16. *Strophomena hecuba* Billings (p. 482).

10, 11, 13. Dorsal valve, dorsal, lateral, and posterior views, USNM 124827. Upper Ordovician, upper dolomitic member, Stony Mountain formation, loc. D90e (CO), Empire State Oil Co., Hathaway No. 1 well, 8,556-8,664 ft.

16. Dorsal view of a less nasute specimen, USNM 124828. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

14. *Strophomena* cf. *S. rugulifera* Wang (p. 483).

Ventral view, USNM 124829. Upper Ordovician, Red River formation, loc. D91e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,023-9,043 ft.

15, 17, 19-21. *Megamyonia* cf. *M. ceres* (Billings) (p. 484).

15. Interior of a ventral valve, USNM 124830.

19. Interior of a dorsal valve, USNM 124831.

17, 20, 21. Lateral, ventral, and posterior views of a ventral valve, USNM 124832. All from Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986-9,010 ft.

18. *Megamyonia* sp. (cf. *M.* sp., Wang, 1949, p. 34, pl. 9C) (p. 485).

Ventral view of ventral valve, USNM 124833. Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986-9,010 ft.

22. *Thaerodonta* sp. (p. 480).

Dorsal view, × 2, USNM 124834. Upper Ordovician, red shaly beds of the uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

23-25. *Megamyonia* cf. *M. unicostata* (Meek and Worthen). (p. 483).

23. Ventral view of ventral valve, immature, tentatively referred this species, × 2, USNM 124835.

24. Interior of ventral valve, a rubber mold made from cast, USNM 124836. Upper Ordovician, Red River formation, loc. D92b (CO), Shell Oil Co., Little Beaver No. 1 well, 8,531-8,540 ft.

25. Ventral view of ventral valve, associated with *Diceromyonia* sp. USNM 124837. Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986-9,010 ft.

26-28. *Thaerodonta* cf. *T. recedens* (Sardeson) (p. 481).

26. Internal cast of ventral valve, associated with *Megamyonia* cf. *M. unicostata*, USNM 124838.

27. Interior of dorsal valve, a rubber mold, × 5, USNM 124839.

28. Interior of ventral valve, a rubber mold of cast shown in fig. 26, slightly distorted to show delthyrial cavities, × 2, USNM 124838. All from Upper Ordovician, Red River formation, loc. D92b (CO), Shell Oil Co., Little Beaver No. 1 well, 8,531-8,540 ft.

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[Figures natural size unless otherwise indicated]

FIGURES 1, 2. *Öpikina*? aff. *Ö. limbrata* Wang (p. 485).
1. Interior of large dorsal valve, USNM 124840.
2. Interior of small dorsal valve, USNM 124841.
Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986–9,010 ft.

3, 4, 7. *Megamyonia* aff. *N. nitens* (Billings) (p. 484).
Posterior, ventral, and lateral views, USNM 124842. Equals in part "*Leptaena nitens*" Billings as described by Twenhofel, 1928. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

5, 6, 9, 12, 16. *Diceromyonia storeya* Okulitch. (p. 487).
5, 12. Dorsal and ventral views, × 2;
6, 9, 16. Anterior, posterior, and lateral views, × 2, USNM 124843. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

8, 10, 11. *Holtedahlina* cf. *H. moniquensis* Foerste (p. 486).
8. Exterior of a dorsal valve, × 2, USNM 124844.
10. Interior of dorsal valve, × 2, USNM 124845.
11. Interior of dorsal valve, × 2, USNM 124846.
All specimens poorly silicified and fragmentary. All from Upper Ordovician, Red River formation, loc. D91d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,103–9,116 ft.

13–15, 17–21. *Diceromyonia* cf. *D. ignota* (Sardeson) (p. 487).
13. Interior of ventral valve, × 2, USNM 124847.
14, 15, 21. Anterior, posterior, and lateral views, × 2.
18, 20. Ventral and dorsal views, × 2, USNM 124848. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.
17. Interior of ventral valve showing narrow ridge between diductor scars, USNM 124849.
19. Interior of dorsal valve, × 2, USNM 124850. Upper Ordovician, lower shale member, Stony Mountain formation, loc. D91f (CO), Shell Oil Co., Pine Unit No. 1 well, 8,986–9,010 ft.

22–26. *Diceromyonia* n. sp. (aff. *D. tersa*) (p. 487).
22, 24, 25. Posterior, lateral, and anterior views, × 2.
23, 26. Ventral and dorsal views, × 2, USNM 124851. Upper Ordovician, red shaly beds in uppermost part of Bighorn dolomite, loc. D1 (CO), South Fork of Rock Creek, Johnson County, Wyo.

PLATE 42

FIGURES 1-4. Fragmentary fish plates.

1, 2, 4. *Eriptychius americanus* Walcott, × 3, × 3, × 4, USNM 20868, 20869, 20870.

3. *Astraspis desiderata* Walcott, × 3, USNM 20871. Winnipeg formation, loc. D69 (CO), Shell Oil Co., Pine Unit No. 1 well, 9,525-9,531 ft.

5, 6, 8-12. *Kirkella* aff. *K. fillmorensis* Hintze (p. 493).

5. Pygidium, × 2, USNM 124852.

6. Ventral view of fragmentary posterior portion of free cheek and dorsal view of immature cranidium, × 3, USNM 124853.

8. Immature pygidium, × 3, USNM 124854.

9. Left free cheek, immature, × 2, USNM 124855.

10. Hypostome, broken, but showing characteristic "wings," × 2, USNM 124857.

11. Cranidium, immature, damaged, × 3, USNM 124856.

12. Cranidium, damaged, rubber cast of original, × 2, USNM 124858. All from Lower Ordovician, Deadwood formation, loc. D66e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,660-9,666 ft.

7. *Ogyginus*? sp. (p. 494).

Pygidium, × 1, USNM 124859. Lower Ordovician, Deadwood formation. loc, D66e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,660-9,666 ft.

13. *Apatokephalus* cf. *A. canadensis* Kobayashi (p. 499).

Cranidium, × 4, USNM 124860. Lower Ordovician, Deadwood formation, loc. D66e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,660-9,666 ft.

14. *Hormotoma*? sp.

Two small specimens, × 1, USNM 124861. Lower Ordovician, Deadwood formation, loc. D66e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,660-9,666 ft.

15, 16, 19, 20. *Megalaspidella* cf. *M. orthometopa* Harrington (p. 492).

15. Cranidium, lacking palpebral lobes, × 2, USNM 124862.

16, 20. Pygidium, dorsal and posterior views, × 3, USNM 124863.

19. Fragmentary hypostome, rubber cast, × 4, USNM 124864. Lower Ordovician, Deadwood formation, loc. D66d-e (CO), Shell Oil Co., Pine Unit No. 1 well, 9,660-9,690 ft.

17. *Kirkella*? sp. (p. 492).

Pygidium, × 2, USNM 124865. Probably same as those figured above. Lower Ordovician, Deadwood formation, loc. D66d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,672-9,678 ft.

18. *Protopliomerops* cf. *P. superciliosa* Ross (p. 503).

Cranidium, × 3, USNM 124866. Lower Ordovician, Deadwood formation, loc. D66d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,672-9,678 ft.

21, 22. *Asaphellus*? sp. (p. 494).

21. Cranidium and ventral surface of pygidium, × 2, USNM 124868.

22. Pygidium, × 2, USNM 124867. Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,698 ft.

23. Unidentified pygidium (p. 503).

× 3, USNM 124869. This should be compared with Hintze, 1952, pl. IX, fig. 19. Lower Ordovician, Deadwood formation, loc. D66d (CO), Shell Oil Co., Pine Unit No. 1 well, 9,678-9,684 ft.

24. *Dictyonema* sp.

× 1, USNM 124870. Lower Ordovician, Deadwood formation, loc. D70 (CO), Shell Oil Co., Richey area, Northern Pacific R. R. No. 1 well, 10,484 ft.

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FIGURES 1–4, 6, 7. *Kayseraspis* aff. *K. asaphelloides* Harrington (p. 497).

1. Fragmentary cranidium and immature pygidium with terminal spine, × 2, USNM 124871.
2. Cranidium lacking palpebral lobes, USNM 124872.
3. Pygidium immature but with mature proportions, × 2, USNM 124873.
4. Mature pygidium cut by coring bit; terminal spine incomplete, × 2, USNM 124874.
6, 7. Immature pygidia, showing slight change in shape and in definition of segmentation, × 4, USNM 124875, 124876. All from Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,701–9,708 ft.

5, 12, 13. *Megalaspis planilimbata* var. *cyclopyge* Harrington (p. 490).

5. Pygidium × 2, USNM 124877.
12. Cranidium with pathologic(?) development of one muscle scar and obverse of pygidium shown in fig. 13, × 2, USNM 124878.
13. Small pygidium, × 2, USNM 124879, Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,701–9,705 ft.

8. *Nanorthis*? sp.

× 2, USNM 124880. Dorsal valve, dorsal view. Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,703–9,710 ft.

9, 10. Unidentified hypostomes (p. 490, 494, 497).

9. Associated with *Asaphellus*? sp. and *Megalaspis planilimbata* var. *cyclopyge* × 2, USNM 124881.
10. Associated with *Kayseraspis* aff. *K. asaphelloides*, × 2, USNM 124882. Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,701–9,709 ft.

11, 17. *Lloydia* cf. *L. saffordi* (Billings) (p. 489).

11. Small pygidium, × 2, USNM 124883.
17. Pygidium, × 2, USNM 124884. Lower Ordovician, Deadwood formation, loc. D66b (CO), Shell Oil Co., Pine Unit No. 1 well, 9,709 ft. (Species also present, D66c (CO), 9,690–9,696 ft.)

14. Syntrophiid brachiopod, not identified generically.

Dorsal valve, × 2, USNM 124885. Lower Ordovician, Deadwood formation, loc. D66a (CO), Shell Oil Co., Pine Unit No. 1 well, 9,711 ft.

15. Unidentified pygidium (p. 503).

× 2, USNM 124886. Compare with Ross, 1951, pl. 19, figs. 30, 31. Lower Ordovician. Deadwood formation, loc. D66a (CO), Shell Oil Co., Pine Unit No. 1 well, 9,715 ft.

16. *Didymograptus*? sp. or *Tetragraptus*? sp.

Immature, × 4, USNM 124887. Lower Ordovician, Deadwood formation (associated with *Bryograptus*? sp.), loc. D66a (CO), Shell Oil Co., Pine Unit No. 1 well, 9,715 ft.

18–20. *Leiostegium manitouensis* Walcott (p. 489).

18. Cranidium, decorticated, × 2, USNM 124888.
19. Hypostome, × 4, USNM 124889.
20. Cranidium, × 2, USNM 124890. All from Lower Ordovician, Deadwood formation, loc. D70a (CO), Shell Oil Co., Richey area, Northern Pacific R. R. No. 1 well, 10,500–10,509 ft.

21, 22, 25, 26. *Hystricurus* sp. (p. 488).

Four cranidia, × 4, USNM 124891, 124892, 124893, 124894, showing change in median preglabellar furrow with growth. 25, 26, may belong to separate species (cf. *H. robustus* Ross). All from Lower Ordovician, Deadwood formation, loc. D70a (CO), Shell Oil Co., Richey area, Northern Pacific R. R. No. 1 well, 10,500–10,509 ft.

23, 24, 27–30. *Kainella* sp. (p. 500).

23. Front of glabella, preglabellar field, and rim, × 3, USNM 124895.
24. Cranidium immature, × 4, USNM 124896.
27. Cranidium, lacking preglabellar field, × 3, USNM 124897.
28. Free cheek, showing granulose ornamentation of ocular platform, × 3, USNM 124898.
29. Obverse of pygidium shown in fig. 30, fragmentary, × 2, USNM 124899.
30. Pygidium, lacking rear of axis, × 2, USNM 124900. All from Lower Ordovician, Deadwood formation, loc. D70a (C), Shell Oil Co., Richey area, Northern Pacific R. R. No. 1 well, 10,500–10,509 ft.