


5-1-1934

Conodonts from the Quadrant Shales of Montana

Don R. Cabbage

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CONODONTS FROM THE
QUADRANT SHALES OF MONTANA

by
DON. R. CUBBAGE

Raymond

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
May, 1934

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w/1496-14097

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C O N O D O N T S F R O M T H E
Q U A D R A N T S H A L E S O F M O N T A N A

By

Don R. Cabbage

I N T R O D U C T I O N

Conodonts have not been known to exist in Montana prior to the discovery of the specimens discussed and described in this paper. With this fact in mind, the author has endeavored to correlate the species of seven genera found in the Quadrant formation of Montana with similiar micro-organisms from other North American areas.

This work was done in partial fulfillment for the requirements of a bachelors degree in Geological Engineering at the Montana State School of Mines.

The rock samples containing the conodonts herein described were obtained from a black fissile shale of Quadrant age, found in the Big Snowy mountains in central Montana. The Big Snowys occupy the southern edge of Fergus County, and the northern extremity of Wheatland and Golden Valley counties.

The material containing the conodonts described and discussed in this paper was furnished by the Montana Bureau of Mines and Geology. Dr. Eugene S. Perry of the Montana School of Mines' faculty suggested the subject of this paper and advised the author on the general procedure to be used in its preparation. Prof. Harold W. Scott, also of the faculty, gave much valuable detailed assistance in the study of conodonts and in the preparation of this paper.

The classification used in this paper is that adopted by Drs. Ulrich and Bassler. Constant reference was also made to various other reports on this subject. The references are listed at the end of this report.

H I S T O R I C A L R E S U M E

Conodonts are restricted to the Paleozoic and are found from the lower Ordovician to the Permian. The greatest number is found in the Devonian, Mississippian, and Pennsylvanian formations. They have been found in all kinds of sediments, but more commonly in black carbonaceous shales.

Conodonts were discovered, named, and described by Dr. C. H. Pander, who found them in Ordovician green sands near Petrograd, Russia, and westward along the Gulf of Finland. He regarded them as the teeth of primitive fishes.

Dr. J. Harley¹ however, believed some specimens of conodonts that he found in the Ludlow bone bed to be merely spines, as they were associated with crustacean remains. Many of these were proven by later authors not to be conodonts.

Great quantities of conodonts were gathered by Dr. J. S. Newberry² from the Cleveland shale near Bedford, Ohio, and submitted by him to various scientists. Professor Louis Agassiz "pronounced them the teeth of Selachians." Professor E. S. Morse quoted: "They bore a strong resemblance to the teeth of Mollusks." Other believed them the teeth of Cyclostomous fishes and still others dermal ossicles. Dr. Newberry agreed on the theory that they were the teeth of Cyclostomous fishes, and

Mr. W. L. Bryant⁴ had the same opinion because of their occurrence in plate-like structures. The theory of the relationship of conodonts to Cyclostomous fishes was first advanced by Dr. J. M. MacFarlane. Dr. Hinde⁶ and Professor Huxley expressed the opinion that conodonts found by them in Ontario corresponded to the teeth of Hagfish (Myxine) more closely than to any other known type of fish, but that the "facts were insufficient to decide the question." In a paper on American Devonian and Mississippian conodonts Drs. E. O. Ulrich and R. S. Bassler¹⁵ definitely stated they "believe the conodonts to be the teeth of primitive fishes and not necessarily all of the same group." S. R. Kirk¹⁹ found conodonts associated with fish remains in the Harding limestone in the vicinity of Canyon City, Colorado. The conodonts showed basal attachment to plates which were referred by Kirk to the Ostracodermi.

Dr. E. O. Ulrich⁵ in 1878 compared conodonts of the Cincinnati region with the chitinous jaws of several living annelids and observed a remarkable resemblance between them. On this evidence he concluded that conodonts are the hooklets of a species of annelid. Drs. J. V. Rohon⁸ and Karl von Zittel⁹, after careful microscopic study of conodonts, found them "wholly unlike the teeth of fishes, Mollusca, or Crustacea, but that they resemble such structures found in the Annelids and Gephyrea." Drs. A. W. Grabau¹⁸ and H. W. Shimer also listed conodonts with the Annelidae, by comparing them with the jaws of modern Annelids. Mr. Richard Owen¹⁰ of the British Museum, concluded that "conodonts have most analogy with the spines, or hooklets, or denticles of naked Mollusks or Annelids."

In commenting on conodonts, Dr. Bashford Dean¹¹ said that "they are microscopic fossil teeth of an unknown family of animals ranging from the Silurian to the lower Carboniferous." Mr. P. V. Roundy¹² stated that "the zoologic relationship of conodonts has been a subject of much controversy, and they have been regarded by various authors as parts of gastropods, fishes, annelid worms, and crustaceans. Until more is known about these organisms their zoologic position must remain unproved." A similarly stated quotation by Dr. A. S. Woodward¹³ was, that "their histological structure is so different from that of any teeth known that their affinities are quite undeterminable." Dr. W. W. Parks¹⁴ restudied the conodonts occurring in the vicinity of Toronto, and said, "they are frequently referred to as the teeth of Cyclostomes, but their affinities are quite uncertain."

Mr. U. P. James⁷ regarded conodonts as "the jaws and lingual teeth of Mollusks."

Conodonts were found in the Permian of Kansas by Mr. F. H. Gunnell,²⁰ which proved that they ranged throughout the Paleozoic era.

In a recent paper published in 1932, Clinton R. Stauffer and Helen Jeanne Plummer¹⁷ believed conodonts should be classified with primitive fishes, because of their resemblance to the teeth of vertebrates.

Frequent associations of genera and species were found in the Montana Quadrant shale. The genera *Prioniodus* and *Hindeodella* were often found together, so it is obvious that these two types of teeth occur in the same organism. Many

large masses of chitinous material were often found containing fragments of several genera of conodonts. It is the opinion of the writer that these masses are remnants of the organism, and that a more extensive search for specimens in the Quadrant shales of Montana will result in the ultimate discovery of a sufficiently preserved organism for definite identification.

S T R U C T U R E O F C O N O D O N T S

Conodont teeth are probably chiefly calcium carbonate as they are quite soluble in hydrochloric acid. Chiten which is often found associated with conodonts is a black substance related to cellulose in composition, $(C_6H_{10}O_5)_x$.

The color of conodonts is usually brown or amber, but they may be white, transparent or colorless. Conodonts commonly consist of a bar or base from which one or more cusps arise; these are often followed by a series of denticles in comb-like fashion. Other forms are thick and massive with short fused denticles on the crest. Many forms previously found in other localities were not present in the Montana Quadrant. More extensive study of the shales of Montana may reveal other genera not found up to the date of the present paper.

L A B O R A T O R Y P R O C E D U R E

Since most forms of conodonts are very delicate, extreme care is necessary in preparing specimens. The black fissile shale is easily split into thin sheets by driving a thin flat blade between the bedding planes.

When the flat surface of a thin slab of shale is held at the angle of reflection to sun light, conodonts may be detected with the naked eye by their glassy luster in contrast to the opaque black shale. Careful observation is necessary as the specimens are only 1 mm to 3 mm in length. Specimens found in the shale were circled with a red pencil and the section cut out of the slab with clippers. The section was about $\frac{1}{2}$ inch square and 0.1 inch thick, which was the most convenient size to mount on a rectangular strip of white cardboard, one inch by three inches in size. Glue was found the most satisfactory to mount the sections to the cardboard. When the sections were mounted, they were ready to be photographed. A binocular microscope was used in the study of the specimens with two power objectives.

Photographs were taken with a petrographic microscope and a Leica camera. A ten power objective and a three power eyepiece gave the best results. The apparatus described by Ulrich and Bassler¹⁵ was used to produce a white sublimate on the specimen before photographing it. The sublimate consisted of ammonium chloride, which was caused by a union of fumes of hydrochloric acid and ammonium hydroxide. The white sublimate made the individual specimens stand out in relief. Removal of the sublimate was readily accomplished by blowing one's breath upon the object so coated.

DESCRIPTION OF SHALE
CONTAINING CONODONTS

The conodonts described in this paper were taken from samples of a black fissile carbonaceous shale. The slabs of shale could be easily broken along the bedding planes into thin sheets with relatively even surfaces. Some of the slabs contained much calcareous material interbedded throughout the section, which made it difficult to find microscopic fossils. However, most of the shale contained very few impurities to obscure the fossils, so that the conodonts could be detected by careful observation with the naked eye.

The shale is very fossiliferous, and contains, besides conodonts, numerous pelecopods, and occasional fish tooth, and a few brachiopods. The fossils are not confined to a bedding plane, but are scattered throughout the shale. The conodonts are calcium carbonate in composition. Therefore, if they are exposed in a rock section, very minute conodonts may be detected by their glassy luster. Numerous small bodies of chitin occur in the shale and commonly are associated with fragments of conodonts.

STRATIGRAPHY

GEOLOGIC SECTION

The sedimentary rocks exposed in the Big Snowy uplift consist of approximately 11,000 feet of strata ranging in age from pre-Cambrian to recent time.*

*Reeves, Frank, geology of the Big Snowy Mountains, Montana, Prof. Paper 165-D, 1930.

Quaternary terrace-gravel deposits overlie the Tertiary and Cretaceous rocks around the base of the mountains.

On the south side of the uplift the Lance formation of late Cretaceous (?) age is exposed in the tilted strata. The Montana group and Colorado shale of Cretaceous age are also best represented in the highly tilted strata on the south flank of the Big Snowys, but the Cretaceous is mostly covered by Quaternary gravels in other parts of the area.

Outcrops of Kootenai, Morrison, Ellis and Quadrant formations occur in the foothills of the Big Snowy mountains. The age of these rocks is Pennsylvanian (Quadrant) to the lower Cretaceous (Kootenai).

Underlying the Quadrant is the Madison limestone which forms the surface of the upper part of the mountains. This formation is marine in character and very fossiliferous. It is readily recognized by its persistent gray color and great thickness.

The formations below the Madison, which are Devonian and Cambrian ages, are represented by the Meagher limestone, Wolsey shale, and Flathead quartzite at the base. These formations crop out at the heads of several canyons in the central part of the mountains. A few patches of pre-Cambrian Belt rocks are found at uppermost extremities of the canyons, and consist of a dark limy shale. Table No. 1, gives the sequence and distinctive features of the formations exposed in the Big Snowy mountains.

TABLE NO. 1
Sedimentary formations exposed in and adjacent to the Big Snowy Mountains. 22

Geologic Age	Group and Formation	Thickness	Character
Cenozoic			
Recent	Alluvium	0-50 $\frac{1}{2}$	Wind-blown sand, flood plain and alluvial-fan deposits of clay, sand, and gravel.
Pleistocene	Terrace gravel	10-50	Deposits of limestone, boulders, and gravel forming flat-topped benches.
Tertiary	Travertine	10-25	Outliers of calcareous tuff deposited by warm springs.
Mesozoic			
<u>Upper Cretaceous</u>	Lance formation	900-4	A brackish to fresh water sandy formation containing brown and gray sandstone, shale, and clay.
	<u>Montana Group</u>		
	Bearpaw shale	1,000	Steel-gray to black marine shale containing beds of bentonite and lumpy concretions.
	Judith River	200-400	Beds of fresh and brackish water origin containing sandstone and sandy shale.
	Claggett shale	500-600	Dark-gray to brownish-black marine shale containing beds of bentonite and yellow calcareous concretions.
	Eagle sandstone	150-250	Beds of white to buff sandstone and sandy shale.
	<u>Colorado shale</u>	2,250	Dark blue to black marine shale containing beds of bentonite, calcareous concretions, sandy shale, and sandstone.
<u>Lower Cretaceous</u>	Kootenai	500	Nonmarine red and green shale, sandstone, and nodular limestone.
Jurassic	Morrison	125	Variegated shales, lenses of sandstone, and thin limestone beds.
Unconformity	Ellis	130-400	Marine sandy limestone, calcareous sandy shale, and sandstone.
Paleozoic			
Pennsylvanian	Quadrant	800-1,300	Beds of marine and nonmarine red and black shale, limestone, sandstone and gypsum.
?			
Mississippian	Madison	1,950	Massive marine limestones.
Cambrian(?)	Meagher L. S.	300	Conglomeratic limestone.
	Wolsey shale	750	Greenish micaceous shale.
	Flathead Quartzite	75	Coarse sandstone and quartz conglomerate.
Proterozoic	Belt series	300	Dark limy shale.

QUADRANT FORMATION

The Quadrant formation occupies a relatively large area on the north and east flanks of the Big Snowys and a comparatively narrow belt on the southern and western flanks where the strata has a sharp dip. Its thickness is approximately 1,300 feet except on the northern flank where it thins in a northerly direction. The beds of the Quadrant consist of red, gray, black, and green shales, marine limestone, brown sandstones, and possibly gypsum beds.

Lithologically the formation can be divided into four parts. A thin bedded, fossiliferous limestone interbedded with red-clayish shale represents the upper 100 to 200 feet of the Quadrant. The limestone is found only on the southern and eastern flanks of the Big Snowys where it forms reddish bluffs; it disappears a few miles north of the mountains and the Ellis lies on the underlying Quadrant beds. On the eastern flank of the Big Snowys are 30 feet of coarse grained sandstone and 150 feet of red shale between the upper Quadrant limestone and the Ellis shale.

Wherever the Quadrant formation is exposed in the Big Snowys are from 300 to 400 feet of shales and sandstones which occur below the upper limestone beds. The shales are black, brown or red in color. At some localities the shales are carbonaceous and at others they are low grade oil shales with a yield of 10 gallons per ton. The black shales are also quite fossiliferous. Cross-bedding is common in the 10 to 70 feet of course grained, reddish brown sandstone. There are three beds

of the sandstone in most localities separated by beds of shale. The lowest sandstone member is approximately on the same horizon as that from which the oil is obtained in the Devils Basin oil field.

About 500 feet of variegated limy shale with thin beds of limestone underlie the shales and sandstone. The upper part of the limy shale in the northern part of the area consists of thin fissile calcareous shales which are quite fossiliferous. The middle section of the limy shale is predominantly green in color.

There are 150 to 200 feet of yellow sandstone, sandy shale, and lenticular beds of gypsum below the limy shale which represents the basal part of the Quadrant formation.

The Quadrant formation is separated from the overlying Ellis by a major unconformity which represents the time interval between the Pennsylvanian and the Jurassic periods. Thus, Jurassic beds are found resting on Carboniferous strata. According to Reeves, contact is easily recognized where the topmost beds of Quadrant are limestone as the limestone surface is often glazed, silicified and penetrated by numerous borings one-eighth to one inch in diameter and one-half to one inch deep. Numerous cracks and pot holes filled with clay and quartzite pebbles are also common in the topmost limestone bed of the Quadrant.

Some common fossils in the limestone of the Quadrant are: ORTHOTETES, CAMAROTOECHIA MUTATA, SPIRIFERINA SPINOSA, PRODUCTUS OVATUS, COMPOSITA SUBQUADRATA, and SPIRIFER INCREBESCENS.

The Quadrant, commonly considered Pennsylvanian in age, is believed to be Mississippian in age by several authors, but considerable doubt and uncertainty was expressed in the articles written by them. The apparent reason for the uncertainty as to whether the Quadrant is Pennsylvanian or Mississippian is that the fossils show that the fauna of the region differed somewhat from the known Carboniferous faunas of other areas. It is the opinion of the writer that the black shales of Quadrant age herein described are of lower Pennsylvanian, because the fauna appears more highly developed than those of the Mississippian. This is illustrated by the conodonts.

C O N C L U S I O N S

The question as to whether the Montana Quadrant formation is Mississippian or Pennsylvanian in age has been the subject of considerable controversy. By the discovery of some good index fossils for this formation, its age may be ascertained with a far greater degree of certainty. It is hoped that conodonts will aid in fulfilling this purpose.

Most of the genera discussed and described in this paper can be correlated with those found in the Mississippian in other localities; but the species appear to be more specialized, which would indicate an age probably younger than Mississippian. A genus was also found (*Duodina*) which could not be compared to any other known genus.

Another subject upon which there has been a wide difference of opinion is that of the phylum to which conodonts belong. Frequent associations of genera and species were found

in the Montana Quadrant, but none were directly associated with fish teeth. This leads to the theory that conodonts are not fish teeth, but belong to an organism living in the same environment as certain types of fish. The association of genera resemble more that of the complex jaw structure of Annelids.

D E S C R I P T I O N O F
G E N E R A A N D S P E C I E S

CLASS Annelidadae

Typical Conodonts- (teeth of primitive worm-like organisms)

FAMILY Prioniodidae-Ulrich and Bassler, 1926

"Conodonts somewhat pick shaped in which the handle or bar (posterior part) is denticulated and the anterior part consists of a strongly developed main cusp usually with a variously modified undenticulated downward extension.

In this family the tooth consists of a main cusp followed posteriorly by a bar of greater or less length, denticulated along its upper margin. Prioniodus, Pander, 1856, exhibits the structure characteristic of the family. In all genera the main cusp is well marked, but the denticulated bar ranges from a slight development in Belodus, (Pander, 1856) to a maximum in the genus Ligonodina, (Ulrich and Bassler, 1926)." Prioniodus represents a mean in length of bar.

Remarks: Ulrich and Bassler list five genera under this family, however, only one genus (Prioniodus) was found in the Montana Quadrant shales.

GENUS *Prioniodus*- Pander, 1856

"Typically the pick shape is well developed in this genus, the main terminal cusp relatively large with both edges sharp. The basal extension, although variable in length, is usually strong and often as long as the cusp itself, the anterior line formed by both being nearly straight. Numerous denticles occur on the bar, their lower half usually fused, but in some cases, although always closely arranged, they remain discrete to the junction with the bar."

Remarks: Specimens found in the Quadrant shales of Montana have the characteristics which place them definitely in the genus. They are similar to *Prioniodus* found by Drs. Ulrich and Bassler of upper Devonian and Mississippian age in the lower Mississippi valley, and those described by Stauffer and Plummer in Pennsylvanian shales of Texas. A large number of species were not found; however, they are excellently preserved.

The presence of the main cusp at the extreme anterior end of the bar serve to make *Prioniodus* readily recognizable from other genera. Association of *Prioniodus* with *Hindeodella* and *Lonchodina* are common.

Prioniodus sp. A

Bar thin toward posterior end, expands anteriorly into the base of the main cusp; under side of bar concave. Main cusp anterior, terminal, long, tapering to sharp point and extending upward and forward from the bar at an angle of 135° as well as downward and forward at the same angle with the bar. The downward projection of the main cusp is short and pointed. Denticles decrease in size posteriorly, and are fused near the base.

Occurrence: Black fissile shale member, Quadrant formation, Big Snowy mountains, Fergus County, Montana.

FAMILY Prioniodinidae- Ulrich and Bassler, 1926

"Similar to the family Prioniodidae but the bar is denticulated both forward and back, the main cusp thus being not terminal but set in the midst of a series of small denticles."

Remarks: Genera of this family which were found in Montana Quadrant shales, are Hindeodella, Bryantodus, Prioniodella, and Lonchodina, (Ulrich and Bassler, 1926). Such genera as Cornuramia, Hibbardella, Prionognathus, and Palmatodella (Ulrich and Bassler, 1926) were not found.

GENUS Prioniodella- Ulrich and Bassler, 1926

"Denticles are subequal, none being particularly larger than the other. Base of tooth more or less curved, crowned with numerous sub-parallel, rounded, discrete or somewhat coalescent denticles all inclined in one direction. One end of the bar, called the posterior because of the slant of the denticles, is commonly produced into a blunt process."

Remarks: The specimens from the Montana Quadrant shale are quite similar to those obtained by Drs. Ulrich and Bassler from the Devonian and Mississippian shales in the lower Mississippi valley, and those by Stauffer and Plummer from the

Pennsylvanian shales of Texas. The number of species were few, but most of those obtained were well preserved and often entirely uncovered in the rock-section.

Subequal length of denticles and lack of prominent main cusp characterize *Prioniodella* and serve to distinguish it from *Bryantodus*, *Prioniodus*, *Hindeodella*, and *Lonchodina*.

The genus is commonly associated with *Polygnathus*. Description of species is not included because their number was inadequate for definite correlation.

GENUS *Hindeodella*- Ulrich and Bassler, 1926

This genus is described as having a long straight bar bearing from "one to ten denticles in front of a long sturdy cusp and a long series of numerous small slender denticles, often alternating in size, behind it. The denticles of each set are approximately equal in size. The part of the bar in front of the cusp is often bowed horizontally as well as downward."

Remarks: In view of the fact that the cusp is sometimes in a slightly different horizontal plane than that of the remainder of the specimen, many of them are found with the cusp or the bar covered. Attempts to remove the overlying material usually results in destruction of the specimen because the members of this genus are very brittle and delicate. A few excellent specimens were obtained. The bar and main cusp of the best preserved ones usually lay in the same plane.

Some of the species are similar to certain ones found by Stauffer and Plummer in the Pennsylvanian shales of Texas.

Hindeodella is readily distinguished from other genera by the long slender straight bar with one to ten denticles in front of the main cusp on the anterior end.

Associations of the same and different species of this genus are quite common. *Prioniodus* is often found in associations with *Hindeodella*.

Hindeodella sp. A

Bar straight and decreasing somewhat in size posteriorly. Denticles irregular in size and spacing. Main cusp slants posteriorly and is followed by eight large denticles separated by two or three smaller denticles, all slant posteriorly at a 60° angle to the bar. There is one relatively long, sharply pointed denticle anterior to the main cusp.

Occurrence: Black fissile shale member, Quadrant formation, Big Snowy mountains, southern extremity of Fergus County, Montana.

Hindeodella sp. B

Similar to sp. A, except denticles are relatively smaller and more even in spacing. Anterior end blunt with bulb-like expansion that probably possessed a denticle.

Occurrence: Same as sp. A

Hindeodella sp. C

Similar to sp. A, except one small denticle between main cusp and large denticle on anterior end. Slight curve upward of bar toward anterior end. Larger denticles more evenly spaced and separated by from three to four smaller denticles of the same relative size.

Occurrence: Same as for sp. A and B.

GENUS *Bryantodus*- Ulrich and Bassler, 1926

"Base of tooth curved, crowned with numerous sub-parallel denticles, with sharp, laterally confluent edges. The main cusp is proportionally much larger and as a rule more conspicuous in its width and with broadly expanded sides confluent with the adjacent denticles. The base forms a narrow flange-like expansion on both sides with a characteristic downward projection on the inner side beneath the main cusp, serving perhaps for securing attachment in the jaw of the animal. The denticles are connected by a membrane-like extension of their edges."

Remarks: Specimens of this genus obtained from the Quadrant shales of Montana were few in number, but were ordinarily in excellent condition when found. They are quite similar in characteristics to some found by Drs. Ulrich and Bassler in Mississippian rocks of Tennessee.

Bryantodus is characterized by a downward projection on the ventral surface beneath the main cusp which distinguishes it from *Prioniodella*. The curvature of the bar makes it readily recognizable from *Prioniodus* or *Hindeodella*.

Bryantodus sp. A

Bar slightly curved, with an accentuated downward turn anteriorly to main cusp, surmounted by eighteen relatively flat confluent denticles. Main cusp strong, nearly twice as wide at the base as any other denticle, slants anteriorly as do the other denticles. Posteriorly to the main cusp there

are three large denticles of nearly the same size, separated from the main cusp by a smaller denticle, and followed by five smaller denticles. Anteriorly to the main cusp there are two elongated less confluent denticles followed by six smaller confluent ones of relatively the same size. Downward projection of bar below main cusp well developed.

Occurrence: Black fissile shale member of Quadrant formation, Big Snowy mountains, Fergus County, Montana.

GENUS *Lonchodina*- Ulrich and Bassler, 1926

Entire bar strongly bowed with ends nearly equal in length, bent in two directions one with the usual upward curvature at the middle and the other outwardly as seen in a view of the underside of the base; denticles more irregular and farther separated. Main cusp sometimes not readily distinguished from the denticles.

The main characteristics of the genus are its outwardly bowed form, the greater length and separation of the rounded needleshaped denticles, and their usual unsymmetrical arrangement. The bowing of the tooth is especially characteristic, this occurring in two directions, upward and outward."

Remarks: Specimens of this genus from the Montana Quadrant formation are difficult to name as to species because only sections of the teeth could be obtained. Various parts of *Lonchodina* are in different planes horizontally and, therefore, break as the shale is fractured along the bedding planes.

Lonchodina is distinguished from *Bryantodus* by the outward curvature of the bar and greater separation of denticles.

FAMILY Polygnathidae- Ulrich and Bassler, 1926

"Plates with high denticulated median crest." Polygnathus, (Hinde) Bryant, 1921, has been referred to this family. Duodina, new genus, has the characteristics which most nearly fit this family and is placed here provisionally.

GENUS Polygnathus (Hinde) Bryant 1921

"Plate subsymmetrically lanceolate, traversed by a high median carina extending stalk-like from the broader end and reaching, although diminishing gradually in height, to the opposite usually pointed end, dividing the plate into two lateral subequal areas. The carina is also indicated by a corresponding ridge on the underside. On the upper surface the summit of the carina carries a row of closely approximated nodes and the depressed sides of the plate are variously ornamented with nodose ridges. The underside is smooth or with fine concentric lines."

Remarks: The specimens obtained from the Montana Quadrant shales seem to have the characteristics of this genus in general. There are differences, however, due to the evolution of the organism from Mississippian to Pennsylvanian time. They are found in excellent state of preservation, and many of them can be entirely removed from the section of shale without injury to the specimen.

The distinguishing characteristics of Polygnathus: straight base of bar unlike Lonchodina or Bryantodus; thickness and height of bar much greater and length much less than Prioniodus, Prion-

iodella, or Hindeodella; and the absence of a distinct main cusp and slender denticles. The denticles of Polygnathus are short and thick in structure like Duodina, but occur in one row which forms the dorsal surface of specimens from this genus.

Polygnathus sp. A

Bar higher at posterior end but thinner laterally; nearly uniform in cross section two-thirds the length of bar longitudinally where it decreases in height and increases in thickness to the anterior end. Base bordered by a strong rim which is more pronounced where the base flares out anteriorly. Shallow groove on both sides of bar near base ending two-thirds the length of bar from posterior end. The extremities of the denticles on the dorsal surface form nearly a straight line longitudinally, but the line traced by their junction with the bar extends downward toward the base at the anterior end giving a greater length to the denticles. Denticles fused, relatively short, blunt, thick, and cover entire dorsal surface of bar in a single row.

Occurrence: Black fissile shale member, Quadrant formation, Big Snowy mountains, southern portion of Fergus County, Montana.

NEW GENUS Duodina

Height nearly one-third the length. Symmetrical longitudinally with an elliptical pattern in both the dorsal and ventral views. Sides convex; dorsal surface wider than ventral surface thus giving it the general shape of a boat. Surface on dorsal

and ventral sides relatively flat, but slightly depressed in the center longitudinally. Base extends laterally forming a rounded ridge on either side. Wide, short, and blunt denticles, fusing near the base, occur in two rows on the margins of the dorsal surface. They extend from the anterior end to the center in slightly increasing size, and continue as minute undulations posteriorly.

Remarks: Specimens of this genus fail to fit the characteristics of any known form.

Several excellently preserved specimens of this genus were found, and with care they could be removed entirely from the shale without injury to them.

Duodina is readily told from Polygnathus by the occurrence of the denticles in two rows longitudinally on the dorsal surface.

Duodina sp. A.

Base of bar concave longitudinally, thin at posterior and anterior ends but enlarges latterally toward the middle into a flange extending outward and downward on both sides of the bar and forming a depression through the center longitudinally. Ridge along side of bar just above base and merging into flange through central portion longitudinally. Groove on both sides of bar just above ridge and flange and extending full length of bar. Sides convex above groove and sloping outward to base of denticles on dorsal surface. One row of massive, bluntly fused denticles on one side of dorsal surface on anterior end terminating in a larger denticle of similar structure one-third

length of bar from anterior extremity. Balance of dorsal surface bordered by a rough ridge extending laterally into a depression at the center. Depression extends full length of dorsal surface through the center. Ends of bar narrow and rounded, sloping upward at anterior end and downward at posterior end. Length of bar four times height and maximum thickness one-half height.

Occurrence: Black fissile shale member of Quadrant formation, Big Snowy mountains, Fergus County, Montana.

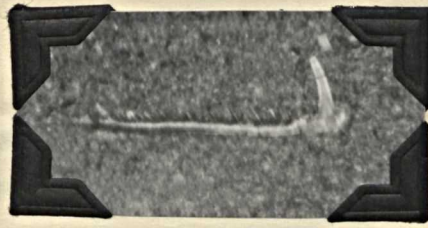
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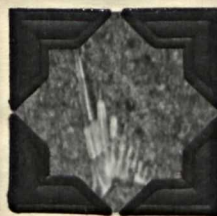
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